Global Operations, Environment, Health & Safety

1 Plastics Avenue
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Via Electronic Mail

February 28, 2024

Mr. Richard Fisher
Office of Site Remediation and Restoration
U.S. Environmental Protection Agency, Region I
5 Post Office Square - Suite 100
Boston, MA 02109-3912

Re: GE-Pittsfield/Housatonic River Site
Rest of River (GECD850)
Upland Disposal Facility Final Design Plan

Dear Mr. Fisher:

In accordance with Section 4.3.2.2 of the Final Revised Rest of River Statement of Work, enclosed for EPA's review and approval is GE's *Upland Disposal Facility Final Design Plan*. Due to the size of this document, the text, tables, and figures are being provided directly by email and a link to a SharePoint site is also provided for the entire document, including the appendices.

Please let me know if you have any questions about this plan.

Very truly yours,

Matthew Calacone/csc

Matthew Calacone
Senior Project Manager – Environmental Remediation

Enclosure

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General Electric Company

Upland Disposal Facility Final Design Plan

GE-Pittsfield/Housatonic River Site

February 2024

Upland Disposal Facility Final Design Plan

GE-Pittsfield/Housatonic River Site

February 2024

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Abbreviations

3H:1V	three horizontal to one vertical
amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
Arcadis	Arcadis U.S., Inc.
BMP	best management practice
CD	Consent Decree for GE-Pittsfield/Housatonic River Site
CFR	Code of Federal Regulations
cfs	cubic feet per second
cm/s	centimeter per second
CMR	Code of Massachusetts Regulations
CRA	cultural resource assessment
cy	cubic yards
EPA	U.S. Environmental Protection Agency
ERE	Environmental Restriction and Easement
Eversource	Eversource Energy
Final Revised SOW	Final Revised Rest of River Statement of Work
GCL	Geosynthetic Clay Liner
GDC	Geosynthetic Drainage Composite
GE	General Electric Company
HDPE	high-density polyethylene
Interim PDI Data Summary	Interim Pre-Design Investigation Data Summary Report for the Upland Disposal Facility Area
MassDEP	Massachusetts Department of Environmental Protection
mil	one thousandth (0.001) of an inch
MWPA	Massachusetts Wetlands Protection Act
NPDES	National Pollutant Discharge Elimination System
PCB	polychlorinated biphenyl
PDI	pre-design investigation
RAP	Response Action Plan

Revised Final PDI Summary	Revised Final Pre-Design Investigation Summary Report for Upland Disposal Facility Area
Revised Permit	Revised Final Modification to GE's Resource Conservation and Recovery Act Corrective Action Permit (December 2020)
ROR	Rest of River
SOW	Statement of Work
Stormwater Handbook	Massachusetts Stormwater Handbook and Stormwater Standards (February 2008)
UDF	Upland Disposal Facility
UDF OMM Plan	Operation, Monitoring, and Maintenance Plan for UDF

1 Introduction

On December 16, 2020, pursuant to the 2000 Consent Decree (CD) for the GE-Pittsfield/Housatonic River Site, the U.S. Environmental Protection Agency (EPA) issued to the General Electric Company (GE) a Revised Final Permit Modification to GE's Resource Conservation and Recovery Act Corrective Action Permit (Revised Permit) specifying a Remedial Action for the ROR (EPA 2020a). The ROR consists of the portion of the Housatonic River and its backwaters and floodplain (excluding portions of certain residential properties) downstream of the confluence of the East and West Branches of the Housatonic River, which is located approximately two miles downstream from GE's former manufacturing facility in Pittsfield, Massachusetts. The selected ROR Remedial Action includes a provision for GE to construct and utilize an Upland Disposal Facility (UDF) on a 75-acre property (the GE Parcel) that was formerly part of an active sand and gravel quarry and that GE acquired from The Lane Construction Corporation in April 2021. The UDF is to be used for the disposal of certain of the sediments, soils, and associated debris to be removed as part of the ROR Remedial Action, subject to criteria specified in the Revised Permit.

In accordance with the requirements of the Revised Permit, GE submitted to EPA a Rest of River Statement of Work (SOW) specifying the deliverables and activities that GE will conduct to design and implement the ROR Remedial Action. After receipt of EPA comments, GE submitted a Final Revised Rest of River SOW on September 14, 2021 (Final Revised SOW; Anchor QEA et al. 2021). That Final Revised SOW included pre-design and design requirements for the UDF and a UDF support area. On September 16, 2021, EPA issued an approval letter for the Final Revised SOW.

On November 24, 2021, in accordance with the Final Revised SOW, GE submitted a Pre-Design Investigation Work Plan for the UDF. That work plan was conditionally approved by EPA on February 25, 2022. GE subsequently conducted the pre-design investigation (PDI) of the UDF area in 2022 and 2023. The PDI activities conducted from March 2022 through June 2023 were described in GE's Final Pre-Design Investigation Summary Report for the Upland Disposal Facility Area (Arcadis and AECOM 2023). EPA issued a conditional approval letter for that report on November 16, 2023, requiring that the conditions therein be addressed in a Revised Final PDI Summary Report. On January 29, 2024, GE submitted a Revised Final Pre-Design Investigation Summary Report for the Upland Disposal Facility Area (Revised Final PDI Summary; Arcadis and AECOM 2024), addressing the conditions in EPA's conditional approval letter and describing the PDI activities conducted through 2023. Those PDI activities are also briefly summarized in Section 2.3 of this plan.

In the meantime, on December 6, 2022, in accordance with Section 4.3.2.1 of the Final Revised SOW, GE submitted a Conceptual Design Plan for the UDF; and EPA issued a conditional approval letter for that Conceptual Design Plan on April 18, 2023. That letter stated that, unless otherwise specified, the conditions in the letter should be addressed in the Final Design Plan for the UDF.

This UDF Final Design Plan (Final Design Plan) presents the final design elements for the UDF) and related UDF support areas. Figure 1 shows the GE Parcel, along with the anticipated limits of the UDF consolidation area (the waste-containing portion of the UDF) and the associated operational area. In addition, the GE Parcel will contain site areas designated for support of UDF operations. These support areas will include access points to the operational area, material and equipment staging areas, and areas for contractor use and are also shown on Figure 1. Other UDF support areas may be needed in the future for UDF operations associated with hydraulic dredging and pumping if performed, such as sediment conveyance, dewatering, and water treatment facilities.

Such additional UDF support areas will be described in later design submittals associated with hydraulic dredging and pumping activities (i.e., design work plans for Reach 6).

1.1 Purpose

This Final Design Plan documents the technical basis for the UDF design in accordance with Section 4.3.2.2 of the Final Revised SOW. As presented herein, the UDF design is at the final design stage and is not expected to change significantly.

1.2 Site Description and History

The GE Parcel generally consists of previously disturbed and barren ground areas void of vegetation, open grassed and wooded areas, and ponds that were created as part of the prior quarry operations. The bordering site features are Valley Street to the north, Woodland Road to the east, the Lee Municipal Landfill to the south, and property of Northeast Paving (a Division of Eurovia Atlantic Coast, LLC) to the west located off Willow Hill Road. The soils on site largely consist of sand and gravel. There is a general east-to-west slope in the groundwater table across the site. There is an existing Eversource Energy (Eversource) utility easement containing overhead electric utility lines on the western and southern sides of the GE Parcel. There are no known underground utilities within the GE Parcel.

1.3 Design Report Organization and Associated Documents

The remainder of this Final Design Plan is organized into the sections listed below. In a number of respects, these sections repeat and/or expand upon the similar sections in the Conceptual Design Plan and add the necessary additional final design information as well as addressing the conditions in EPA's April 18, 2023 conditional approval letter.

- Section 2 provides a summary of the performance standards, site features, and design elements for the UDF and includes a brief summary of PDI activities conducted.
- Section 3 presents a summary of the components and purpose of the baseliner system.
- Section 4 presents a summary of the components and purpose of the final cover system.
- Section 5 provides an overview of various operational and supporting activities for the UDF.
- Section 6 provides a discussion of measures to address habitat impacts at the UDF area.
- Section 7 addresses topics related to closure of the UDF.
- Section 8 discusses sustainability considerations and greenhouse gas emissions associated with the UDF and plans to address them.
- Section 9 addresses the long-term post-closure monitoring and maintenance of the UDF area.
- Section 10 lists the references cited in this Final Design Plan.

This Final Design Plan is accompanied by an Operation, Monitoring, and Maintenance Plan for the UDF (UDF OMM Plan) in accordance with the requirements of Section 4.3.2.3 of the Final Revised SOW. Following selection of a contractor for the UDF construction and operation, GE will submit a Supplemental Information Package (SIP) for the UDF in accordance with Section 4.3.2.4 of the Final Revised SOW.

2 Design Summary

This section provides a summary of the basis of the UDF design, including the performance standards in the Revised Permit, applicable or relevant and appropriate requirements (ARARs), PDI information obtained to support the design, the overhead electric utility line easement, the berm and baseliner system, the final cover system, management of leachate and surface water, and the UDF operational and support areas. The primary components of the UDF design are presented on the design drawings included in Appendix A.

2.1 Performance Standards for UDF

Section II.B.5.a of the Revised Permit sets forth the performance standards for the UDF. In summary, those performance standards require that the UDF meet the following construction and design requirements (paraphrased), as also previously listed in the UDF Conceptual Design Plan:

- Be constructed at the location shown on Figure 6 of the Revised Permit.
- Provide a maximum design capacity of 1.3 million cubic yards (cy).
- Have a consolidation area with a maximum footprint of 20 acres and a maximum elevation of 1,099 feet above mean sea level (amsl). If the seasonally high groundwater elevation is determined to be higher than 950 feet amsl, the maximum elevation of the consolidation area may be increased by the number of feet between the seasonally high groundwater and 950 feet amsl in order to achieve the maximum waste capacity of 1.3 million cy.
- Include two bottom liners (referred to herein as a baseliner), separated by a drainage layer, and incorporate primary and secondary leachate collection systems.
- Have the baseliner a minimum of 15 feet above a conservative estimate of the seasonal high groundwater elevation. The seasonal high groundwater elevation is to be projected using site-specific groundwater elevation data collected in the location of the UDF and modified to account for historical groundwater level fluctuations at similarly sited off-site, long-term monitoring wells in Massachusetts. This estimation is to be performed pursuant to a methodology reviewed and approved by EPA.[1]
- Provide for the consolidation area to be covered with a low-permeability cap that includes a hydraulic barrier, drainage layer(s), and vegetation.
- Ensure that the liners/barriers for both the bottom of the UDF and the cap have a permeability equal to or less than 1×10^{-7} centimeters per second (cm/s) and a minimum thickness of 30 thousandths of an inch (mil) and are chemically compatible with polychlorinated biphenyls (PCBs).
- Include a stormwater management system to control surface runoff and minimize the potential for surface erosion or stormwater contribution to leachate generation.

[1] An evaluation of the groundwater elevation gauging data collected during the PDI monitoring period at the GE Parcel was performed to provide a conservative estimate of the seasonal high groundwater elevation at the GE Parcel. This conservative estimate of the seasonal high groundwater elevation was used in the design of the UDF to establish a separation distance between the bottom of the lowest baseliner system elevation and the estimated seasonally high groundwater elevation. A summary of the evaluation conducted to estimate the seasonal high groundwater elevation is provided in the January 2024 Revised Final PDI Summary.

- Include a groundwater monitoring network around the UDF to monitor for PCBs and other constituents identified in the groundwater monitoring plan as approved or modified by EPA.

Compliance with these performance standards is discussed as appropriate throughout this Final Design Plan.

2.2 Applicable or Relevant and Appropriate Requirements and Other Pertinent Regulations

In addition to the performance standards for the UDF presented in Section II.B.5.a of the Revised Permit and summarized in the preceding section, the Revised Permit identifies, in Attachment C, the ARARs for the ROR Remedial Action. The listed ARARs that are pertinent to and considered for the UDF design are presented in Table 1 (attached), using the same format as in Attachment C to the Revised Permit. The actions to be taken in the UDF design to comply with these ARARs (where not waived by EPA) are also described in Table 1.

In addition to these listed ARARs and the performance standards in the Revised Permit, the design of the baseliner and final cover system components for the UDF has considered as a guide the technical requirements of 310 Code of Massachusetts Regulations (CMR) 19.000 (*Solid Waste Management*) relating to such components of a solid waste landfill (notably, 310 CMR 19.110 and 19.112).

2.3 Pre-Design Investigation

A comprehensive PDI was conducted in March 2022 through November 2023 (with an additional well sampled in December 2023) to acquire data to support engineering evaluations and design of the UDF. The results of the activities and investigations conducted as part of the PDI are presented in the Revised Final PDI Summary. Those activities include, among others, a baseline habitat assessment, a topographic and bathymetric field survey, a soil geotechnical evaluation, engineering and environmental soil testing, piezometer and monitoring well installation, groundwater elevation and quality testing, and a cultural resource assessment (CRA). These activities are briefly summarized below.

2.3.1 Baseline Habitat Assessment

A baseline habitat assessment of the GE Parcel was conducted by AECOM to form a detailed baseline ecological characterization and assessment of existing conditions and to serve as the foundation for developing the Final Cover/Closure Plan for the UDF area and UDF support areas. All field investigations were conducted with oversight by scientists representing EPA. This assessment concluded that the east-central part of the GE Parcel contains an area that constitutes a wetland under federal and state criteria and a resource area under the Massachusetts Wetlands Protection Act (MWPA) and also includes a certifiable vernal pool, and that one of the three artificial gravel-pit ponded areas on the parcel also constitutes a resource area under the MWPA. This habitat assessment is described in detail in the Revised Final PDI Summary, and the revised habitat assessment report is provided as Appendix C to it. See also Section 6 below.

2.3.2 Topographic and Bathymetric Field Survey

A topographic survey of the GE Parcel was conducted by Hill Engineers, Architects, and Planners, Inc., in 2022 and 2023 (provided in Appendix D to the Revised Final PDI Summary). Existing topography across the GE Parcel is variable and features several localized high and low points, including pond areas, likely attributable to the site's history as a sand and gravel quarry. The topographic field surveys were combined with bathymetric surveys of the water-filled depressions to yield a continuous top-of-existing-ground-surface model. This combined topographic/bathymetric information is depicted on Design Drawings 2A and 2B.

2.3.3 Geotechnical Evaluation

As a part of the PDI, a soil boring program was implemented to evaluate the engineering properties for site soils. These properties were used in the UDF design to evaluate slope stability, settlement, and other geotechnical parameters. The soil classifications were also used in the design of stormwater infiltration basin(s). Subsurface data collected during the geotechnical investigation indicate that the soils at the GE Parcel are consistent with the characteristics and stratification of a glacial outwash deposit. The composition, elevation, and general slope of the underlying bedrock surface were also identified during the soil boring program of the geotechnical investigation. Details of the geotechnical investigation are presented in the Revised Final PDI Summary.

2.3.4 Engineering and Environmental Soil Testing

A series of soil testing was performed through both field and laboratory means to determine the engineering properties and the environmental quality of site soils. Standard penetration testing was performed to ascertain values that were used during the design of the UDF to estimate engineering properties of site soils. Soil classification and soil index properties were also derived for use in the development of engineering parameters, such as shear strength and soil elastic modulus, to support the stability and settlement evaluations, as well as for determining re-use criteria of excavated materials during construction of the UDF and for estimation of the permeability of the site soils. Soil testing for environmental quality was also conducted to determine the presence and concentration of chemical constituents (if any) in the existing soil that allow the establishment of baseline chemical conditions for comparative evaluations during UDF operations and post-closure monitoring of the UDF. Details of soil testing performed as part of the PDI are provided in the Revised Final PDI Summary.

2.3.5 Piezometer and Monitoring Well Installation

Six piezometers (i.e., pipes placed in boreholes to measure groundwater elevation) and 11 monitoring wells, including two deep-shallow monitoring well pairs, were installed within the GE Parcel.[2] Collectively, these piezometers and monitoring wells were used to collect groundwater elevation data across the GE Parcel. The monitoring wells may also be used for long-term monitoring of site groundwater during construction, operation, and post-closure of the UDF. Further discussions on the installation of the piezometers and monitoring wells are provided in the Revised Final PDI Summary.

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[2] One of the 11 monitoring wells, well MW-2022-1S, was decommissioned and replaced by MW-2023-1SR on November 13-15, 2023.

2.3.6 Groundwater Elevation Monitoring

Groundwater elevation monitoring was conducted within and outside of the GE Parcel utilizing the six piezometers, the 11 monitoring wells installed within the GE Parcel, two pre-existing monitoring wells located outside of the GE Parcel at the Lee Municipal Landfill, and three surface water monitoring points located on an artificial pond within the GE Parcel and on the Housatonic River at the Schweitzer Bridge. Seasonal high groundwater elevations in the area of the UDF were developed using the groundwater elevation data in each well, modified by a technical method that has been reviewed and approved by EPA. The resulting, conservative estimate of the seasonal high groundwater elevations is used in the UDF design to establish the bottom elevation of the UDF and to evaluate slope stability. Descriptions of the monitoring locations and results of the groundwater elevation monitoring, including an estimate of the seasonal high groundwater elevation, are provided in the Revised Final PDI Summary.

2.3.7 Groundwater Quality Monitoring

Semi-annual groundwater quality monitoring was conducted at the GE Parcel for purposes of establishing baseline groundwater chemical quality conditions prior to construction of the UDF. This monitoring commenced in June 2022 and was completed in November 2023[3].The results from the groundwater quality monitoring are presented in the Revised Final PDI Summary. The baseline groundwater chemical quality conditions will be used in developing a groundwater monitoring plan that will be implemented during construction and operation of the UDF and during the UDF final cover/closure period. Further discussion of UDF groundwater monitoring is provided in Section 5 and in the UDF OMM Plan.

2.3.8 Cultural Resources Assessment

An initial Phase IA CRA of the GE Parcel was conducted by AECOM under an EPA-approved work plan. The Phase IA CRA did not identify any previously recorded or visible cultural resources within that parcel. However, three locations within portions of the GE Parcel that could potentially be used for UDF support activities were identified as having a potential to contain archaeological resources. A subsequent Phase 1B intensive archaeological survey was then performed at those areas under another EPA-approved work plan and with oversight by EPA representatives. It concluded, based on the combined background research and field studies, that the GE Parcel does not contain any significant cultural resources and that no additional CRA studies or mitigation measures are required. The findings of these assessments are described in detail in the Revised Final PDI Summary and Appendices L and M to it.

2.4 Overhead Electric Utility Line Easement

An existing Eversource utility line easement is located on the western and southern sides of the GE Parcel, as shown on Design Drawings 2A and 2B. A system of overhead electric wires, towers, and guy wires are located within the easement. The planimetric layout of the UDF has been developed to accommodate the easement and the utilities therein. Specifically, the UDF perimeter berm fill placement has been designed to avoid interference with the towers and guy wires. Although perimeter berm fill does extend into the easement, the fill projection is

[3] Groundwater quality sampling included sampling of monitoring well MW-2023-1SR during the November 2023 sampling event. Former well MW-2022-1S was not sampled during that event.

limited to the extent practicable and occurs at locations that are between the towers. The access road atop the perimeter berm is located completely outside of the easement so that vehicle traffic on the access road is not required to travel beneath the overhead wires and is not restricted by overhead clearance to the wires. Finally, the waste consolidation area for the UDF is also located completely outside of the easement. Design grading and location of other UDF-related features, including stormwater management system components and vehicle access areas along the easement, are shown on Design Drawings 4A and 4B.

GE initiated communications with Eversource early in the design process, commencing with providing Eversource with a copy of the Conceptual Design Plan in December 2022. In November 2023, GE transmitted to Eversource for its review a Permitted Use Application, which included the proposed UDF grading within portions of the Eversource rights-of way that is necessary to support the construction and operation of the UDF. In December 2023, GE conducted a meeting with Eversource at the GE Parcel to review the proposed UDF design grading depicted in the Permitted Use Application, observe site conditions in the areas of the UDF grading, and discuss how the proposed UDF design will allow for continued access by Eversource to their equipment. As of the date of preparation of this Final Design Plan, GE has not received comments or input from Eversource regarding these matters.

Once Eversource comments are received, GE will coordinate with Eversource as necessary regarding its comments and provide EPA with an update summarizing those comments and any resulting revisions to the UDF Final Design Plan.

2.5 Disposition of On-Site Debris Piles

As discussed in the Revised Final PDI Summary, the GE Parcel contains stockpiled debris, The initial characterization of the debris piles indicated that the debris consists primarily of crushed concrete, concrete slabs, pavement millings, and brick and rubble. These materials will be further characterized and evaluated for possible on-site reuse or off-site disposal, with the results and proposal for disposition to be presented in the UDF SIP.

2.6 UDF Components

2.6.1 Perimeter Berm and Baseliner System

The UDF will be encircled by a perimeter berm as shown on Design Drawings 4A and 4B. The perimeter berm is anticipated to be constructed from site soils excavated from within and adjacent to the UDF footprint. The perimeter berm will be elevated to protect the UDF from inundation by surface water run-on from outside of the UDF footprint and will provide support of systems designed to contain leachate generated within the consolidation area. The perimeter berm also will provide vehicle access to the UDF perimeter and, following closure, stormwater conveyance for runoff from the final cover. Design Drawing 13 shows additional details of the perimeter berm.

The UDF design includes a baseliner system beneath the consolidation materials, extending across the floor of the UDF and along the interior side slopes of the perimeter berm. The baseliner system will consist of two composite liners – an upper (primary) liner and a lower (secondary) liner. The primary liner will consist of a combination of a high-density polyethylene (HDPE) geomembrane underlain by a geosynthetic clay liner. The secondary liner will consist of a combination of an HDPE geomembrane underlain by a geosynthetic clay liner and a one-foot-thick compacted clay liner.

For reference purposes, Figure 2 shows the distance between the UDF limits of consolidated material (i.e., approximate edge of the UDF baseliner system) and the Housatonic River 500-year floodplain, which is estimated to be 1,340 feet. The ground elevation at the 500-year flood boundary closest to the UDF consolidation limit is about 950 feet (based on interpolation of FEMA panel 250028/0003/B and the 2008 topographic survey elevation contours by SK Design Group). The lowest elevation at the perimeter berm crest (baseliner bottom at the top of the berm sideslope) is approximately 1010 feet. The lowest bottom of baseliner on the cell floor is approximately 974 feet (excluding sump depth).

A primary leachate collection system will be included above the primary liner, and a secondary leachate collection system will be included between the primary and secondary liner systems. The primary system will collect leachate from the overlying consolidation material and convey the leachate to a sump(s) for removal from the UDF. The secondary leachate collection system will function as a secondary system for the primary liner and will also convey leachate to a sump(s). As required by EPA's April 18, 2023 conditional approval letter for the UDF Conceptual Design Plan, GE has developed a Response Action Plan (RAP) to describe the monitoring and response actions for leachate that may be detected in the secondary liner system. That RAP is provided as Appendix B.

The UDF will be divided into two cells separated by an intercell berm constructed of compacted clay. In terms of leachate management, the cells will be hydraulically separated, and each will have its own collection sump. The cells may be constructed at the same time or in phases as waste disposal capacity is needed. Further detail regarding the perimeter berm and baseliner system is provided in Section 3.

2.6.2 Final Cover System

The UDF final cover system design includes cover soils capable of supporting permanent vegetation and subsurface geosynthetics to minimize the percolation of precipitation into the consolidation area and, hence, leachate generation, following closure. The final cover system will be constructed on a soil layer that will provide separation from the underlying consolidation materials, allow for finish grading and smoothing of the final cover subbase surface, and serve as a gas venting layer. A composite layer of an HDPE geomembrane underlain by a geosynthetic clay liner will comprise the hydraulic barrier of the final cover system and will be placed directly on the prepared subgrade. A geocomposite drainage layer directly above that barrier will provide for collection and conveyance of precipitation that infiltrates through the overlying cover soils. The drainage layer will also improve stability of the cover system by limiting buildup of porewater pressure in the cover soils. Design grading and configuration of the final cover, which consider surface water management and slope stability, are shown on Design Drawings 8 and 25. Additional discussion regarding the final cover system is provided in Section 4.5; and further details will be provided in the Final Cover/Closure Plan for the UDF, to be submitted at least a year before the UDF is full or excavation and dredging activities are complete, in accordance with Section 4.3.2.5 of the Final Revised SOW.

2.6.3 Leachate Management System

As mentioned in Section 2.5, the UDF includes two individual cells, each with its own primary and secondary leachate collection systems. Leachate will be removed from each cell using a sideslope riser pipe that extends from the top of the perimeter berm down to the leachate collection sump at the toe of the perimeter berm. Each sump will be subdivided into primary and secondary systems by the UDF baseliner. Separate primary and secondary sideslope riser pipes will be located in each cell's subdivided sump. A submersible pump will be maintained in each sideslope riser pipe within the sumps to allow for automated evacuation of leachate that collects. These pumps have been sized and modeled to ensure that the estimated leachate flow rate into the sumps can be adequately removed. The submersible pumps will convey leachate though a flexible hose that connects the pumps to pressurized, double-contained HDPE pipes (referred to as force main pipes) buried in the perimeter berm. These leachate force main pipes will extend to a leachate storage facility at the southern end of the UDF, as shown on Design Drawing 19. Further details regarding the leachate management system design are provided in Section 3.3.6.

During initial UDF operations, collected leachate will be conveyed to and temporarily stored in two on-site storage tanks, as described in Section 3.3.6.4. The stored leachate will then be removed and transferred by tanker truck for treatment and disposal at GE's Building 64G water treatment facility at its Pittsfield facility or another approved treatment facility outside the UDF property. Additional details regarding such off-site treatment and disposal, including the identification of an approved off-site treatment facility other than Building 64G if such a facility is planned to be used, will be provided in the UDF SIP.

During future UDF operations associated with hydraulic dredging and pumping (if performed), collected leachate may be treated at an on-site treatment facility at the GE Parcel and discharged to the Housatonic River. In that case, the management and treatment of leachate and discharge of treated effluent will be in accordance with appropriate NPDES discharge limits as provided in Table 1. The on-site treatment facility and related effluent discharge systems (if required) will be designed in coordination with design submittals associated with hydraulic dredging and pumping activities (i.e., the design work plans for Reach 6); and the on-site treatment facility design, as well as a description of the requirements for sampling and testing of the effluent from that treatment facility, will be submitted to EPA for review and approval at that time.

2.6.4 Stormwater Management System

The UDF final design includes a comprehensive stormwater management system consisting of open channels (ditches), culverts, and infiltration basins. A drainage ditch located along the full perimeter of the consolidation area has been designed to collect and convey surface water runoff to an infiltration basin (North Stormwater Basin) located north of the UDF. The southern portion of the UDF operations area will drain via overland flow and perimeter ditch flow to an infiltration basin (South Stormwater Basin) located at the southern end of the GE Parcel. Runoff from peripheral areas, including the exterior side slope of the UDF perimeter berm above the former gravel pond, will be managed by smaller infiltration areas along the edges of the UDF. These smaller infiltration areas have been designed to manage UDF-related runoff in a manner that provides for management of the volume of runoff that is equal to or less than the runoff that would be generated under existing site conditions. The UDF stormwater management system is shown on Design Drawing 9. Further details of the UDF stormwater management system design are provided in Section 4.6.[4]

2.7 UDF Operational and Support Areas

The UDF operational and support areas included in this Final Design Plan have been designed to facilitate the placement and containment of consolidated soil and sediment materials within the consolidation area shown on Design Drawing 7. The UDF operational area will include features such site access roads, stormwater

[4] That section also includes an evaluation of current (existing) surface water drainage features and routes at the GE Parcel and how the UDF will alter those drainage features, including areas subject to increased and decreased surface water runoff and any potential negative impacts of such a change.

management system components, leachate conveyance, storage and loadout facilities, and other areas designated for contractor use during operations. UDF support areas associated with this Final Design Plan include site areas and locations that provide access to the operational areas, areas for material and equipment staging, and areas for contractor use, as shown on Design Drawings 4A and 4B. As mentioned in Section 1, other UDF support areas that may be needed for future UDF operations associated with hydraulic dredging and pumping (if performed) include areas for sediment conveyance, sediment dewatering, and on-site leachate treatment facilities. Such additional support areas will be described in later design submittals associated with hydraulic dredging and pumping activities (i.e., design work plans for Reach 6).

3 Perimeter Berm and Baseliner System

As discussed in Section 2.5, the UDF design includes an earthen berm around the circumference of the UDF and a baseliner system beneath the consolidation material and up the interior side slope of the perimeter berm, as shown on Design Drawing 5. Cross-sections depicting the perimeter berm and baseliner system and their relationship to other components of the UDF design are shown on Design Drawing 13. The baseliner system will have two composite liner systems (primary and secondary) and two leachate collection systems (primary and secondary). The components of the baseliner system are depicted on Design Drawing 14.

3.1 Performance Standards

The UDF baseliner system will comply with the performance standards stipulated in Section II.B.5.a of the Revised Permit. Additionally, the UDF baseliner system will be consistent with applicable standards for primary and secondary liner system components found in 310 CMR 19.110: *Ground Water Protection Systems*.

3.2 Perimeter Berm Design

The perimeter berm is a fundamental component of the UDF and will provide numerous functions. The perimeter berm will control both surface water run-on from outside of the UDF and, in combination with the baseliner system, leachate from within the UDF. The perimeter berm will also provide vehicle access to the UDF and include stormwater drainage features that will function during operation of the UDF as well as following closure of the UDF. Both the baseliner and final cover systems will terminate on the perimeter berm. Finally, the perimeter berm will provide space in which to construct utilities needed during UDF operation.

As designed, the perimeter berm will create a waste consolidation area of approximately 13.1 acres, which is less than the maximum of 20 acres allowed by the Revised Permit. Design conditions that established the size of the consolidation area include accommodation of the Eversource overhead electric utility line easement and associated features to the west and south of the UDF, the parcel boundary configuration to the east of the UDF, and the habitat areas to the north of the UDF. Given those constraints, the resulting 13.1-acre consolidation area represents the maximum horizonal limits for positioning of the UDF perimeter berm and associated stormwater management features. Given those maximum horizontal limits, the remaining design variables controlling the UDF waste consolidation capacity are the depth of the baseliner (relative to groundwater and associated minimum separation distance) and the height (peak elevation) of the final cover.

The perimeter berm will be trapezoidal in cross-section with a perimeter drainage ditch formed into the top surface near the berm centerline. The perimeter drainage ditch located along outside edge of the perimeter berm will be v-notch in cross-section with three-foot horizontal to one-foot vertical (3H:1V) side slopes. The perimeter drainage ditch will be of sufficient depth to convey surface water runoff from the perimeter access road and, following closure, from the final cover system. Runoff collected by the perimeter drainage ditch will be routed to an infiltration basin located to the north of the UDF (the North Stormwater Basin). A 25-foot-wide perimeter access road is included along the outside edge of the perimeter drainage ditch. The access road will be surfaced with aggregate and will have an inward cross slope of 1 to 2% to direct runoff into the perimeter drainage ditch. The outside and inside side slopes of the perimeter berm will be sloped at 3H:1V. The exterior side slope (areas outside of the perimeter access road) of the perimeter berm will be covered with topsoil and stabilized with vegetation. The interior side slope (areas inside of the perimeter drainage ditch) will be covered by the baseliner system. The perimeter berm grading is depicted as part of the subgrade design on Design Drawing 4A, and a typical perimeter berm detail is shown on Design Drawing 13.

3.3 Baseliner Design

This section describes the baseliner design, including system components, groundwater and bedrock offsets, grading design, settlement, and leachate collection system design. The UDF design includes a baseliner consisting of a double liner system in compliance with the Revised Permit. Both the upper (primary) and lower (secondary) liner systems are composite liners having two components. The primary liner system will consist of a 60-mil HDPE geomembrane underlain by a geosynthetic clay liner. The secondary liner system will consist of a 60-mil HDPE geomembrane underlain by a geosynthetic clay liner and one foot of compacted clay with a maximum allowable permeability of 1×10^{-7} cm/s. The primary leachate collection system includes a geocomposite drainage layer. On the floor areas of the UDF, the primary leachate collection system also includes a one-foot-thick granular drainage layer above the geocomposite. The primary leachate collection system will be constructed directly above the primary liner system. The secondary leachate collection system will consist of the same components as the primary system and will be constructed between the primary and secondary liner systems.

3.3.1 Baseliner System Components

The baseliner system has two different configurations, depending on whether the baseliner is installed on floor areas of the UDF or against the side slopes of the UDF perimeter berm or intercell berm. On floor areas, the baseliner system will be composed of the following components (in descending order from top to bottom):

- *Operations Layer*
  - One foot of graded aggregate underlain with non-woven geotextile;
- *Primary Leachate Collection System*
  - One foot of granular drainage stone; and
  - Geosynthetic drainage composite (GDC);
- *Primary Liner System*
  - 60-mil textured high density polyethylene (HDPE) geomembrane; and
  - Geosynthetic clay liner (GCL);
- *Secondary Leachate Collection System*
  - One foot of granular drainage stone; and
  - GDC;
- *Secondary Liner System*
  - 60-mil textured HDPE geomembrane;
  - GCL; and
  - One foot of compacted soil clay liner having a maximum permeability of 1×10^{-7} cm/s.

On side slopes, the baseliner components have been modified to eliminate the granular drainage layers of the primary and secondary leachate collection systems, but to provide additional thickness to the operations layer so that the primary liner retains the same cover thickness for protection of the baseliner system components from heavy equipment during consolidation activities. On side-slope areas, the baseliner system will be composed of the following components (in descending order from top to bottom):

- *Operations layer*
  - Two feet of graded aggregate;
- *Primary leachate collection system*
  - GDC;
- *Primary liner*
  - 60-mil textured HDPE geomembrane; and
  - GCL;
- *Secondary leachate collection system*
  - GDC;
- *Secondary liner*
  - 60-mil textured HDPE geomembrane;
  - GCL; and
  - One foot of compacted clay liner having a maximum permeability of 1×10^{-7} cm/s.

The HDPE geomembranes in the baseliner system are widely used in environmental containment systems and are chemically compatible with PCBs. The permeability of intact geomembranes is very low and typically on the order of 1×10^{-13} cm/s, which is many times less permeable than the maximum value allowed by the Revised Permit. The maximum allowable permeability for the compacted clay layer in the secondary liner complies with the value identified in the Revised Permit. The thicknesses of the HDPE geomembranes are greater than (i.e. double) the minimum required by the Revised Permit. Components of the baseliner system are depicted on Design Drawing 14. Material specifications for construction of the baseliner system components (i.e., geosynthetics and soil materials) are provided in Appendix C.

3.3.2 Groundwater and Bedrock Offsets

The Revised Permit and Massachusetts solid waste landfill regulations both stipulate minimum vertical offsets from bedrock and groundwater. Section II.B.5.a of the Revised Permit requires that the UDF baseliner have a minimum 15-foot vertical offset above the seasonal high groundwater elevation. According to 310 CMR 19.110(6), the lowermost low-permeability layer of the baseliner must be a minimum of four feet above the top of bedrock or the maximum high groundwater table. Complying with Revised Permit requirement, therefore, also satisfies the groundwater offset specified in 310 CMR 19.110(6).

Groundwater elevation gauging at the UDF site was a component of the PDI, as discussed in Section 2.3.6. The collected elevation gauging data has been evaluated and modified by a technical method (Frimpter method) that was reviewed and accepted by EPA. The Frimpter method takes into account historical groundwater level fluctuations at similarly sited long-term monitoring wells in Massachusetts. The Frimpter method calculation results have been used in the final UDF design to establish the bottom elevation of the UDF baseliner system that provides an offset distance between the estimated seasonal high groundwater elevation and the UDF baseliner of at least 15 feet. As shown on Design Drawing 12, the final UDF design provides an offset distance that exceeds the minimum required 15-foot offset. Two geologic cross-sections (east-west and north-south) have been prepared showing the UDF design grading for the perimeter berm, baseliner, and final cover system limits in relation to groundwater elevations, including the estimated seasonal high groundwater elevation. The locations of those cross-sections are shown on Figure 3, and the cross-sections are provided on Figures 4 and 5.

The top-of-bedrock elevation was confirmed at three boring locations as part of the PDI. The highest top-of-bedrock elevation occurred at 957.5 feet at the boring for monitoring well MW-2022-1D. The top of bedrock was lower at the other two locations (in the borings for monitoring wells MW-2022-2 and MW-2022-3). A comparison of the final UDF baseliner floor elevations with the three confirmed bedrock elevations determined the offset to be significantly greater than the four-foot minimum specified in 310 CMR 19.110(6) – specifically, at least 15 feet based on the lowest bottom of baseliner elevation of 972.6 and the highest bedrock elevation of 957.6 at boring MW-2022-1.

3.3.3 Grading Design

The floor of the baseliner will have a minimum slope of 2% (post-settlement) to conform with 310 CMR 19.110 and to ensure drainage within the primary and secondary leachate collection systems towards the designated leachate collection sump areas. To maximize airspace efficiency, the floor of the UDF will be sloped to generally mirror the slope trend of the [Frimpter-]estimated seasonal high groundwater elevations across the GE Parcel in the UDF area. The maximum slope of the baseliner system will be 3H:1V against the interior side slopes of the perimeter berm and against the side slopes of the intercell berm. These slope gradients are commonly used in landfill baseliner design and construction. The UDF subgrade is depicted on Design Drawing 4B. Within the consolidation area, the grading depicted on Design Drawing 4B is the bottom of the baseliner system while the grading shown outside of the limits of consolidation is final grade. Grading for the top of the baseliner system is depicted on Design Drawing 5. The top of consolidation material grading is shown on Design Drawing 7 and final grade, which includes the final cover system thickness, is depicted on Design Drawing 8.

3.3.4 Baseliner Subgrade Excavation Stability

Stability of the temporary subgrade excavation condition was evaluated using deep-seated circular failure surfaces for static conditions. This analysis was performed using the Spencer method, which satisfies both moment and force equilibrium, at critical cross-section locations. Circular searches with forced exit and entry locations were used to evaluate failure surfaces for each cross-section. The limits of the exit/entry zones are varied to estimate the critical failure surface and corresponding minimum factor of safety.

The evaluation was conducted with a construction surcharge of 250 pounds per square foot positioned at the top of slope for each section and compared to a minimum factor of safety of 1.30 for the temporary excavation subgrade. Factor-of-safety values for the sections analyzed for the baseline subgrade condition meet or exceed this minimum required value. Calculations pertaining to the baseliner stability evaluations are provided in Appendix D-1.

3.3.5 Settlement Analysis

Design of the UDF baseliner system considers settlement with regard to consolidation of soils underlying the UDF in response to constructed overburden materials (i.e., baseliner system, consolidated material, final cover system). Analyses and evaluations pertaining to potential floor settlement conditions within the UDF baseliner area were conducted, which estimated that up to about 1.6 feet of settlement could occur within the floor area. Those evaluations showed that settlement would be greatest in the deeper areas of the UDF cells, which could result in the post-settlement baseliner floor grades becoming steeper (not flatter). As such, the baseliner floor subgrade is designed at 2% to conform with 310 CMR 19.110 but could potentially increase in areas to around 3.5% following consolidation. Assessment of the baseliner geomembrane performance in response to the estimated floor settlement was also conducted. That assessment showed that geomembrane strain resilience (tensile properties) for a 60-mil HDPE geomembrane will be sufficient to maintain barrier integrity after settlement. Calculations pertaining to leachate collection system components for the baseliner system floor have been designed based on the 2% gradient and are therefore considered conservative given that the floor gradients could become steeper with consolidation (i.e., the capacity of the drainage components would increase with steeper gradients).

The baseliner subgrade floor grades and corresponding slopes (pre-settlement condition) are shown on Design Drawing 4B. Settlement calculations for the UDF baseliner floor area are provided in Appendix D-2. Calculations pertaining to the baseliner liner geomembrane response to settlement are also provided in Appendix D-2.

3.3.6 Leachate Collection System Design

The leachate collection system components within the limits of UDF baseliner include primary and secondary collection pipes, sumps, and side-slope riser pipes as well as riser vaults). Identification of those components and their general layout are shown on Design Drawing 6. The leachate transfer and storage system components (i.e., the components located beyond the leachate collection system components) include force main pipes, manholes, storage tanks, and loadout area. Those components and their general layout are shown on Design Drawing 18. Further details of the leachate collection, transfer, and storage systems are provided in the following sections. As noted above, GE's Response Action Plan for leachate that may be detected in the secondary leachate collection system is provided in Appendix B.

3.3.6.1 Drainage Layer Design

The UDF baseliner system includes two separate drainage layers, referred to as the primary and secondary drainage layers. The primary drainage layer will collect liquids generated within the limits of the baseliner system resulting from precipitation in uncapped areas of the UDF and consolidation water generated from the waste materials placed within the UDF. The secondary drainage layer will capture liquid that may inflow from the baseliner primary liners. Design of the primary leachate collection system considers the rate of liquid reaching the drainage layer under active (uncapped) conditions and closed (capped) conditions, with the former anticipated to govern the system design capacity.

A water balance model was developed for the UDF leachate collection system design using the EPA's Hydrologic Evaluation of Landfill Performance software, which estimates the peak rate of liquid reaching the primary leachate collection system. Although the primary system includes both a granular drainage layer and a synthetic drainage layer (geocomposite) in the floor areas of the UDF, the geocomposite will be designed to provide capacity to convey this estimated peak flow to the downstream features (e.g., leachate collection pipes or sumps) without relying on the capacity contribution from the overlying granular drainage layer. On side-slope areas of the UDF baseliner, the granular drainage layer is omitted because of the greater capacity within the geocomposite due to steeper gradients on the side-slope areas. The geocomposite in the secondary leachate collection system will be composed of the same material and have the same hydraulic capacity as the primary geocomposite. Because the secondary system typically has much lower flow rates than the overlying primary system, this will provide a conservative design basis for the secondary leachate collection system. Calculations for the primary drainage layer design are provided in Appendix E-1, including calculations for the ability of the drainage layer to properly drain leachate to the collection system.

3.3.6.2 Leachate Collection Pipe Design

Leachate collection pipes will be used to remove collected leachate from the geocomposite layer (discussed in Section 3.3.5.1) and convey the liquid to leachate collection sumps located within each cell. Leachate collection piping is included in both the primary and secondary leachate collection system of each cell. The collection piping will be perforated to allow leachate to enter the piping along the floor of the UDF. Non-perforated cleanouts pipes will extend from the perforated pipes to a height above final grade along the top of the perimeter berm. These cleanouts will allow for periodic, remote inspection and/or maintenance access as needed.

Both perforated and non-perforated piping will consist of fused solid wall (standard dimension ratio type) HDPE construction. Collection piping will be located based on the designed baseliner system grading (e.g., coincident with areas of leachate confluence) and/or at appropriate spatial intervals as needed based the capacity of the contributing geocomposite and the rate at which leachate is expected to reach the primary leachate collection system. Similar to the geocomposite in the primary and secondary leachate collection systems, the leachate collection pipe design for the secondary system is identical to that in the primary system. The capacity of the collection piping will be based on the Manning equation for pipe-full conditions. The structural performance of the leachate collection piping has been analyzed to verify that the pipe strength is sufficient to withstand the anticipated loading from burial and equipment operations in the UDF. Calculations for the leachate collection pipe design are provided in Appendix E-2.

3.3.6.3 Leachate Sump Design

Each UDF cell will include a primary and a secondary leachate collection sump located at the cell low points shown on Design Drawings 5 and 6. The sumps will serve to collect leachate draining to them from upgradient (perforated) leachate collection pipes as well as from baseliner areas immediately surrounding the sumps. As shown on Design Drawings 16 and 17, the sumps will consist of a depression constructed at the toe of the perimeter berm, which will allow for installation of sump collection and connected sidewall riser pipes that provide access to the sumps from the top of the perimeter berm for leachate removal purposes. The sump depression will be of sufficient size (length, width, and depth) to allow for installation of the floor baseliner system components (both primary and secondary), perforated HDPE leachate collection pipes (eight-inch diameter), and sump collection pipes (24-inch diameter primary and 18-inch diameter secondary). For leachate removal (pumping) purposes, the sump configuration provides additional depth (approximately six inches) for reservoir capacity.

Access to the primary and secondary sumps to facilitate leachate removal will be provided by (solid wall) riser pipes that connect to the sump collection pipes and extend up to the crest of the perimeter berm where the pipes then enter the riser vault structure. The riser pipes and underlying baseliner system components will be recessed in a trench on the cell side slope. The riser pipes, trench, and vault structures are shown on Design Drawings 15, 17, and 19. As with the leachate collection pipes, the structural performance of the sump collection and side-slope riser pipes has been analyzed to verify that the pipe strength is sufficient to withstand the anticipated loading from burial and equipment operations in the UDF. Calculations for those pipe designs are provided in Appendix E-3.

3.3.6.4 Leachate Conveyance Design and Storage Tank Sizing

As described above, leachate collected in the UDF cells will be pumped from the primary and secondary sumps to a vault structure constructed for each cell at the top of the perimeter berm. From the vaults, the leachate will be routed to a double-wall HDPE force main located in the perimeter berm access road, which will convey the pumped leachate to two double-wall steel tanks for temporary storage. As shown on the design drawings, two separate leachate conveyance force mains will allow for servicing of the force main pipes with little interruption of leachate conveyance to the storage tanks.

Stored leachate will be transferred into tanker trucks at the leachate loadout area. The locations of the leachate force mains, storage tanks, and loadout area are shown on Design Drawings 6, 18, and 19. Calculations pertaining to the leachate conveyance system and tank sizing are provided in Appendix E-4 and E-5, respectively. As noted in Section 2.6.3, the tanker trucks will then transfer the leachate to GE's Building 64G water treatment facility at its Pittsfield facility or another approved treatment facility outside the UDF property (to be identified in the UDF SIP).

3.4 Site Excavation and Backfill Earthwork Quantities

Following the site preparation illustrated on Design Drawings 3A and 3B, excavation for UDF construction will proceed to the subgrade elevations within the consolidation area depicted on Design Drawings 4A and 4B. Note that those drawings also depict fill placement needed to construct the perimeter berm. It is anticipated that excavated soil can be used as fill to create the perimeter berm and other peripheral features requiring fill. The intention is to maximize the re-use of excavated soil material while achieving compliance with the performance standards of the Revised Permit (discussed in Section 2.1).

A mass earthwork analysis was performed as part of this Final Design Plan. That analysis was inclusive of the perimeter berm and peripheral grading shown on Design Drawings 4A and 4B, which includes the North and South Stormwater Basins and exterior site access roads. The estimated gross earthwork quantities have been adjusted to account for material quantities associated with the gravel access roads and topsoiled site areas. .

Provided below in Table 2 are mass earthwork quantities generated from the analysis of the UDF site design. These quantities exclude the on-site debris stockpiles to be characterized at a later date. The surplus excavated materials will be evaluated for potential reuse as part of the overall ROR Remedial Action.

Table 2. Mass Earthwork Volume Estimate

Gross Excavation Volume	Gross Fill Volume[1]	Gross Surplus Excavation Volume
715,000 cy	430,000 cy	285,000 cy

Note:

[1] Assumes that excavated material is suitable for re-use in construction for required fill components.

4 Buildout and Final Cover System

Buildout of the UDF includes completion of consolidation material placement and installation of the final cover system. During operation of the UDF, consolidation materials delivered to the cells will be placed to generally achieve the design grades depicted on Design Drawings 7 and 13. Following placement of consolidation materials, the consolidation area will be covered with a multilayered geosynthetic final cover system to isolate the consolidated material from direct contact with the environment, minimize leachate generation, and support the establishment of vegetation. Final cover construction will be performed in a phased manner as described below. The final cover system has been designed to minimize precipitation infiltration through the final cover system liner.

4.1 Performance Standards

The design of the UDF final buildout and cover system complies with the performance standards specified in Section II.B.5.a of the Revised Permit. Additionally, the UDF final cover system is designed to be consistent with the relevant standards for the final cover system components found in 310 CMR 19.112: *Landfill Final Cover Systems*.

4.2 Final Cover Phasing and Fill Plan

Final cover construction will be performed in a phased manner to reduce the generation of leachate due to rainfall and snowmelt and to confine the consolidation material at the earliest opportunity. The timing and extent of each phase of final cover construction will be driven by the actual rate of consolidation material placement, the ability to achieve final consolidation grade while leaving sufficient open area for ongoing consolidation filling operations, and the ability to manage stormwater runoff and maintain separation between contact and non-contact water.

Construction of the UDF cells (Cells 1 and 2) will be completed during the initial phase (Phase 1). Cell operations will commence in Phase 2 with consolidated material placement beginning in Cell 1. During Phase 2, consolidated material placement and associated truck access will be restricted to Cell 1 and contact water (precipitation and run on to Cell 1) will be managed by the Cell 1 leachate collection-removal system. Because no consolidation material will be placed in Cell 2 during Phase 2 and therefore no contact water will be generated, water accumulation within Cell 2 will be managed as non-contact water that can be removed from the cell and discharged to the UDF stormwater drainage system. Placement of consolidated materials in Cell 2 will commence in Phase 3, at which time water accumulation in Cell 2 will be managed as contact water and removed by the Cell 2 leachate collection-removal system. Material consolidation filling will continue in both Cells 1 and 2 during Phase 4 with placement elevations reaching design grades shown on Design Drawing 7 in areas of the UDF (anticipated to be in the northern portion of Cell 1 first). During Phase 5, the first portion of final cover will be constructed with continued consolidation material filling occurring in the remaining portions of the UDF cells. Filling of the uncapped cell areas will be completed in Phase 5 to the design grades shown on Design Drawing 7. The remaining portion of final cover will be constructed in Phase 6, at which time the UDF will enter the post-closure phase. The potential sequence for consolidation material placement and final cover construction is illustrated on Design Drawing 10.

Design drawings and technical specifications specific to each phase of final cover construction will be developed and submitted for EPA review and approval prior to construction.

4.3 Buildout

Buildout of the consolidation material grading will be dependent on the actual, final volume of material delivered to the UDF. At a minimum, it is expected that consolidation filling will exceed the elevations of the final cover diversion berm shown on Design Drawing 9. Completion of filling above the diversion berm elevations will allow for collection and routing of stormwater runoff to the North Stormwater Basin in a controlled manner that minimizes erosion. The diversion berm also serves to enhance stability of the UDF consolidation material and final cover system. The final elevation of the UDF plateau area may vary from those shown on Design Drawing 7 due to potential variation in the final disposal volume. In the event that consolidation material placement is completed below the design elevations, the actual completed elevations will be evaluated, and any adjustments made to ensure that the final elevations satisfy the requirements necessary for final cover construction.

4.3.1 Global Stability

Cross-section(s) through the UDF representing design excavation subgrade completed for construction of the baseliner system and final closure conditions have been evaluated for global stability. Global stability of the design conditions was evaluated based on the Spencer method of analysis using SLOPE/W (Geo-Slope International Ltd., Slope/W 2019), a slope stability modeling software. Design slopes were analyzed for both static and pseudo-static (seismic) conditions. Further discussion of this slope stability analysis is provided in the following subsections.

4.3.1.1 Model Development

Input parameters and results for the global stability models are discussed below. Soil parameters used in the slope stability model evaluations were estimated for each material type (i.e., dredged soil and sediment consolidation materials, underlying soils, and compacted perimeter berm and final cover soils). The input soil parameters corresponding to these material types included material unit weight (in pounds per cubic foot), shear strength in terms of internal angle of friction (in degrees), and cohesion (in pounds per square foot), as applicable. These estimated material properties were derived from a review of boring logs of soil borings advanced at the UDF area and from the results of geotechnical laboratory testing.

Geosynthetic shear strength parameters could represent the weakest interface shear strength for the UDF. For purposes of this global stability evaluation, the baseliner system components were modeled as one layer. The assumed shear strength for this single modeled layer represents the critical (weakest) interface of the collective layers that it represents. Groundwater was included in the stability models and was based on elevation data collected from the site groundwater monitoring wells and piezometers.

For the pseudo-static evaluations, a peak ground acceleration was developed from the Unified Hazard Tool of the U.S. Geological Survey Earthquake Hazards Program. Based on the site location, the Unified Hazard Tool estimated a peak ground acceleration of 0.084 of the acceleration due to gravity. Consistent with industry standards for seismic stability using the pseudo-static approach, vertical acceleration is taken as 0.0.

The results of the global stability analyses are summarized in the following subsection.

4.3.1.2 Global Static and Seismic Stability

Global stability of the UDF was evaluated using both deep-seated circular failure surfaces through the UDF and sliding-block failures surfaces within the UDF baseliner system. These evaluations addressed both static and pseudo-static conditions. Five sections through the UDF limits were evaluated under final grading conditions, including, where appropriate, evaluations of the perimeter berm. The analyses were performed using the Spencer method, which satisfies both moment and force equilibrium. Searches with forced exit and entry locations were used to evaluate failure surfaces for each cross-section. Searches for circular surfaces were used to evaluate the global stability of the consolidated material and the perimeter berm. To evaluate the stability of the weakest interface in the baseliner system, searches for sliding-block surfaces were completed along both the bottom baseliner and the side slopes of the lining system. The limits of the exit/entry locations are varied to estimate the critical failure surface and corresponding minimum factor of safety.

The static cases were evaluated with a temporary construction surcharge of 250 pounds per square foot positioned at the top of slope for each section and compared to a minimum factor of safety of 1.50. For the (seismic) pseudo-static evaluations, a minimum factor of safety of 1.0 was required. Factor-of-safety values for the sections analyzed for this conceptual design meet or exceed these minimum required values. Calculations for the global stability evaluations are provided in Appendix D-1.

4.4 Liquefaction Analysis

Liquefaction is associated with a reduction in soil shear strength and volumetric reconsolidation that can result in ground deformations and settlement. To assess the potential for liquefaction for the foundation soils at the UDF, a widely used method referred to as the “simplified procedure” was used to analyze the triggering of liquefaction (Youd et al. 2001). Standard penetration test (SPT) data from site borings drilled for this project were used to estimate the cyclic resistance of the soils encountered in the borings. The cyclic stresses during seismic shaking were calculated using the simplified approach developed for the “simplified procedure.” Input parameters also included earthquake magnitude and maximum acceleration at the ground surface. Based on the analysis results, the foundation soils at the UDF are not expected to liquefy during the design seismic event. Calculations for the liquefaction analysis are provided in Appendix D-3.

4.5 Final Cover Design

This section describes the final cover design, including system components, grading design, settlement, slope stability, and disposal capacity. More details regarding the final cover will be provided in the Final Cover/Closure Plan for the UDF in accordance with Section 4.3.2.5 of the Final Revised SOW when the UDF is closer to being closed.

4.5.1 Final Cover System Components

The final cover system will consist of the following components (in descending order from top to bottom):

- Six-inch-thick topsoil layer;
- Eighteen-inch-thick general fill soil layer;
- Geocomposite drainage layer;

- 60-mil textured HDPE geomembrane;
- Geosynthetic clay liner; and
- Six-inch-thick gas venting soil subbase layer.

The layering and individual final cover components will meet the applicable performance standards in the Revised Permit and the relevant standards in 310 CMR 19.112 for final cover system components. The total cover soil thickness of 24 inches (excluding the gas venting soil subbase layer) is greater than the minimum thickness required by 310 CMR 19.112(9). As with the baseliner, the HDPE geomembrane in the final cover system is widely used in environmental containment systems and is chemically compatible with PCBs. The permeability of intact geomembranes is very low and typically on the order of 1×10^{-13} cm/s, which is many times less permeable than the maximum value allowed by the Revised Permit. The thicknesses of the HDPE geomembrane to be used in the final cover is greater than (i.e. double) the minimum required by the Revised Permit. Components of the final cover system are depicted on Design Drawing 25. Material specifications for construction of the final cover system components – i.e., geosynthetics and soil materials – are provided in Appendix C. They include criteria for the concentrations of PCBs and other chemical constituents in the soil materials to be used for the cover construction.

4.5.2 Grading Design

The UDF final grading plan following final cover installation is depicted on Design Drawing 8. The maximum (peak) elevation of the UDF, inclusive of the final cover, is 1,099 feet, which is the maximum elevation described by the Revised Permit.

The plateau of the final cover system is designed to promote positive drainage of surface water runoff to collection drainage swales and culverts and to minimize infiltration of precipitation within the consolidation area. These drainage features are located on the final cover such that overland flow of stormwater runoff is intercepted at a flow length that controls soil loss conditions to less than two tons per acre per year. Calculations pertaining to the estimated soil loss conditions for the UDF final cover are provided in Appendix F-1. A minimum slope of 5% is provided on the plateau of the final cover to comply with 310 CMR 19.112(2). The side slopes of the final cover system will have a maximum slope of 3H:1V that considers slope stability requirements and complies with 310 CMR 19.112(2). Further discussion of slope stability is provided in Section 4.5.4.

4.5.3 Gas Venting System

Based on the types of materials to be consolidated at the UDF (i.e. river sediment, floodplain soil, and associated debris), it is not anticipated that significant degradation of organic material will occur within the consolidation cells. Additionally, the placement method(s) used to consolidate materials in the UDF cells (i.e., controlled and compacted lift thicknesses, minimized occurrence of concentrated organic material) will further reduce the potential for gas generation. However, as a conservative measure, the UDF final cover system includes a provision for management of potential gas accumulations beneath the final cover. Gas generation and its potential effects on the final cover (veneer) stability are preliminarily addressed in the final cover system design in this Final Design Plan. The final design of the components and layout of the UDF gas-venting system will be provided in the UDF Final Cover/Closure Plan and will consider laboratory test data obtained from the soil and sediment excavation designs for the river and completed consolidation material grading conditions. Further discussion of the components and preliminary layout of the UDF gas venting system is provided below.

The UDF final cover system will include a soil subbase layer that will be composed of permeable soils. This subbase soil may be sourced from selected on-site soils composed largely of sandy material or may be imported from off-site sources. The subbase layer will be placed over the full extent of the final cover area to a minimum thickness of six inches and will provide a means for gas collection and conveyance to highpoints beneath the final cover system. Strips of GDC will be placed along ridge lines (highpoints) and at other designated locations to facilitate gas movement to venting locations. Vertical vent pipes will be installed at a number of locations on the final cover to allow for venting of collected gas; the preliminary locations of the vent pipes are shown on Design Drawing 8. Additional preliminary details regarding the vent pipes and collection system are shown on Design Drawing 38.

4.5.4 Slope Stability Analysis

The final cover system veneer stability has been evaluated for long-term static stability, short-term static stability (during construction with equipment loading) and seismic conditions. A procedure developed by Koerner and Soong (Reference 4) for finite slope lengths has been used to evaluate stability for the static (both peak and residual) and seismic conditions. This method is often referred to as the GRI-215 method and is performed by evaluating the gravitational forces acting on a finite length of the cover system, including the buttressing effects of soil at the bottom of the slope. Minimum required shear strengths are calculated for short-term, long-term, and seismic conditions based on achieving minimum target FOS values. These target FOS values are dependent on the condition being evaluated.

In order to achieve the minimum factors of safety under long-term static conditions, a minimum shear strength equivalent to a friction angle of 25.5 degrees (peak) and 20.6 degrees (residual) over normal loads ranging from 250 psf to 1,000 psf is required. For short -term static conditions with equipment loading, a minimum shear strength equivalent to a friction angle of 23.1 degrees (peak) and 18.1 degrees (residual) over normal loads ranging from 250 psf to 1,000 psf is required. Results for the seismic condition require a minimum shear strength equivalent to a friction angle of 21.9 degrees (residual) for the same normal load range as the static cases. Therefore, the long-term static condition requirements govern the required peak interface shear strength. Calculations for the veneer stability analysis are provided in Appendix D-4.

Acceptability of the proposed cover system materials will be determined by laboratory testing of each soil-to-geosynthetic and geosynthetic-to-geosynthetic interface (ASTM D5321) and by direct shear testing (internal friction angle) of fill materials (ASTM D3080). Testing will occur at representative normal loads to establish shear resistance over the range of conditions. Laboratory test results will be required to demonstrate interface and internal shear strengths equal to or greater than the minimum acceptable friction angles summarized above, prior to material acceptance. Testing will be in accordance with project specifications.

4.5.5 Settlement Analysis

Design of the UDF final cover system considers settlement with regard to consolidation of the materials placed within the UDF which directly underly the final cover system. That settlement may potentially occur as porewater entrained within the pore space of the consolidated soil and sediment materials is squeezed out due to loading and subsequent compression of the materials. The amount of settlement estimated for the consolidated materials in the UDF plateau area (i.e., the final cover area with the flattest slope gradient and thickest fill depth) is less than approximately two inches. Evaluation of the estimated settlement conditions (i.e., the depths and locations within the UDF cells) and the design grading for the final cover system shows that the minimum 5% grade provided for the final cover is sufficient to maintain proper drainage of surface runoff and infiltration water collected in the final cover drainage layer post-settlement. Settlement calculations pertaining to the final cover system are provided in Appendix D-2.

4.5.6 Consolidation Capacity Design

The estimated gross volume capacity of the UDF has been determined by making a volumetric comparison of the consolidation grade elevations shown on Design Drawing 7 to the top of baseliner elevations shown on Design Drawing 5 within the consolidation area limits. The results of this comparison indicate that the gross volume capacity for consolidation material placement will be 1.3 million cy. The UDF final grading has been designed to allow for adjustment of final grades (both consolidation material and final cover) that may be necessary to accommodate possible variation in the final disposal volume if it should be less than the 1.3 million cy capacity provided in this Final Design Plan.

4.5.7 Final Cover Installation

As discussed in Section 4.2. the UDF final cover will be installed in a phased manner on areas that have achieved final grade and where installation of the final cover will not impact continued operation of the UDF as required prior to final closure, considering the management of stormwater in a manner that minimizes generating contact water resulting from final cover areas and continuing consolidation material placement operations. Design Drawing 10 depicts a possible sequence for two phases of final cover construction (Phases 5 and 6). The amount of final cover completed during the initial installation phase will be dependent on a number of factors, including but not limited to, the acreage of completed consolidation filling allowing for final cover construction, provisions for the management of contact and non-contact runoff, and filling progression schedule.

4.5.8 Drainage Layer Design

The geocomposite drainage layer included in the final cover system is designed to collect and convey non-contact water that infiltrates into the final cover soil layers. This layer minimizes hydraulic head on the underlying geomembrane and geosynthetic clay liner, thereby reducing infiltration into the consolidation material and the subsequent generation of leachate. The geocomposite drainage layer enhances slope stability for the overlying final cover system layers. The design of the geocomposite drainage layer transmissivity was calculated using the maximum rate of infiltration in addition to anticipated applied loading on the final cover (sides slopes and plateau of the UDF), and the design accounts for appropriate reduction factors and factors of safety. These design parameters, among others, will be used for transmissivity testing of the geocomposite material (in both the machine and transverse directions) as part of final cover construction to confirm that the geocomposite material used will satisfy the drainage layer design conditions. Calculations pertaining to design of the final cover drainage layer capacity are provided in Appendix F-2.

4.5.9 Collection and Conveyance Piping Design

Subsurface collection and conveyance piping is designed to remove non-contact water from the geocomposite layer (discussed in Section 4.5.8) and will release the collected water into the stormwater management features on and around the perimeter of the UDF. The pipe lengths are based on the flow that reaches each foot of pipe from geocomposite drainage. The collection piping is perforated to allow non-contact water to enter the piping. Non-perforated conveyance piping will be used wherever the piping is to provide a conveyance function only.

Both types of piping are modelled as corrugated HDPE construction. Collection piping will be located coincident with surface water drainage features as shown on Design Drawing 9. The subsurface pipes will also be located at appropriate spatial intervals as needed given the capacity of the contributing geocomposite and the rate at which non-contact water infiltrates through the cover soil to the geocomposite drainage layer. The capacity of the collection and conveyance piping assumes pipe-full conditions. The flow through the pipes is calculated using the Manning Equation for 6" and 8" pipes in both the plateau and side-slope areas. Calculations pertaining to design of the final cover drainage layer collection and conveyance piping are provided in Appendix F-3.

4.6 Stormwater Management System Design

The UDF stormwater management system has been designed in accordance with the Massachusetts Department of Environmental Protection (MassDEP) Stormwater Handbook and Stormwater Standards (Stormwater Handbook; MassDEP 2008). Construction and operation of the UDF will employ best management practices (BMPs) that control stormwater runoff while minimizing erosion, sediment migration, and other potential negative impacts to adjacent areas to the UDF. The UDF will utilize multiple BMPs including infiltration basins, conveyance ditches, and stormwater management areas. Further discussion on the UDF drainage system components and their design is provided below. A Stormwater Pollution Prevention Plan for stormwater management during UDF construction and operations will be included in the UDF SIP.

4.6.1 Existing Drainage Patterns

Existing stormwater drainage conditions and runoff flow patterns at the GE Parcel were evaluated as part of the UDF stormwater management system design. This evaluation generally included the delineation of tributary watershed areas, determination of evaluation point locations that represent where existing and UDF development drainage areas coincide (i.e., points where both existing and UDF development drainage discharges from the UDF area), and assessment of watershed runoff characteristics (e.g., surface cover types, hydrologic soil groups, time of concentration flow lengths). The results of this evaluation were used as the basis for evaluation of the UDF stormwater management system to ensure that that system was designed to manage stormwater in a manner that will result in discharges that are equal to or less than existing site discharges. The design does so by providing that the UDF surface water runoff and any potential negative impacts of a change in existing conditions are mitigated in the UDF stormwater management system design, as discussed below in Section 4.6.2. The results of this evaluation of existing stormwater drainage conditions are provided in Appendix G-2.

The evaluation of existing drainage patterns determined that stormwater runoff occurring on the UDF area, which includes run-on from upgradient watershed areas, drains primarily to low points on the GE Parcel, where the accumulated runoff infiltrates into the soils. In addition to these infiltration areas, runoff was also determined to drain to the gravel pond located at the northern end of the UDF area and to a low point on the western side of the UDF area. Drainage to the gravel pond is contained within the pond. Site runoff draining to the western low point accumulates in a depressed area where it both infiltrates into the soils and overflows to an existing drainageway on the neighboring property that leads to a man-made gravel pond.

4.6.2 Design Drainage Patterns

Stormwater runoff from the final cover plateau and side slopes areas will be intercepted by surface water diversion berms on the side slope of the UDF and by drainage ditches at the top edge of the final cover plateau and on the perimeter berm. This collected stormwater will be conveyed by perimeter berm ditches and culverts to an infiltration basin (North Stormwater Basin) located north of the consolidation area. Stormwater runoff from the UDF perimeter access road will also be collected by the perimeter berm ditches and conveyed to the North Stormwater Basin. Runoff from the UDF operations areas south of the consolidation area will drain to an infiltration basin (South Stormwater Basin) located at the southern end of the GE Parcel. Runoff from the remaining UDF operational areas located outside of the UDF perimeter access road will drain to five site areas identified as stormwater management areas (SMAs). These SMAs are areas where stormwater runoff currently drains under existing conditions and where it is managed via infiltration, or in one location at SMA-4, a combination of both infiltration and direct discharge to an off-site drainageway. Further description of the UDF stormwater management system and its function to avoid negative impacts compared to current drainage conditions is provided below.

UDF drainage conveyed to the North Stormwater Basin will discharge via infiltration of soils within the basin floor. An overflow spillway (consisting of a broad-crested weir) will be located on the northern side of the basin to allow for controlled release of ponded water contained in the basin during extreme storm events. As designed, the North Basin will contain stormwater inflow up to the 100-year/24-hour design storm event without release of water through the overflow spillway. During the 100-year storm event, outflow through the spillway will be limited to about four cubic feet per second (cfs) and will flow within a reinforced channel down to an existing on-site drainage ditch that borders the basin to the north. This spillway discharge during the 100-year storm event is close to the current drainage from the North Basin area to the bordering ditch, which drains to an on-site low-lying area to the northwest of the UDF, where accumulated water is discharged via soil infiltration.

UDF drainage conveyed to the South Stormwater Basin will likewise discharge via infiltration of soils within the basin floor area. An overflow structure (inlet manhole) will be located on the western side of the basin to allow for controlled release of ponded water contained in the basin during extreme storm events. As designed, the South Basin, like the North Basin, will contain stormwater inflow up to the 100-year/24-hour design storm event without release of water through the overflow structure. During the 100-year storm event, outflow through the overflow structure will be less than one cfs and will flow within a drainpipe that outlets to a designed drainage ditch that borders the UDF perimeter berm to the south that leads to SMA-4 (discussed below).

SMA-1 is located within an existing low-lying area that receives runoff from both on-site and off-site watershed areas. The existing topography surrounding the low-lying area allows for overflow into the on-site wetland area to the north. As designed, SMA-1 will maintain the same hydrologic function as occurs under current conditions. Specifically, discharge of runoff inflow to SMA-1 will occur primarily via infiltration of soils within the designed bottom area. An overflow spillway (consisting of a broad-crested weir) will be placed on the northern side of the SMA to allow for controlled release of ponded water contained in the SMA during extreme storm events. As designed, SMA-1 will contain stormwater inflow up to the 100-year/24-hour design storm event without release of water through the overflow spillway. During the 100-year storm event, outflow through the spillway will be approximately equal to the outflow rate and peak elevation under current conditions. Outflow from the spillway will drain within a reinforced channel down to the existing wetland area north of SMA-1.

SMA-2 is likewise located within an existing low-lying area that receives runoff from both on-site and off-site watershed areas. As designed, SMA-2 will maintain the same hydrologic function as occurs under current conditions. Specifically, discharge of runoff inflow to SMA-2 will occur via infiltration of soils within the designed bottom area. Since the designed watershed area tributary to SMA-2 will be reduced compared to the existing watershed area, and since there will be only minimal changes to the watershed’s characteristics (e.g., curve number, time of concentration), SMA-2 requires no overflow feature and will manage runoff in a manner generally consistent with current conditions.

SMA-3 (composed of 3A and 3B areas) is situated in an existing low-lying area that receives runoff from on-site watershed areas. The existing topography surrounding the low-lying area allows for off-site drainage to the south near the southeastern corner of the GE Parcel. As designed, SMA-3 will maintain the same hydrologic function as occurs under current conditions. Specifically, discharge of runoff inflow to SMA-3A and 3B will occur primarily via infiltration of soils within the designed bottom areas. SMA-3A is designed to contain runoff from smaller-size storm events, with overflow via a broad-crested weir into SMA-3B during larger storm events. Collectively, SMA-3 will manage runoff resulting from the design storm events (including the 100-year storm event) in a manner consistent with current conditions and will include no greater off-site drainage than occurs under current conditions.

SMA-4 is located within an existing low-lying area that receives runoff from on-site watershed areas. The existing topography surrounding the low-lying area allows for overflow into an off-site drainageway. As designed, SMA-4 will maintain the same hydrologic function as occurs under current conditions. Specifically, discharge of runoff inflow to SMA-4 will occur partly via infiltration of soils within the designed bottom area and partly through small-diameter outflow drainpipes. An overflow spillway (consisting of a broad-crested weir) will be located on the western side of the SMA to allow for controlled release of ponded water contained in the SMA during more significant storm events. SMA-4 will contain stormwater inflow up to the 100-year/24-hour design storm event without release of water through the overflow spillway. During the 100-year storm event, the combined outflow from the drainpipes and overflow spillway will be slightly less than the outflow rate under current conditions. Overflow from the spillway will flow within a reinforced channel down to the existing off-site drainageway located to the west of SMA-4.

SMA-5 is located at the western edge of the existing man-made gravel pond that will be filled in as part of UDF construction. The gravel pond (which includes the SMA-5 area) receives runoff from on-site areas. Runoff entering the gravel pond discharges via lateral soil infiltration (i.e., dissipation into surrounding groundwater), with overflow into the adjacent gravel pond to the west via a small swale in the dividing land area. As designed, SMA-5 will maintain the same hydrologic function as occurs under current (existing) conditions. Specifically, discharge of runoff inflow to SMA-5 will occur partly via infiltration of soils within the designed bottom area and partly through an outflow drainpipe that outlets into the western gravel pond. An overflow spillway (consisting of a broad-crested weir) will be placed at the same location as the outlet drainpipe to allow for controlled release of ponded water contained in the SMA during extreme storm events. Although the 100-year peak flow from SMA-5 into the adjacent gravel pond increases under proposed conditions, the flow volume for the same event is reduced. Because the flow volume is reduced and the receptor is a pond and not a conveyance feature, the proposed conditions for SMA-5 do not create off-site flooding.

In summary, the UDF stormwater management system has been designed to control surface water runoff resulting from the UDF area in a manner that is generally consistent with current conditions (i.e., discharge via infiltration and off-site drainage) and avoids potential changes to surface water runoff conditions that might result in negative impacts to downgradient areas. Calculations associated with the UDF stormwater management system are provided in Appendix G. Additional design details are provided in the following sections.

4.6.3 Open Channel Design

Stormwater runoff from the UDF will be collected and conveyed to designated management locations in open channels. These channels include the perimeter drainage ditch located along the outside edge of the perimeter berm, surface water diversion berms located on the side slopes of the UDF itself as well as on a portion of the perimeter berm side slope above the former gravel pond, and other ditches located near the perimeter of the UDF operations area. The open channel design for these drainage features included assessment of the tributary watershed area conditions, the channel geometry and capacity (flow rate), and erosive forces. Channel capacity was evaluated using Manning's equation for open channel flow and is a function of the channel geometry that includes invert slope, cross-section, and channel roughness (based on the selected channel lining type). The potential for erosion in the open channels was evaluated for both newly constructed (bare soil) and established (vegetated) conditions, the results of which dictate the need for temporary or permanent erosion protection such as matting, riprap, or other armoring material type. The location and identification of the drainage ditch types are shown on Design Drawing 9. Calculations for the drainage ditch designs are provided in Appendix G-2.

4.6.4 Culvert Design

Culverts will be used where needed to convey stormwater beneath access roads or other features to maintain continuity of those crossing features. Culverts will also convey stormwater down the side slopes of the UDF from the plateau drainage ditch and the final cover diversion berm and from the north slope diversion berm. The culvert designs are based on the calculated peak design flow rate at the culvert inlet and accounts for energy losses within the barrel as well as at the culvert entrance and exit. The culvert designs also account for tailwater effects associated with downstream features where applicable. Each culvert includes outlet protection to dissipate flow energy and minimize erosion of the receiving (exit) ground surface. The location and identification of the drainage culverts are shown on Design Drawing 9. Calculations for the drainage culverts designs are provided in Appendix G-2.

4.6.5 Stormwater Basin Design

The two stormwater basins (North and South Stormwater Basins) shown on Design Drawing 9 have been designed to treat on-site runoff; the North Stormwater Basin will treat runoff from the final cover of the UDF and the access roads, and the South Stormwater Basin will treat the runoff form the operations area south of the consolidation area. Both stormwater basins will function as infiltration basins and have been sized and analyzed using the Dynamic Field Method referenced in the MassDEP Stormwater Handbook. Field investigations were conducted at the GE Parcel as part of the UDF PDI activities to determine design soil infiltration rates in the stormwater basin areas. The stormwater basins will act as both a water quality treatment measure and as a means for peak flow attenuation during precipitation events. The size and depth of the stormwater basins have been designed based on the estimated peak storm event flow rates and volumes resulting from the UDF post-closure site condition. The basins are designed with forebay areas to reduce inflow velocities and mitigate the migration of sediments to the basin primary infiltration area. The stormwater basin designs also include overflow spillways that allow the discharge of basin stormwater during large storm events. Overflow from these spillways will be conveyed in a controlled manner of protected (lined) channels to downstream receiving areas. Calculations for the North and South Stormwater Basins are provided in Appendix G-3.

Since the stormwater basins are designed to function as infiltration basins, it will be necessary for the basin floor areas to be maintained with exposed sandy-gravelly soils. The exposed soil bottom areas will provide optimized infiltration capacities for basin inflow which is expected to drain fully from the basins within approximately two to three days. Maintenance of the basin floor areas will consist of periodic clearing of volunteer vegetation by means of scraping with mechanized equipment.

In accordance with EPA's April 18, 2023 conditional approval letter, GE has evaluated aspects of these stormwater basins that would make those basins unattractive for use by vernal pool species from the nearby vernal pool at the GE Parcel. That evaluation is included in Section 6.2 of Appendix H. In brief, due to the short drawdown time for pooled water within the infiltration basins and the unvegetated (sandy-gravelly) substrate, the basins will not be attractive areas for those vernal pool species. In contrast, environments conducive to vernal pool species are typically composed of sustained vegetation (mixed plants, wildflowers, forest and leaf litter) and have seasonally prolonged water bodies. An additional factor that will detract from vernal pool species' use of the basins is the lack of forested fringe environments given that the areas surrounding the basins will be maintained as mowed grass and gravel surfaces. The lack of a forested fringe will leave the basin ponding areas fully exposed to sunlight with no beneficial shading from forest canopies to manage pooled water temperatures, which will further diminish their conduciveness to use by vernal pool species.[5]

[5] As further directed EPA's April 18, 2023 conditional approval letter, GE has also evaluated other areas of the UDF site for the possibility of attracting wildlife into other operational areas during construction, as well as measures to avoid such attraction. This evaluation is also included in Section 6.2 of Appendix H.

5 UDF Operational and Supporting Activities

This section describes several operational and supporting activities to be conducted during construction and operation of the UDF.

5.1 Site Security

The portion of the GE Parcel that will include the UDF consolidation area will be surrounded by a chain-link fence, portions of which have already been installed and the remaining portions of which will be installed prior to UDF construction. Access into the fenced area will be provided at discrete locations via locking gates. These gate locations are anticipated to coincide at crossings with existing and proposed roads within the GE parcel. Additionally, the UDF operational area and related support areas will be secured by a chain-link fence (the same fence described for the consolidation area). Signs stating "No Trespassing" will be posted on the chain-link security fence at designated locations and on the access gates. Other portions of the GE Parcel that may be later designated as UDF support areas may include chain-link fencing and signs in certain locations.

5.2 Consolidated Material Management and Placement

As of the date of this Final Design Plan, the methods for transporting dredged or excavated material to the UDF for disposal are still being evaluated but will include trucking of soil and sediment materials to the UDF, potentially use of rail for a portion of the transport, and (for some sediments) hydraulic conveyance via slurry within a pipe to the UDF. The methods and procedures for transport of materials to the UDF were initially described in GE's On-Site and Off-Site Transportation and Disposal Plan (T&D Plan; Arcadis 2023), submitted on October 31, 2023, and will be revised in a revised T&D Plan. The methods for unloading, managing, and placing such materials within the UDF are dependent on the means of delivery of the material from the remediation areas. For material that is delivered by truck to the UDF for disposal, that material will be routed directly to the UDF cells where the material will be dumped for subsequent spreading and compaction by earthmoving equipment in accordance with Section 4.1.1 of the UDF OMM Plan and Technical Specification 31 05 13 - Soils for Earthwork. The material will be placed in a manner that optimizes the capacity and operation of the UDF.

In the event of future hydraulic conveyance of sediments via slurry within a pipe to the UDF, the UDF filling operations of consolidated materials associated with such hydraulic conveyance will be managed in parallel with the handling of consolidation materials delivered via truck. In such a case, if both placement methods are occurring simultaneously, the filling operations will be coordinated to optimize fill material placement and management of contact water generated within the UDF cells resulting from precipitation events and slurry filling operations.

Measures employed to control incidental releases of contaminated materials outside of the consolidation area baseliner footprint during active operations prior to final capping of the UDF cells are described in Section 3.2.2 of the UDF OMM Plan.

5.3 Management of Contact and Non-Contact Waters

Waters from the UDF may include runoff from rainfall or snow melt, decant water from the consolidation operation, and leachate collected in the primary or secondary leachate collection systems. Regardless of origin, the management of waters generated from or encountered within the UDF will depend on whether the waters have had the potential for contact with the consolidation material (contact water) or not (non-contact water).

Non-contact waters may include any of the following:

- Water or runoff from the existing ground surface within the UDF or UDF support area footprint;
- Water encountered in the ground or managed during the excavation of soils for construction of the UDF and during baseliner installation;
- Runoff from a newly constructed cell prior to placement of consolidation material;
- Runoff from unused portions of a cell that are segregated from active portions of cells by geomembrane;
- Runoff from the UDF perimeter berm;
- Runoff from interim cover(s); and
- Runoff from the UDF final cover at any stage of construction following completed installation of the final cover geomembrane.

Contact waters include any other waters besides those listed above. By default, waters will be assumed to be contact waters unless the origin and potential for non-contact with consolidation materials are determined. Once final cover has advanced to and includes completion of the geomembrane layer, runoff from the final cover area will be assumed to be non-contact water. Therefore, maintaining separation between contact and non-contact waters is necessary for proper management of UDF waters.

5.4 UDF Support Areas

As noted in Sections 1 and 2.7, the GE Parcel will contain areas designated for support of UDF operations. These support areas will include access points to the operational area, material and equipment staging areas, and areas for contractor use. Access points that will support UDF operations are shown on Design Drawings 4A and 4B and include the main UDF area entrance road located off Woodland Road, the access road extension from the Eversource easement located north of the UDF area, and the access point located on the western side of the GE Parcel adjacent to monitoring well MW 2022-5. Material and equipment storage areas will support UDF activities and will be available for contractor use during construction and operation of the UDF and following closure of the UDF. These storage areas will be co-located with the UDF areas shown on Design Drawings 4A and 4B as operational areas. Contractor-related support areas will be designated for on-site office trailers, staff parking, sanitary facilities, etc., and will also be located in the areas shown on the design site plans as operational areas. Lastly, as also noted previously, other UDF support areas may be needed for future UDF operations associated with hydraulic dredging and pumping if performed, such as sediment conveyance, dewatering, and water treatment facilities. Such additional UDF support areas will be described in later design submittals associated with hydraulic dredging and pumping activities (i.e., design work plans for Reach 6).

5.5 UDF Operation, Monitoring, and Maintenance

Operation, monitoring, and maintenance activities to be carried out during the construction and operation of the UDF are described in the UDF OMM Plan being submitted concurrently with this Final Design Plan. The primary components of the UDF OMM Plan include the following:

- Construction-phase controls and monitoring, including construction oversight, implementation of Quality Assurance/Quality Control (QA/QC) measures, routine site controls, air and noise monitoring, road use, inspections and maintenance, and reporting;
- Operations-phase controls and monitoring, including routine site controls, environmental monitoring (including air, groundwater, meteorological, noise, and odor monitoring), road use, inspections and maintenance, and reporting;
- Consolidation material filling and management operations, including consolidation material placement and monitoring, fill progression and capacity monitoring, daily and temporary waste covering and inspections, and stormwater management system inspections; and
- Facility operations, including leachate management and leachate generation tracking and inclement weather operations.

The UDF OMM Plan covers activities occurring through completed consolidation material filling operations. It does not cover monitoring and maintenance activities that will be implemented during the UDF closure phase, including final cover construction. Those activities will be described in the UDF Final Cover/Closure Plan in accordance with Section 4.3.2.5 of the Final Revised SOW. Following the final cover construction, post-closure monitoring and maintenance activities will be conducted under a Post-Closure Monitoring and Maintenance Plan that will be prepared and submitted prior to closure of the UDF in accordance with Section 5.2 of the Final Revised SOW.

6 Measures to Address Habitat Impacts

This section provides an overview of the anticipated habitat impacts associated with the UDF, and it describes the proposed measures to address those habitat impacts. Appendix H provides greater detail on both the anticipated impacts and the need for and type of measures proposed to address those impacts. This assessment of habitat impacts draws from the detailed habitat information presented in the Revised Baseline Ecological Characterization and Habitat Assessment Report for the UDF, which is Appendix C to the Revised Final PDI Summary submitted in January 2024 and is referred to herein as the UDF Baseline Habitat Assessment.

6.1 Summary of Habitat Impacts

Habitat impacts within the consolidation area will be limited due to the prevailing habitat cover types in this area and the associated land use history as a recently disturbed earth removal area. This area comprises approximately 15.5 acres, roughly 92% of which were previously subject to this past earth work and are currently either in a non-vegetated condition (2.66 acres or 17%) or composed of recently established grassland with some scattered woody shrubs and forbs (11.58 acres or 75%). Only 1.22 acres of the consolidation area (7.9%) consist of forested cover habitat. Since the habitat value of such disturbed cover conditions is generally limited to a small suite of wildlife species adapted to such disturbed conditions and given the land use history of such recent disturbances, the impacts related to this loss of habitat will be minimal.

Further, consistent with recent discussions with officials from the Town of Lee, the long-term post-closure state of the consolidation area, along with the side slopes, perimeter berm, and other disturbed areas within the operational area, is anticipated to consist of a grassland cover, with the addition of plant pollinator species, as discussed further in Section 7.2. Under this approach, the final closed condition of the UDF will consist of a roughly 30-acre grassland habitat area, which will not only provide a stable surface, but will also provide important wildlife habitat functions, including appeal to pollinators (see Section 2 of Appendix H and Attachment B to that appendix). Thus, the long-term habitat impacts from the UDF will be minor, and, in fact, the restored final surface will constitute an improvement in the habitat.[6]

Activities in the operational area outside of the consolidation area will affect a greater range of habitat conditions, including a gravel pit pond and both early successional grassland/non-vegetated habitat and mature forested cover, as described in the UDF Baseline Habitat Assessment (and shown on Figure 5 of that report). Habitat impacts from construction activities in such areas will be addressed by several best management measures, including short-term measures (e.g., sedimentation/erosion controls and potentially time-of-year restrictions for some construction activities), and long-term measures (e.g., vegetative screening or buffers and habitat restoration or enhancement as grassland cover, and wetland/water mitigation).

The impacts from the construction and operation of the UDF on the identified regulated wetlands and MWPA resource areas at the GE Parcel (described in the UDF Baseline Habitat Assessment) have been further evaluated during the final design process. Briefly, direct impacts to MWPA-regulated wetland resource areas will occur in two locations: (1) filling of the 0.67-acre southeastern-most gravel pit pond off the northwestern edge of

[6] Details regarding the construction of this grassland habitat in the closed UDF area, including planting specifications, will be provided in the UDF Final Cover/Closure Plan; and the long-term monitoring and maintenance requirements for it will be provided in the UDF Post-Closure Monitoring and Maintenance Plan.

the consolidation area;[7] and (2) crossing of an intermittent stream and associated Bordering Vegetated Wetland (BVW) on the northeastern side of the operational area with a small (25-foot wide) access roadway that will facilitate passage from the northern part of the GE Parcel to the operational and consolidation areas. As described in the UDF Baseline Habitat Assessment, "[c]onsidering the man-made, degraded conditions of the [southeastern] pond, wildlife habitat functional impacts resulting from filling of this ponded area will be minimal." Similarly, the access road crossing of the intermittent stream and wetland will also have only minor impacts; roughly 1,000 sf of BVW will be filled, and the intermittent stream will have a short (approximately 30-foot long) section of an arched culvert span across it. Nevertheless, on-site mitigation in the form of vernal pool enhancement and wetland expansion is proposed as mitigation for these impacts, as described in Section 6.2 and Appendix H.

6.2 Measures to Address Wetland Resource Impacts

As described in Section 6.1, direct impacts to wetland resource areas are anticipated at the following two locations in the operational area of the UDF (no wetland impacts will occur within the consolidation area): (1) filling of the 0.67-acre southeastern-most gravel pit pond; and (2) crossing of the intermittent stream and associated BVW on the northeastern side of the operational area with a small access roadway. Both of these resource impact areas have been reviewed relative to the substantive regulatory requirements of the MWPA regulations. Specifically, this review has focused on the MWPA regulatory requirements for "limited projects" associated with remediation in accordance with the Massachusetts Contingency Plan, as specified in 310 CMR 10.53(3)(q), which are considered applicable to the ROR Remedial Action, as discussed in Table 1 (the ARARs table).[8] The impacts on these resource areas are described below and are discussed in greater detail in Appendix H along with a description of proposed mitigation associated with these impacts. The gravel pit pond does not constitute federally regulated waters of the U.S. since it was created in an upland setting for the purpose of treating water as part of the gravel pit wash-water system. However, the intermittent stream and adjacent wetland are considered waters of the U.S., and the proposed mitigation is also intended to meet federal mitigation requirements.

6.2.1 Southeastern Gravel Pit Pond Filling

As noted above, based on GE's current understanding, the southeastern pond has been inactive as part of the gravel pit operations for at least five or more consecutive years, and therefore would be considered a Pond under the MWPA regulations (310 CMR 10.04: definition of Pond). As such, this area would contain Land Under a Waterbody (LUW) of 0.67 acre and 900 linear feet of Bank resource areas at the mean low water line (310 CMR 10.56 and 10.54, respectively). Specifically, the LUW encompasses the pond up to the mean low water level (which here is approximated by the lower limit of marsh emergent plant growth, which is primarily the invasive

[7] This southeastern pond has been inactive as part of the gravel pit operations for at least five or more consecutive years, and therefore would be considered a Pond under the MWPA regulations (310 CMR 10.04, definition of Pond). As such, this area would contain Land Under a Waterbody (LUW) and Bank resource areas under those regulations (310 CMR 10.56 and 10.54, respectively), as discussed in Section 6.2.1.

[8] It is recognized that the review of such limited projects may also consider the magnitude of the alteration and the significance of the project site to the interests identified in the MWPA, the availability of reasonable alternatives to the proposed activity, the extent to which adverse impacts are minimized, and the extent to which mitigation measures, including replication or restoration, are provided to contribute to the protection of the interests identified in the Act (310 CMR 10.53(3)). These factors have been considered here, as discussed in Appendix H.

plant *Phragmites australis*); and the Bank of the pond extends from mean low water up to the first observable break in slope or the mean annual flood level, whichever is lower. This upper limit of Bank (i.e., top of bank) is delineated at this pond by the upper limit of the marsh emergent plant growth, which corresponds to the mean annual flood level (given that there is no discernible break in slope above mean low water within the ponded water regime). Erosion from the steep side-slopes around the southern, eastern, and northern sides of the pond has been gradually filling in the edges of the pond for many years, resulting in a long, gradual slope of silty-sand mineral deposition extending from outside to well inside the pond.

The MWPA regulatory requirements for "limited projects" require that, for impacts on resource areas, "mitigating measures shall be implemented that contribute to the protection of the interests identified in [the MWPA]" (310 CMR 10.53(3)(q).2.c). In this case, to mitigate the impacts on the southeastern pond, on-site mitigation is proposed, as described in Section 6.2.3 and in Appendix H, to enhance an important wildlife function on the GE Parcel relative to vernal pool breeding habitat.

6.2.2 Access Road Crossing of Intermittent Stream and BVW

As described in the UDF Baseline Habitat Report, an intermittent stream crosses the GE Parcel from east to west, extending from Woodland Road through the BVW area and out to the transmission line right-of-way. For site operations, it will be necessary to provide an access road across this intermittent stream to allow for north-south on-site traffic and conveyance of dredge material to the disposal/consolidation area. There is no location on the GE Parcel where access from north to south could feasibly be provided with no impact to this stream or wetland. Site investigations have been conducted by both environmental scientists and engineers to determine the best location and design for a road crossing, considering environmental, engineering, logistical, and other factors. In doing so, an effort was made to select a crossing location with minimal direct impact to the stream and BVW, and design considerations were applied to minimize environmental impacts consistent with current regulatory provisions. The following points summarize the selected access road crossing location and factors considered in the design process to minimize habitat impacts:

- The selected crossing location is where the intermittent stream width is minimal (typically about 10 feet wide) and where adjacent BVW width is only 10-30 feet wide.
- The width of the access road has been held to 25 feet, with minimal side-slope widening necessary beyond the roadway limits (and no side slopes at the actual stream crossing, where only a 30-foot-long arch culvert will be placed).
- The resulting overall footprint of the crossing on BVW and stream/bank habitat is limited to 1,300 sf (with roughly 1,000 sf of BVW impact).
- The intermittent stream will be spanned by an arch-culvert, such that no disturbance to the stream bottom habitat will occur.
- The arch-culvert will span the channel width a distance of 1.2 times or more the bankfull width of the stream.
- The road crossing design complies with the Massachusetts Stream Crossing Standards (see MA Stream Crossing Handbook (mass.gov).

The MWPA regulatory requirements for "limited projects" under 310 CMR 10.53(3)(q) require that, for temporary alterations to resource areas, such as access roads, such areas must be substantially restored after use, with at least 75% of the surface of any area of disturbed vegetation reestablished with indigenous wetland plant species within two growing seasons (310 CMR 10.53(3)(q).2.f). In this case, in the event that the access road across the intermittent stream is ultimately removed as part of the UDF closure, the wetland area affected by the road will be restored in accordance with these requirements. In addition, as noted above, these regulations require implementation of mitigating measures for impacts on resource areas; and the mitigation for impacts caused by this access road is the on-site mitigation described in Section 6.2.3 and Appendix H.

6.2.3 Proposed On-Site Wetland Mitigation

Despite the minimal functional impacts to resource areas from the filling of the on-site gravel pit pond and the access road construction, options for mitigation of these impacts have been evaluated both on-site and off-site, with a focus on addressing any loss of the wildlife habitat function. Consideration was first given to the creation of wetland/water habitat features in the western part of the GE Parcel along the edges of the other two gravel pit ponded areas. However, it has been determined that the grading of the steep slopes along these ponds, in combination with the transmission line right-of-way just east of the ponds, make the creation of such wetland/water mitigation features impracticable.

EPA's November 16, 2023 conditional approval letter for GE's August 7, 2023 Final PDI Summary for the UDF directed that, "[d]ue to the observed drying out of the vernal pool prior to wood frog metamorphosis, GE shall consider as *a*n on-site habitat mitigation measure in the [UDF] Final Design the incorporation of features or site modifications that direct properly managed, non-impacted, surficial stormwater run-off into the vernal pool area to sustain spring water levels in the vernal pool for a longer period of time to support full development of wood frog larvae to adult emigration during all hydroperiods."[9]

In accordance with this directive, GE has evaluated potential enhancement measures at the vernal pool along Woodland Road to improve the habitat in that pool for wood frog breeding and potentially other vernal pool species. This assessment has included conducting numerous soil test pits throughout the vernal pool, as well as detailed analyses of the surface water flows in and around the vernal pool. Based on the results of this assessment, GE has developed a proposed on-site mitigation plan to expand and enhance the vernal pool and adjacent wetland and buffer habitat. The investigations conducted and plan developed are described in detail in Appendix H. The following points summarize the proposed mitigation plan:

- The surface water flow paths into the vernal pool will be changed to re-direct flow from an additional 38 acres of woodland watershed into the vernal pool area.
- The existing 0.23-acre vernal pool habitat will not be physically modified except at the northern end to allow for increased surface water flow into it.
- The limits of vernal pool breeding habitat will be increased by roughly 0.13 acre to the north of the existing vernal pool.
- In addition to the additional vernal pool habitat, roughly 2,700 sf (0.06 acre) of BVW creation area will be established at the northern edge of the vernal pool, and vegetated buffer areas will be established over roughly 0.09 acre around the northern side of the mitigation area.

As a result of these improvements, roughly 0.54 acre of enhanced and created vernal pool, wetland habitat, and vegetated buffer will be established. Given the habitat provided by the vernal pool and the lack of other vernal

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[9] The basis for this recommendation was GE's finding, reported in the UDF Baseline Habitat Report, that surveys during both 2022 and 2023 found that the duration of flooding in the UDF vernal pool was not sufficient to allow wood frog metamorphosis to proceed to its final stage of adult emigration from the pool.

pool habitat on and in proximity to the GE Parcel, this proposed mitigation will provide a suitable functional equivalence of important wildlife habitat to compensate for the impacts to wetland resource areas, including both the impacts from the filling of the southeastern gravel pit pond and the impacts from the access road crossing of the intermittent stream and associated BVW.

6.3 Need for Measures to Address Potential Impacts on Threatened or Endangered Species

In addition to evaluating other habitat impacts, GE has considered the potential effects of construction and operation of the UDF on the habitat of threatened or endangered species – specifically, the northern long-eared bat (NLEB), a federally listed endangered species (described in Section 4.5 of the UDF Baseline Habitat Assessment). The 1.22 acres of forested habitat in the consolidation area, as well as any forested cover on the GE Parcel, have a limited potential of providing some habitat functions for the NLEB. The NLEB winters in caves or underground mines and inhabits dead trees and trees with loose bark in forested areas for summer roosting sites and small nursery/maternity colonies. However, according to the most recent available mapping (Mass.gov January 2023), the nearest documented NLEB hibernacula is located approximately 7.6 miles west-southwest of the GE Parcel, near Rockdale Mills in the town of Stockbridge, MA. Further, no known maternity roosts are mapped on or near the GE Parcel, no observations of NLEB on or near to the GE Parcel were made during the UDF field investigations, and there were no documented observations of NLEB on or near to the GE Parcel. In these circumstances, as discussed in Section 6.1 of Appendix H, no mitigation measures are considered necessary or warranted at the UDF area to address NLEB.

As directed in EPA’s November 16, 2023 conditional approval letter for the initial Final PDI Summary Report, GE has also considered potential measures to promote increased use of the UDF site by monarch butterflies, a candidate species for federal listing (also described in Section 4.5 of the UDF Baseline Habitat Assessment). Based on that consideration, GE is proposing such measures, consisting of transplanting and seeding of milkweed plants, as also discussed in Section 6.1 of Appendix H, to encourage increased use of the GE Parcel by monarch butterflies for potential breeding and likely migration habitat functions.

7 UDF Closure and Preparation for Post-Closure

This section provides a general summary of the UDF closure activities other than construction of the final cover (which was discussed in Section 4). As previously noted, more details relating to future closure activities will be presented in the Final Cover/Closure Plan for the UDF (described in Section 4.3.2.5 of the Final Revised SOW).

7.1 Documentation of Final Cover Construction

As described in Section 4,2, final cover construction will be performed in a phased manner. A certification report will be prepared following the completion of each phase of final cover construction that will document aspects of the completed work including consolidation grades achieved within the final cover area, materials installed and construction quality assurance testing results, and final grade elevations.

7.2 Discussion of and Preparation for Post-Closure

In accordance with Section III.H of the February 2020 Settlement Agreement that led to the Revised Permit, GE has consulted with officials from the Town of Lee regarding the potential future use or condition of the UDF area following closure of the UDF. The Town officials indicated that establishment of a grassland cover in the UDF area following closure would be appropriate so long as it would be attractive to pollinators. As a result, GE is planning to convert the UDF consolidation area and surrounding disturbed areas within the operational areas to a grassland habitat, with the addition of plant pollinator species, as discussed further in Section 2 of Appendix H. This planned post-closure condition of the UDF area will be taken into account in the UDF Final Cover/Closure Plan, as required by Section 4.2.3.5 of the Final Revised SOW. That plan will also provide details and specifications for the planting of this grassland cover.

7.3 Future Land Use Restrictions

In accordance with Section II.B.7.d.(2) of the Revised Permit, GE will prepare and record a Grant of Environmental Restriction and Easement (ERE) in accordance with the CD to prohibit excavation of the closed UDF, prohibit extraction, consumption, or utilization of groundwater underneath the UDF area (including a 500-foot zone around the waste consolidation area) and restrict the future use of and access to the UDF area. The Final Cover/Closure Plan for the UDF will describe GE's plans for preparing and recording this ERE and for conducting subsequent inspections to evaluate compliance with the ERE.

8 UDF Sustainability and Climate Change Considerations

Section II.H.14 of the Revised Permit required GE to prepare a sustainability and climate adaptation plan that includes measures to ensure that the remediation activities to be conducted in the ROR are designed and constructed to be resilient to potential impacts from climate change and to incorporate, where practicable and appropriate, methods to minimize greenhouse gas (GHG) emissions. GE submitted that plan, entitled Sustainability and Climate Adaptation Plan (Anchor QEA 2022), on September 16, 2022; and it was conditionally approved by EPA on January 27, 2023. As required by EPA's conditional approval letter, this section discusses those issues in the specific context of UDF construction and operation and includes a vulnerability assessment for those activities. The assessment was performed in a manner consistent with EPA's 2019 *Climate Resilience Technical Fact Sheet: Contaminated Sediment Sites* (Fact Sheet; EPA 2019); and it presents a conceptual evaluation of potential climate change resiliency measures and measures to minimize GHG emissions. This section provides a summary of the tools used to estimate climate change impacts and GHG emissions from UDF construction and operation activities and a summary of the measures incorporated into this Final Design Plan to address such impacts and to minimize GHG emissions.

8.1 Vulnerability Assessment

A vulnerability assessment was conducted to define and summarize potential vulnerabilities of the UDF construction and operation activities to climate change and to identify potential resiliency measures to avoid or mitigate such impacts. Results of this assessment are described in the following subsections and summarized in Tables 3 and 4.

As described in the EPA 2019 Fact Sheet, the following steps were performed as part of the vulnerability assessment: (1) an exposure assessment to identify particular hazards of concern and characterize exposure to those hazards caused by climate change; (2) a sensitivity assessment to evaluate the likelihood that those hazards would reduce the effectiveness of the UDF construction and operation activities; (3) identification of potential resiliency measures to mitigate high-priority vulnerabilities; and (4) an adaptive management approach to adjust to climate variability and extremes caused by climate change. Each of these elements is described further in the following subsections.

8.1.1 Exposure Assessment

An exposure assessment was performed to identify potential hazards of concern to UDF construction and operation due to extreme weather events. The identified hazards were then used as part of the sensitivity analysis to assess the likelihood of such hazards (Section 8.1.2) and to identify potential resiliency measures to address the hazards (Section 8.1.3). UDF construction is anticipated to be completed within the next two to three years. Operation of the UDF is then anticipated to occur over an approximate 15-year period. While extreme weather events have increased in the last five years, models have been developed by Northeast Regional Climate Center and EPA that predict potential changes in the frequency of such events over a longer duration. The results of these models were reviewed to assess exposure during the anticipated UDF operations period. Based on those model results, the historical data on precipitation were modified to determine the estimated future precipitation amounts used in the design. This process and associated calculations are described in Appendix G-1.

The components of this UDF Final Design Plan subject to the exposure assessment include the construction of the UDF elements (described in Sections 3 and 4) and the placement of consolidation materials (described in Section 5). The exposure assessment related to impacts from extreme weather events included a review of potential hazards to the site operations and infrastructure related to transportation of equipment and materials. Potential hazards that may arise during UDF construction and operation implementation due to extreme weather events include the following:

- More frequent and/or more intense rainfall than historical trends, which could result in increased volume of stormwater that must be managed, an increased potential for erosion, and flash flooding that could change conditions on the UDF access roads;
- Potential high winds, resulting in more frequent power outages or impacts to materials and activities;
- Increased potential for drought conditions with the changes in precipitation patterns, which could compromise the vegetative ground cover and lead to erosion or loss of soils;
- Potential changes in groundwater elevations from historical levels due to changes in precipitation and associated groundwater recharge conditions; and
- Changes in duration for periods of cold and heat, which could impact the operation of equipment at the site.

8.1.2 Sensitivity Assessment

The sensitivity assessment included an evaluation of the likelihood that the climate-change hazards of concern would impact the construction and operation of the UDF. Although some of the general effects of climate change are universal, regions may experience different levels of effects based on geography and land development patterns. The Commonwealth of Massachusetts has developed the *Massachusetts Climate Change Projections – Statewide and for Major Drainage Basins: Temperature, Precipitation, and Sea Level Rise Projections* (Northeast Climate Adaptation Science Center 2018). This document indicates that, in Massachusetts, winters may become dominated by rain instead of snow, which would decrease spring-generated snow melts. Rain patterns may change with the result of increases in rain intensity and potential longer periods of drought. If increased rain intensity or more frequent intense storms occur, the likelihood of the potential hazards identified in Section 8.1.1 could increase.

The hazards identified in Section 8.1.1 have the potential to disrupt or delay UDF construction and operation activities (and thus implementation of the ROR Remedial Action) for a period of time during any construction season in which an extreme weather event occurs. Because of the phased nature of the project and because the UDF activities are planned to occur over multiple years, particularly with operations, the potential chance of such disruption or impact is increased. During UDF construction and operation, extreme weather events could cause physical damage to the following:

- Site access roads;
- Erosion control and storm water management features;
- Ongoing and completed earthwork;
- Materials and equipment staging; and
- Utilities, including power and leachate management systems.

Physical damage is not the only risk due to extreme weather. With the changing precipitation patterns, water damage is also a potential for the UDF elements outlined above. Schedule delays could arise from disruption of work related to this physical damage and damage from water. Additionally, if utility disruptions occur, the production rates for the management of the leachate may be reduced and may be dependent upon alternate, temporary power sources. While the UDF is in an elevated area, access to that area could be impacted for materials and equipment supply as well as maintenance activities.

Potential vulnerabilities for the UDF construction and operation are summarized in Table 3 which is formatted in a manner consistent with EPA's 2019 Fact Sheet. That summary considers extreme weather and to identifies potential direct effects, including physical damage, water damage, power interruption, and reduced access to and within the UDF.

8.1.3 Resiliency Measures

In accordance with EPA's 2019 Fact Sheet, potential resiliency measures were developed to address the high-priority vulnerabilities identified in Table 3. Table 4 lists the vulnerabilities identified and provides a priority designation (low, medium, or high) for each identified vulnerability and potential impact. Table 4 also describes the potential resiliency measures that have been identified for each vulnerability and incorporated into this design. Resiliency measures are also discussed in the following paragraphs.

The condition of the roads identified as access roads that will be used for delivery of materials and equipment to the UDF area will be inspected and documented to confirm usability throughout the ROR Remedial Action, as discussed in Section 6 of GE's Quality of Life Compliance Plan (Anchor QEA and Arcadis 2023). Included in the inspection will be identification of low-lying areas that could be prone to flooding or wash out. If such areas are identified, then guidance on routing of trucks through those areas will be incorporated, and weather forecasts will be consulted in scheduling the consolidation material deliveries.

Additional potential resiliency measures that have been incorporated into the UDF design include those listed below and those summarized in Table 4.

- Contingency plans will be developed to identify response actions associated with potential extreme weather events (e.g., monitoring weather forecasts and relocating equipment and personnel when extreme weather events are forecasted).
- Stormwater management capacity has been designed based on estimated future escalations in precipitation (determined by use of climate modeling results to modify historical precipitation data, as described in Appendix G-1) for long-term drainage features.
- The leachate storage system has the capacity to provide for approximately 10 days of leachate storage during the estimated wettest month of the year without off-site trucking of leachate for treatment in case of access limitations.
- The leachate management system has been designed to allow for remote operation and monitoring and to provide for shutdown of system operations in the event of an extended power outage. The system's sensors are interconnected so that operation of pumps upstream is governed by tank level sensors downstream to prevent excessive filling of the tanks.
- While climate change-related impacts to groundwater are uncertain for the UDF area hydrogeologic setting, it is likely they will result in lower-than-average groundwater levels relative to current and historical conditions.

Thus, by designing to a modified seasonal high groundwater based on historical trends (as described in Section 3.3.2), infringement of the designed groundwater-baseliner offset (greater than the required 15 feet minimum) will be avoided.

- Utilities will be installed below the ground surface to reduce potential damage from high winds.
- UDF access roads will be inspected after extreme weather events and repairs will be conducted promptly if the roads are found to be in disrepair, so as to minimize project delays.

8.1.4 Adaptive Management

Section II.F of the Revised Permit requires that an adaptive management approach be incorporated into the design and implementation of the ROR Remedial Action to adapt requirements or activities based on new information and to make changes as needed to achieve the expected benefits of the project. This approach was described in GE's Adaptive Management Plan (Anchor QEA 2023). Specifically, that plan described the adaptive management process that will be implemented to adapt and optimize project activities to account for lessons learned from work conducted at earlier stages of the project, new information, and changing conditions. That plan is incorporated here by reference and the procedures outlined in that plan will be followed during the construction and operation of the UDF.

8.2 Greenhouse Gas Emissions Evaluation

GHGs are gases that trap heat in the atmosphere. The most prominent GHGs contributing to this process are carbon dioxide (CO_2), methane, and nitrous oxide. CO_2 is the primary GHG emitted through human activities and comprises approximately 80% of GHG emissions. The carbon dioxide equivalent (CO_2e) consists of the calculated total GHG emissions taking into account the global warming potential of each of its components. Global warming potential is the heat absorbed by any GHG in the atmosphere as a multiple of the heat that would be absorbed by the same mass of CO_2. UDF construction and operation activities are anticipated to generate GHG emissions. The potential sources of GHG emissions anticipated during construction and operation of the UDF will include direct sources (e.g., on- and off-road vehicles and fuel combustion from equipment operation), indirect sources (electricity use), and upstream contributions (e.g., production of materials used for UDF baseliner construction).

A GHG assessment has been performed based on assumed numbers and types of construction equipment and proximities of the equipment, personnel, and materials to the UDF during both construction and operation. The tool called Spreadsheets for Environmental Footprint Analysis (SEFA) (Version 3.0) was used to estimate GHG emissions from the ROR Remedial Action. SEFA is a Microsoft Excel-based tool developed by EPA and can be found on EPA's Contaminated Site Clean-Up Information website (EPA 2020b). This tool has been designed to help analyze the environmental footprint of a site cleanup project, including GHG emissions. Based on use of this tool, estimated GHG emissions associated with UDF construction total 6,889 tons CO_2e, and the estimated operational-phase GHG emissions over the 15-year operational period total 11,489 tons CO_2e (766 tons CO_2e per year). Calculations for the estimated GHG emissions are presented in Appendix I.

Various methods to minimize GHG emissions will be incorporated into the UDF construction and operation to the extent practicable. These will include measures to address direct emissions, indirect emissions, and upstream emissions and will include the following:

- Use of a previously disturbed site for UDF;
- Reuse of material excavated for UDF construction as fill in other areas;
- Possible reuse of on-site concrete debris for the aggregate required by UDF-related activities;
- Use of vehicle and equipment BMPs, such as fuel-efficient on-road vehicles, idling restrictions, electric or hybrid vehicles (as that market grows), and route planning;
- Evaluation of alternative modes of transportation to on-road vehicles – i.e., rail transport where efficient and practicable and hydraulic transport where feasible;
- Employment of local workers where available and practicable; and
- BMPs to reduce electricity use, such as use of motion detectors.

Table 5 lists these minimization measures and explains how those measures will reduce GHG emissions.

9 UDF Post-Closure Monitoring and Maintenance

Following closure, activities to be conducted at the UDF will include long-term groundwater and air monitoring, routine periodic inspections and maintenance or repair of the final cover, stormwater management, and leachate management systems. Inspections and maintenance/repairs of other, ancillary components of the UDF including, security fences, gates, and signs will also be conducted along with inspections to ensure compliance with the ERE for the UDF area, and associated documentation and reporting. Further details pertaining to UDF post-closure activities will be provided in the UDF Post-Closure Monitoring and Maintenance Plan (described in Section 5.2 of the Final Revised SOW).

10 References

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Tables

Table 1
Applicable or Relevant and Appropriate Requirements for Upland Disposal Facility
Upland Disposal Facility Final Design Plan

ARCADIS

Statute/Regulation	Citation[1]	Synopsis of Pertinent Requirements	Status	Action(s) to be Taken to Achieve ARARs
CHEMICAL-SPECIFIC ARARs				
Federal ARARs				
None				
State ARARs				
None				
LOCATION-SPECIFIC ARARs				
Federal ARARs				
Clean Water Act – Section 404 and Implementing Regulations	33 USC 1344 33 CFR Parts 320-323, 325, 332 (Army Corps of Engineers) 40 CFR Part 230 (EPA)	For discharge of dredge or fill material to waters of the United States, including wetlands: (a) there must be no practicable alternative with less adverse impact on aquatic ecosystem (including wetlands); (b) the discharge cannot jeopardize the existence of any threatened or endangered (T&E) species; (c) the discharge cannot cause or contribute to significant degradation of waters of the U.S., including significant adverse effects on human health or welfare, aquatic life, aquatic ecosystem, or recreational, aesthetic, and economic values; and (e) the discharger must take appropriate and practicable steps to minimize or mitigate potential adverse effects on aquatic ecosystem. Mitigation/restoration is required for unavoidable impacts to aquatic ecosystem.	Applicable to the extent that the Upland Disposal Facility (UDF) or support facilities will affect a water of the United States	To the extent that UDF-related earthwork or other activities will involve the discharge of material into a water of the U.S., including the wetland located in the east-central portion of the GE Parcel, the associated stream, and/or the vernal pool at the northern end of the wetland, that activity will be conducted in accordance with these standards. Specifically, there would be no practicable alternative with less adverse impact on the aquatic ecosystem (including wetlands); and implementation of the subject activities will meet the other requirements of these regulations, including performance of appropriate and practicable steps to minimize potential adverse impacts of the discharge on the wetland, stream, and/or pool. In particular, filling and grading work will be managed in a manner that limits impacts to adjacent site areas and avoids the uncontrolled discharge of stormwater runoff beyond areas designated and provided for management of construction-based stormwater. As necessary, mitigation/restoration will be conducted consistent with these regulations. The mitigation/restoration actions to be taken for impacts on waters of the U.S. are described in Section 6 and Appendix H of the Final Design Plan.

Statute/Regulation	Citation[1]	Synopsis of Pertinent Requirements	Status	Action(s) to be Taken to Achieve ARARs
Protection of Wetlands	44 CFR Part 9	Regulation sets forth policy, procedure and responsibilities to implement and enforce Executive Order 11990, Protection of Wetlands.	Relevant and appropriate	To the extent that UDF-related activities will affect the above-referenced wetland in the east-central portion of the GE Parcel, those activities will be conducted in accordance with the policy, procedure and responsibilities stated in this regulation to implement the Executive Order. See also prior entry.
Fish and Wildlife Coordination Act	16 U.S.C. 662 *et seq*.	Sets forth requirements related to federal actions that may modify a stream or ither water body.	Applicable	To the extent that UDF-related activities will modify a stream or other water body at the GE Parcel, the activities subject to this Act will comply with any substantive requirements in this Act.
National Historic Preservation Act and Regulations	54 USC 300101 *et seq*. 36 CFR Part 800	A federal agency must take into account the project's effect on properties included or eligible for inclusion in the National Register of Historic Places (NRHP).	Applicable (but determined not to require further actions here)	Investigations conducted at the GE Parcel have determined that that parcel does not contain, and the UDF-related activities will not impact, any cultural resources that are listed or meet the eligibility criteria for listing on the NRHP. Thus, the listed ARAR will not require further actions at the GE Parcel.
Archaeological and Historic Preservation Act	54 U.S.C. 312501 *et seq*.	When a federal agency finds, or is notified, that a federal construction project may cause irreparable loss or destruction of significant scientific, prehistorical, historical, or archeological data, it must notify Department of Interior (DOI). If DOI determines that the data are significant and may be irrevocably lost or destroyed, it is to conduct a survey and other investigation of the affected area and recover and preserve such data as necessary in the public interest.	Applicable (but determined not to require further actions here)	Investigations conducted at the GE Parcel have determined that that parcel does not contain any significant cultural resource and that the UDF-related activities will not cause loss or destruction of significant scientific, prehistorical, historical, or archeological data. Thus, the listed ARAR will not require further actions at the GE Parcel.

Statute/Regulation	Citation[1]	Synopsis of Pertinent Requirements	Status	Action(s) to be Taken to Achieve ARARs
Executive Order 11990 (Protection of Wetlands)	Executive Order	Federal agencies are required to avoid adversely impacting wetlands unless there is no practicable alternative, and the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use.	To be considered	To the extent that UDF-related activities will affect the above-referenced wetland in the east-central portion of the GE Parcel, those activities will be conducted in accordance with the substantive requirements in this Executive Order. Specifically, there would be no practicable alternative to performing the UDF-related activities in the wetland; and any filling or grading in the wetland will be conducted in a manner designed to minimize the extent of impact to the wetland.
Endangered Species Act and Regulations	16 USC 1536(a)-(d) 50 CFR Part 402, Subparts A&B 50 CFR 17	A federal agency must ensure that any action authorized, funded, or carried out by it is not likely to jeopardize the continued existence of a listed threatened or endangered (T&E) species or result in destruction or adverse modification of critical habitat, unless an exemption is granted. If a listed species or critical habitat may be present in the action area, the steps set forth in the regulations must be followed, including implementation of mitigation measures where necessary.	Applicable	GE has considered the potential impacts of UDF-related activities on the habitats of a federally listed endangered species, the northern long-eared bat (NLEB), and a candidate species for listing, the monarch butterfly. As discussed in Section 6 and Appendix H of the Final Design Plan, GE has determined that, in the circumstances, no specific mitigation measures are warranted to address the NLEB, and is proposing measures to promote increased use of the GE Parcel by monarch butterflies.
State ARARs				
Clean Water Act – Water Quality Certification Regulations	314 CMR 9.00 et seq., Including 9.06 and 9.07	For discharge of dredged or fill material to waters of the U.S. in Massachusetts, section 9.06 requires, *inter alia*, that: (a) no such discharge is allowed if there is a practicable alternative with less adverse impact on aquatic ecosystem (including wetlands); (b) appropriate and practicable steps must be taken to avoid and minimize adverse effects on wetlands; (c) there must be no	Section 9.06 is applicable if the UDF or support facilities will affect a wetland that constitutes a water of the United States. Section 9.07 is partially applicable.	To the extent that UDF-related earthwork or other activities will involve the discharge of material into a water of the U.S., including the wetland located in the east-central portion of the GE Parcel, the associated stream, and/or the vernal pool at the northern end of the wetland, that activity will be conducted in accordance with the standards in section 9.06. Specifically, there would be no practicable alternative with less adverse impact on the aquatic ecosystem (including wetlands); and implementation of the subject activities will meet

Statute/Regulation	Citation[1]	Synopsis of Pertinent Requirements	Status	Action(s) to be Taken to Achieve ARARs
		discharge that would adversely affect estimated habitat of rare wildlife species under Wetlands Protection Act; and (d) stormwater discharges must be controlled with best management practices (BMPs). For dredged material management, section 9.07 contains limited requirements that apply to the management of such material at an upland facility. These include requirements that dredged material management be conducted to ensure protection of human health, public safety, public welfare, and the environment, and that dredged material placed at upland locations is subject to notification requirements and thresholds in the Massachusetts Contingency Plan (MCP).		the other requirements of these regulations, including performance of appropriate and practicable steps to minimize potential adverse impacts of the discharge, avoiding any impact to the estimated habitat of rare species, and controlling stormwater discharges with BMPs. The steps to be taken to address these requirements are those described in Section 6 and Appendix H of the Final Design Plan. The UDF will meet the limited requirements of section 9.07 for upland disposal of dredged material except that the notification requirements and thresholds in the MCP are not applicable to disposal at the UDF in accordance with the Revised Permit.
Massachusetts Wetlands Protection Act and Regulations	MGL c. 131, section 40 310 CMR 10.00, including 10.53	These requirements govern removal, dredging, filling, or altering of banks, land under a waterbody, bordering vegetated wetland, riverfront areas, and other designated resource areas. Provisions include 10.53(3), which authorizes certain projects as “limited projects,” including, in 10.53(3)(q), responses to a release or threat of release of oil and/or hazardous materials in accordance with the MCP if: (a) there is no practicable alternative consistent with the MCP that would be less damaging to resource areas; and (b) steps are taken to avoid or minimize impacts to resource areas,	Applicable if UDF or support facilities would affect a regulated resource area under these regulation	To the extent that UDF-related earthwork or other activities will remove, dredge, fill, or alter resource areas under these regulations, including the southeastern-most gravel-pit ponded area and the intermittent stream and bordering vegetated wetland in the east-central portion of the GE Parcel, those activities will be conducted in accordance with the requirements of these regulations, including the “limited project” requirements of 10.53(3)(q) (which are considered applicable to the Rest of River remedy). Specifically, there would be no practicable alternative that would be less damaging to resource areas; and GE will take steps to avoid or minimize impacts to the resource areas, including meeting specific standards for a “limited project”

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Statute/Regulation	Citation[1]	Synopsis of Pertinent Requirements	Status	Action(s) to be Taken to Achieve ARARs
		including meeting specific standards to the maximum extent practicable. Those standards include requirements to implement mitigating measures that contribute to the protection of the interests identified in the Wetlands Protection Act and to restore temporary alterations to resource areas (e.g., access roads in such areas).		to the maximum extent practicable. Such steps will include actions necessary to restore, replicate, or mitigate loss of or damage to the resource areas. The mitigation measures to be taken to offset impacts to resource areas at the UDF property are described in Section 6 and Appendix H of the Final Design Plan, and the wetland resource area affected by a temporary access road across the intermittent stream at the UDF property will be restored in accordance with these regulations, as also described in Section 6 and Appendix H.
Massachusetts Site Suitability Criteria	310 CMR 16.40(3) & (4)	Site suitability criteria for solid waste facilities, including facility-specific and general site suitability criteria. They include a prohibition on location of a solid waste management facility in an Area of Critical Environmental Concern (ACEC) (310 CMR 16.40(4)(d).	Potentially applicable or relevant and appropriate	To the extent that these criteria would apply to the siting of the UDF, most of those criteria are met. However, for any such criteria that are not met, including 310 CMR 16.40(4)(d), EPA has determined that such requirements are not appropriate for the UDF, but that if they are deemed an ARAR, EPA has waived those requirements under Section 121(d)(4)(B) of CERCLA on the ground that compliance with them would pose a greater risk to human health and the environment than use of the UDF. See Attachment C of the Revised Permit at pp. C-10 – C-11.
Massachusetts Hazardous Waste Facility Location Standards	310 CMR 30	Location standards for hazardous waste disposal facilities, including landfills. They include a requirement that no such facility may be located in an ACEC (310 CMR 30.708), as well as various other locational requirements for the active portion of the facility. Any waste containing PCBs at a concentration equal to or greater 50 mg/kg constitutes a listed hazardous waste under the Massachusetts	Potentially applicable or relevant and appropriate for UDF because it will receive some material with a PCB concentration equal to or greater than 50 mg/kg. Specifically, the prohibition on location of a	To the extent that material to be disposed of at the UDF is deemed to be a Massachusetts hazardous waste solely because of presence of PCBs at concentrations greater than 50 mg/kg, EPA has determined that the requirements of these regulations are not appropriate for the UDF, but that if any provision of these regulations is deemed an ARAR, EPA has waived such provision under Section 121(d)(4)(B) of CERCLA on the ground that compliance would pose a greater risk to human health and the environment than use of the UDF. See Attachment C of the Revised Permit at p. C-13.

Statute/Regulation	Citation[1]	Synopsis of Pertinent Requirements	Status	Action(s) to be Taken to Achieve ARARs
		hazardous waste regulations (310 CMR 30.131). However, the locational requirements for hazardous waste landfills do not apply to disposal facilities for wastes with a PCB concentration equal to or greater than 50 mg/kg if such facilities comply with the applicable requirements of EPA's TSCA regulations (40 CFR Part 761) except with respect to a disposal facility located in an ACEC (see 310 CMR 30.501(3)(a)).	hazardous waste landfill in an ACEC would apply unless waived. The other locational requirements in these regulations are subject to the TSCA exemption given EPA's determination that the UDF will comply with the TSCA regulations through a risk-based determination under 40 CFR 761.61(c).	This waiver would apply to the provision of these regulations prohibiting location of a hazardous waste facility in an ACEC.
Massachusetts Historical Commission Act and Regulations	MGL c. 9, section 27c 950 CMR 71.07	If a project has an area of potential impact that could cause a change in the historical, architectural, archaeological, or cultural qualities of a property on the State Register of Historic Places, these provisions establish a process for notification, determination of adverse impact, and evaluation of alternatives to avoid, minimize or mitigate such impacts.	Relevant and appropriate (but determined not to require further actions here)	Investigations conducted at the GE Parcel have determined that that parcel does not contain, and the UDF-related activities will not impact, any historical, architectural, archaeological, or cultural qualities of a property on the State Register of Historic Places. Thus, the listed ARAR will not require further actions at the GE Parcel.

Statute/Regulation	Citation[1]	Synopsis of Pertinent Requirements	Status	Action(s) to be Taken to Achieve ARARs
Massachusetts Endangered Species Act (MESA) and Regulations	MGL c. 131A 321 CMR 10.00, Parts I, II, and V. 321 CMR 10.00, Part IV	A proposed activity in mapped Priority Habitat for a state-listed threatened or endangered species or species of special concern, or other area where such a species has occurred may not result in a "take" of such species, unless it has been authorized through a conservation and management plan that provides a long-term net benefit to the conservation of the affected state-listed species.	Applicable (but determined not to require further actions here)	Investigations conducted at the GE Parcel have determined that that parcel does not contain Priority Habitat for a state-listed species. Thus, the listed ARAR will not require further actions at the GE Parcel, and no conservation and management plan is necessary.
Establishment of ACECs	301 CMR 12.11(1)(c)	Provides for establishment of ACECs in the State. An ACEC designation affects other state laws and regulations.	Relevant and appropriate	The ACEC regulations pertain to State agency actions and are not applicable to the federal EPA action. However, the UDF-related activities comply with the substantive requirements of 301 CMR 12.11(1)(c), which may be relevant and appropriate, by advancing the values of 301 CMR 12.11(1)(c), while avoiding adverse effects on identified values in section 12.11(1)(c) to the extent practicable.
ACTION-SPECIFIC ARARs				
Federal ARARs				
TSCA Regulations on Disposal of PCB Remediation Waste	40 CFR 761.61(c)	Provides for risk-based approval of a disposal method for PCB Remediation Waste (i.e., waste containing PCBs with concentrations at or above 50 mg/kg) based on a finding that the method will not pose an unreasonable risk of injury to human health or the environment.	Applicable (because some waste to be placed in the UDF will contain material with a PCB concentration of 50 mg/kg or greater)	Will be met because the Revised Permit contains a determination by EPA under 40 CFR 761.61(c) that the selected remedy, including on-site disposal at the UDF, will not pose an unreasonable risk of injury to human health or the environment. See Attachment D to Revised Permit.

Table 1
Applicable or Relevant and Appropriate Requirements for Upland Disposal Facility
Upland Disposal Facility Final Design Plan

Statute/Regulation	Citation[1]	Synopsis of Pertinent Requirements	Status	Action(s) to be Taken to Achieve ARARs
TSCA Regulations on Storage of PCB Remediation Waste	40 CFR 761.50 40 CFR 761.65 40 CFR 761.61(c)	General and specific requirements for storage of PCB Remediation Waste. Regulations include allowance for risk-based approval by EPA of storage method (761.61(c)), based on demonstration that it will not pose an unreasonable risk of injury to health or the environment.	Applicable to storage of waste containing PCB concentrations of 50 mg/kg or greater at UDF prior to closure	Will be met because the Revised Permit contains a determination by EPA under 40 CFR 761.61(c) that the selected remedy, which includes storage at the UDF prior to disposal, will not pose an unreasonable risk of injury to human health or the environment. See Attachment D to Revised Permit.
TSCA Regulations on Discharge of PCB-containing Water	40 CFR 761.50(a)(3)	Prohibits discharge of water containing PCBs to navigable waters unless PCB concentration is <3 mg/L or discharge is in accordance with NPDES discharge limits.	Applicable	Contact water and leachate generated within the UDF consolidation area will be managed and treated prior to discharge in accordance with NPDES discharge limits. Any discharge to navigable waters will comply with this provision.
TSCA Regulations on Decontamination	40 CFR 761.79	Establishes decontamination standards and procedures for removing PCBs from water, organic liquids, and various types of surfaces.	Applicable	Construction and operation of the UDF will involve the handling of PCB-impacted material and equipment. Where decontamination is conducted, it will comply with this provision.
Clean Water Act – National Pollutant Discharge Elimination System (NPDES) Regulations	33 USC 1342 40 CFR 122, including (but not limited to) 122.3(d) and 122.44(a)&(e) 40 CFR 125.1-125.3	Point source discharge must meet technology-based effluent limitations and effluent limitations and conditions necessary to meet state water quality standards, except that discharges in compliance with instructions of On-Scene Coordinator (OSC) acting pursuant to the National Contingency Plan (NCP) are exempt from these requirements (122.3(d)).	Applicable to discharges of dewatering water and treated leachate effluent from the UDF to the Housatonic River	Discharges from the UDF will be in compliance with OSC instructions or as otherwise authorized by EPA.
Clean Water Act – NPDES Regulations (stormwater discharges)	40 CFR 122.26(c)(1)(ii)(C) 40 CFR 122.44(k)	Best management practices (BMPs) must be employed to control pollutants in stormwater discharges during construction activities.	Applicable	The UDF design includes stormwater management features. Construction and operation of the UDF will employ BMPs that will control stormwater runoff from the UDF area in a manner that minimizes erosion, sediment migration, and other potential impacts to drainage conditions downgradient of the UDF.

Statute/Regulation	Citation[1]	Synopsis of Pertinent Requirements	Status	Action(s) to be Taken to Achieve ARARs
State ARARs				
Massachusetts Clean Water Act and Wetlands Protection Act – Stormwater Management Standards	310 CMR 10.05(6)(k) 314 CMR 9.06(6)(a)	Projects subject to regulation under the Wetlands Protection Act or that involve discharge of dredged or fill material into a water of the U.S. must incorporate stormwater BMPs to attenuate pollutants in stormwater discharges, as well as to provide a setback from receiving waters and wetlands, in accordance with specified stormwater management standards.	Applicable if UDF or support facilities would affect a resource area under the Wetlands Protection Act and/or a water of the U.S.	To the extent that UDF-related earthwork or other activities will affect regulated resource areas and/or waters of the U.S., including the wetland in the east-central portion of the GE Parcel, the associated stream and/or vernal pool, and/or the southeastern-most gravel-pit ponded area, the requirements of these regulations will be met to control stormwater discharges during such activities. In addition, after the UDF has been finally covered and closed, non-contact stormwater will continue to be managed and there will no longer be any contact stormwater.
Massachusetts Air Pollution Control Regulations	310 CMR 7.00	These provisions regulate air emissions, dust, odor, and noise, among other things.	Applicable	The UDF will include measures for air monitoring, and control and mitigation of dust emissions associated with the construction and operation of the UDF. The UDF activities will comply with these regulatory provisions.
To Be Considered				
TSCA PCB Spill Cleanup Policy	40 CFR Part 761, Subpart G	Policy used to determine adequacy of cleanup of spills resulting from the release of materials containing PCBs at concentration of 50 mg/kg or greater.	To be considered for any new PCB spills that occur during work at the UDF area.	Will be considered in the event of any new spill that results from the release of PCBs at a concentration of 50 mg/kg or greater and that occurs during the construction or operation of the UDF.

Note:

1. ARARs consist only of the substantive requirements of the provisions cited in this column, not any administrative requirements included therein, including any requirement to obtain permits for on-site actions.

Table 3
Potential Vulnerabilities Associated with Potential Climate Change Impacts
Upland Disposal Facility Final Design Plan
Housatonic River – Rest of River

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Upland Disposal Facility Components		Potential Vulnerabilities Due to Extreme Weather: Physical Damage	Water Damage	Power Interruption	Reduced Access
Construction Phase	UDF access roads	•	•		•
	Erosion control and stormwater management features (ditches, culverts, basins, check dams, siltation barriers)	•			
	Earthwork activities (excavation, filling, grading)	•	•		•
	Material staging areas	•	•		•
	Utilities and baseliner-leachate systems installation	•	•	•	
Operation Phase	UDF access roads	•	•		•
	Erosion control and stormwater management features (ditches, culverts, basins, check dams, surface vegetation)	•			•
	Maintenance and equipment areas	•	•		
	Utilities and leachate management system (collection and conveyance systems, buildings, tanks)	•	•	•	
	Leachate loadout facilities			•	

Table 4
Potential Resiliency Measures to Address High-Priority Vulnerabilities
Upland Disposal Facility Final Design Plan
Housatonic River – Rest of River

ARCADIS

Potential Points of System Vulnerability		Potential System Disruption Due to Extreme Weather				Potential Resiliency Measures for High-Priority Vulnerabilities
		Physical Damage	Water Damage	Power Interruption	Reduced Access	
Construction Phase	UDF access roads	◐	○		◐	• Implement contingency plans prepared by the construction and operation contractors that identify response actions associated with potential extreme weather events (e.g., monitoring weather forecasts and relocating equipment and personnel when extreme weather events are forecasted). • Inspect UDF access roads after extreme weather events and conduct repairs if the roads are found to be in disrepair. • Incorporate connections to facilitate use of temporary generators for pump operation if needed during power outages.
	Erosion control and stormwater management features (ditches, culverts, basins, check dams, siltation barriers)	▣				• Use drought-resistant grasses for seeding (where practicable) to maintain vegetation during dry periods to provide soil erosion resistance at times of intense rainfall. • Increase capacity of stormwater management features to accommodate predicted increased rainfall amounts (see Appendix G-1) • Incorporate infiltration methods in stormwater management system design to reduce elevated temperatures in receiving water bodies and to promote groundwater recharge.
	Earthwork activities (excavation, filling, grading)	◐	○		○	• Implement contingency plans prepared by the construction and operation contractors that identify response actions associated with potential extreme weather events (e.g., monitoring weather forecasts and relocating equipment and personnel when extreme weather events are forecasted).
	Contractor Use Areas (maintenance, equipment, material staging)	◐	○		○	• Locate material stockpiles outside of flood prone areas to the extent practicable. • Implement flood protection measures developed by construction and operation contractors for staging areas and other contractor use areas that consider topography, drainage patterns, and access.
	Utilities and baseliner-leachate systems installation	▣	◐	○		• Use automated leachate management system to allow remote monitoring and notifications. • Incorporate connections for use of temporary generators if needed during power outages.

Table 4
Potential Resiliency Measures to Address High-Priority Vulnerabilities
Upland Disposal Facility Final Design Plan
Housatonic River – Rest of River

Potential Points of System Vulnerability		Potential System Disruption Due to Extreme Weather				Potential Resiliency Measures for High-Priority Vulnerabilities
		Physical Damage	Water Damage	Power Interruption	Reduced Access	
Operation Phase	Site access roads	◐	○		◐	• Implement contingency plans prepared by the construction and operation contractors that identify response actions associated with potential extreme weather events (e.g., monitoring weather forecasts and relocating equipment and personnel when extreme weather events are forecasted). • Inspect UDF access roads after extreme weather events and conduct repairs if roads are found to be inaccessible or in disrepair.
	Erosion control and stormwater management features (ditches, culverts, basins, check dams, surface vegetation)	⊡			◐	• Use drought-resistant grasses for seeding (where practicable) to maintain vegetation during dry periods to provide provides soil erosion resistance at times of intense rainfall. • Increase capacity of stormwater management features to accommodate predicted increased rainfall amounts (see Appendix G-1). • Incorporate infiltration methods in stormwater management system design to reduce elevated temperatures in receiving water bodies and to promote groundwater recharge.
	Contractor use areas (maintenance, equipment, material staging)	○	○			• Locate material stockpiles outside of flood prone areas to the extent practicable. • Implement flood protection measures developed by construction and operation contractors for staging areas and other contractor use areas that consider topography, drainage patterns, and access.
	Utilities and leachate management system (collection and conveyance systems, buildings, tanks)	⊡	◐	⊡		• Use automated leachate management system to allow remote monitoring and notifications. • Incorporate connections for use of temporary generators if needed during power outages.
	Leachate loadout facilities			⊡		• Implement contingency plans prepared by the construction and operation contractors that identify response actions associated with potential extreme weather events (e.g., monitoring weather forecasts and relocating equipment and personnel when extreme weather events are forecasted). • Inspect UDF access roads after extreme weather events and conduct repairs if the roads are found to be in disrepair. • Incorporate connections to facilitate use of temporary generators for pump operation if needed during power outages.

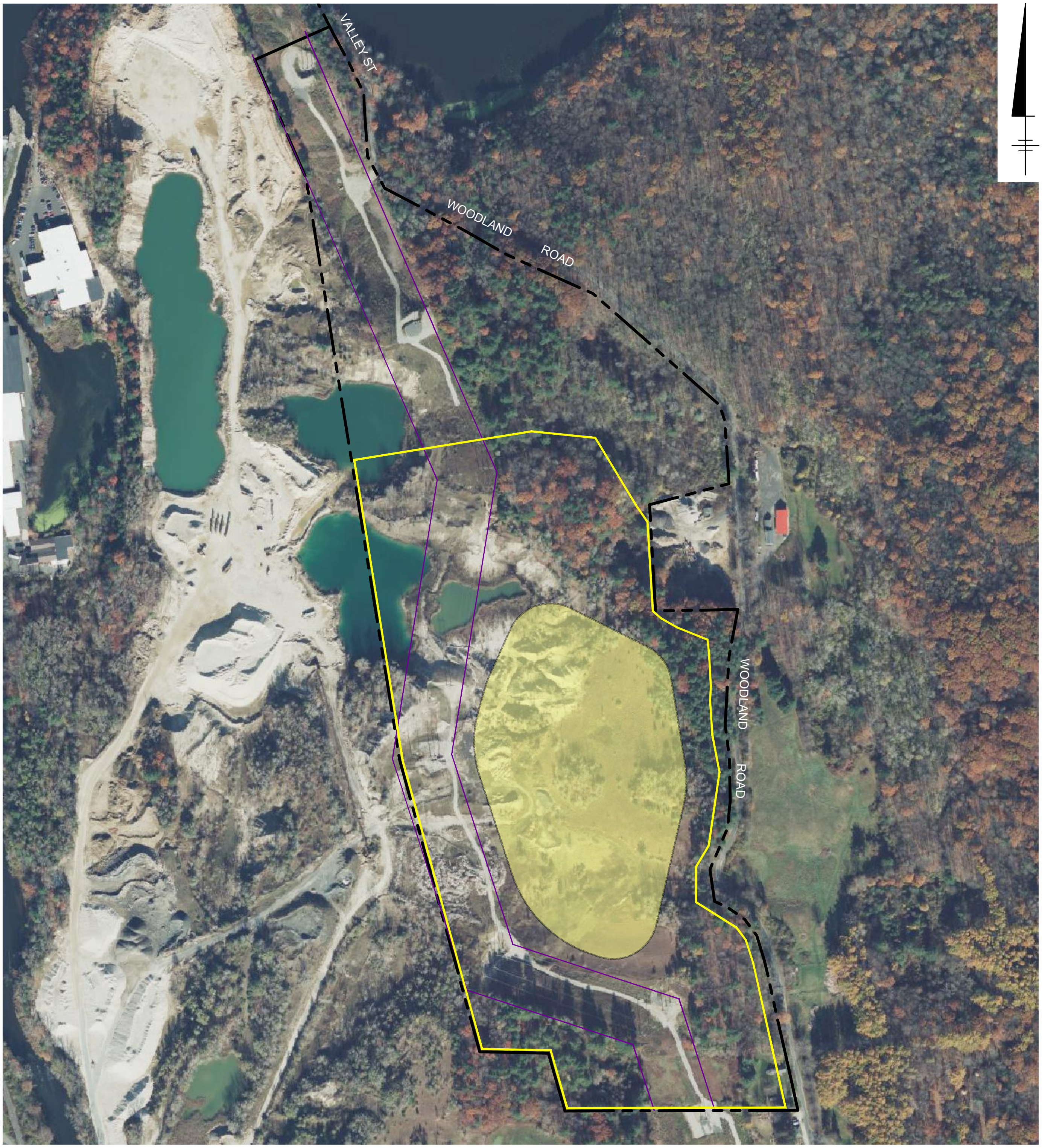
Notes:
⊡ = high priority
◐ = medium priority
○ = low priority

Table 5
Potential Greenhouse Gas Mitigation Measures
Upland Disposal Facility Final Design Plan
Housatonic River – Rest of River

ARCADIS

Measure	Reduction	Emission Type		
		Direct	Indirect	Upstream
Use of previously disturbed site for UDF	Site was previously a borrow pit and largely devoid of vegetation that would have otherwise required clearing.	✓		✓
Reuse of material excavated for UDF construction as fill in other areas	UDF construction will involve considerable earthmoving. Material that is excavated will be used as fill in other areas, thus reducing the need to import soil fill material.	✓		✓
Possible reuse of on-site concrete debris for aggregate required by UDF-related activities	Site contains concrete slabs and other debris that require relocation to accommodate UDF. Material can be processed for reuse as aggregate to surface roads and operational areas, thus beneficially reusing what would otherwise be a waste stream and reducing the need to import processed material.	✓		✓
Use of vehicle and equipment BMPs	Measures including use of fuel-efficient on-road vehicles, idling restrictions, electric or hybrid vehicles as that market continues to grow, and route planning will reduce fuel use and thereby reduce overall GHG emissions associated with fuel combustion and fuel transport.	✓		✓
Evaluation of alternative modes of transportation to on-road vehicles	Consideration will be given to the use of alternative modes of transportation to on-road vehicles for material hauling, such as rail transport (if efficient and practicable) and hydraulic transport (where feasible), to reduce overall GHG emissions associated with fuel combustion and fuel transport.	✓		✓
Employment of local workers	Use of local workers to perform site work, where available and practicable, will limit long-distance commuting to the site.	✓		✓
Employment of BMPs to reduce electricity use	BMPs for electricity use, such as use of motion detectors, will reduce electrical use for the project and thereby reduce GHG emissions from electricity generation.		✓	

Figures



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GRAPHIC SCALE

LEGEND:

- GE PARCEL BOUNDARY
- UPLAND DISPOSAL FACILITY LIMITS OF CONSOLIDATED MATERIAL
- UPLAND DISPOSAL FACILITY OPERATIONAL AREA
- EXISTING OVERHEAD TRANSMISSION EASEMENT

NOTES:

1. SITE FEATURES OBTAINED FROM DRAWING ENTITLED "PLAN OF LAND SURVEYED FOR THE LANE CONSTRUCTION CORPORATION" PREPARED BY SK DESIGN GROUP, INC., DATED JUNE 4, 2010.
2. AERIAL IMAGERY: © MICROSOFT CORPORATION © 2022 MAXAR ©CNES (2022) DISTRIBUTION AIRBUS DS.
3. UPLAND DISPOSAL FACILITY LIMITS OF CONSOLIDATED MATERIAL, OPERATIONAL AREA, AND SUPPORT AREAS SHOWN ARE CONCEPTUAL ONLY.

GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS
GE-PITTSFIELD/HOUSATONIC RIVER SITE

SITE PLAN

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FIGURE
1

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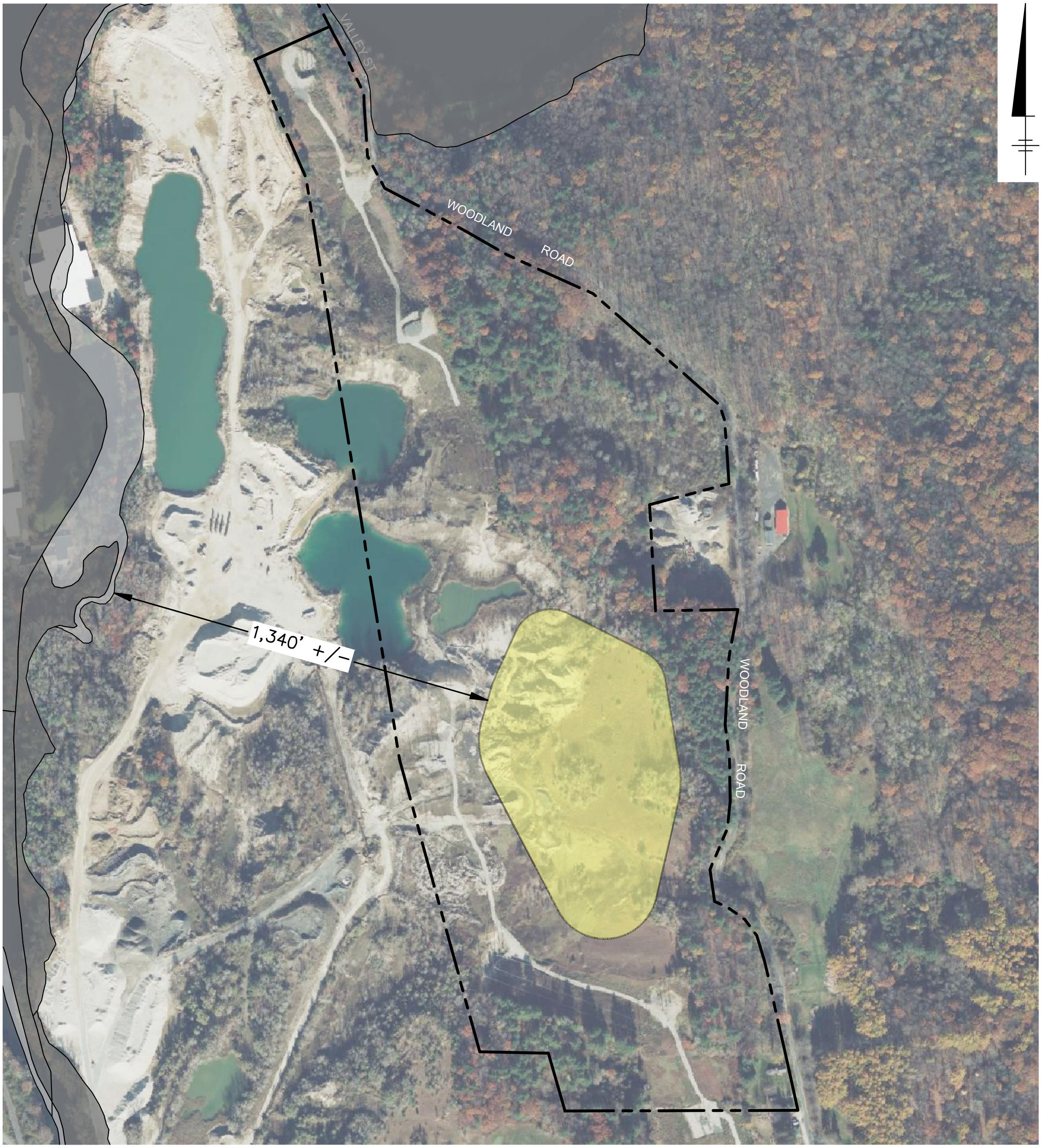

LEGEND:

- GE PARCEL BOUNDARY
- UPLAND DISPOSAL FACILITY LIMITS OF CONSOLIDATED MATERIAL
- 100-YEAR FLOODPLAIN
- 500-YEAR FLOODPLAIN

NOTES:

1. SITE FEATURES OBTAINED FROM DRAWING ENTITLED "TOPOGRAPHIC SURVEY" PREPARED BY HILL ENGINEERS, ARCHITECTS, PLANNERS, INC., DATED JULY 15, 2022.
2. AERIAL IMAGERY: © MICROSOFT CORPORATION © 2022 MAXAR ©CNES (2022) DISTRIBUTION AIRBUS DS.
3. FLOODPLAIN AREAS SHOWN TAKEN FROM FIRM MAPPING ON COMMUNITY PANEL NUMBER 250028 0003 B, EFFECTIVE DATE JUNE 1, 1982.

GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS
GE-PITTSFIELD/HOUSATONIC RIVER SITE

500-YEAR FLOODPLAIN DISTANCE FROM CONSOLIDATION AREA

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FIGURE
2

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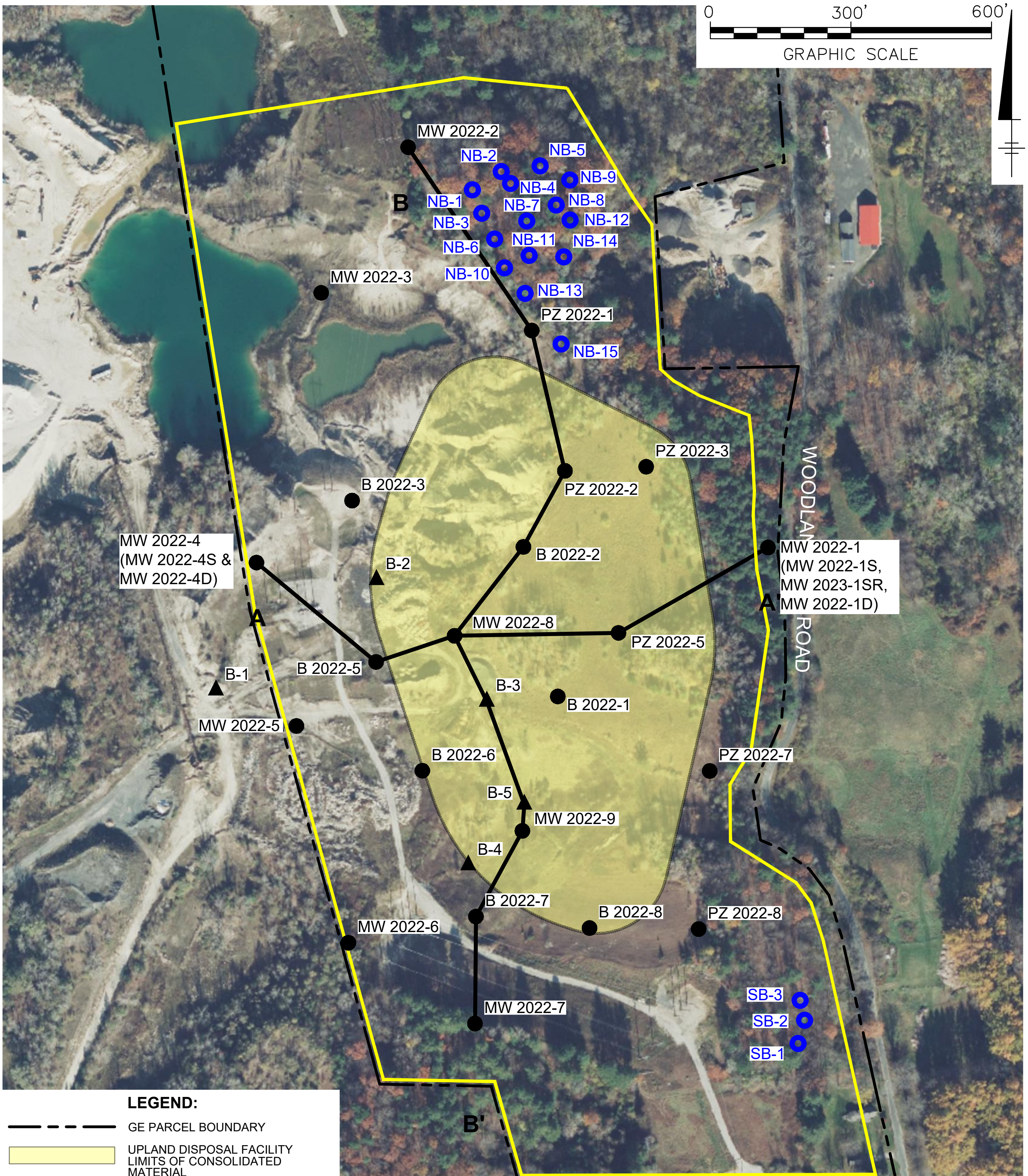


LEGEND:

- GE PARCEL BOUNDARY
- UPLAND DISPOSAL FACILITY LIMITS OF CONSOLIDATED MATERIAL
- UPLAND DISPOSAL FACILITY OPERATIONAL AREA
- ▲ HISTORICAL GEOPROBE LOCATIONS
- ● SOIL BORINGS WITH GEOTECHNICAL SAMPLING
- ○ STORMWATER BASIN TEST BORING
- A——A' GEOLOGIC CROSS SECTION LOCATION

NOTES:

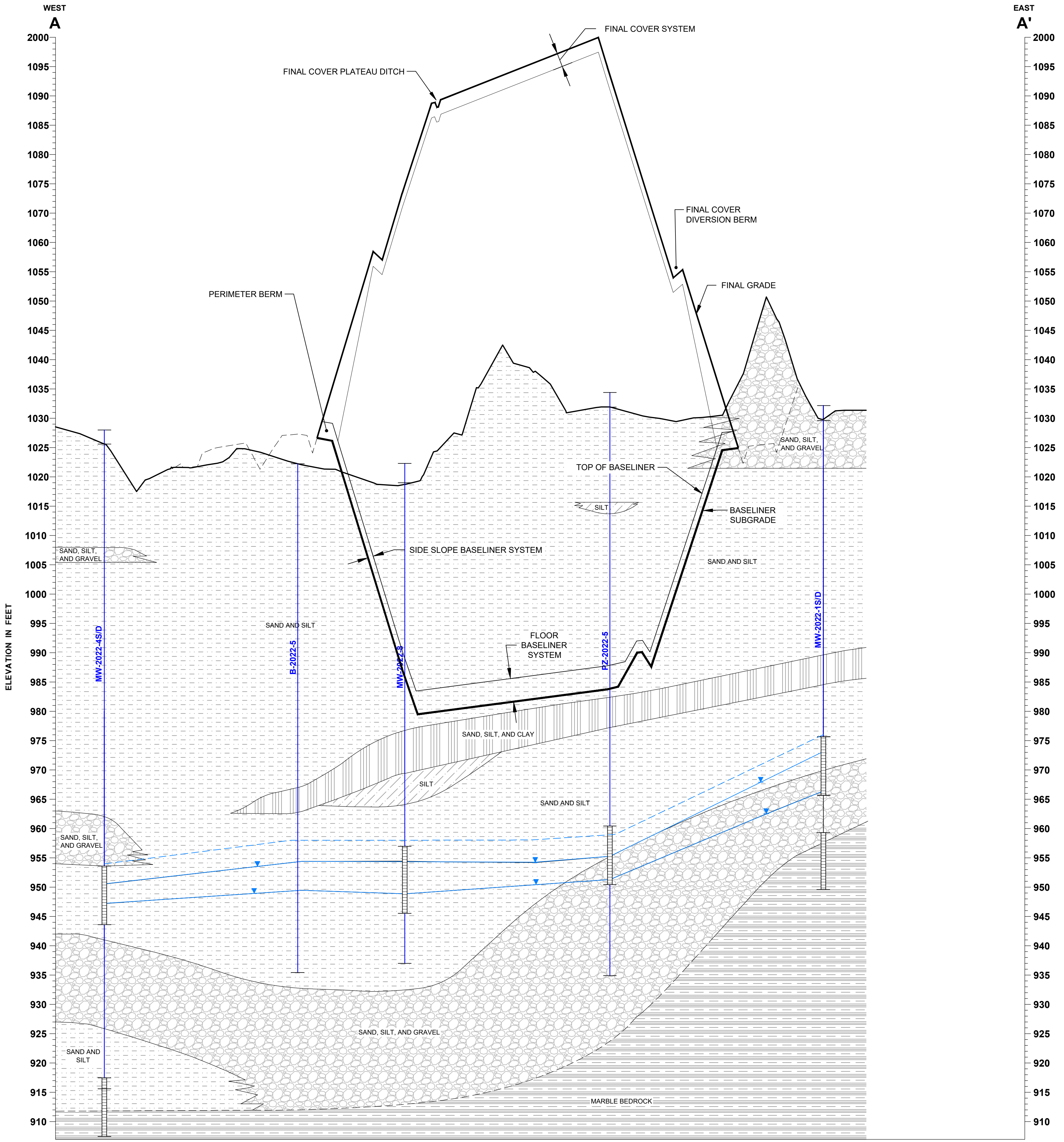
1. SITE FEATURES OBTAINED FROM DRAWING ENTITLED "PLAN OF LAND SURVEYED FOR THE LANE CONSTRUCTION CORPORATION" PREPARED BY SK DESIGN GROUP, INC., DATED JUNE 4, 2010.
2. AERIAL IMAGERY: © MICROSOFT CORPORATION © 2022 MAXAR ©CNES (2022) DISTRIBUTION AIRBUS DS.
3. UPLAND DISPOSAL FACILITY LIMITS OF CONSOLIDATED MATERIAL, OPERATIONAL AREA, AND SUPPORT AREAS SHOWN ARE CONCEPTUAL ONLY.
4. AS-BUILT SOIL INFILTRATION TESTING LOCATIONS PROVIDED BY HILL ENGINEERS ON JULY 17, 2023.
5. MW 2022-1S ABANDONED NOVEMBER 2023 AND REPLACED BY MW 2023-1SR.

GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS
GE-PITTSFIELD/HOUSATONIC RIVER SITE

SOIL GEOTECHNICAL INVESTIGATION

ARCADIS

FIGURE
3



LEGEND:

- MW-1 — BORING/PIEZOMETER/ WELL NUMBER
- GROUND SURFACE
- ESTIMATED SEASONAL HIGH GROUNDWATER ELEVATION (SEE NOTE 2)
- HIGH AND LOW GROUNDWATER ELEVATION MEASURED IN WELL (JUNE 2022–JUNE 2023)
- SCREENED INTERVAL
- UNIT CONTACT
- UNIT CONTACT (INFERRED)
- BOTTOM OF PZ/WELL
- BOTTOM OF BORING

NOTE:

1. GROUNDWATER ELEVATIONS MEASURED BY PRESSURE TRANSDUCERS DEPLOYED IN WELLS AND PIEZOMETERS FROM JUNE 6, 2022 – JUNE 8, 2023.
2. THE ESTIMATE OF SEASONAL HIGH GROUNDWATER ELEVATION SHOWN IS BASED ON THE METHODOLOGY AND RESULTING CALCULATIONS DESCRIBED IN SECTION 3.6.2 OF THE REVISED FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024).

GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS
GE-PITTSFIELD/HOUSATONIC RIVER SITE

A-A' WEST-EAST GEOLOGIC CROSS SECTION

ARCADIS

FIGURE
4

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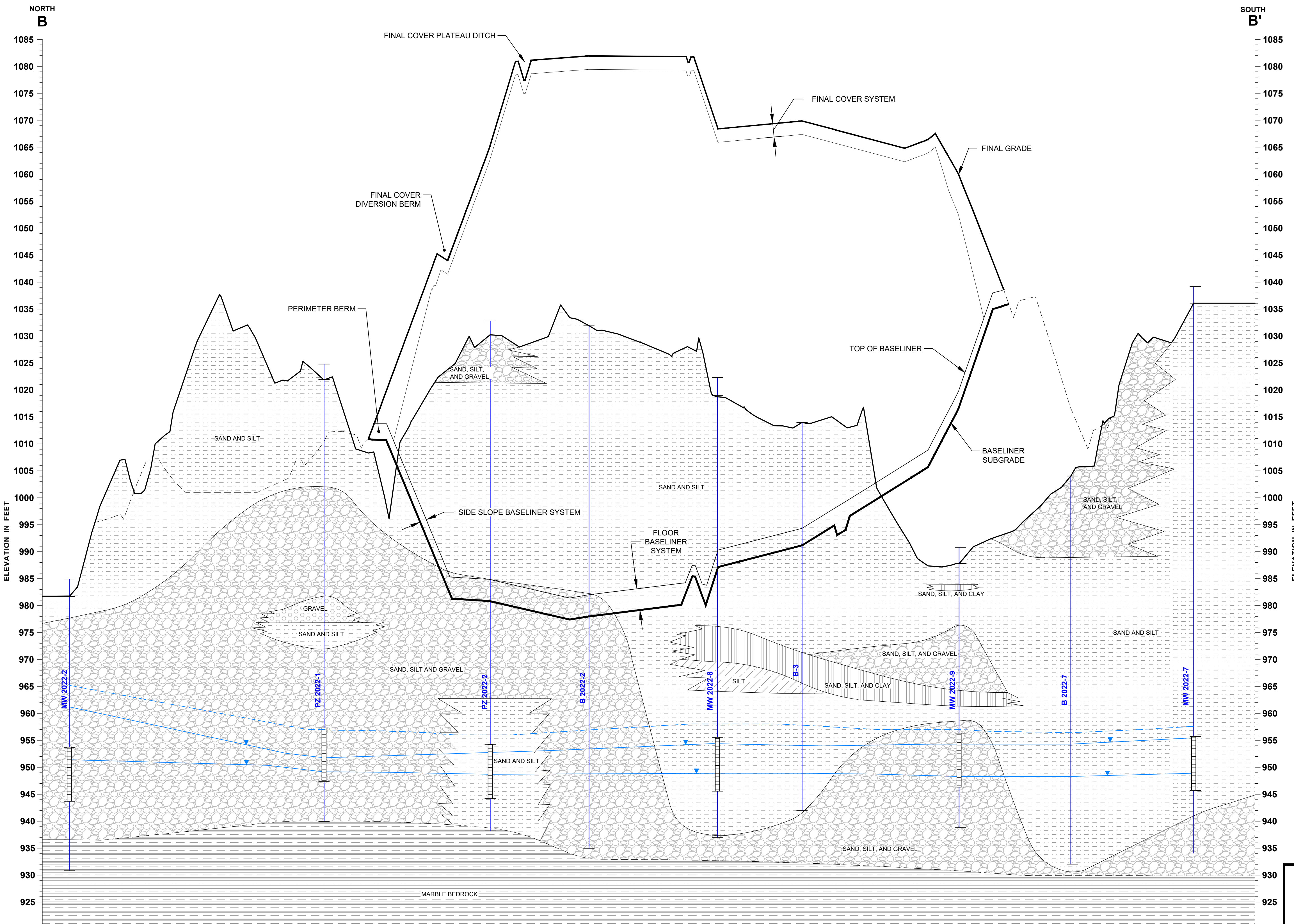

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- UNIT CONTACT (INFERRED)
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2. THE ESTIMATE OF SEASONAL HIGH GROUNDWATER ELEVATION SHOWN IS BASED ON THE METHODOLOGY AND RESULTING CALCULATIONS DESCRIBED IN SECTION 3.6.2 OF THE REVISED FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024).

GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS
GE-PITTSFIELD/HOUSATONIC RIVER SITE

B-B' NORTH-SOUTH GEOLOGIC CROSS SECTION

ARCADIS

FIGURE
5

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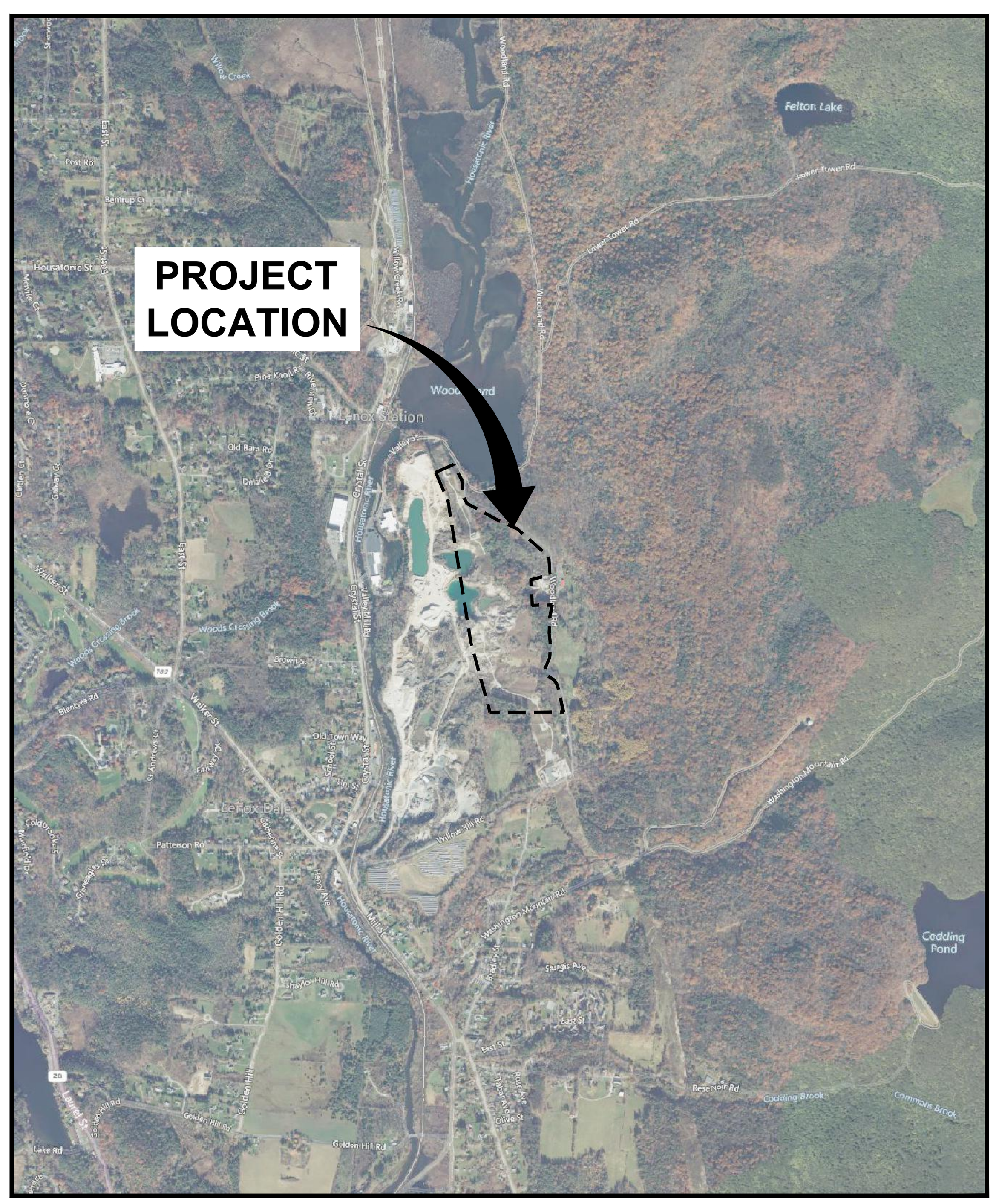
Appendices

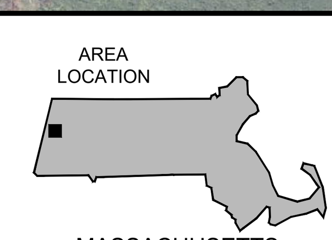
Appendix A

Design Drawings

DESIGN DRAWINGS

GE-PITTSFIELD/HOUSATONIC RIVER SITE UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN





LOCATION MAP

0 2000' 4000'
GRAPHIC SCALE

DATE ISSUED / DATE REVISED

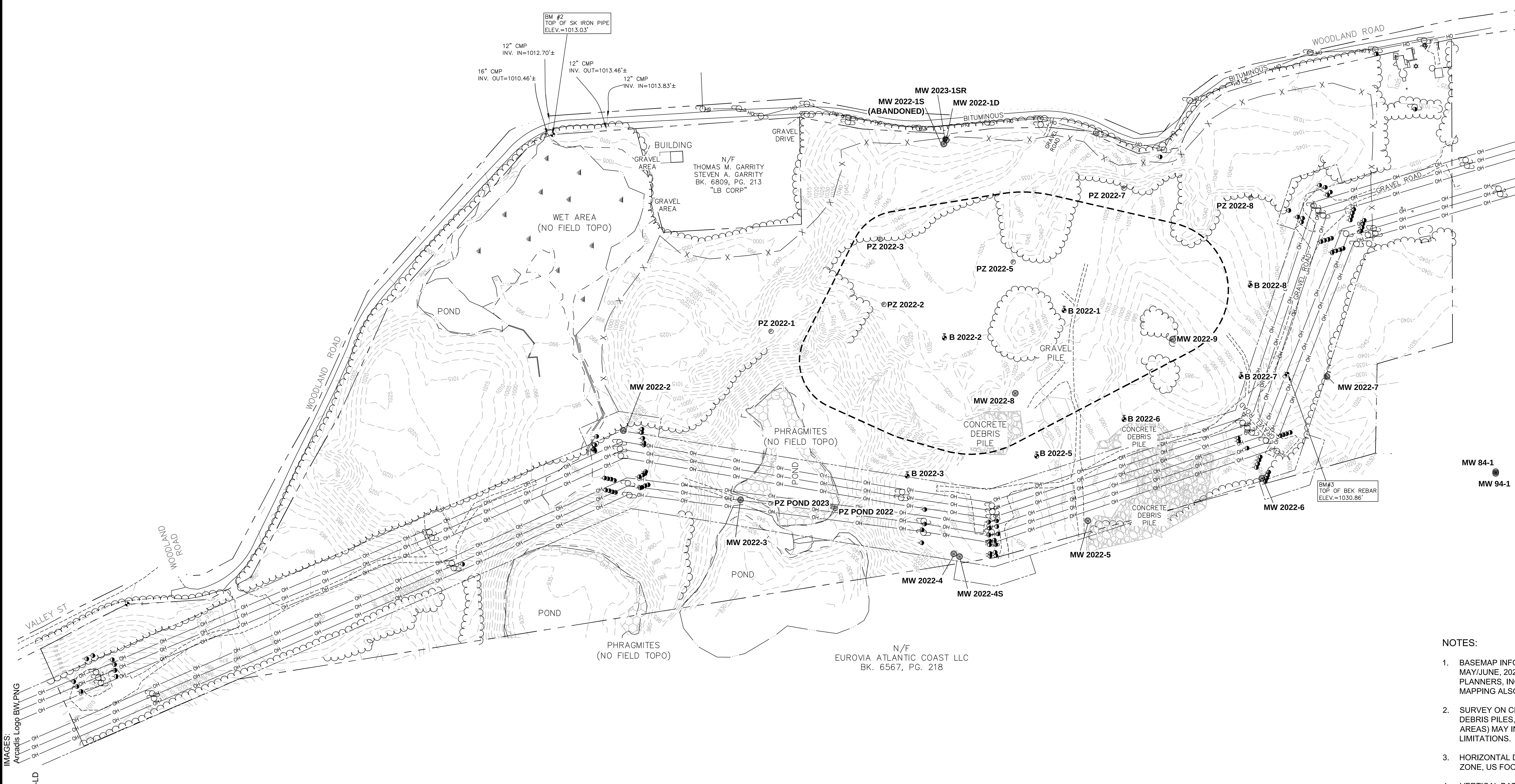
FEBRUARY 2024

LEE, MASSACHUSETTS
BERKSHIRE COUNTY

GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS

ARCADIS
ARCADIS U.S., INC.

INDEX TO DRAWINGS



EXISTING FEATURES LEGEND

- REBAR FOUND
- IRON PIN FOUND
- CONCRETE BOUND FOUND
- GRANITE BOUND FOUND
- BENCH MARK
- LAMP POST
- UTILITY POLE
- GUY WIRE
- MW 2022-2 — MONITORING WELL
- PZ 2022-8 — PIEZOMETER
- B 2022-8 — SOIL BORING
- WET AREA
- 1101.7 — SPOT ELEVATION
- APPROXIMATE PROPERTY BOUNDARY
- EDGE OF GRAVEL
- EDGE OF BITUMINOUS
- EDGE OF WATER
- EDGE OF WETLAND
- STONEWALL
- OH — OVERHEAD WIRES
- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- 1010 — ELEVATION CONTOUR (5-FOOT INTERVAL)
- EVERSOURCE RIGHT- OF-WAY
- UDF LIMITS OF CONSOLIDATED MATERIAL
- X — UDF SECURITY FENCE

NOTES:

1. BASEMAP INFORMATION BASED ON A FIELD SURVEYS CONDUCTED IN MAY/JUNE, 2022 AND AUGUST, 2023 BY HILL-ENGINEERS, ARCHITECTS, PLANNERS, INC. EXCEPT WETLAND LIMITS WHICH WERE PROVIDED BY AECOM. MAPPING ALSO INCLUDES BATHYMETRY SURVEY WITHIN POND AREAS.
2. SURVEY ON CERTAIN PORTIONS OF THE PARCEL (E.G., SLOPED AREAS, DEBRIS PILES, GRAVEL PILES, SUBMERGED LAND, AND HEAVY VEGETATION AREAS) MAY INCLUDE ONLY LIMITED SURVEY INFORMATION DUE TO ACCESS LIMITATIONS.
3. HORIZONTAL DATUM IS NSRS 2007 MASSACHUSETTS STATE PLANE, MAINLAND ZONE, US FOOT.
4. VERTICAL DATUM IS NORTH AMERICAN VERTICAL DATUM 1988 (NAVD88).
5. PARCEL AREA WITH DWELLING STRUCTURE CONTAINS VARIOUS FEATURES INCLUDING, BUT NOT LIMITED TO, RESIDENTIAL PROPANE TANK, POSTS, GROUND-LEVEL COVERS, OUTBUILDINGS, WATER SUPPLY WELL.

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XREFS: X-UDF-EXISTING SITE X-2023-EX-CONTOURS X-INT DRAFT-UDF-BDR-C-LD X-2023-P-FENCE

IMAGES: Arcadis Logo BW.PNG

150' 0 150' 300'
1"=150'

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

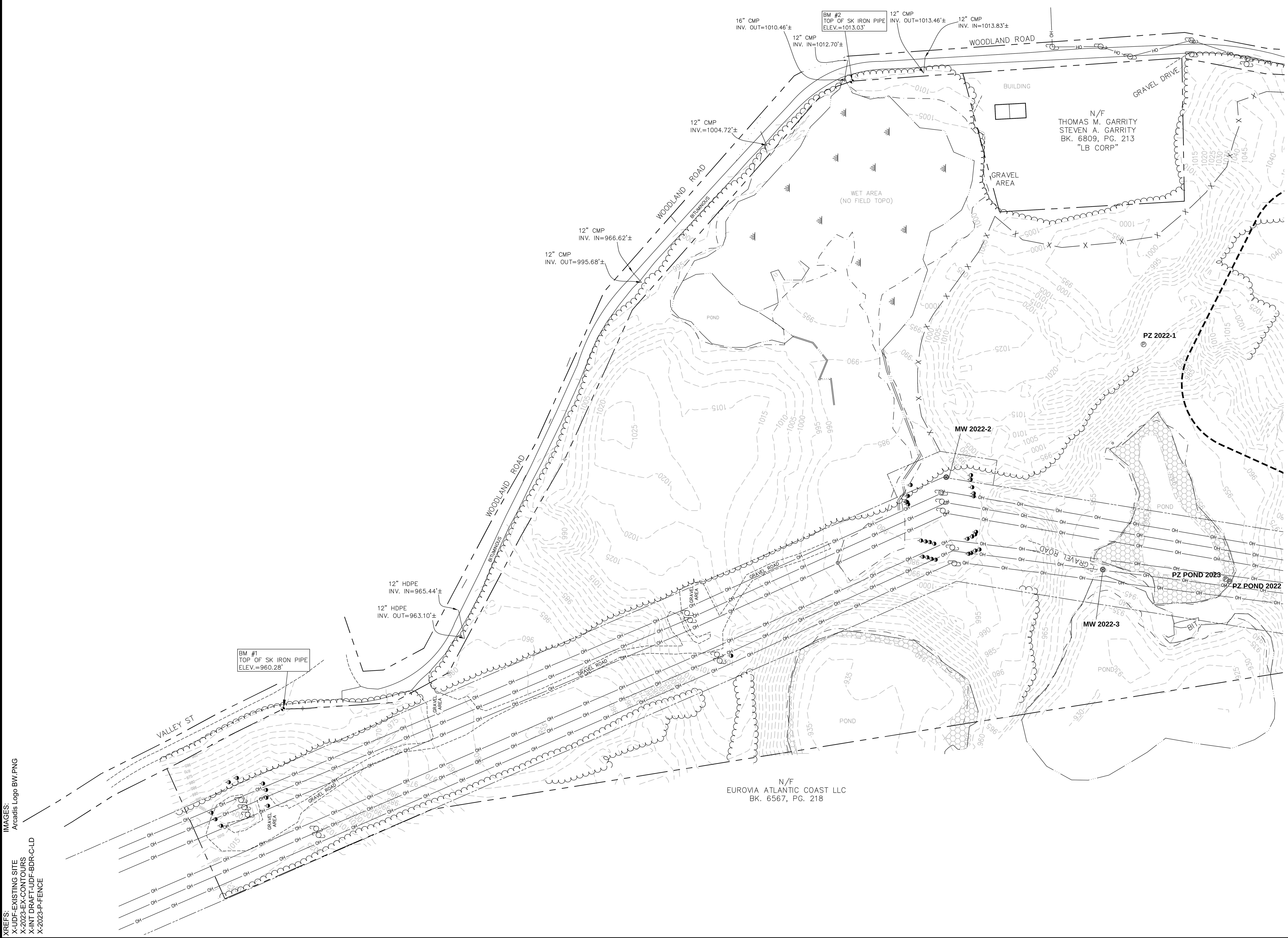
OVERALL SITE PLAN

ARCADIS Project No. 30197838

Date: FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

1



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3. HORIZONTAL DATUM IS NSRS 2007 MASSACHUSETTS STATE PLANE, MAINLAND ZONE, US FOOT.
4. VERTICAL DATUM IS NORTH AMERICAN VERTICAL DATUM 1988 (NAVD88).

XREFS: X-UDF-EXISTING SITE, X-2023-EX-CONTOURS, X-INT DRAFT-UDF-BDR-C-LD, X-2023-P-FENCE
IMAGES: Arcadis Logo BW.PNG

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

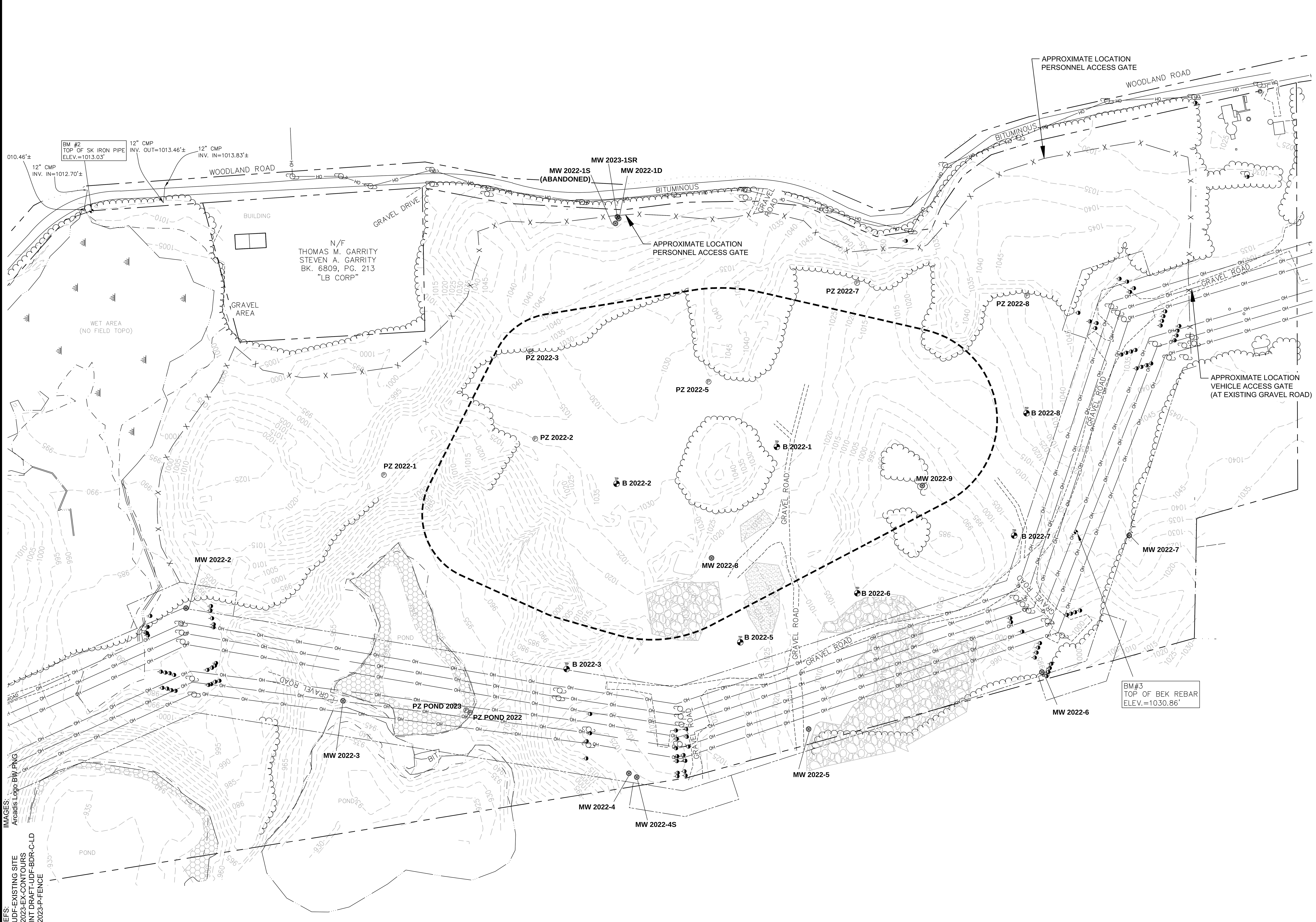
ARCADIS
ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

EXISTING CONDITIONS PLAN (NORTH)

ARCADIS Project No. 30197838
Date FEBRUARY 2024
ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

2A



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IMAGES: Arcadis Logo BW.PNG

100' 0 100' 200'
1"=100'

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Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

ARCADIS

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GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

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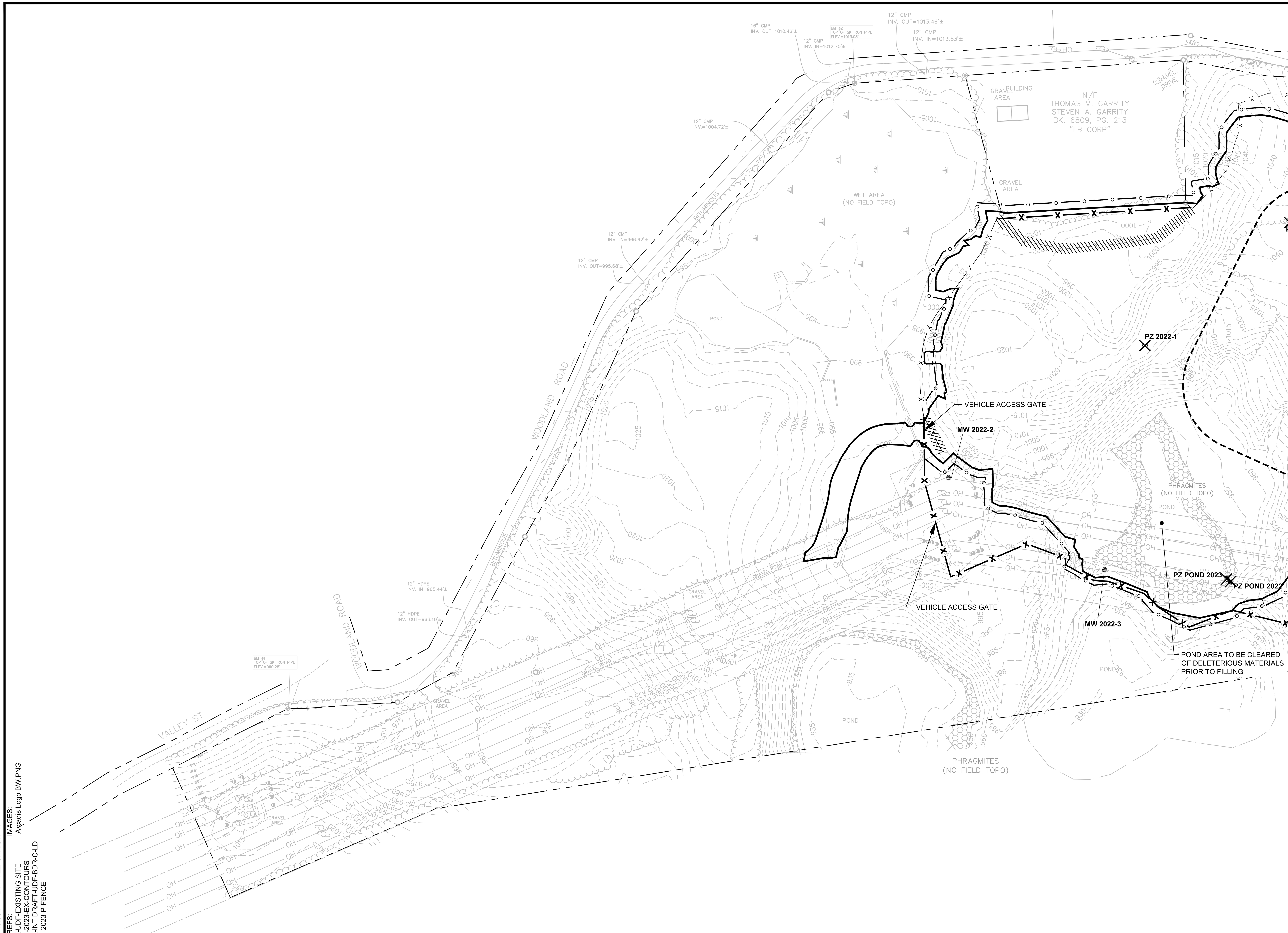

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- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- INSTALLED UDF SECURITY FENCE

DESIGN FEATURES LEGEND

- EROSION CONTROL MEASURE (SEE NOTE 4 AND 5)
- APPROXIMATE LIMITS OF GRADING
- UDF LIMITS OF CONSOLIDATED MATERIAL
- ABANDONMENT OF EXISTING MONITORING WELL/PIEZOMETER
- UDF SECURITY FENCE ADDITION
- UDF SECURITY FENCE REMOVAL (SEE NOTE 3)

NOTES:

1. REFER TO DRAWINGS 2A AND 2B FOR BASEMAP INFORMATION.
2. DEBRIS PILES WITHIN LIMITS OF GRADING TO BE RELOCATED TO AN AREA OUTSIDE OF THE LIMITS OF GRADING AT A LOCATION ACCEPTABLE TO OWNER.
3. REMOVAL OF INSTALLED UDF SECURITY FENCE EXTENTS ARE BASED ON INTERFERENCE OF UDF FEATURES AND FENCE LOCATIONS.
4. EROSION CONTROL MEASURE LOCATIONS SHOWN ARE CONCEPTUAL ONLY. ACTUAL LOCATIONS MAY VARY BASED ON FIELD CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION.
5. EROSION CONTROL MEASURES INCLUDE, BUT ARE NOT LIMITED TO, SILT FENCE, STRAW WATTLES, AND STONE CHECK DAMS. REFER TO DRAWING 34 FOR DETAILS.

XREFS:
X-UDF-EXISTING SITE
X-2023-EX-CONTOURS
X-INT DRAFT-UDF-BDR-C-LD
X-2023-P-FENCE

IMAGES:
Arcadis Logo BW.PNG

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MA		DK
Designed by	**Drawn by**	**Checked by**
BMS	KLS	PHB

ARCADIS

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS

UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

SITE PREPARATION PLAN (NORTH)

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ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
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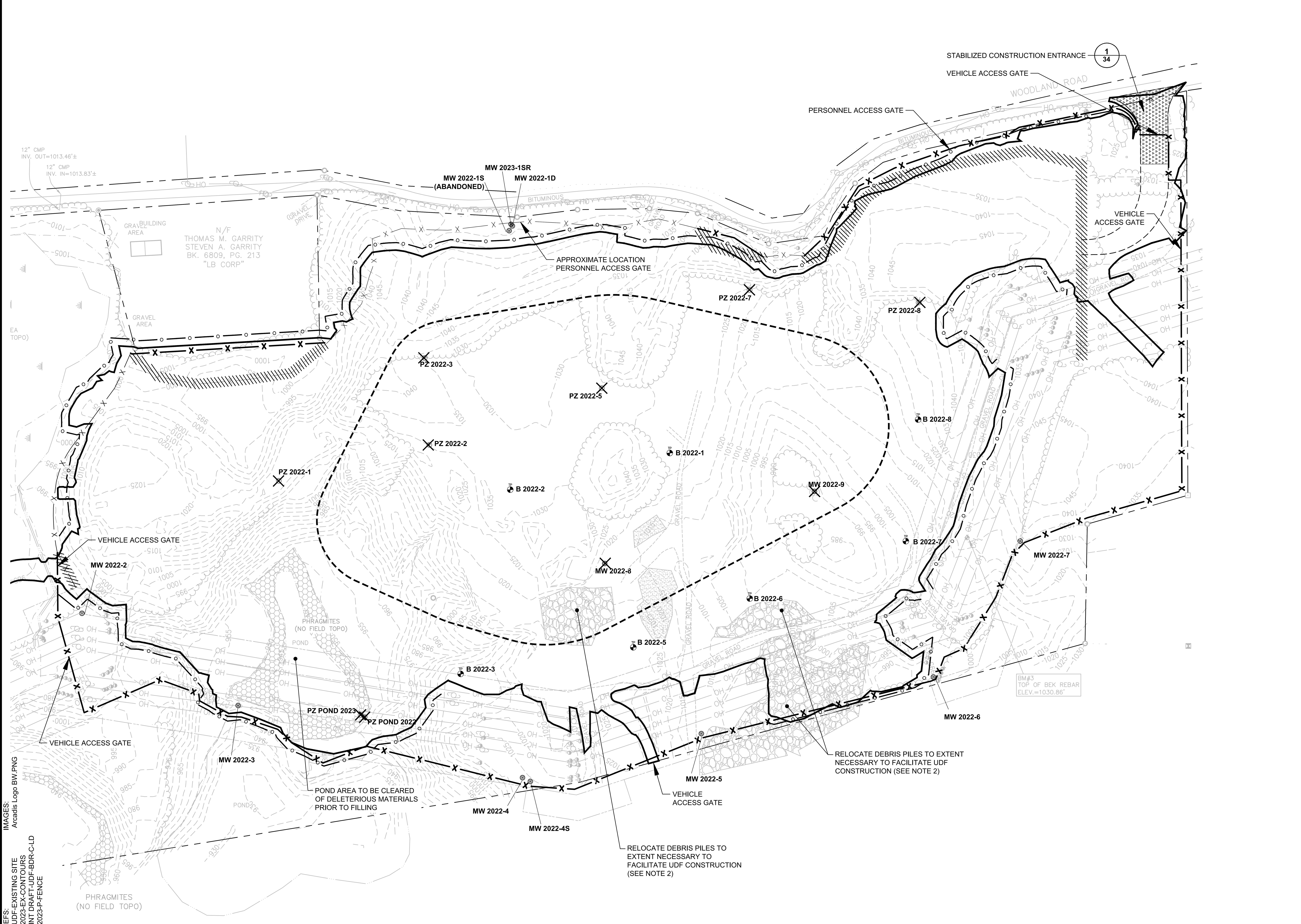
3A



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No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed:	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

ARCADIS

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

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ARCADIS Project No. 30197838

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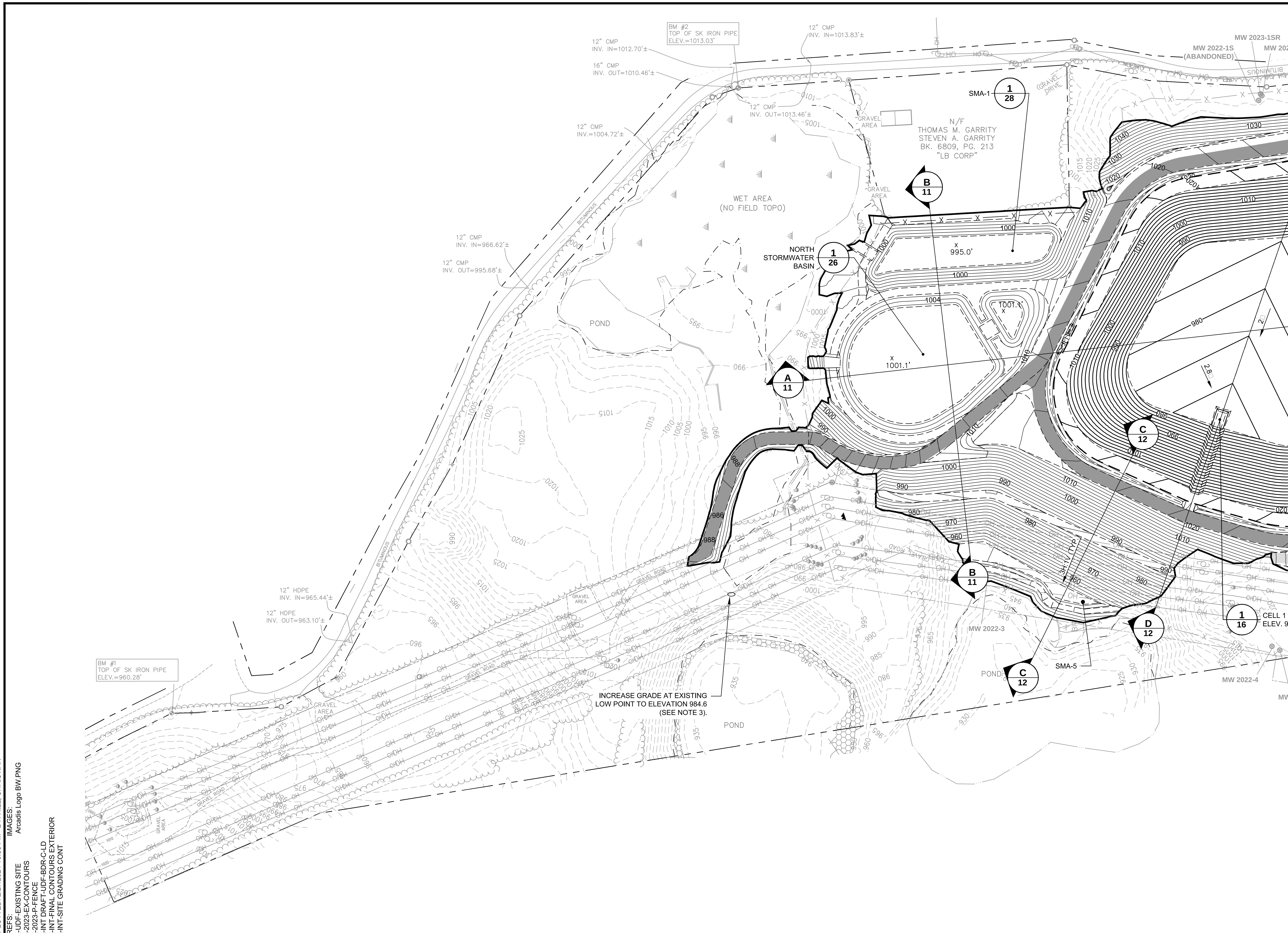
3B



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- 1010 — ELEVATION CONTOUR (5-FOOT INTERVAL)
- EVERSOURCE RIGHT-OF-WAY

DESIGN FEATURES LEGEND

- ELEVATION GRADE BREAK
- 1020 — INDEX ELEVATION CONTOUR (5-F00T INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOUR (2-F00T INTERVAL, SEE NOTE 2)
- X — UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON SHEET 3A)
- UDF LIMITS OF CONSOLIDATED MATERIAL
- APPROXIMATE LIMITS OF GRADING
- SMA — STORMWATER MANAGEMENT AREA
- DETAIL/SECTION REFERENCE NUMBER
- DRAWING REFERENCE NUMBER
- UDF ACCESS ROAD
- UTILITY RIGHT OF WAY ACCESS ROAD
- x 1101.7' — SPOT ELEVATION

NOTES:

1. REFER TO DRAWING 2A AND 2B FOR BASEMAP INFORMATION.
2. DESIGN ELEVATIONS SHOWN WITHIN UDF BASELINER LIMITS REPRESENT LINER SYSTEM SUBGRADE ELEVATIONS. DESIGN ELEVATIONS SHOWN OUTSIDE UDF BASELINER LIMITS REPRESENT FINAL GRADE ELEVATIONS.
3. INCREASE LOW POINT GRADE USING COMPACTED TOPSOIL AND INSTALL TEMPORARY EROSION CONTROL MAT.

XREFS: X-UDF-EXISTING SITE, X-2023-EX-CONTOURS, X-2023-P-FENCE, X-INT DRAFT-UDF-BDR-C-LD, X-INT-FINAL CONTOURS EXTERIOR, X-INT-SITE GRADING CONT

IMAGES: Arcadis Logo BW.PNG

100' 0 100' 200'
1"=100'

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

ARCADIS

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

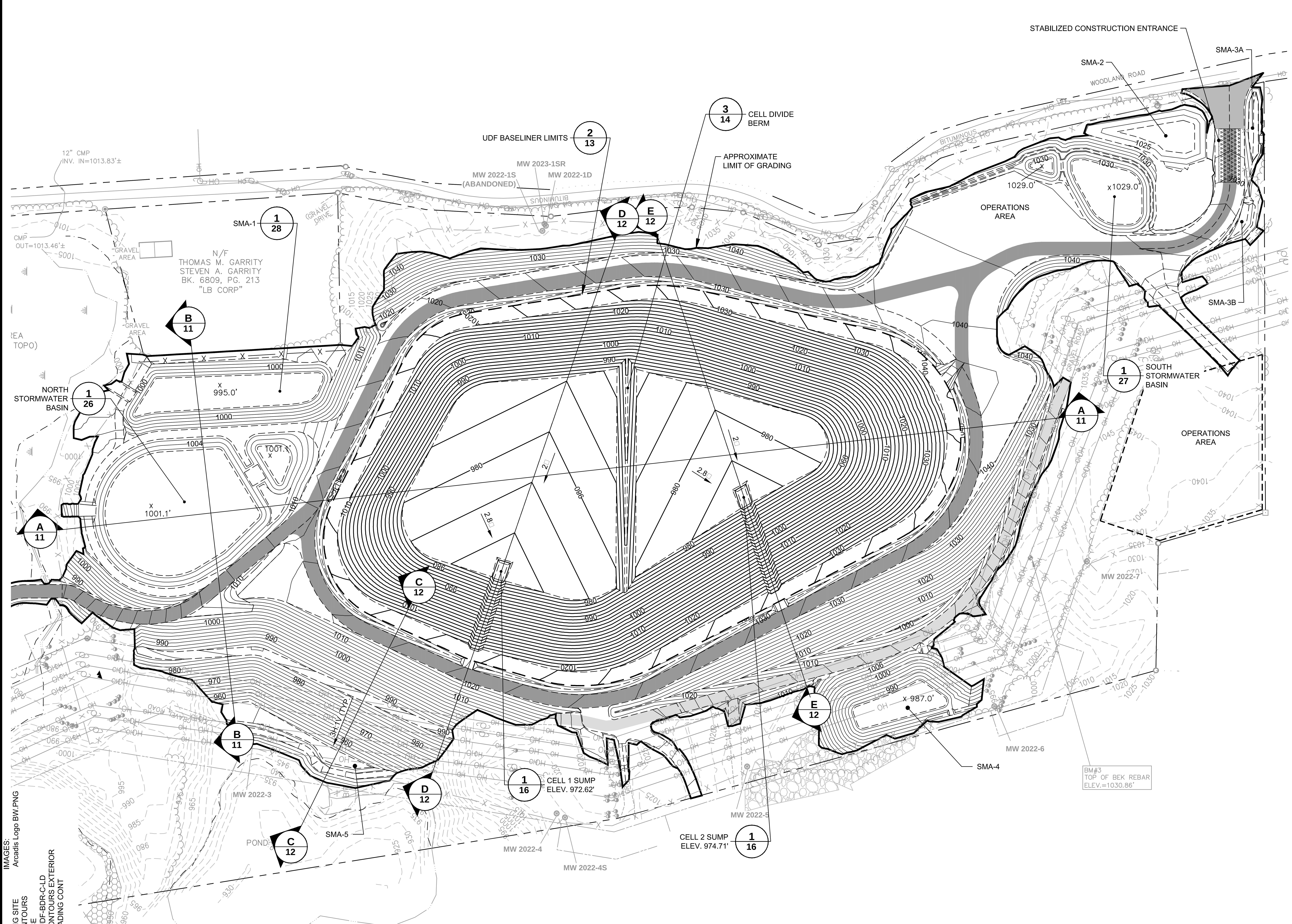
INITIAL SITE GRADING PLAN (NORTH)

ARCADIS Project No. 30197838

Date: FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

4A



EXISTING FEATURES LEGEND

- REBAR FOUND
- IRON PIN FOUND
- CONCRETE BOUND FOUND
- GRANITE BOUND FOUND
- BENCH MARK
- UTILITY POLE
- LAMP POST
- GUY WIRE
- MW 2022-2 — MONITORING WELL
- PZ 2022-8 — PIEZOMETER
- B 2022-8 — SOIL BORING
- WET AREA
- APPROXIMATE PROPERTY BOUNDARY
- EDGE OF GRAVEL
- EDGE OF BITUMINOUS
- EDGE OF WATER
- EDGE OF WETLAND
- STONEWALL
- OH — OVERHEAD WIRES
- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- 1010 — ELEVATION CONTOUR (5-FOOT INTERVAL)
- EVERSOURCE RIGHT-OF-WAY

DESIGN FEATURES LEGEND

- ELEVATION GRADE BREAK
- 1020 — INDEX ELEVATION CONTOUR (5-F00T INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOUR (2-F00T INTERVAL, SEE NOTE 2)
- X — UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON SHEET 3A)
- UDF LIMITS OF CONSOLIDATED MATERIAL
- APPROXIMATE LIMITS OF GRADING
- SMA — STORMWATER MANAGEMENT AREA
- DETAIL/SECTION REFERENCE NUMBER
- DRAWING REFERENCE NUMBER
- UDF ACCESS ROAD
- UTILITY RIGHT OF WAY ACCESS ROAD
- x 1101.7' — SPOT ELEVATION

NOTES:

1. REFER TO DRAWING 2A AND 2B FOR BASEMAP INFORMATION.
2. DESIGN ELEVATIONS SHOWN WITHIN UDF BASELINER LIMITS REPRESENT LINER SYSTEM SUBGRADE ELEVATIONS. DESIGN ELEVATIONS SHOWN OUTSIDE UDF BASELINER LIMITS REPRESENT FINAL GRADE ELEVATIONS.

XREFS: X-UDF-EXISTING SITE, X-2023-EX-CONTOURS, X-2023-P-FENCE, X-INT DRAFT-UDF-BDR-C-LD, X-INT-FINAL CONTOURS EXTERIOR, X-INT-SITE GRADING CONT
IMAGES: Arcadis Logo BW.PNG

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PLOTSTYLETABLE: ---- PLOTTED: 2/27/2024 10:33 PM BY: HILL, CHRISTIAN

100' 0 100' 200'
1"=100'

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No.	Date	Revisions	By	Ckd

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Professional Engineer's Name: **MARK O. GRAVELDING**
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

INITIAL SITE GRADING PLAN (SOUTH)

ARCADIS Project No. 30197838
Date: FEBRUARY 2024
ARCADIS, ONE LINCOLN CENTER, 110 WEST FAYETTE STREET, SYRACUSE, NEW YORK 13202, TEL. 315.446.9120

4B

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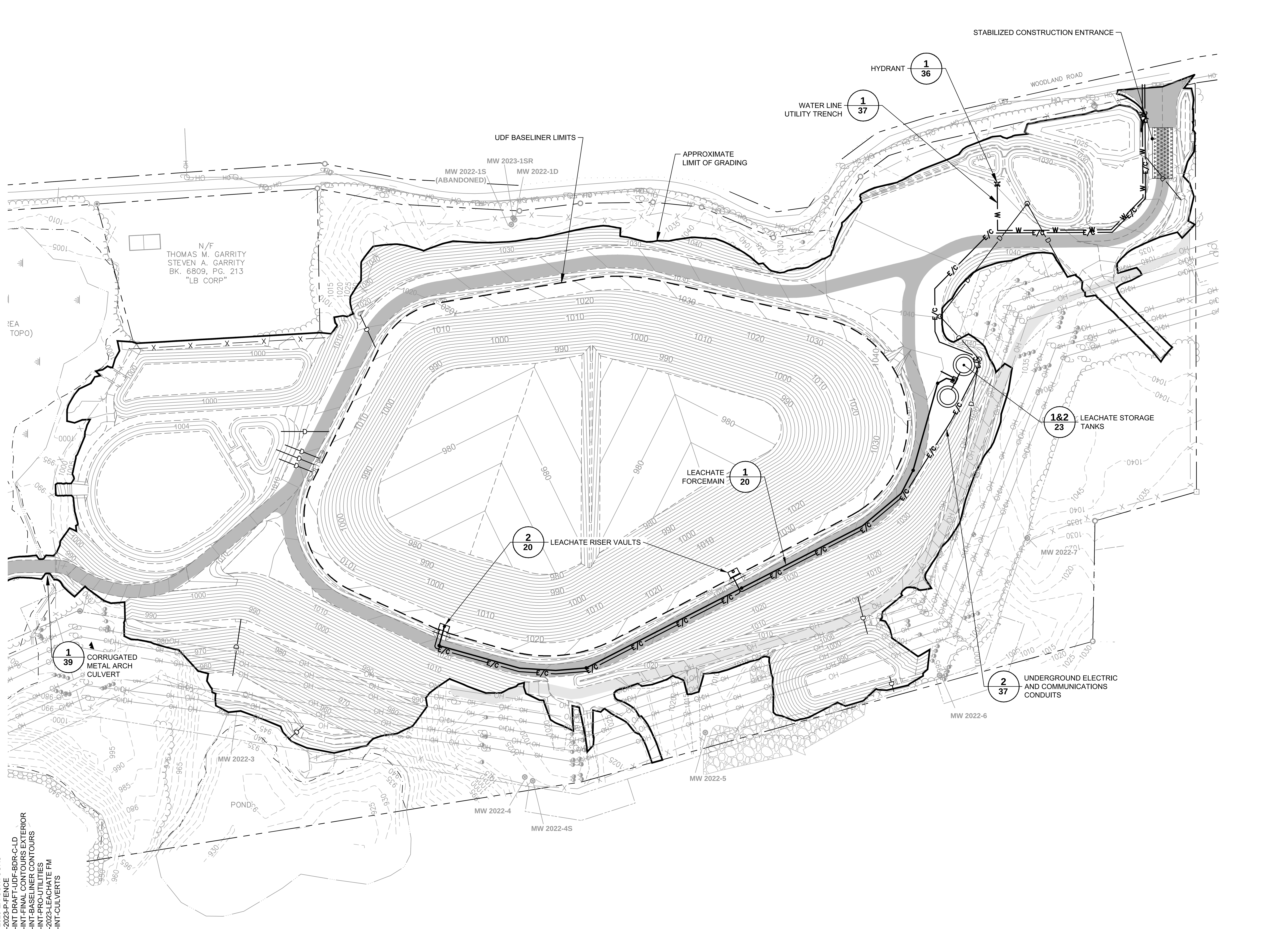
XREFS: X-UDF-EXISTING SITE X-2023-EX-CONTOURS X-2023-P-FENCE X-INT DRAFT-UDF-BDR-C-LD X-INT-FINAL CONTOURS EXTERIOR X-INT-BASELINER CONTOURS X-INT-PRO-UTILITIES X-2023-LEACHATE FM X-INT-CULVERTS

IMAGES: Arcadis Logo BW.PNG



EXISTING FEATURES LEGEND

- REBAR FOUND
- IRON PIN FOUND
- CONCRETE BOUND FOUND
- GRANITE BOUND FOUND
- BENCH MARK
- UTILITY POLE
- LAMP POST
- GUY WIRE
- MW 2022-2 — MONITORING WELL
- PZ 2022-8 — PIEZOMETER
- B 2022-8 — SOIL BORING
- WET AREA
- APPROXIMATE PROPERTY BOUNDARY
- EDGE OF GRAVEL
- EDGE OF BITUMINOUS
- EDGE OF WATER
- EDGE OF WETLAND
- STONEWALL
- OH — OVERHEAD WIRES
- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- 1010 — ELEVATION CONTOUR (5-FOOT INTERVAL)
- EVERSOURCE RIGHT-OF-WAY

DESIGN FEATURES LEGEND

- ELEVATION GRADE BREAK
- 1020 — INDEX ELEVATION CONTOUR (5-F00T INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOUR (2-F00T INTERVAL, SEE NOTE 2)
- X — X — UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON SHEET 3A)
- UDF LIMITS OF CONSOLIDATED MATERIAL
- APPROXIMATE LIMITS OF GRADING
- SMA — STORMWATER MANAGEMENT AREA
- DETAIL/SECTION REFERENCE NUMBER
- DRAWING REFERENCE NUMBER
- UDF ACCESS ROAD
- UTILITY RIGHT OF WAY ACCESS ROAD
- E/C — UNDERGROUND ELECTRIC AND COMMUNICATIONS CONDUITS
- W — WATER SERVICE LINE
- D — STORMWATER DRAIN PIPE 3/37

NOTES:

1. REFER TO DRAWING 2A AND 2B FOR BASEMAP INFORMATION.
2. DESIGN ELEVATIONS SHOWN WITHIN UDF BASELINER LIMITS REPRESENT LINER SYSTEM SUBGRADE ELEVATIONS. DESIGN ELEVATIONS SHOWN OUTSIDE UDF BASELINER LIMITS REPRESENT FINAL GRADE ELEVATIONS.
3. REFER TO DRAWING 9 FOR STORMWATER CONVEYANCE INFORMATION.
4. REFER TO DRAWING 18 FOR LEACHATE TRANSFER AND STORAGE INFORMATION.

100' 0 100' 200'
1"=100'

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name: **MARK O. GRAVELDING**
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	**Drawn by**	**Checked by**
BMS	KLS	PHB

ARCADIS

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

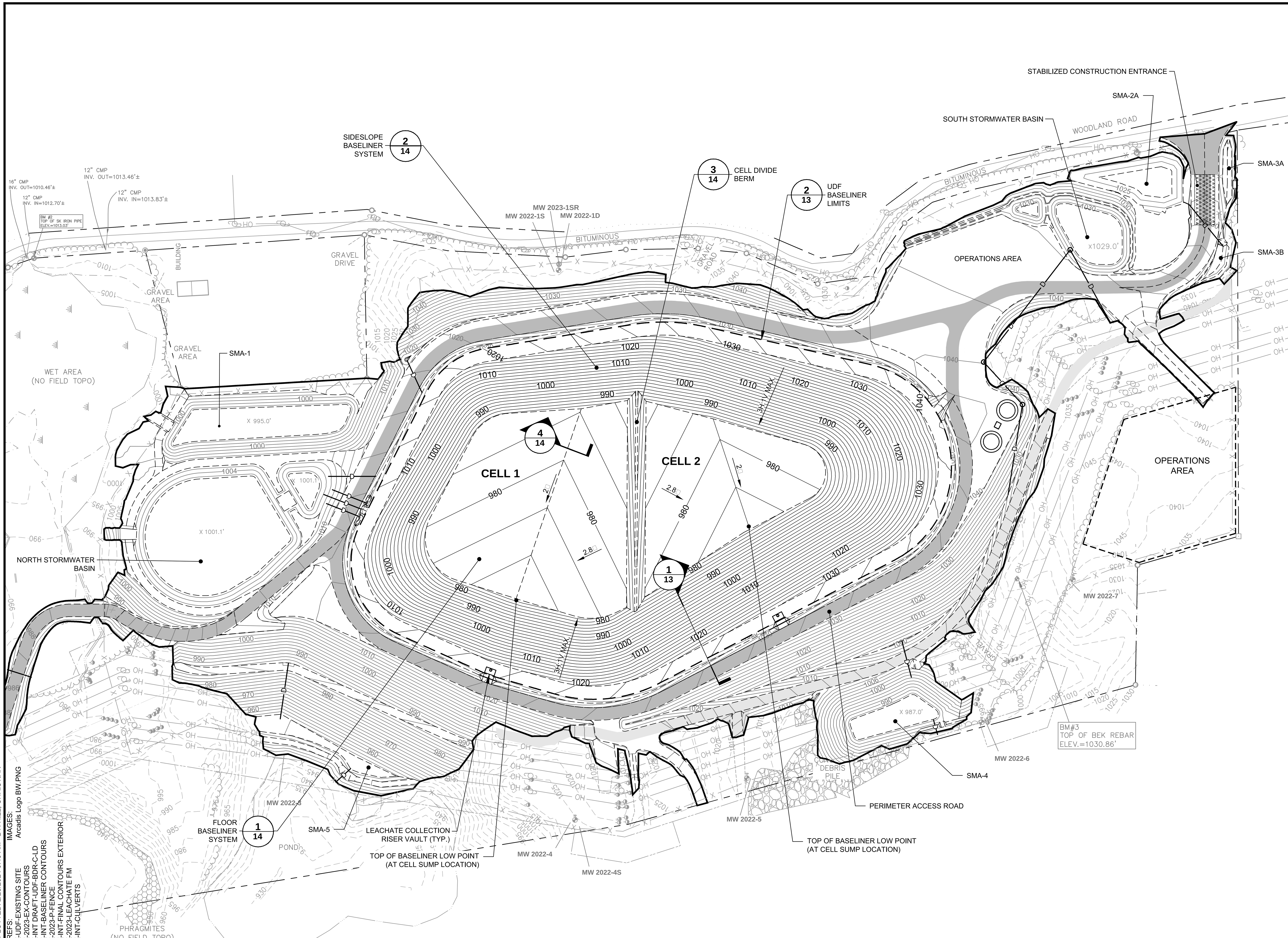
SITE UTILITY PLAN

ARCADIS Project No. 30197838

Date: FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

4C



EXISTING FEATURES LEGEND

- REBAR FOUND
- IRON PIN FOUND
- CONCRETE BOUND FOUND
- GRANITE BOUND FOUND
- BENCH MARK
- UTILITY POLE
- LAMP POST
- GUY WIRE
- MW 2022-2 MONITORING WELL
- PZ 2022-8 PIEZOMETER
- WET AREA
- APPROXIMATE PROPERTY BOUNDARY
- EDGE OF GRAVEL
- EDGE OF BITUMINOUS
- EDGE OF WATER
- EDGE OF WETLAND
- STONEWALL
- OH OVERHEAD WIRES
- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- 1010 ELEVATION CONTOUR (5-FOOT INTERVAL)
- EVERSOURCE RIGHT-OF-WAY

DESIGN FEATURES LEGEND

- 1060 INDEX ELEVATION CONTOUR (2-FOOT INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOUR (2-FOOT INTERVAL, SEE NOTE 2)
- ELEVATION GRADE BREAK
- UDF LIMITS OF CONSOLIDATED MATERIAL
- APPROXIMATE LIMITS OF GRADING
- X UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON DRAWING 3A)
- SMA STORMWATER MANAGEMENT AREA
- DETAIL/SECTION REFERENCE
- DRAWING REFERENCE NUMBER
- UDF ACCESS ROAD
- UTILITY RIGHT OF WAY ACCESS ROAD
- 1101.7' X SPOT ELEVATION
- D STORMWATER DRAIN PIPE 3/37

NOTES:

1. REFER TO DRAWING 2A AND 2B FOR BASEMAP INFORMATION.
2. DESIGN ELEVATIONS SHOWN WITHIN UDF BASELINER LIMITS REPRESENT LINER SYSTEM SUBGRADE ELEVATIONS. DESIGN ELEVATIONS SHOWN OUTSIDE UDF BASELINER LIMITS REPRESENT FINAL GRADE ELEVATIONS.
3. REFER TO DRAWING 6 FOR ADDITIONAL BASELINER LEACHATE COLLECTION SYSTEM INFORMATION.

100' 0 100' 200'
1"=100'

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

TOP OF BASELINER GRADING PLAN

ARCADIS Project No. 30197838
Date FEBRUARY 2024
ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

5

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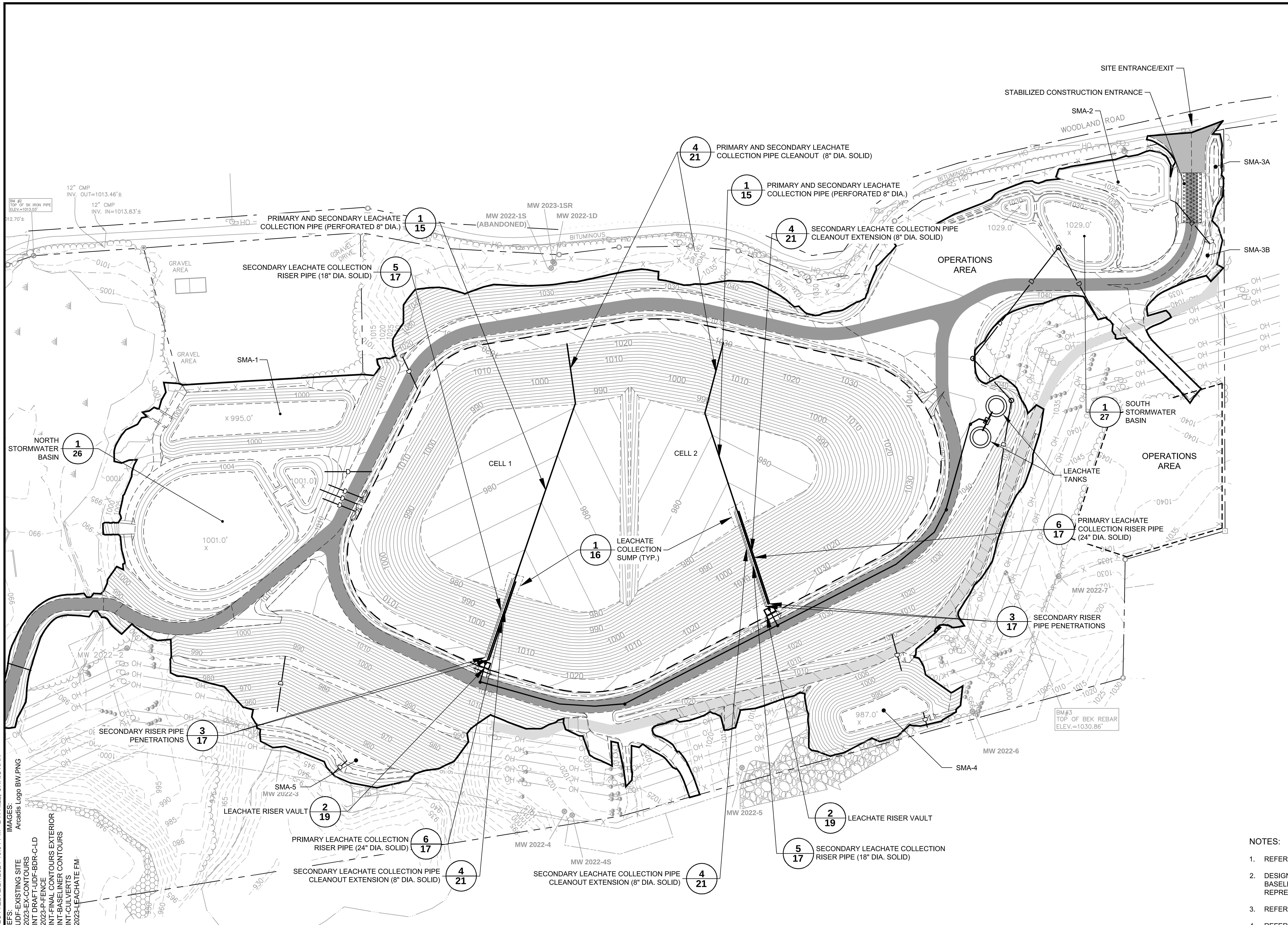
XREFS: X-UDF-EXISTING SITE X-2023-EX-CONTOURS X-INT DRAFT-UDF-BDR-C-LD X-INT-BASELINER CONTOURS X-2023-P-FENCE X-INT-FINAL CONTOURS EXTERIOR X-2023-LEACHATE FM X-INT-CULVERTS
IMAGES: Arcadis Logo BW.PNG



EXISTING FEATURES LEGEND

- REBAR FOUND
- IRON PIN FOUND
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- GRANITE BOUND FOUND
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- LAMP POST
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- B 2022-8 — SOIL BORING
- WET AREA
- APPROXIMATE PROPERTY BOUNDARY
- EDGE OF GRAVEL
- EDGE OF BITUMINOUS
- EDGE OF WATER
- EDGE OF WETLAND
- STONEWALL
- OH — OVERHEAD WIRES
- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- 1010 — ELEVATION CONTOUR (5-FOOT INTERVAL)
- OVERHEAD LINE EASEMENT

DESIGN FEATURES LEGEND

- D — STORMWATER DRAIN PIPE
- 1060 — INDEX ELEVATION CONTOUR (2-FOOT INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOUR (2-F00T INTERVAL, SEE NOTE 2)
- ELEVATION GRADE BREAK
- APPROXIMATE LIMITS OF GRADING
- X — UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON DRAWING 3A)
- DETAIL/SECTION REFERENCE
- DRAWING REFERENCE NUMBER
- UDF ACCESS ROAD
- UTILITY RIGHT OF WAY ACCESS ROAD
- 1101.7' x — SPOT ELEVATION

NOTES:

1. REFER TO DRAWINGS 2A AND 2B FOR BASEMAP INFORMATION.
2. DESIGN ELEVATIONS SHOWN WITHIN THE UDF BASELINER LIMITS REPRESENT TOP OF BASELINER SYSTEM. DESIGN ELEVATIONS SHOWN OUTSIDE UDF BASELINER LIMITS REPRESENT FINAL GRADE ELEVATIONS.
3. REFER TO DRAWING 4C FOR UTILITY INFORMATION.
4. REFER TO DRAWINGS 40 THROUGH 43 FOR PROCESS AND INSTRUMENTATION DIAGRAMS.

C:\Users\CSHILL\DC\ACCDocs\Arcadis ACC US\AUS-99999999-GE_HOUSATONIC_PITTSFIELD_MA\Project Files\10_WIP\10T_ARC_ENV\2024\01-DWG\INT-UDF-DWG_06-LEACHATE COLLECTION PLN.dwg LAYOUT: 6 SAVED: 2/27/2024 8:59 PM ACADVER: 24.2S (LMS TECH) PAGESETUP: ----
PLOTSTYLETABLE: ---- PLOTTED: 2/27/2024 10:34 PM BY: HILL, CHRISTIAN

XREFS: X-UDF-EXISTING SITE X-2023-EX-CONTOURS X-INT DRAFT-UDF-BDR-C-LD X-2023-P-FENCE X-INT-FINAL CONTOURS EXTERIOR X-INT-BASELINER CONTOURS X-INT-CULVERTS X-2023-LEACHATE FM

IMAGES: Arcadis Logo BW.PNG

1"=100' — 100' 0 100' 200'

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name: **MARK O. GRAVELDING**
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

ARCADIS

ARCADIS U.S., INC.

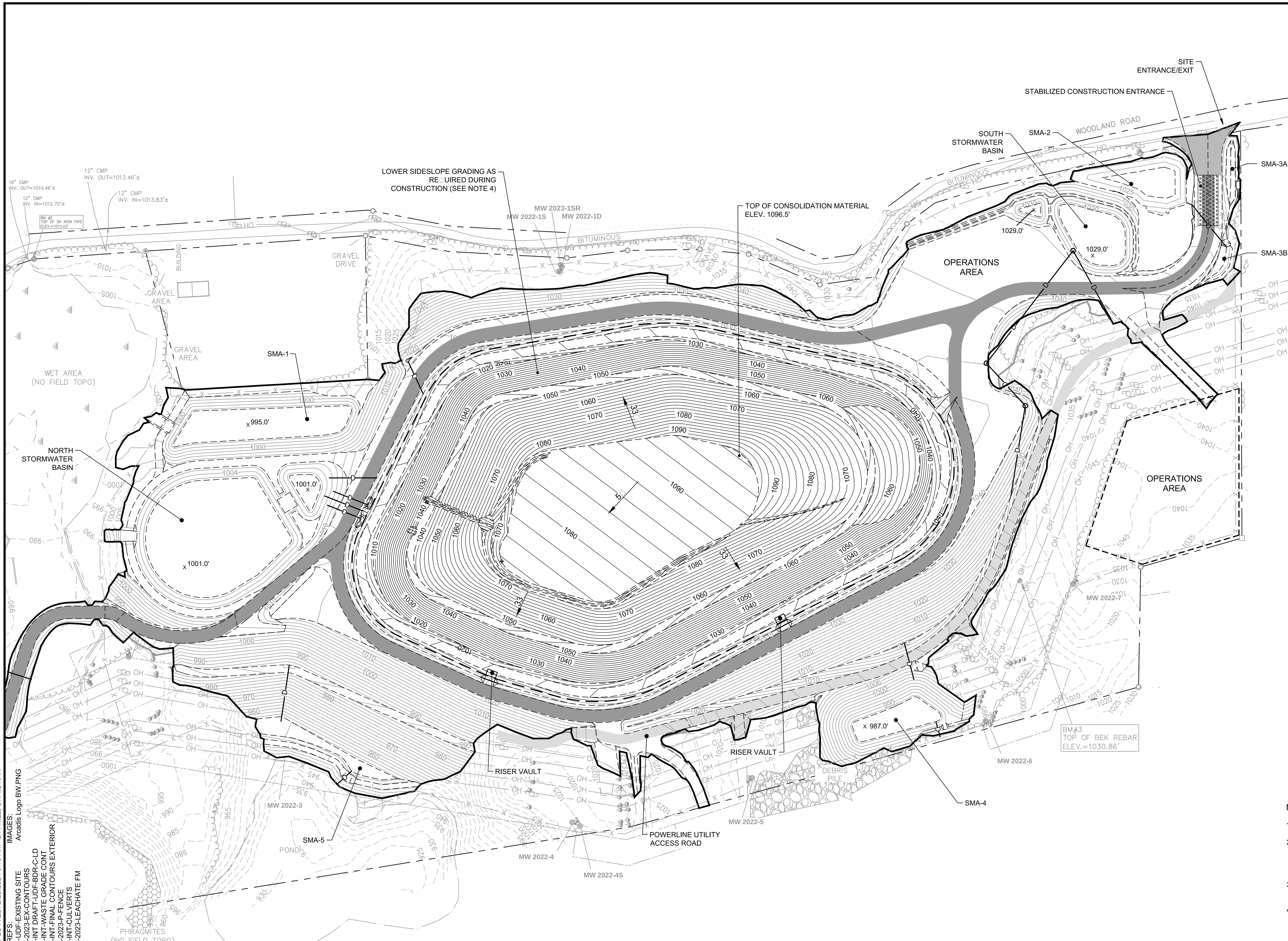
GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LEACHATE COLLECTION PLAN

ARCADIS Project No. 30197838

Date FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120



EXISTING FEATURES LEGEND

- REBAR FOUND
- IRON PIN FOUND
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- GRANITE BOUND FOUND
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- LAMP POST
- UTILITY POLE
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- MW 2022-2 — MONITORING WELL
- PZ 2022-8 — PIEZOMETER
- B 2022-8 — SOIL BORING
- WET AREA
- APPROXIMATE PROPERTY BOUNDARY
- EDGE OF GRAVEL
- EDGE OF BITUMINOUS
- EDGE OF WATER
- EDGE OF WETLAND
- STONEWALL
- OH — OVERHEAD WIRES
- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- 1010 — ELEVATION CONTOUR (5-FOOT INTERVAL)
- OVERHEAD LINE EASEMENT

DESIGN FEATURES LEGEND

- D — STORMWATER DRAIN PIPE
- ELEVATION GRADE BREAK
- 1010 — INDEX ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- APPROXIMATE LIMITS OF GRADING
- X — X — UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON SHEET 3A)
- UDF ACCESS ROAD
- UTILITY RIGHT OF WAY ACCESS ROAD
- x 1101.7' — SPOT ELEVATIONS
- SMA — STORMWATER MANAGEMENT AREA

NOTES:

1. REFER TO DRAWINGS 2A AND 2B FOR BASEMAP INFORMATION.
2. DESIGN ELEVATIONS SHOWN WITHIN THE UDF BASELINER LIMITS REPRESENT TOP OF CONSOLIDATION MATERIAL PRIOR TO FINAL COVER INSTALLATION EXCEPT ON LOWER SIDESLOPE AREAS (SEE NOTE 4). DESIGN ELEVATIONS SHOWN OUTSIDE UDF BASELINER LIMITS REPRESENT FINAL GRADE ELEVATIONS.
3. FINAL TOP OF CONSOLIDATION MATERIAL MAY BE ADJUSTED TO ACCOMMODATE ACTUAL VOLUMES OF CONSOLIDATION MATERIAL.
4. CONSOLIDATION GRADING SHOWN ON LOWER SIDESLOPE PROVIDES FOR TEMPORARY CONSTRUCTION OF AN INTERIOR DRAINAGE DITCH FOR MANAGEMENT OF CONTACT STORMWATER RUNOFF AT PERIMETER OF CELL. SEE DETAIL 1 ON DRAWING 13 FOR ADDITIONAL INFORMATION.

XREFS: X-UDF-EXISTING SITE, X-2023-EX-CONTOURS, X-INT DRAFT-UDF-BDR-C-LD, X-INT-WASTE GRADE CONT, X-INT-FINAL CONTOURS EXTERIOR, X-2023-P-FENCE, X-INT-CULVERTS, X-2023-LEACHATE FM
IMAGES: Arcadis Logo BW.PNG

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PLOTSTYLETABLE: ---- PLOTTED: 2/28/2024 9:19 AM BY: HILL, CHRISTIAN

100' 0 100' 200'
1"=100'

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Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

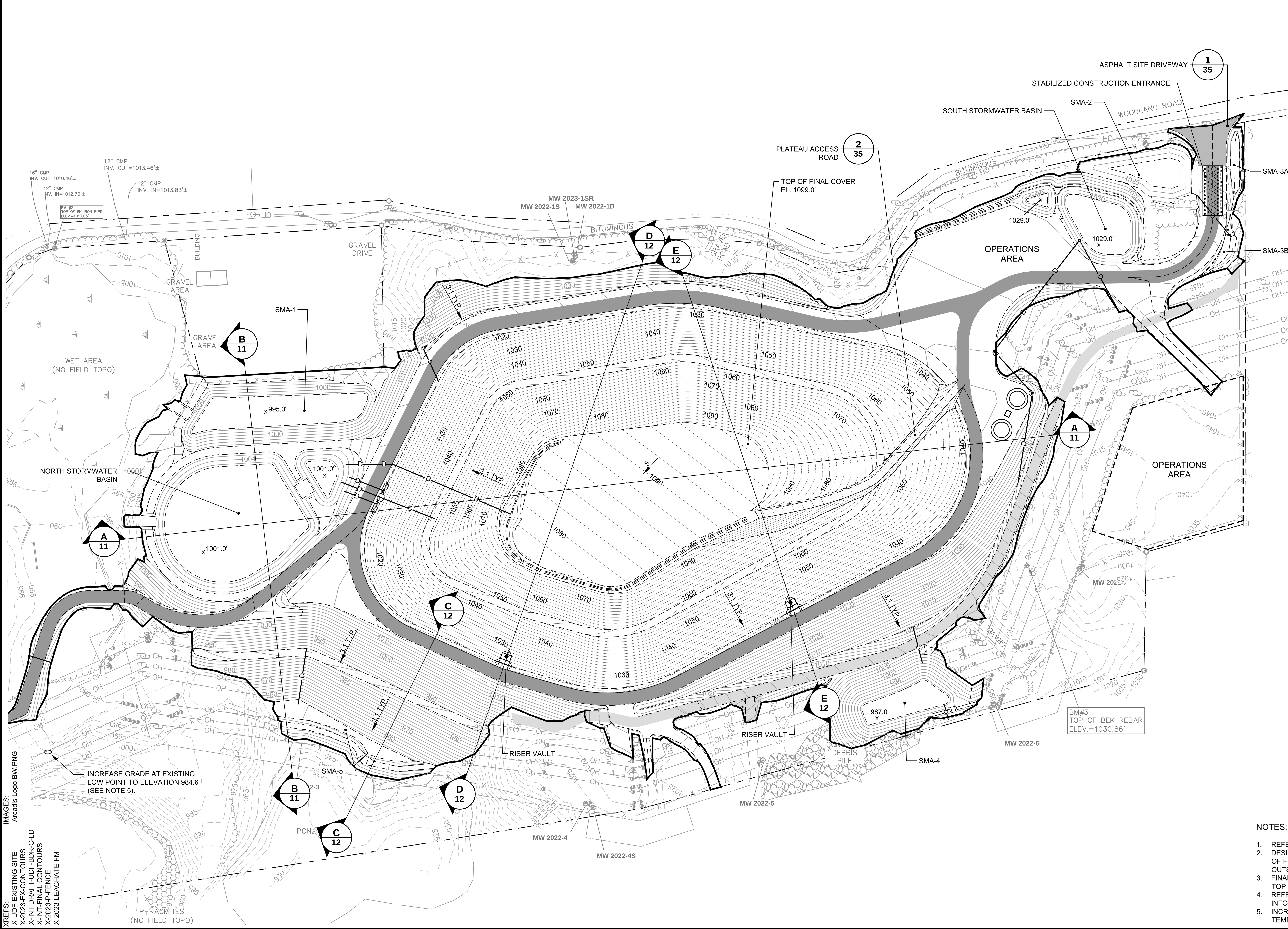
ARCADIS
ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE ● LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

CONSOLIDATION GRADING PLAN

ARCADIS Project No. 30197838
Date: FEBRUARY 2024
ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

7



EXISTING FEATURES LEGEND

- REBAR FOUND
- IRON PIN FOUND
- CONCRETE BOUND FOUND
- GRANITE BOUND FOUND
- BENCH MARK
- LAMP POST
- UTILITY POLE
- GUY WIRE
- MW 2022-2 — MONITORING WELL
- PZ 2022-8 — PIEZOMETER
- B 2022-8 — SOIL BORING
- WET AREA
- APPROXIMATE PROPERTY BOUNDARY
- EDGE OF GRAVEL
- EDGE OF BITUMINOUS
- EDGE OF WATER
- EDGE OF WETLAND
- STONEWALL
- OH — OVERHEAD WIRES
- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- 1010 — ELEVATION CONTOUR (5-FOOT INTERVAL)
- OVERHEAD LINE EASEMENT

DESIGN FEATURES LEGEND

- D — STORMWATER DRAIN PIPE
- ELEVATION GRADE BREAK
- 1010 — INDEX ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- APPROXIMATE LIMITS OF GRADING
- 1029.0' x — SPOT ELEVATION
- X — UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON SHEET 3A)
- DETAIL/SECTION REFERENCE NUMBER
- DRAWING REFERENCE NUMBER
- SMA — STORMWATER MANAGEMENT AREA
- UDF ACCESS ROAD
- UTILITY RIGHT OF WAY ACCESS ROAD

NOTES:

1. REFER TO DRAWINGS 2A AND 2B FOR BASEMAP INFORMATION.
2. DESIGN ELEVATIONS SHOWN WITHIN THE UDF BASELINER LIMITS REPRESENT TOP OF FINAL COVER AND PLATEAU ACCESS ROAD. DESIGN ELEVATIONS SHOWN OUTSIDE UDF BASELINER LIMITS REPRESENT FINAL GRADE ELEVATIONS.
3. FINAL TOP OF FINAL COVER MAY BE ADJUSTED TO ACCOMMODATE CONSTRUCTED TOP OF CONSOLIDATION MATERIAL GRADES.
4. REFER TO DRAWING 9 FOR ADDITIONAL STORMWATER MANAGEMENT SYSTEM INFORMATION.
5. INCREASE LOW POINT GRADE USING COMPACTED TOPSOIL AND INSTALL TEMPORARY EROSION CONTROL MAT.

XREFS: X-UDF-EXISTING SITE, X-2023-EX-CONTOURS, X-INT DRAFT-UDF-BDR-C-LD, X-INT-FINAL CONTOURS, X-2023-P-FENCE, X-2023-LEACHATE FM

IMAGES: Arcadis Logo BW.PNG

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PLOTSTYLETABLE: ---- PLOTTED: 2/27/2024 10:34 PM BY: HILL, CHRISTIAN

1"=100' — 100' 0 100' 200'

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Professional Engineer's Name: **MARK O. GRAVELDING**
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

ARCADIS

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

FINAL GRADING PLAN

ARCADIS Project No. 30197838

Date: FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

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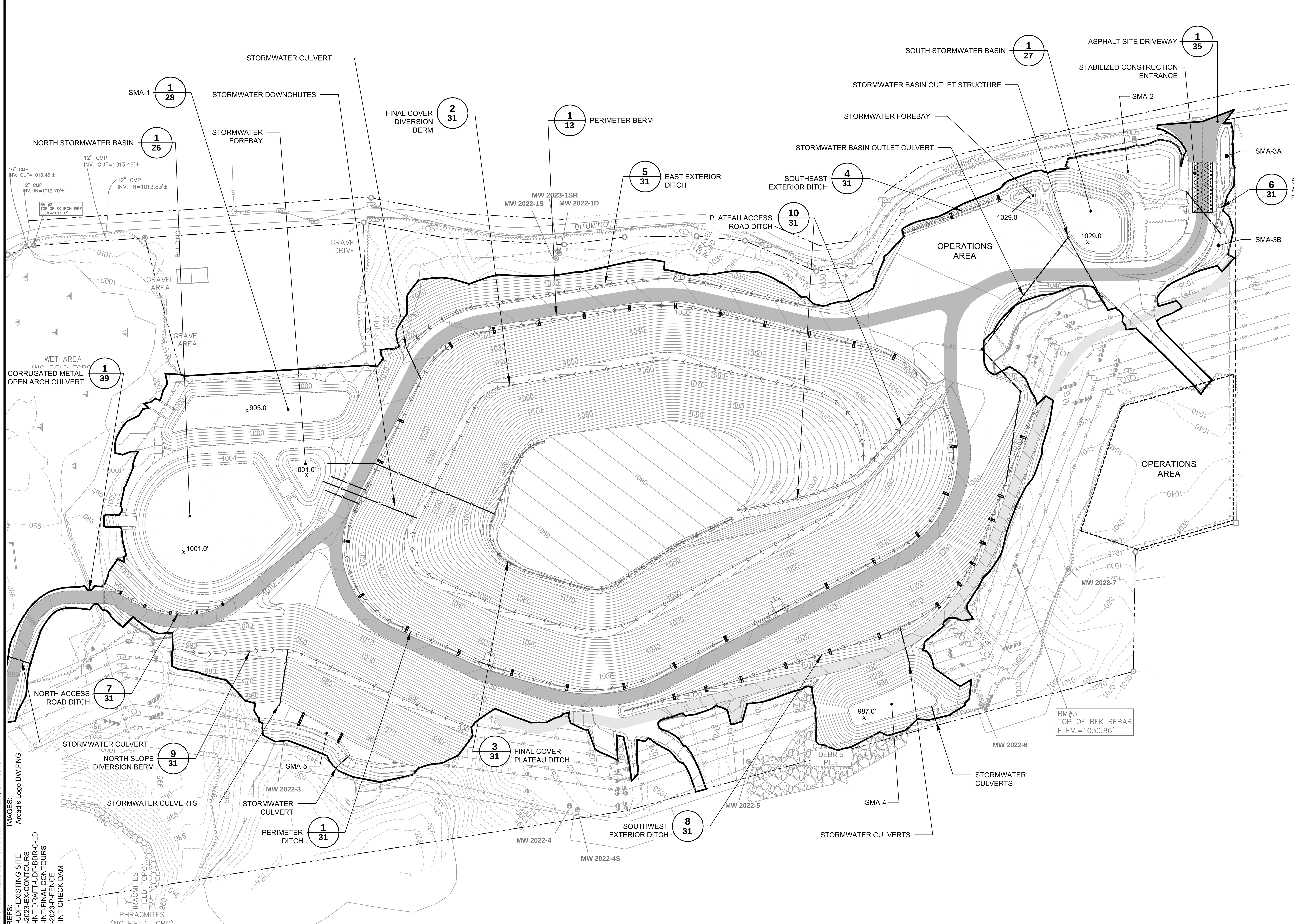

EXISTING FEATURES LEGEND

- REBAR FOUND
- IRON PIN FOUND
- CONCRETE BOUND FOUND
- GRANITE BOUND FOUND
- BENCH MARK
- LAMP POST
- UTILITY POLE
- GUY WIRE
- MW 2022-2 MONITORING WELL
- PZ 2022-8 PIEZOMETER
- B 2022-8 SOIL BORING
- WET AREA
- APPROXIMATE PROPERTY BOUNDARY
- EDGE OF GRAVEL
- EDGE OF BITUMINOUS
- EDGE OF WETLAND
- STONEWALL
- OVERHEAD WIRES
- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- 1010 ELEVATION CONTOUR (5-FOOT INTERVAL)
- OVERHEAD LINE EASEMENT

DESIGN FEATURES LEGEND

- ELEVATION GRADE BREAK
- 1010 INDEX ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- APPROXIMATE LIMITS OF GRADING
- 1029.0 x SPOT ELEVATION
- UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON SHEET 3A)
- STORMWATER DRAINAGE DITCH
- DETAIL/SECTION REFERENCE NUMBER
- DRAWING REFERENCE NUMBER
- SMA STORMWATER MANAGEMENT AREA
- UDF ACCESS ROAD
- UTILITY RIGHT OF WAY ACCESS ROAD
- STONE CHECK DAM
- D STORMWATER DRAIN PIPE 3/37

NOTES:

1. REFER TO DRAWINGS 2A AND 2B FOR BASEMAP INFORMATION.
2. DESIGN ELEVATIONS SHOWN REPRESENT TOP OF FINAL COVER AND PLATEAU ACCESS ROAD WITHIN THE BASELINER LIMITS.

C:\Users\CSHill\DC\ACCDocs\Arcadis ACC US\AUS-99999999-GE_HOUSATONIC_PITTSFIELD_MA\Project Files\10_WIP\10T_ARC_ENV\2024\01-DWG\INT-UDF-DWG_09-STORMWATER MNGMNT PLN.dwg LAYOUT: 9 SAVED: 2/28/2024 9:28 AM ACADVER: 24.2S (LMS TECH) PAGESETUP: ----
PLOTSTYLETABLE: ---- PLOTTED: 2/28/2024 9:46 AM BY: HILL, CHRISTIAN

XREFS: X-UDF-EXISTING SITE X-2023-EX-CONTOURS X-INT DRAFT-UDF-BDR-C-LD X-INT-FINAL CONTOURS X-2023-P-FENCE X-INT-CHECK DAM

IMAGES: Arcadis Logo BW.PNG

100' 0 100' 200'
1"=100'

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Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

ARCADIS

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

STORMWATER MANAGEMENT PLAN

ARCADIS Project No. 30197838

Date FEBRUARY 2024

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110 WEST FAYETTE STREET
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C:\Users\CSHILL\DC\ACCDocs\Arcadis ACC US\AUS-99999999-GE_HOUSATONIC_PITTSFIELD_MA\Project Files\10_WIP\10T_ARC_ENV\2024\01-DWG\INT-UDF-DWG_10-OPERATION SE□UENCE PLN.dwg LAYOUT: 10 SAVED: 2/27/2024 9:04 PM ACADVER: 24.2S (LMS TECH) PAGESETUP: ----
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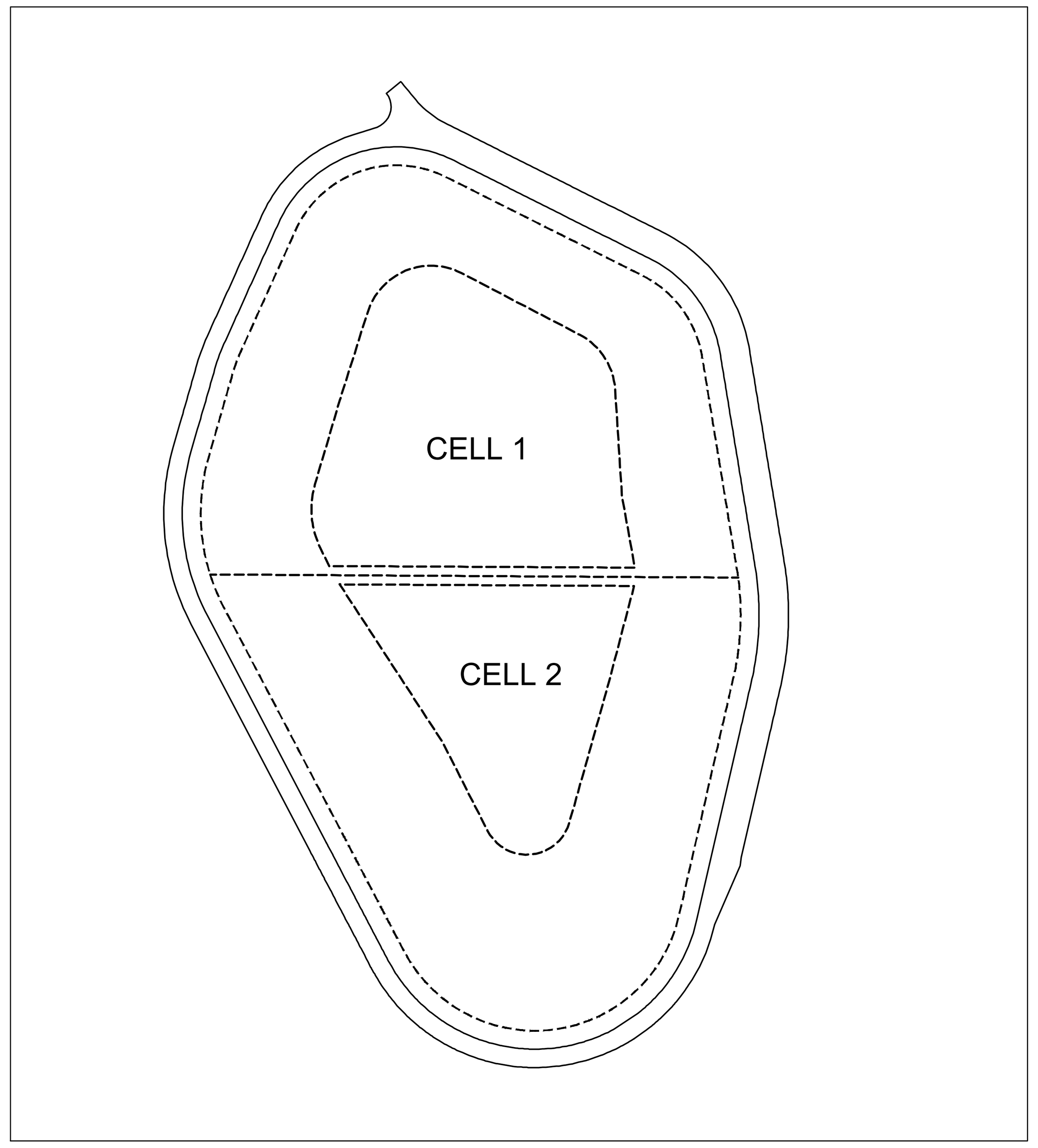
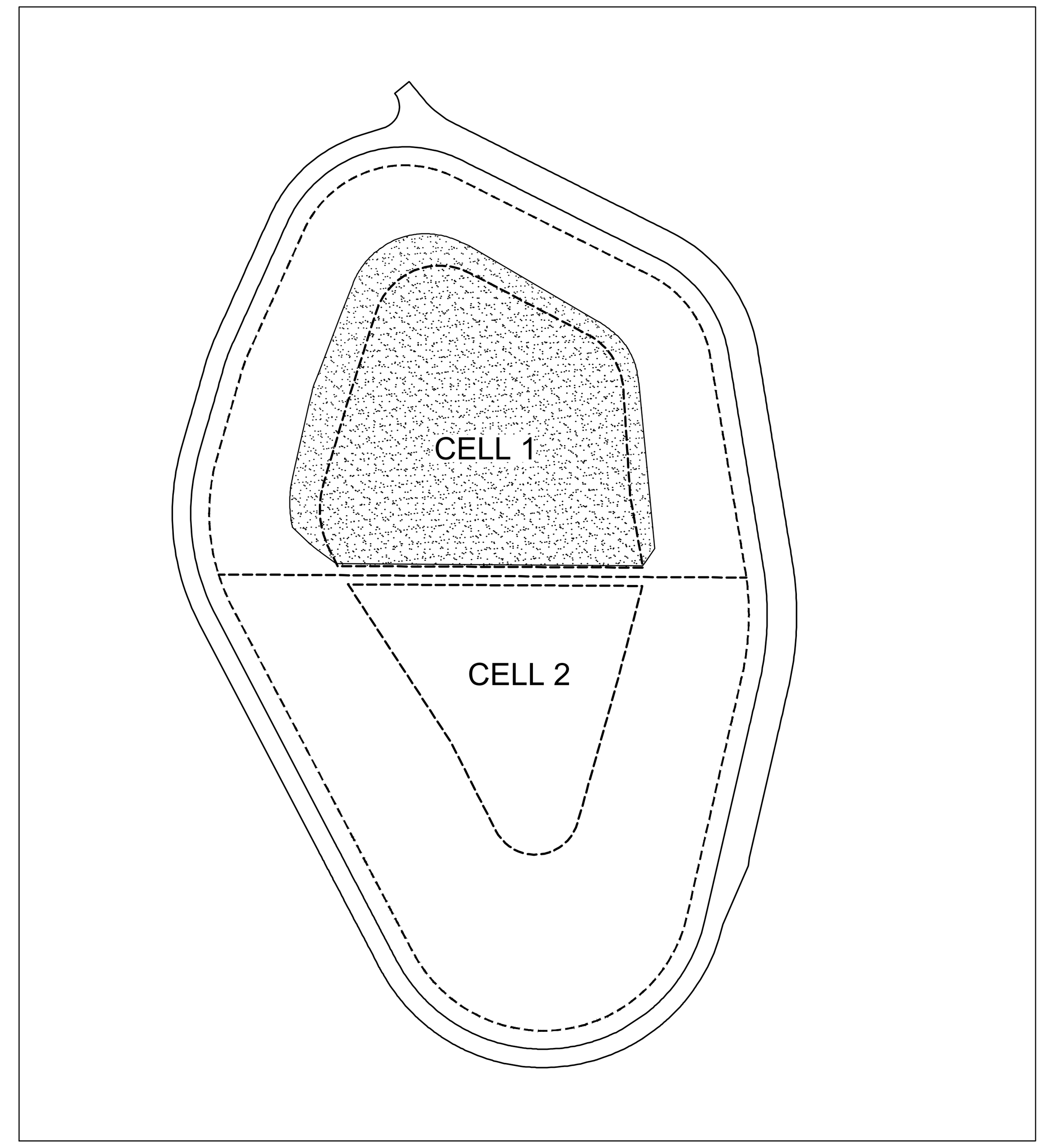


NOTE:
1. CELLS 1 AND 2 ARE NEWLY CONSTRUCTED.

PHASE 1

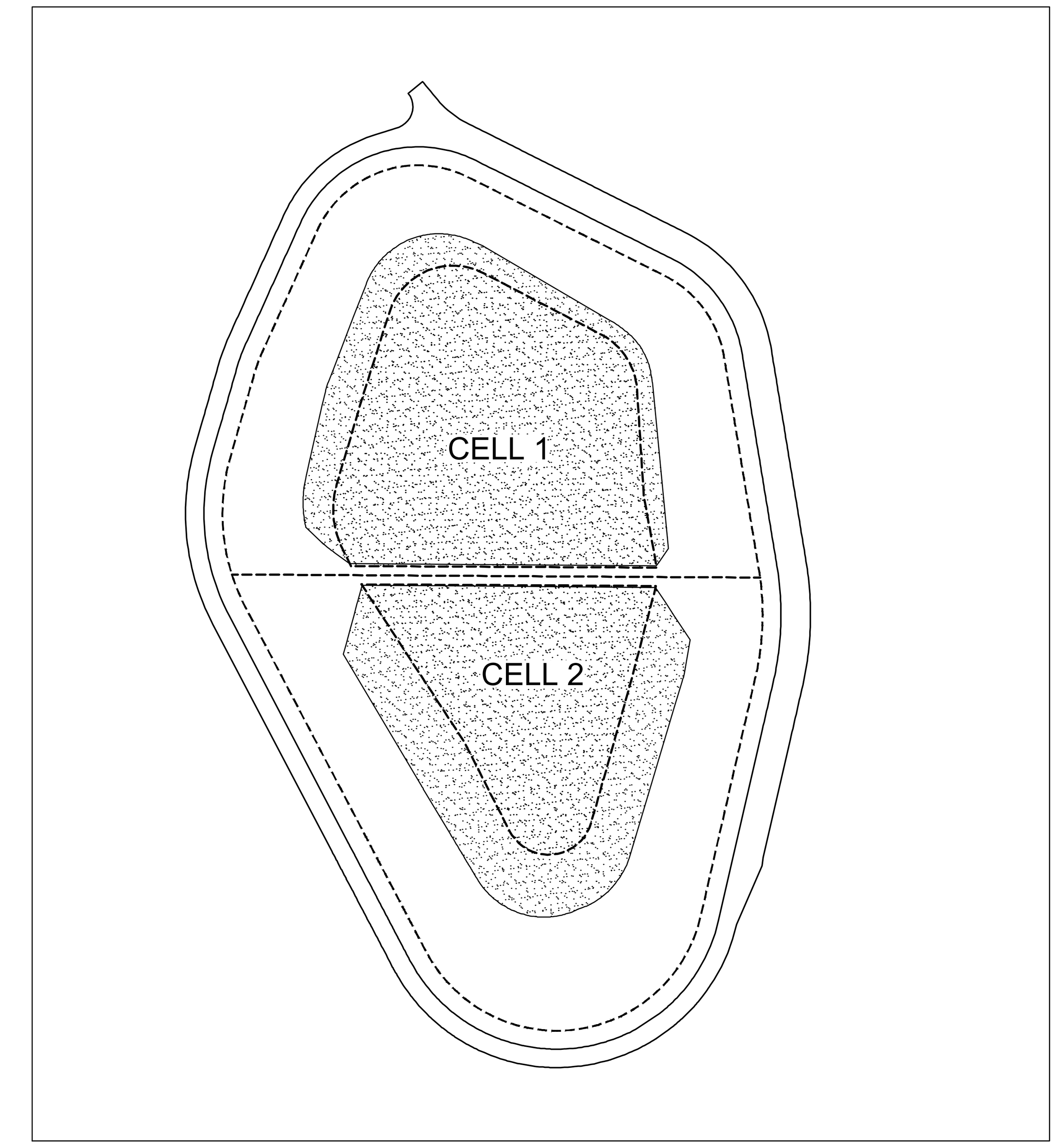
SCALE 1" □300'



NOTE:
1. CELL 1 IS ACTIVE WITH INITIAL CONSOLIDATION MATERIAL PLACEMENT OCCURRING.

PHASE 2

SCALE 1" □300'



NOTE:
1. CELLS 1 AND 2 ARE ACTIVE WITH INITIAL CONSOLIDATION MATERIAL PLACEMENT OCCURRING IN CELL 2.

PHASE 3

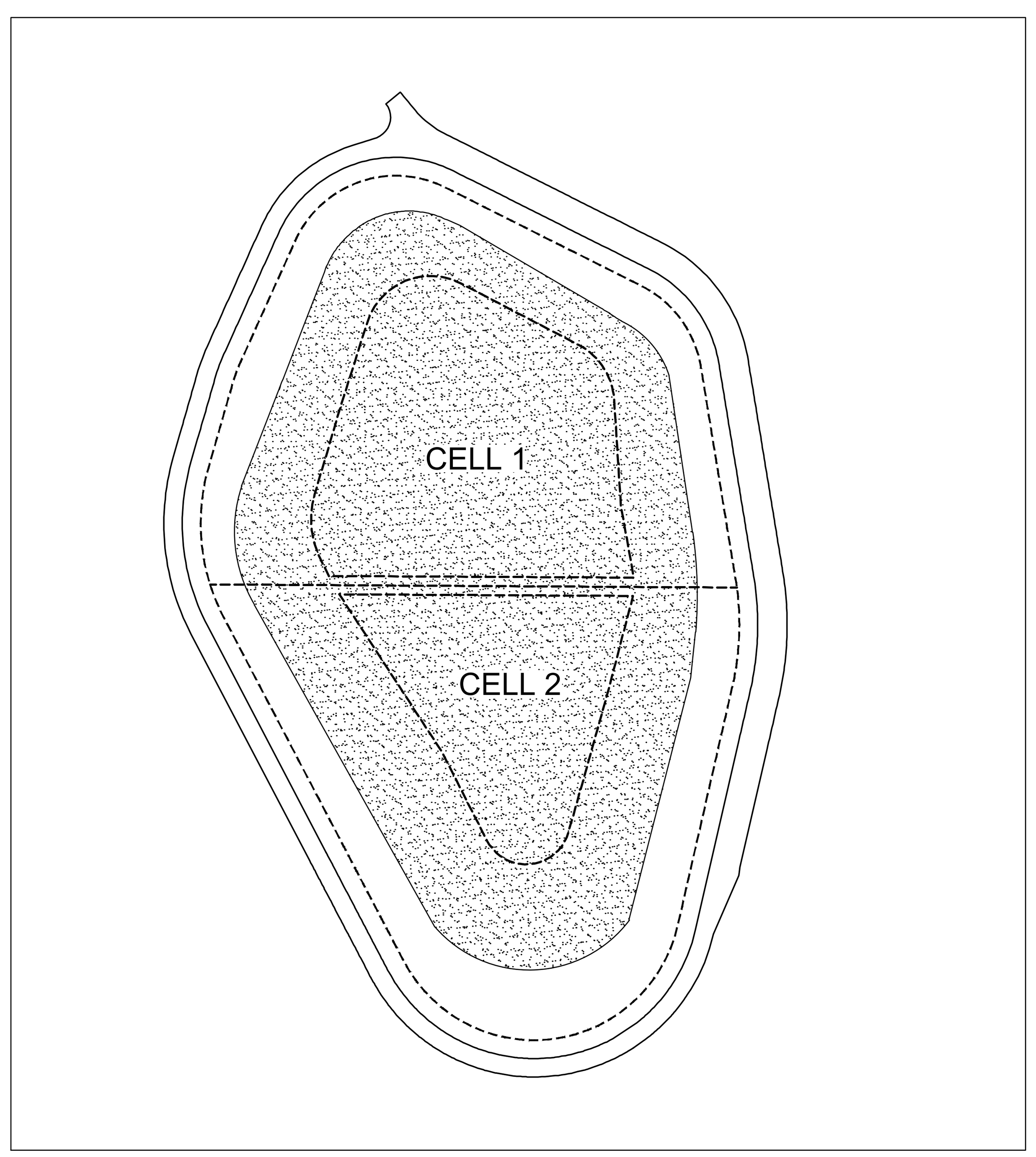
SCALE 1" □300'

LEGEND

- CONSOLIDATION MATERIAL PLACEMENT
- NEWLY INSTALLED FINAL COVER
- FINAL COVER INSTALLED DURING PRIOR PHASES

GENERAL NOTES:

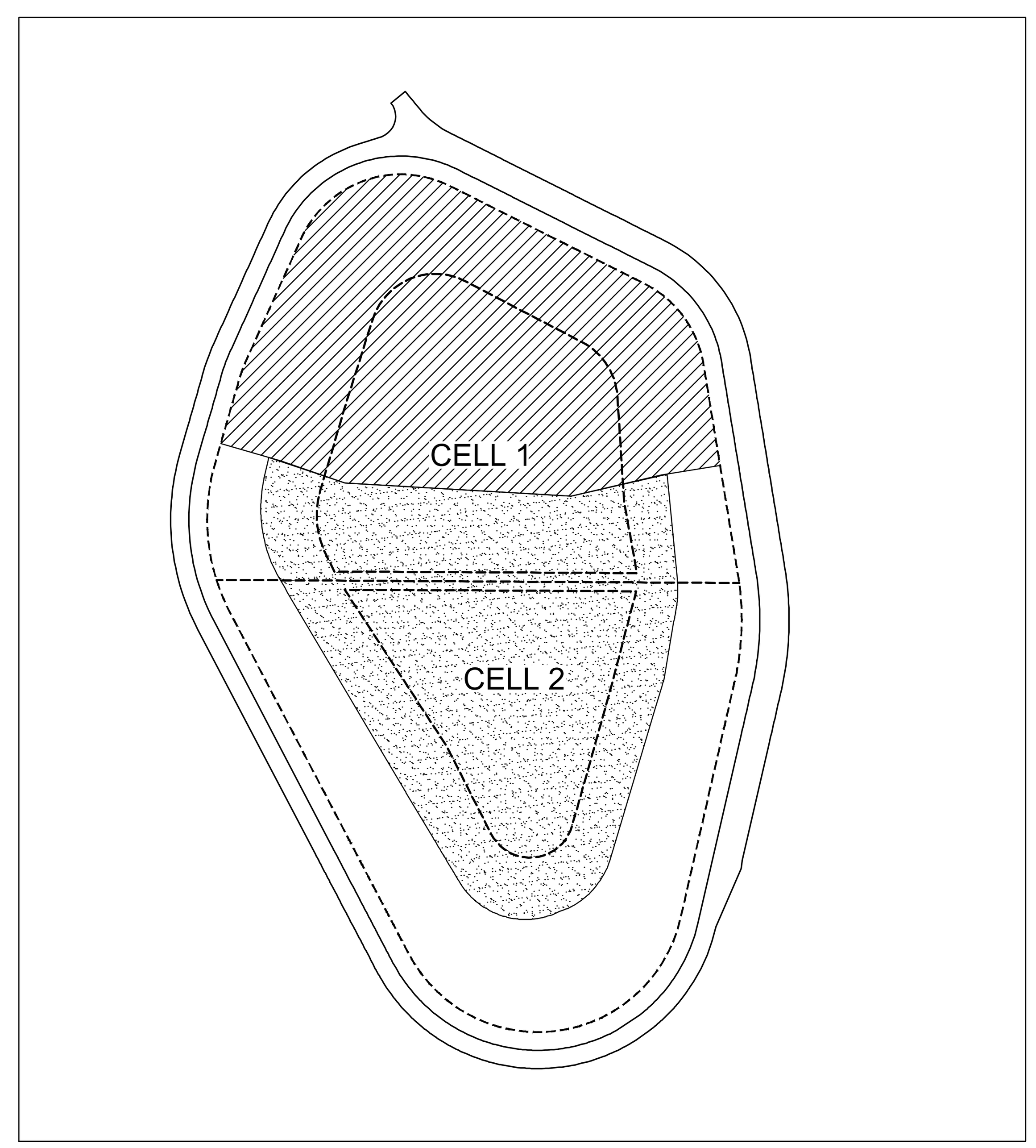
1. THIS DRAWING DEPICTS POTENTIAL CONSOLIDATION MATERIAL PLACEMENT AND FINAL COVER CONSTRUCTION SE□UENCING SCENARIOS. OTHER SE□UENCING SCENARIOS ARE POSSIBLE AND MAY BE EMPLOYED.
2. DUE TO THE CONCEPTUAL NATURE OF THIS DRAWING, DIFFERENCES IN ACTUAL PLACEMENT OF CONSOLIDATION MATERIAL AND FINAL COVER SE□UENCING SHOULD BE EXPECTED.



NOTE:
1. CELLS 1 AND 2 ARE ACTIVE WITH CONSOLIDATION MATERIAL PLACEMENT OCCURRING.

PHASE 4

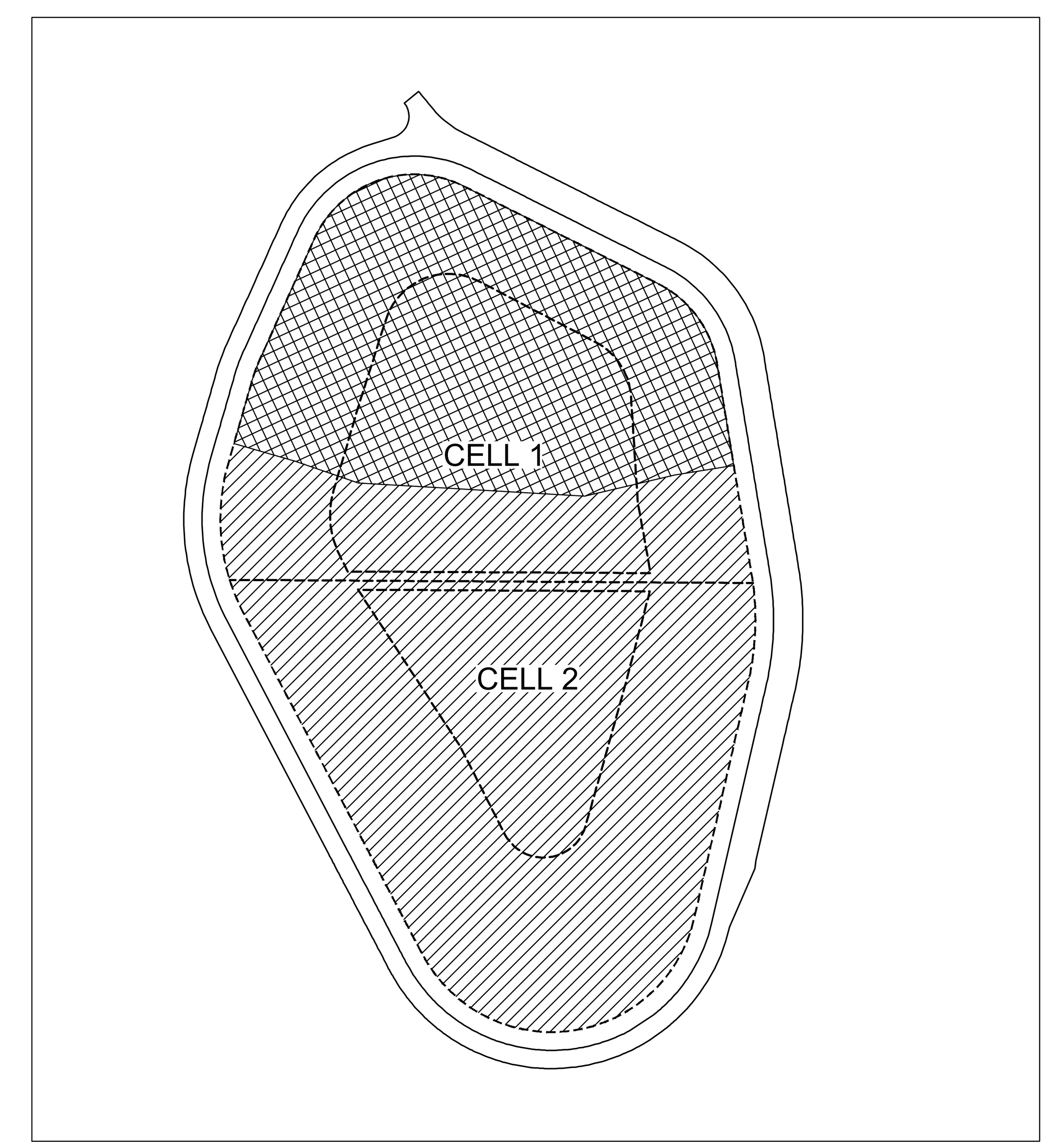
SCALE 1" □300'



NOTE:
1. CELLS 1 AND 2 ARE ACTIVE WITH CONSOLIDATION MATERIAL PLACEMENT OCCURRING. INITIAL PORTION OF FINAL COVER IS CONSTRUCTED.

PHASE 5

SCALE 1" □300'



NOTE:
1. CONSOLIDATION MATERIAL PLACEMENT IS COMPLETED. LAST PORTION OF FINAL COVER IS CONSTRUCTED.

PHASE 6

SCALE 1" □300'

150' 0 150' 300'
1"=150'

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

OPERATION SEQUENCE PLAN

ARCADIS Project No. 30197838

Date FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

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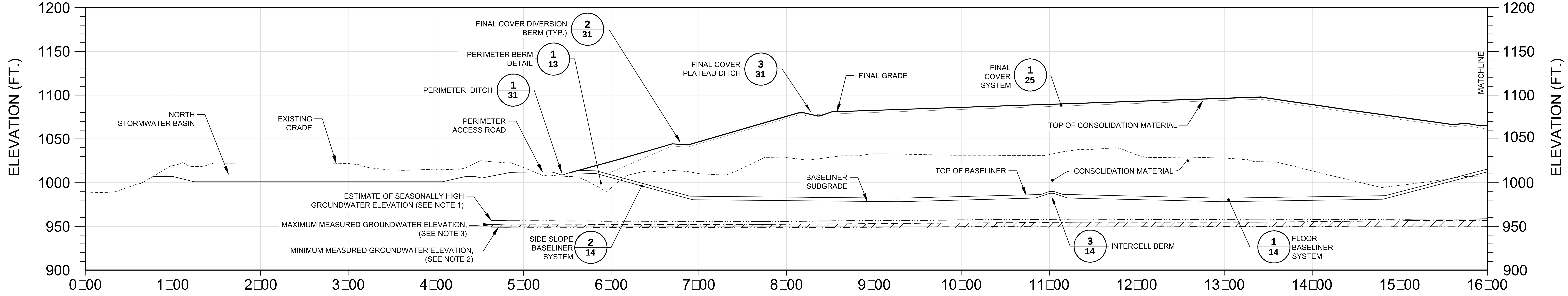
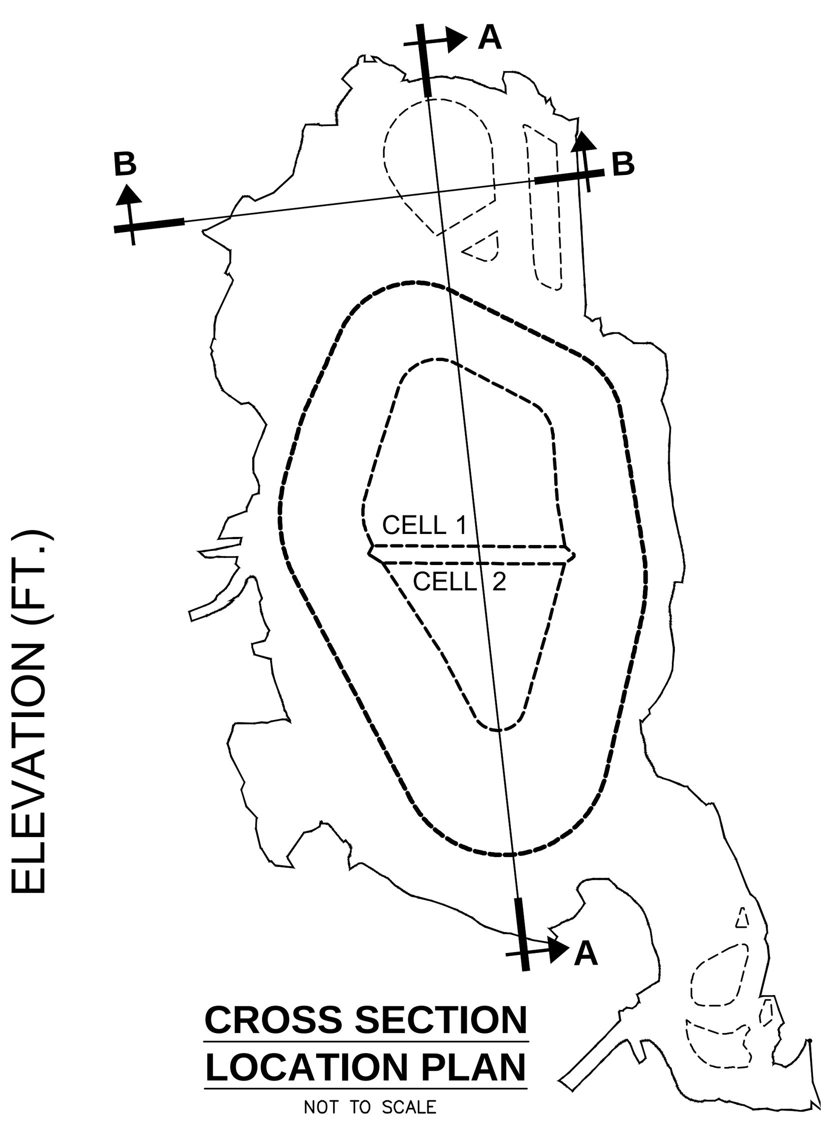


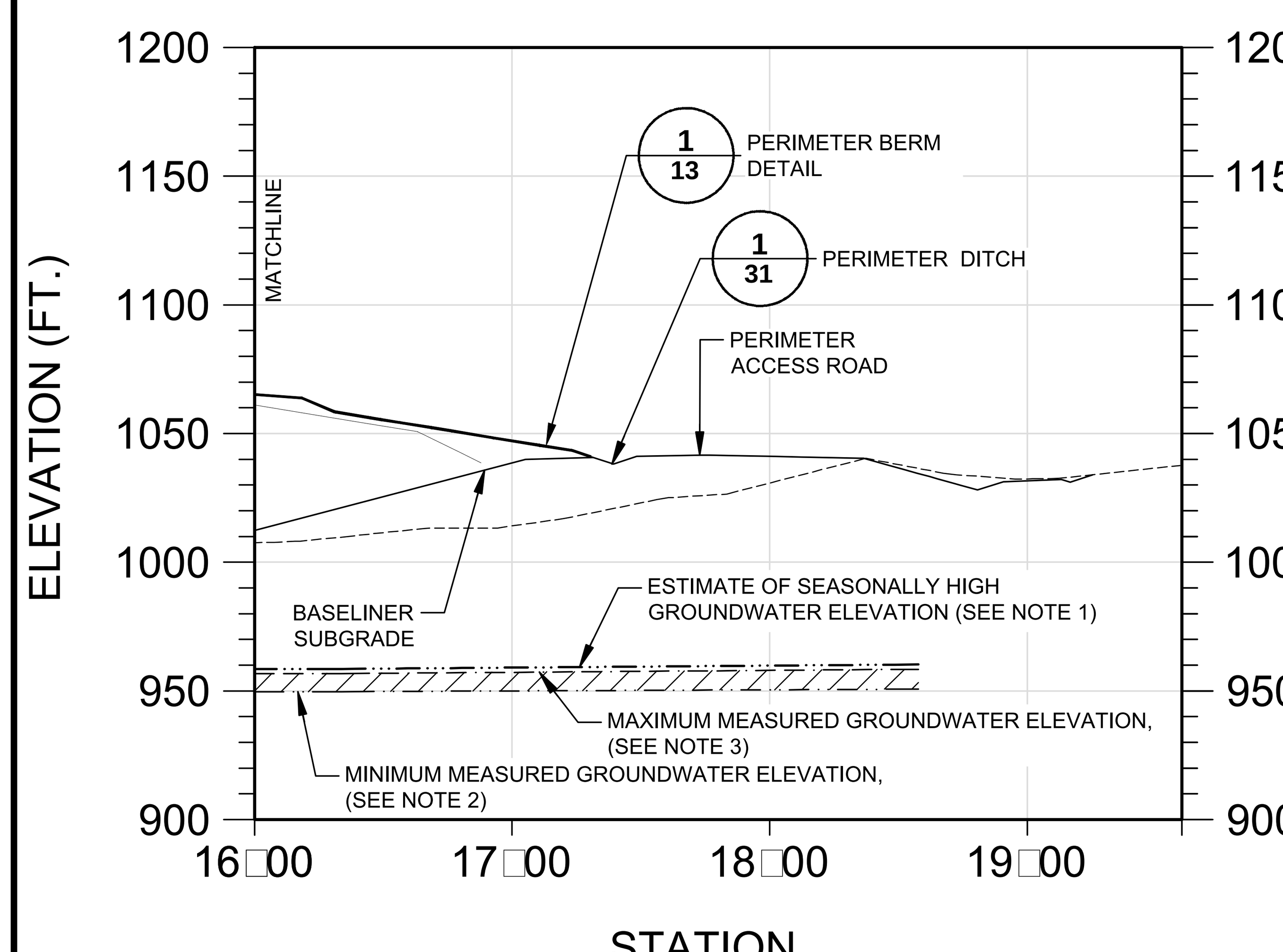
SITE CROSS SECTION (A)

SCALE: 1" = 60'
(NO VERTICAL EXAGGERATION)



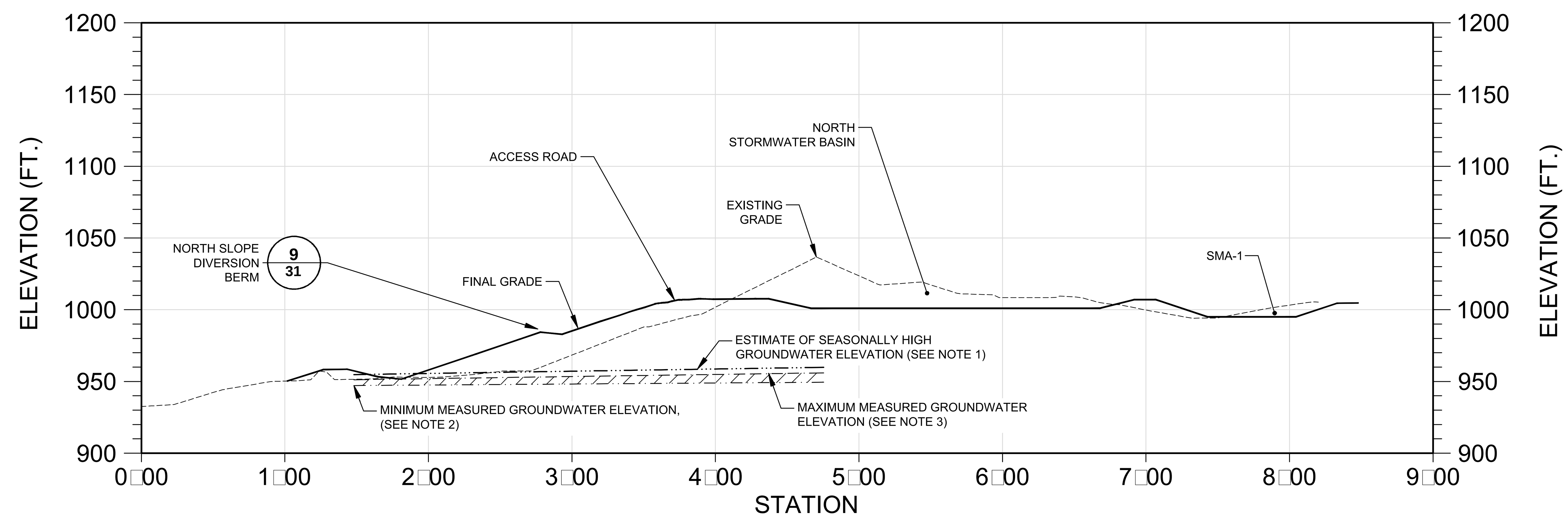
CROSS SECTION LOCATION PLAN

NOT TO SCALE



SITE CROSS SECTION (CONTINUED) (A)

SCALE: 1" = 60'
(NO VERTICAL EXAGGERATION)



SITE CROSS SECTION (B)

SCALE: 1" = 60'
(NO VERTICAL EXAGGERATION)

NOTES:

1. THE ESTIMATE OF SEASONALLY HIGH GROUNDWATER ELEVATION SHOWN IS BASED ON THE METHODOLOGY AND RESULTING CALCULATIONS DESCRIBED IN SECTION 3.6.2 OF THE REVISED FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024).
2. MINIMUM MEASURED GROUNDWATER ELEVATION IS BASED ON TRANSDUCER AND MANUAL GROUNDWATER ELEVATION GAUGING CONDUCTED FROM JUNE 2022 THROUGH JUNE 2023 AS DESCRIBED IN SECTION 3.6.1 OF THE REVISED FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024). THE ELEVATIONS SHOWN REPRESENT THE LOWEST RECORDED GROUNDWATER ELEVATIONS FOR THE TRANSDUCER GAUGING PERIOD.
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PLOTTED: 2/27/2024 10:35 PM BY: HILL, CHRISTIAN

XREFS: X-INT DRAFT-UDF-BDR-C-LD X-INT-XS-PROPOSED
IMAGES: Arcadis Logo BW.PNG

60' 0 60' 120'
1"=60'

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name: **MARK O. GRAVELDING**
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

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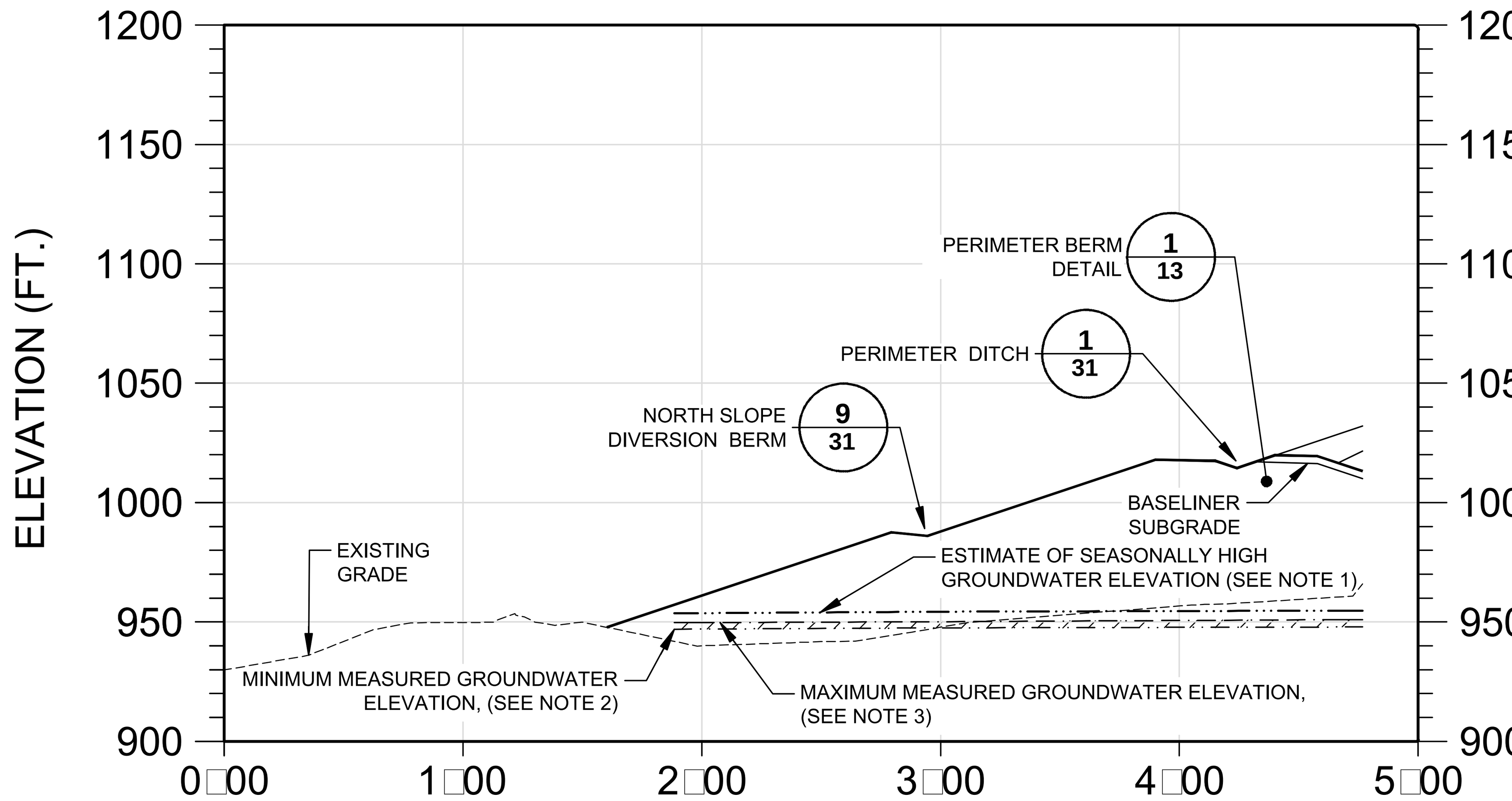
GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

SITE CROSS SECTIONS - 1

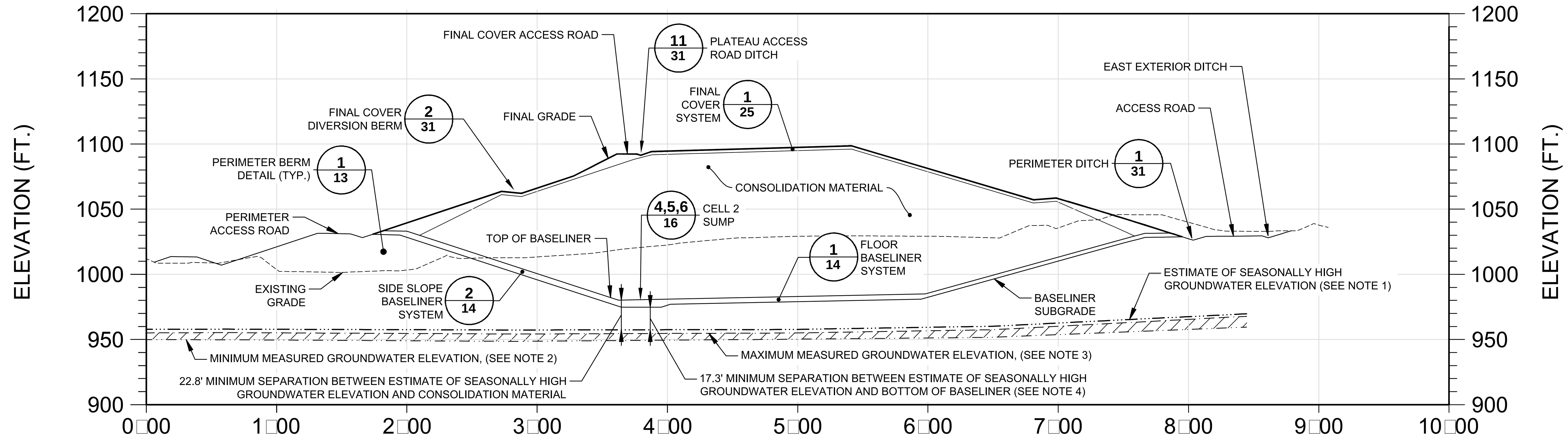
ARCADIS Project No. 30197838
Date: FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120



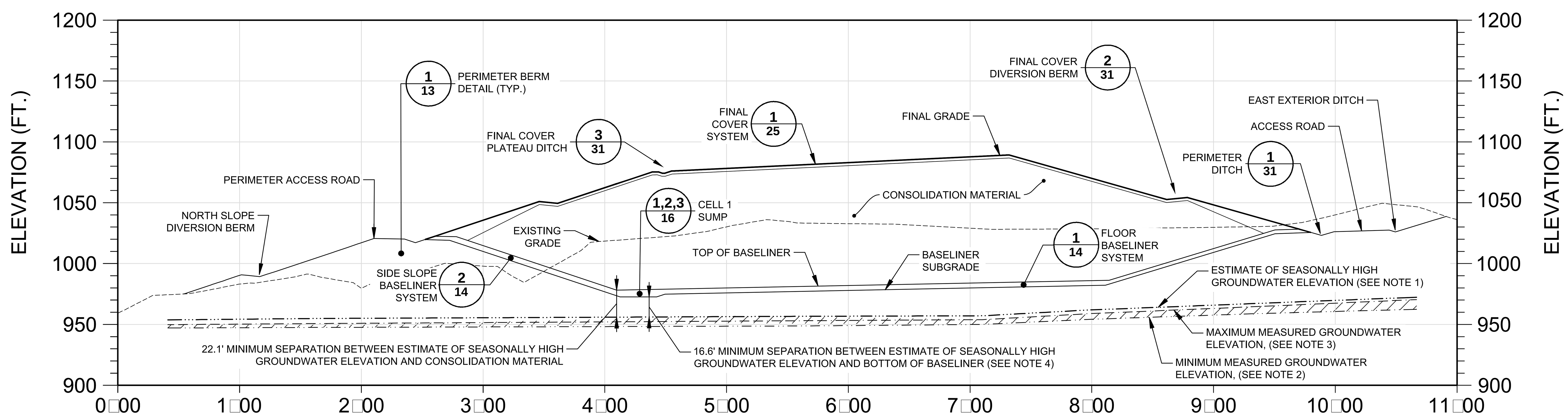
SITE CROSS SECTION C

SCALE: 1" = 60'
(NO VERTICAL EXAGGERATION)



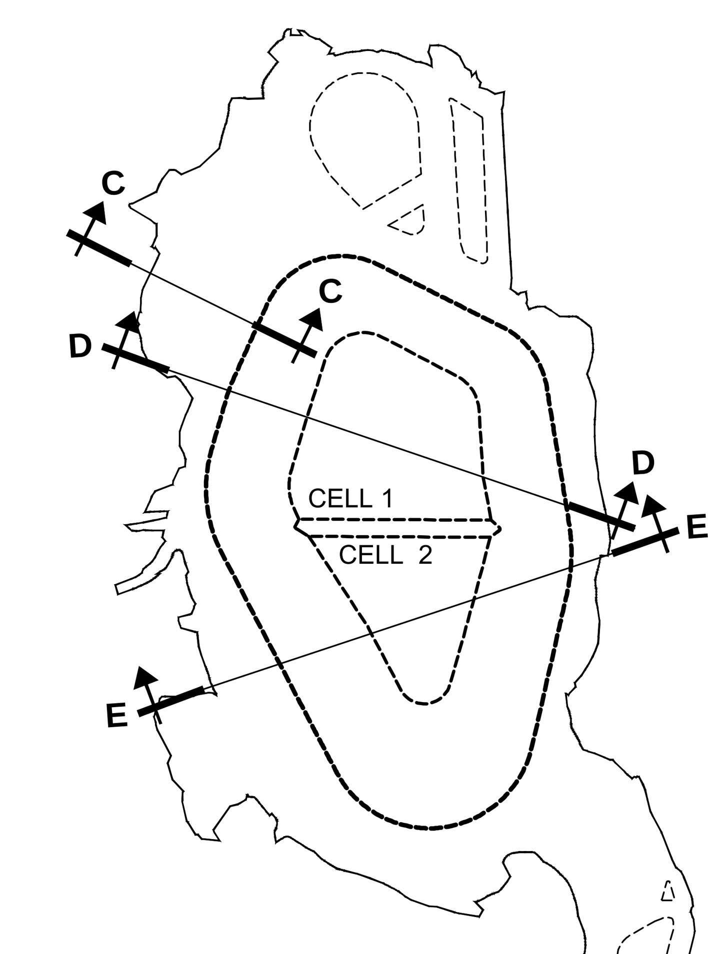
SITE CROSS SECTION E

SCALE: 1" = 60'
(NO VERTICAL EXAGGERATION)



SITE CROSS SECTION D

SCALE: 1" = 60'
(NO VERTICAL EXAGGERATION)



CROSS SECTION LOCATION PLAN

NOT TO SCALE

NOTES:

1. THE ESTIMATE OF SEASONALLY HIGH GROUNDWATER ELEVATION SHOWN IS BASED ON THE METHODOLOGY AND RESULTING CALCULATIONS DESCRIBED IN SECTION 3.6.2 OF THE REVISED FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024).
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4. SECTION II.B.5.A OF THE REVISED PERMIT SETS FORTH THE PERFORMANCE STANDARDS FOR THE UDF THAT REQUIRES THE BASELINER BE A MINIMUM OF 15 FEET ABOVE A CONSERVATIVE ESTIMATE OF THE SEASONALLY HIGH GROUNDWATER ELEVATION. THE SEASONALLY HIGH GROUNDWATER ELEVATION SHOWN ON THIS DRAWING AND USED FOR DESIGN OF THE UDF IS BASED ON THE FRIMPTER METHOD WHICH PROVIDES A CONSERVATIVE ESTIMATE OF THE GROUNDWATER ELEVATIONS USING SITE-SPECIFIC GROUNDWATER ELEVATION DATA COLLECTED IN THE LOCATION OF THE UDF THAT IS MODIFIED (PROJECTED) TO ACCOUNT FOR HISTORICAL GROUNDWATER LEVEL FLUCTUATIONS AT SIMILARLY SITED OFF-SITE, LONG-TERM MONITORING WELLS IN MASSACHUSETTS.

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PLOTTED: 2/27/2024 10:35 PM BY: HILL, CHRISTIAN
XREFS: X-INT DRAFT-UDF-BDR-C-LD X-INT-XS-PROPOSED
IMAGES: Arcadis Logo BW.PNG

60' 0 60' 120'
1"=60'

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983
State: MA | Date Signed: | Project Mgr.: DK
Designed by: BMS | Drawn by: KLS | Checked by: PHB

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GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

SITE CROSS SECTIONS - 2

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Date FEBRUARY 2024
ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
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TEL. 315.446.9120

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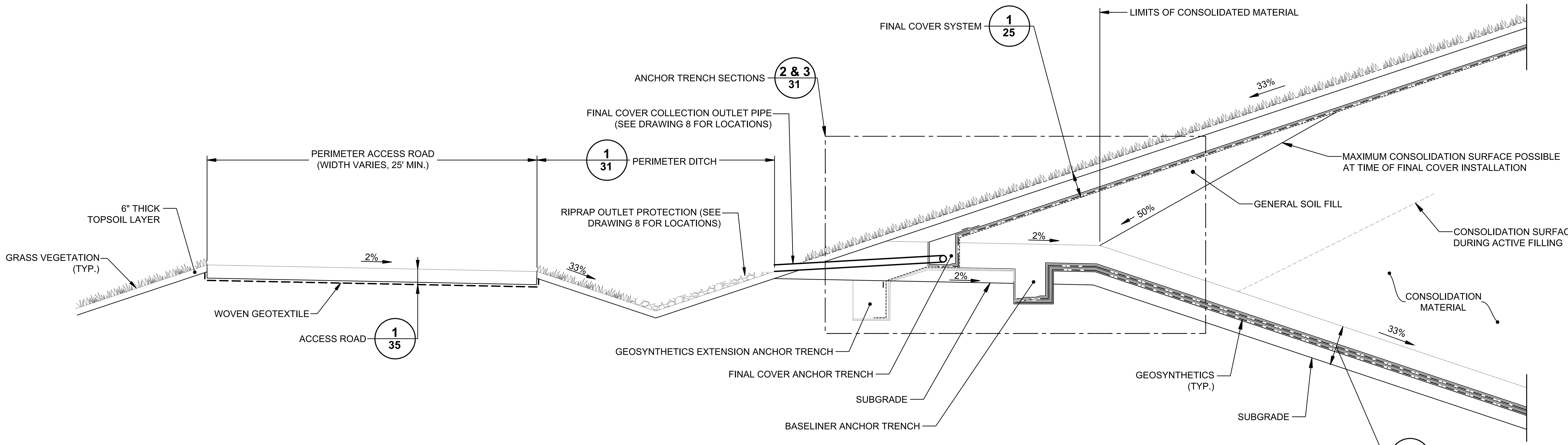
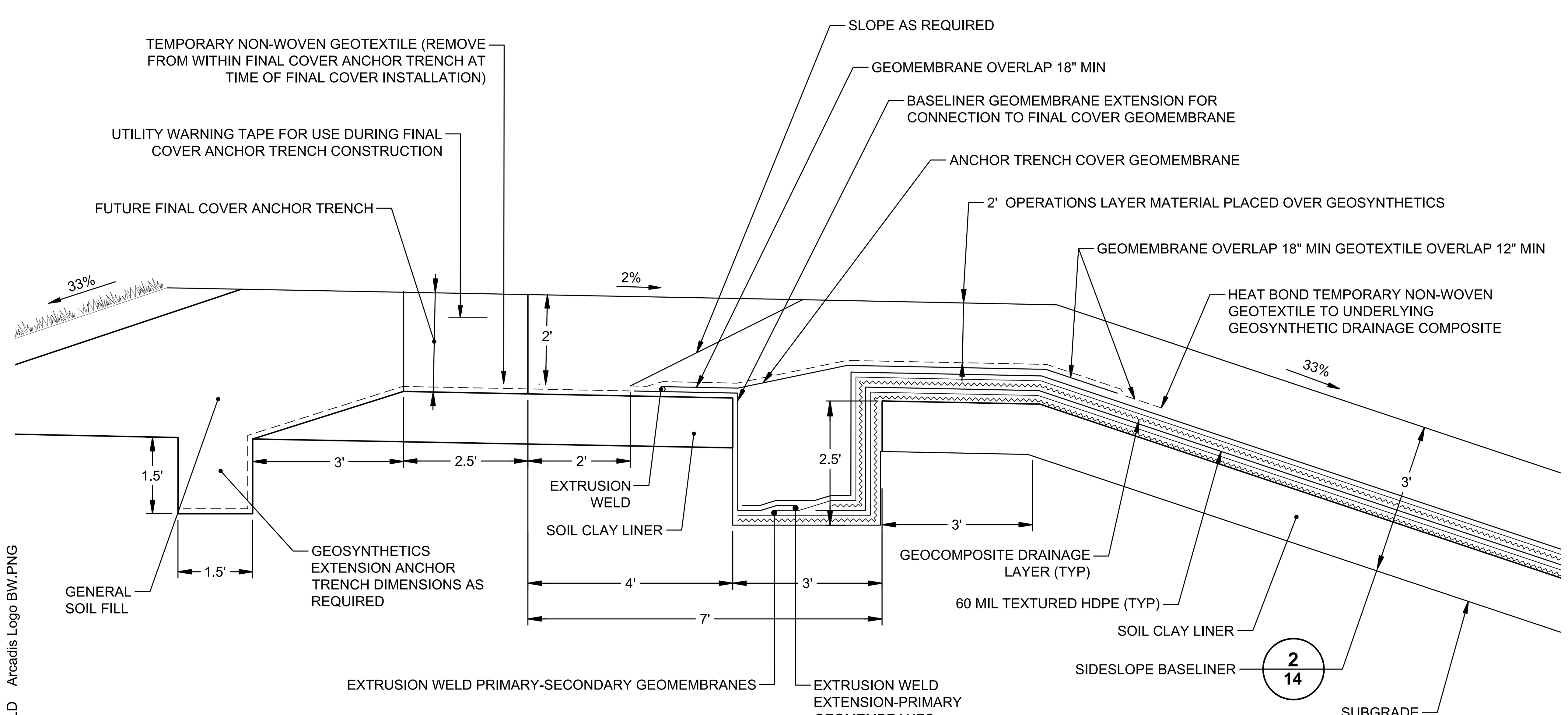


PERIMETER BERM SECTION 1

SCALE: 1"=5'

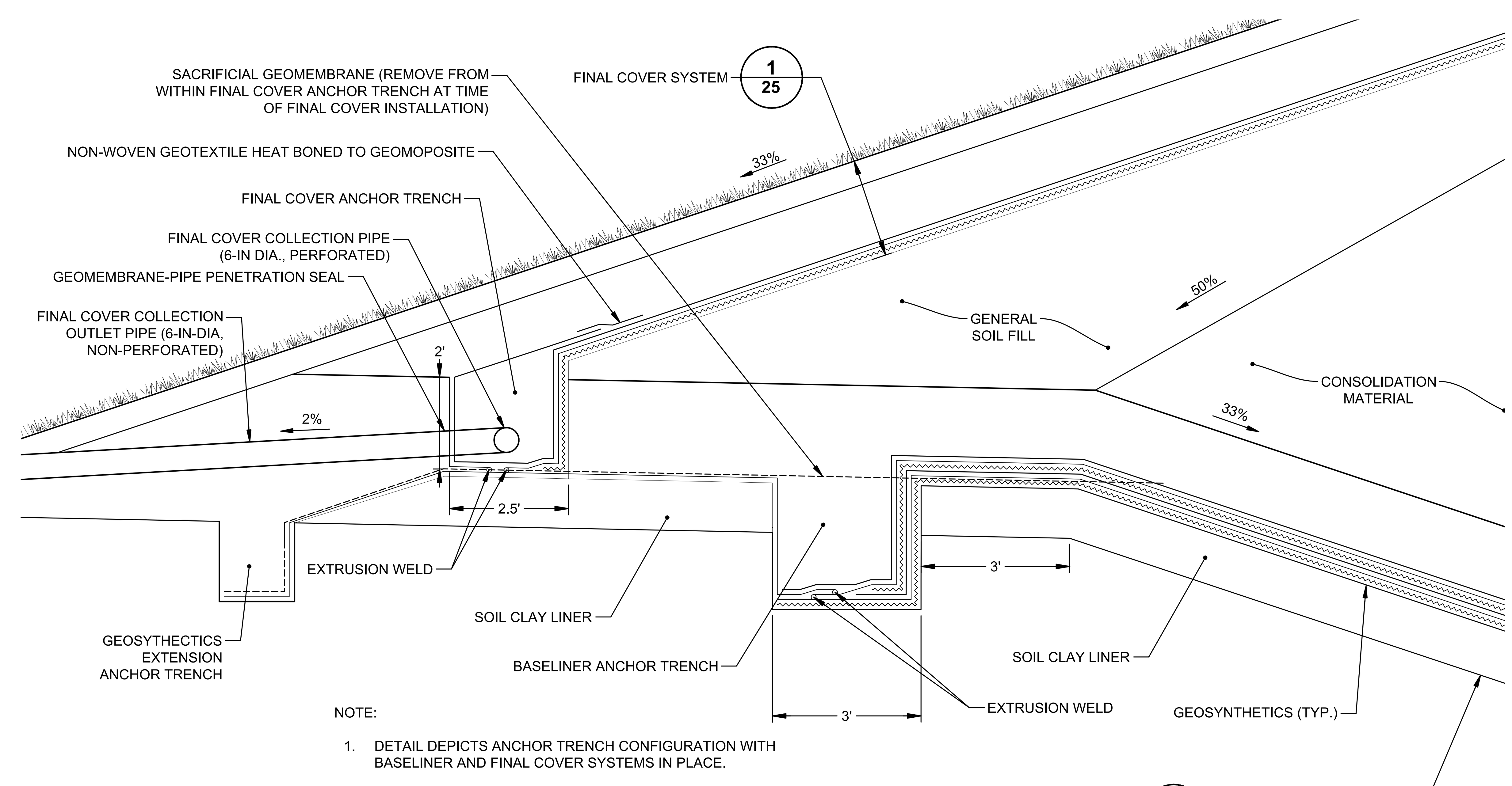


NOTE:

1. DETAIL DEPICTS ANCHOR TRENCH CONFIGURATION WITH BASELINER SYSTEM IN PLACE AND BEFORE FINAL COVER IS CONSTRUCTED.

ANCHOR TRENCH SECTION INITIAL CONDITION 2

SCALE: 1"=2'



NOTE:

1. DETAIL DEPICTS ANCHOR TRENCH CONFIGURATION WITH BASELINER AND FINAL COVER SYSTEMS IN PLACE.

ANCHOR TRENCH SECTION FINAL CONDITION 3

SCALE: 1"=2'

SCALE(S) AS INDICATED

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

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UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

PERIMETER BERM DETAILS

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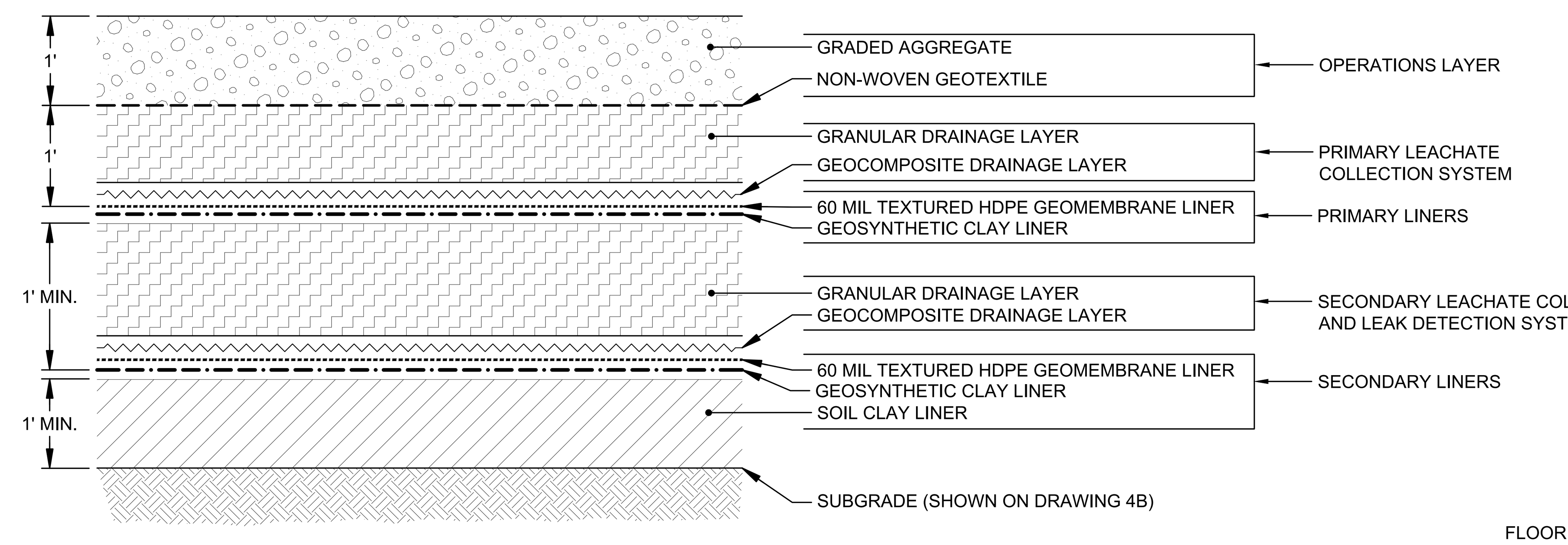
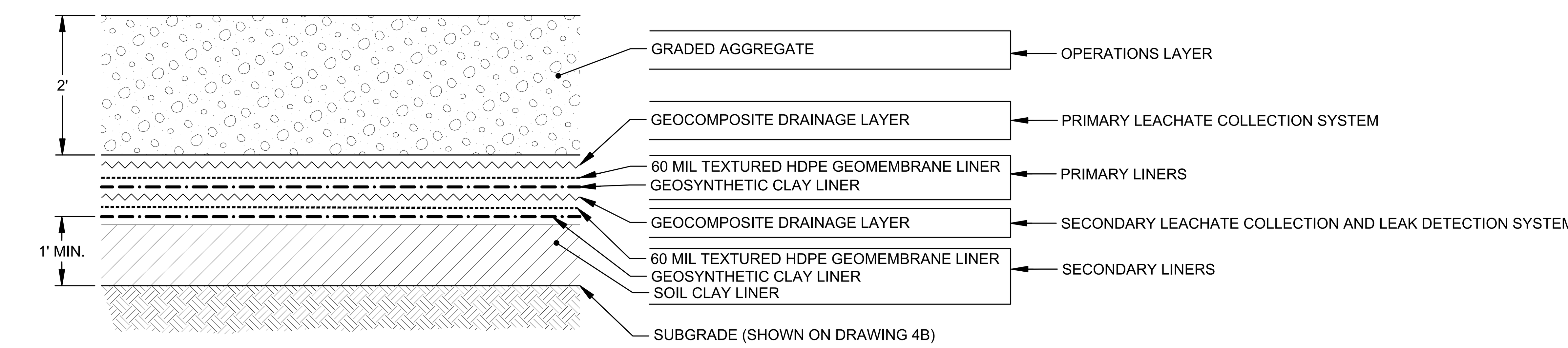


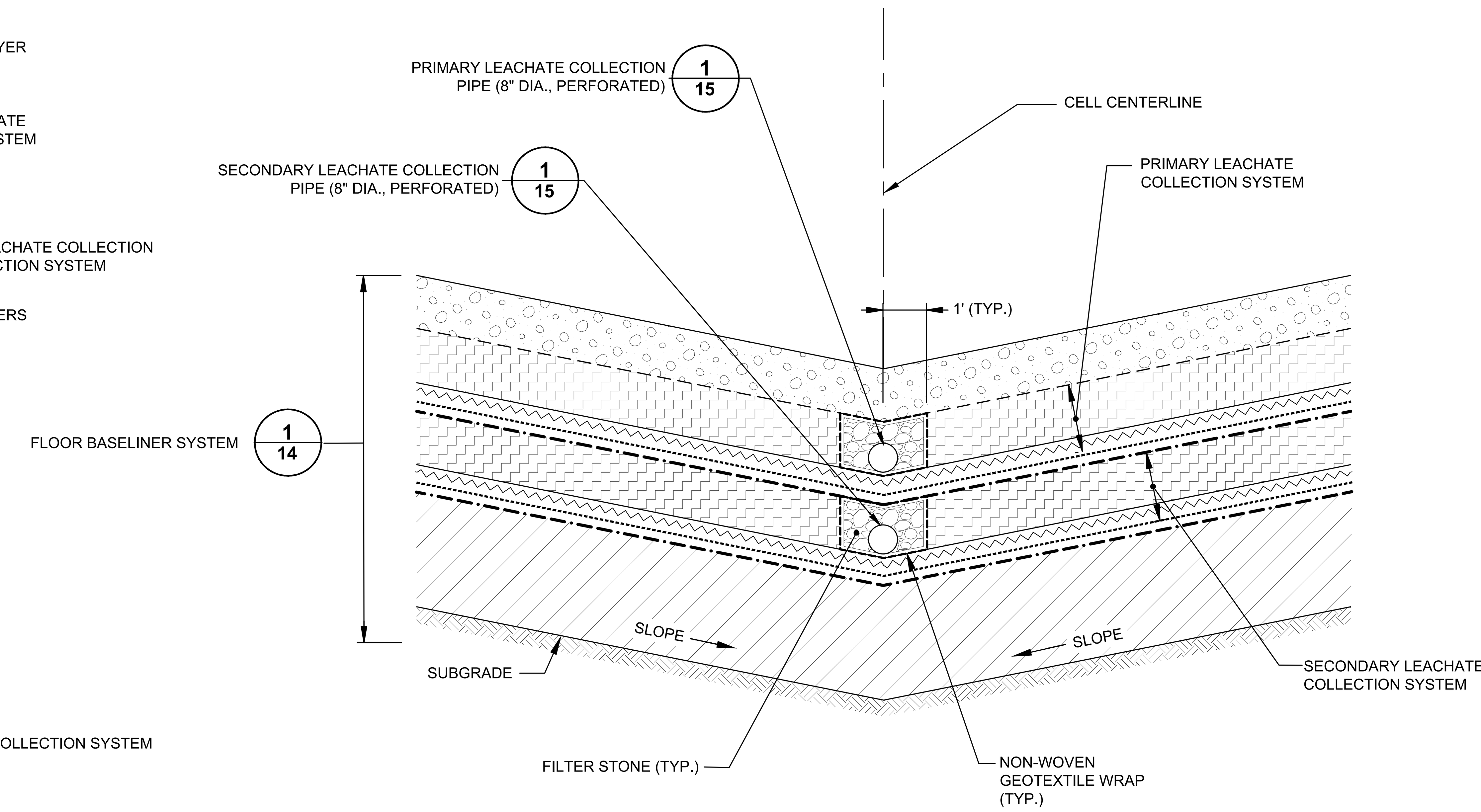
FLOOR BASELINER SYSTEM (1)

NOT TO SCALE



SIDESLOPE BASELINER SYSTEM (2)

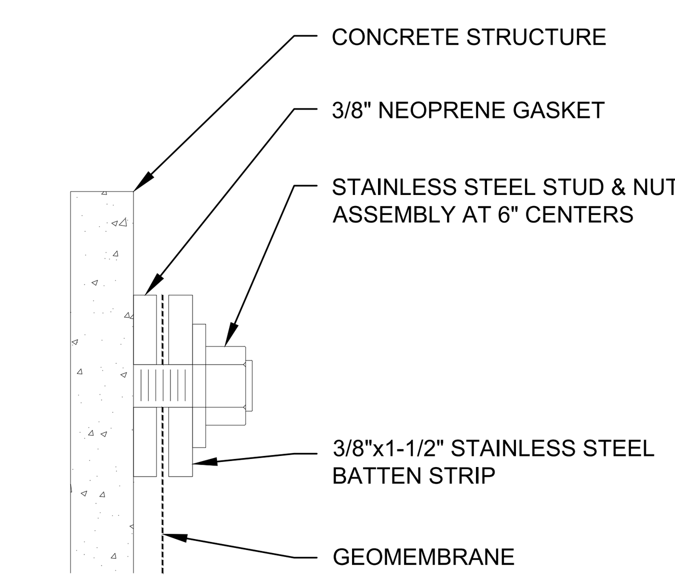
NOT TO SCALE



NOTE:
1. GEOTEXTILE OVERLAP SEAM TO BE SEWN OR HEAT-BONDED.

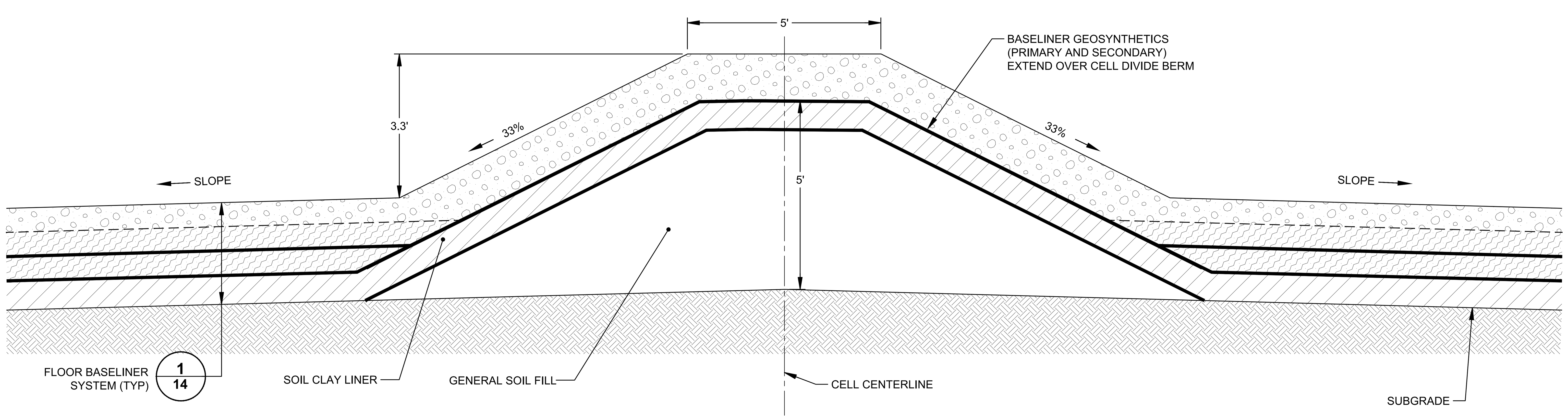
LEACHATE COLLECTION PIPE SECTION (4)

NOT TO SCALE



GEOMEMBRANE/ CONCRETE SEAL (5)

NOT TO SCALE



CELL DIVIDE BERM (3)

NOT TO SCALE

GENERAL NOTE:

1. GEOSYNTHETICS ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.

NOT TO SCALE

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983

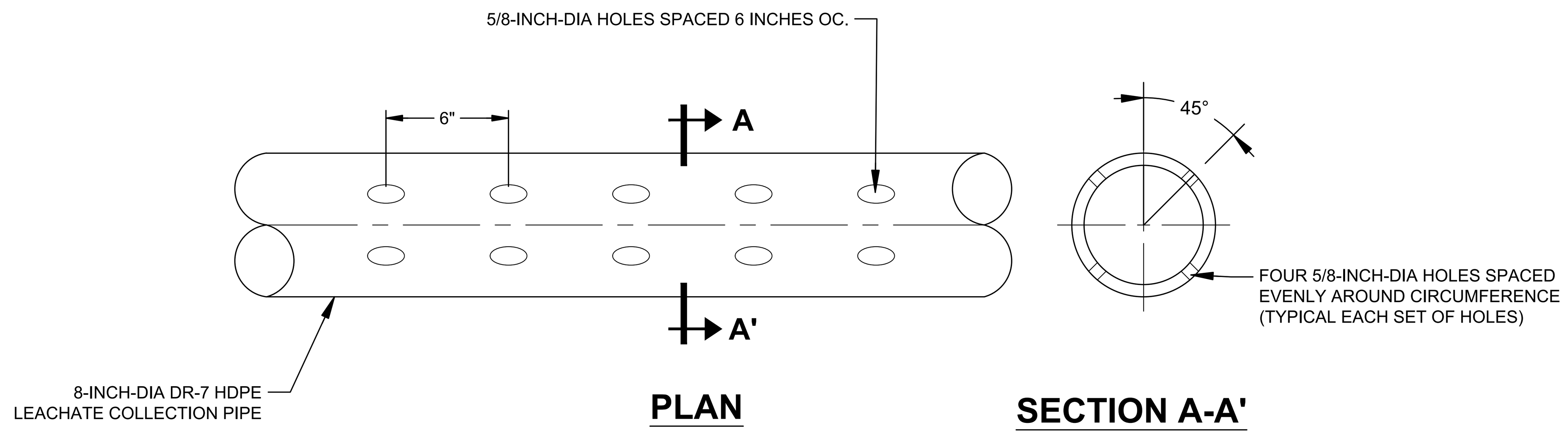
State	Date Signed	Project Mgr.
MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LINER SYSTEM DETAILS - 1

ARCADIS Project No. 30197838
Date FEBRUARY 2024
ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120



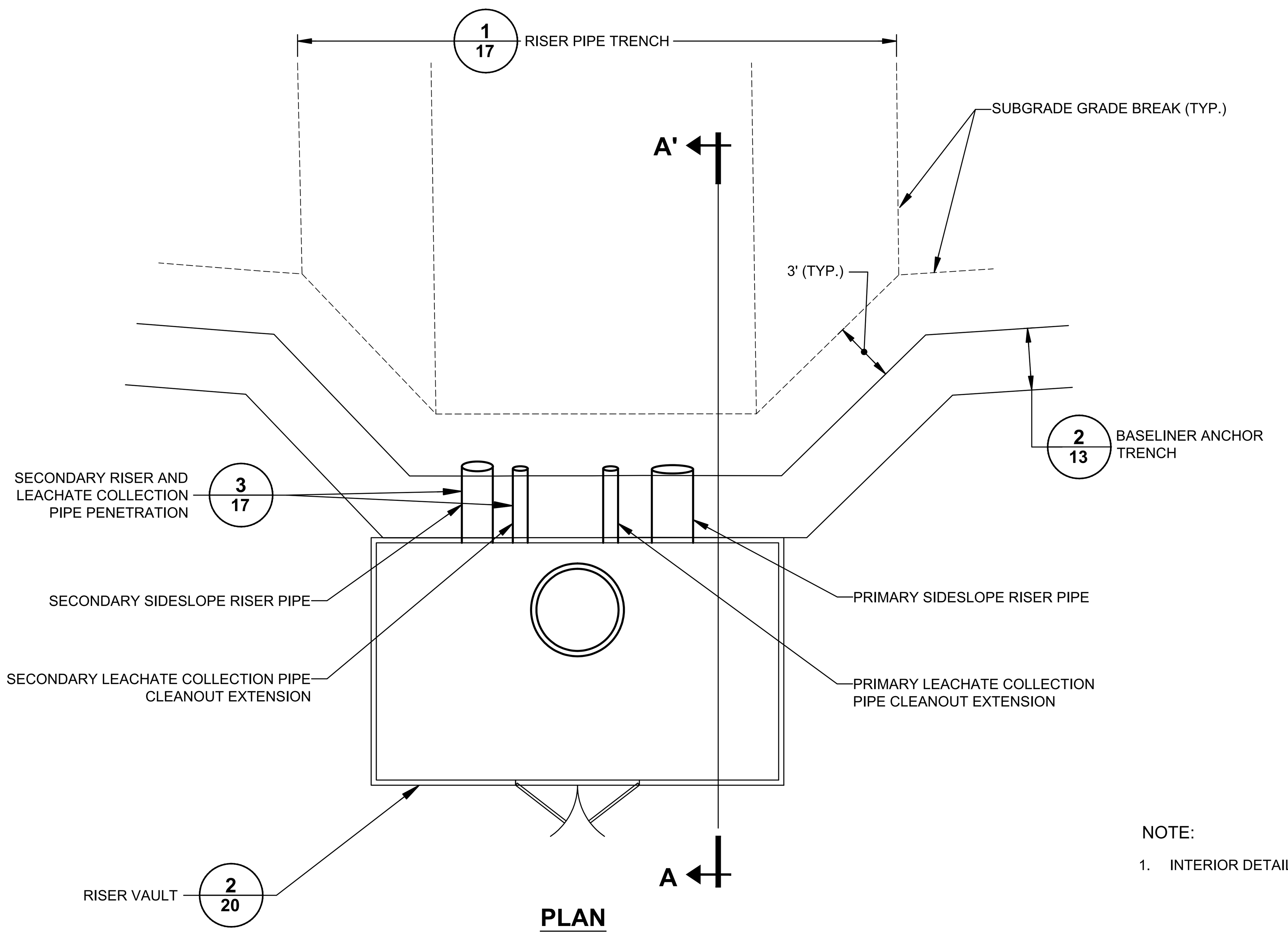
NOTE:

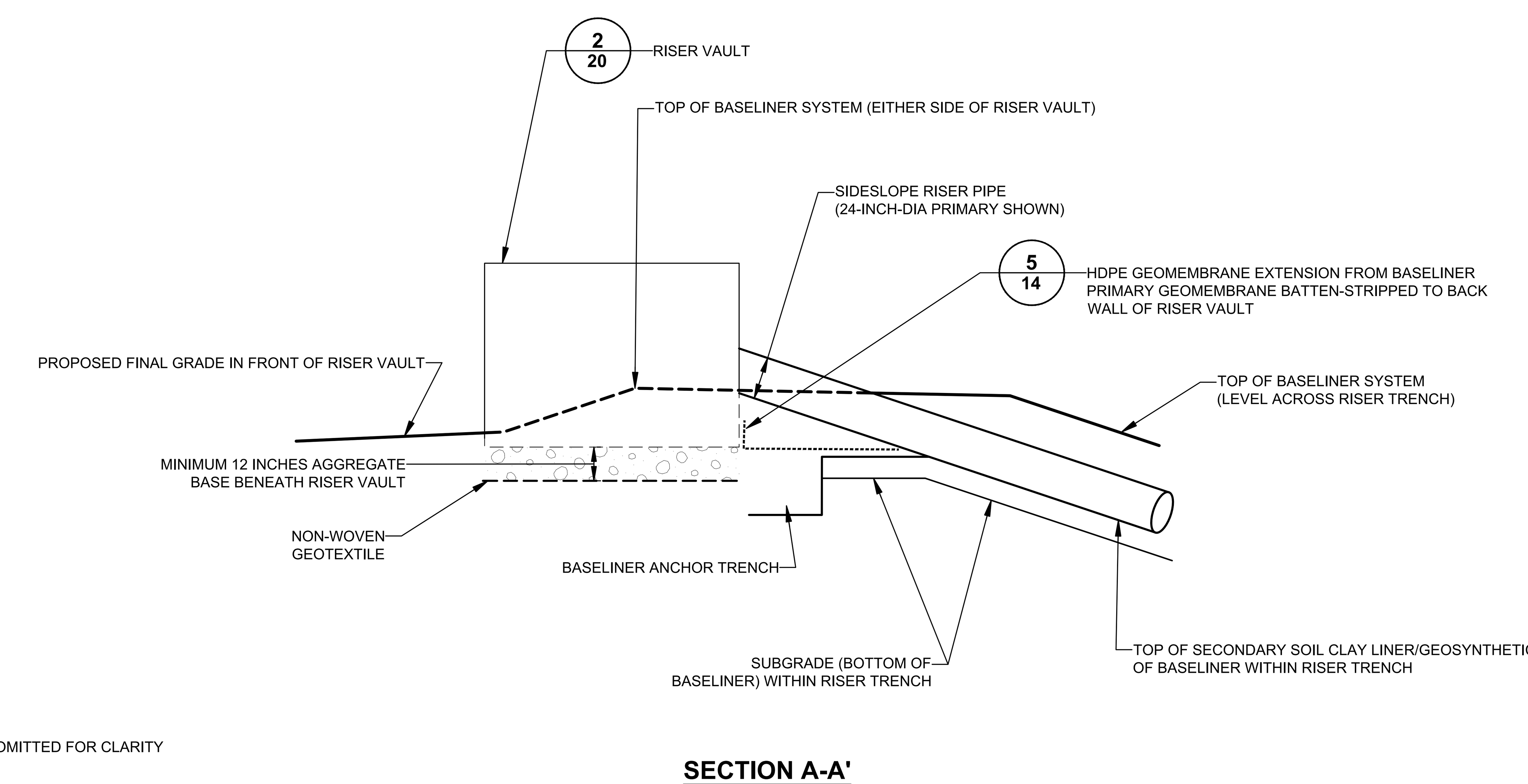
1. PERFORATION DETAIL APPLIES TO BOTH PRIMARY AND SECONDARY LEACHATE COLLECTION PIPES.

LEACHATE COLLECTION PIPE PERFORATION DETAIL (1)

0 6" 12"

SCALE: 1"=6"





NOTE:

1. INTERIOR DETAILS OF RISER VAULT OMITTED FOR CLARITY

BASELINER TERMINATION AT RISER VAULT (2)

0 5' 10'

SCALE: 1"=5'

SCALE(S) AS INDICATED		
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UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LINER SYSTEM DETAILS - 2

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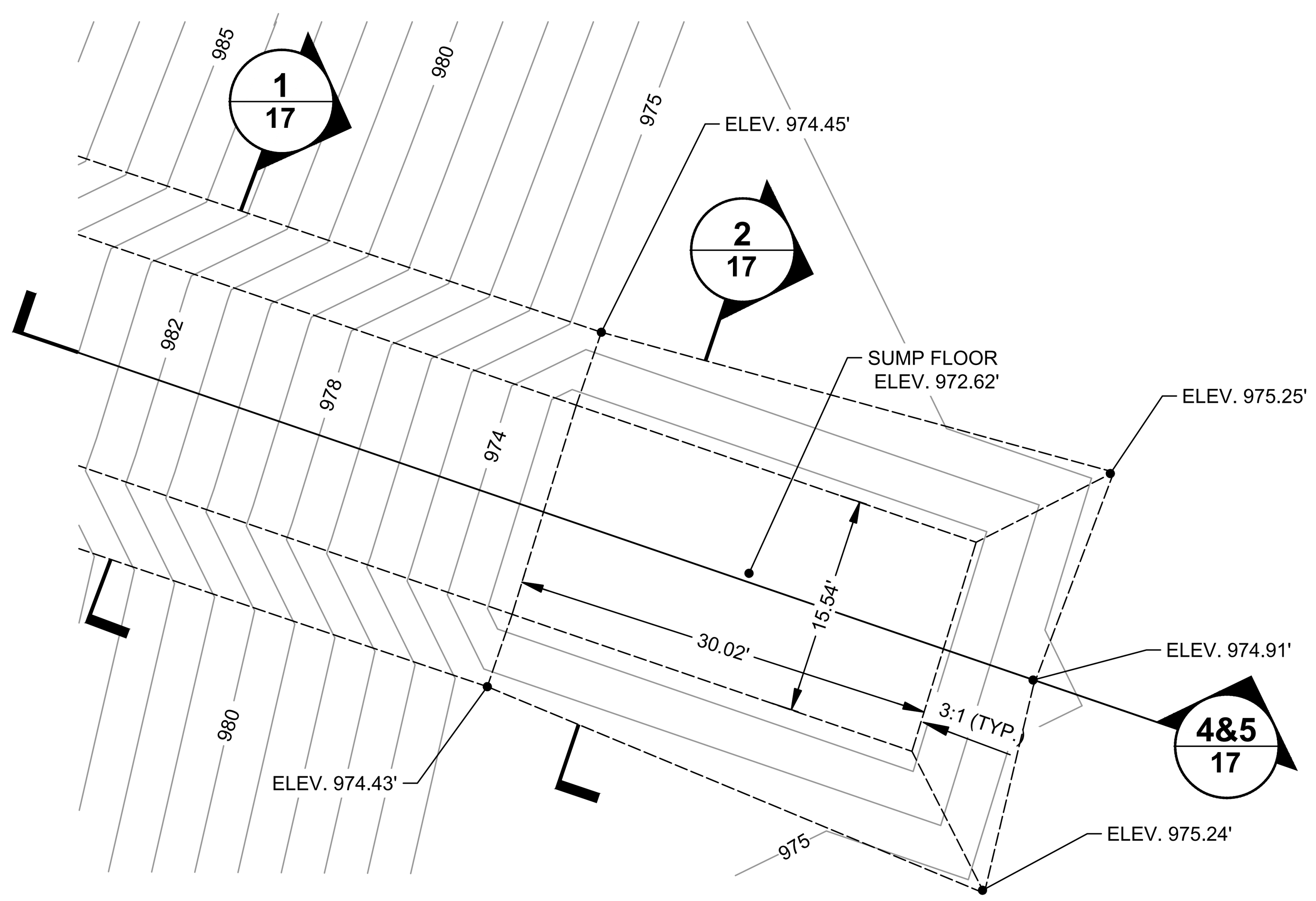
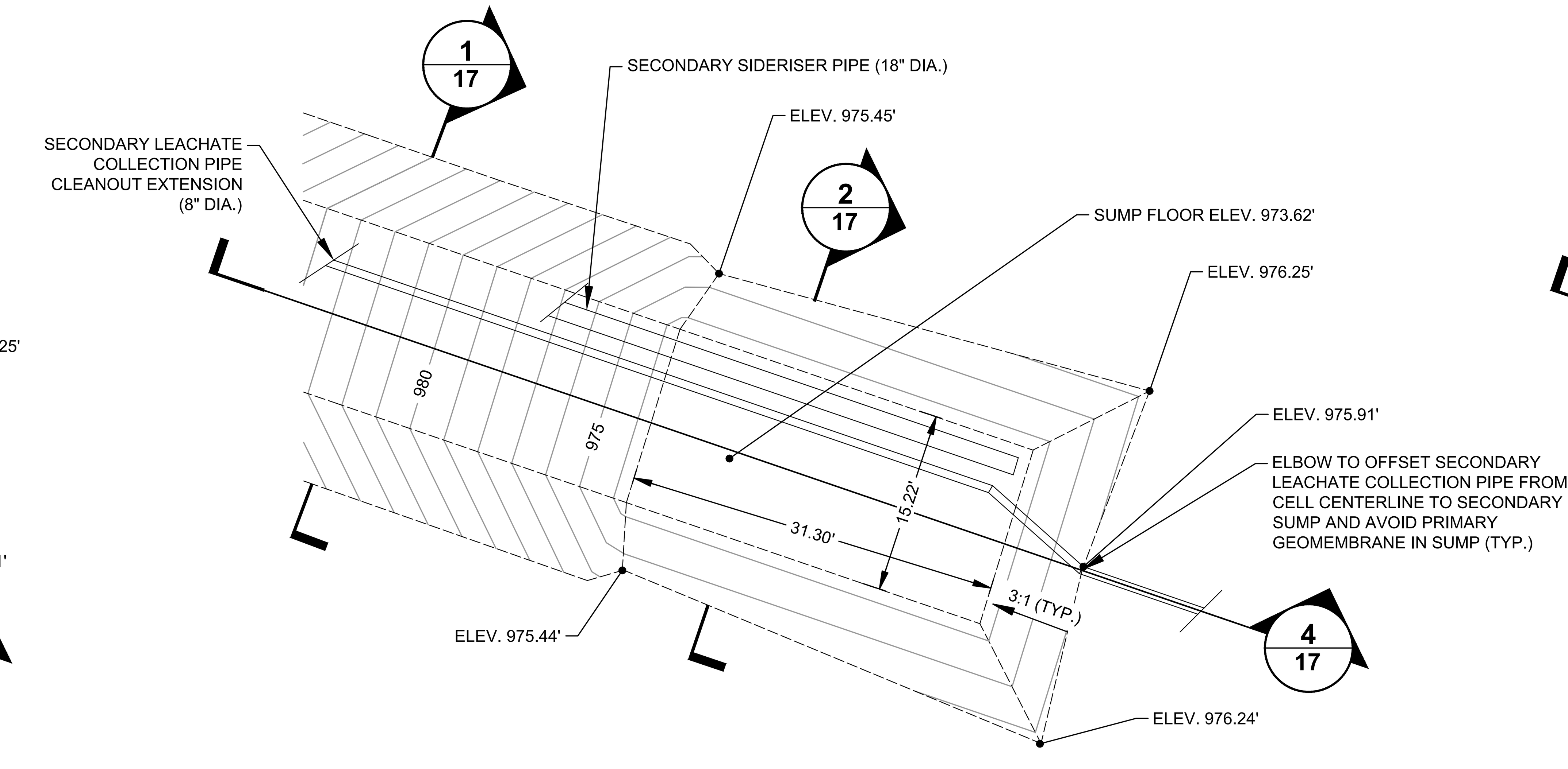
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

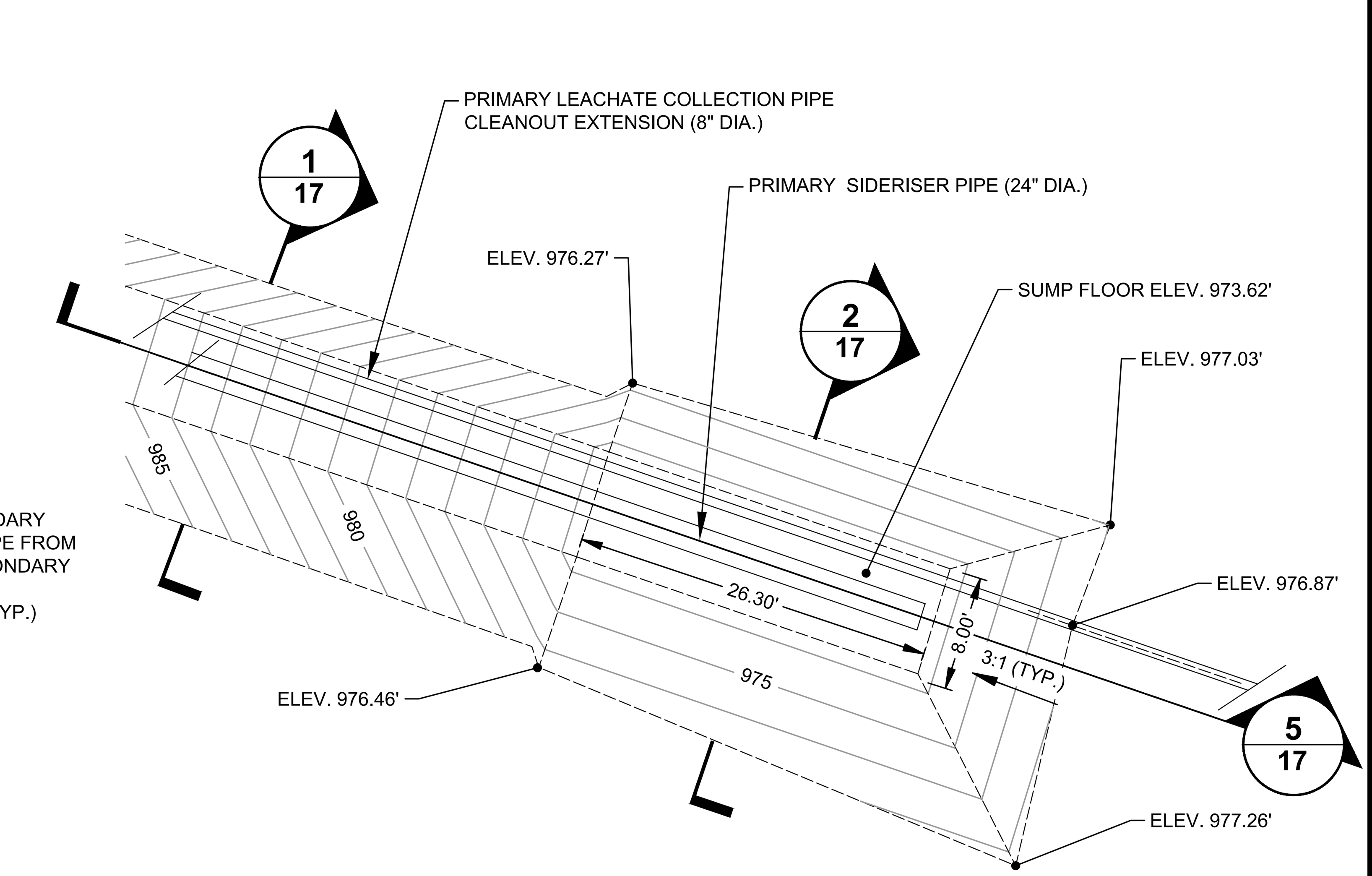
15



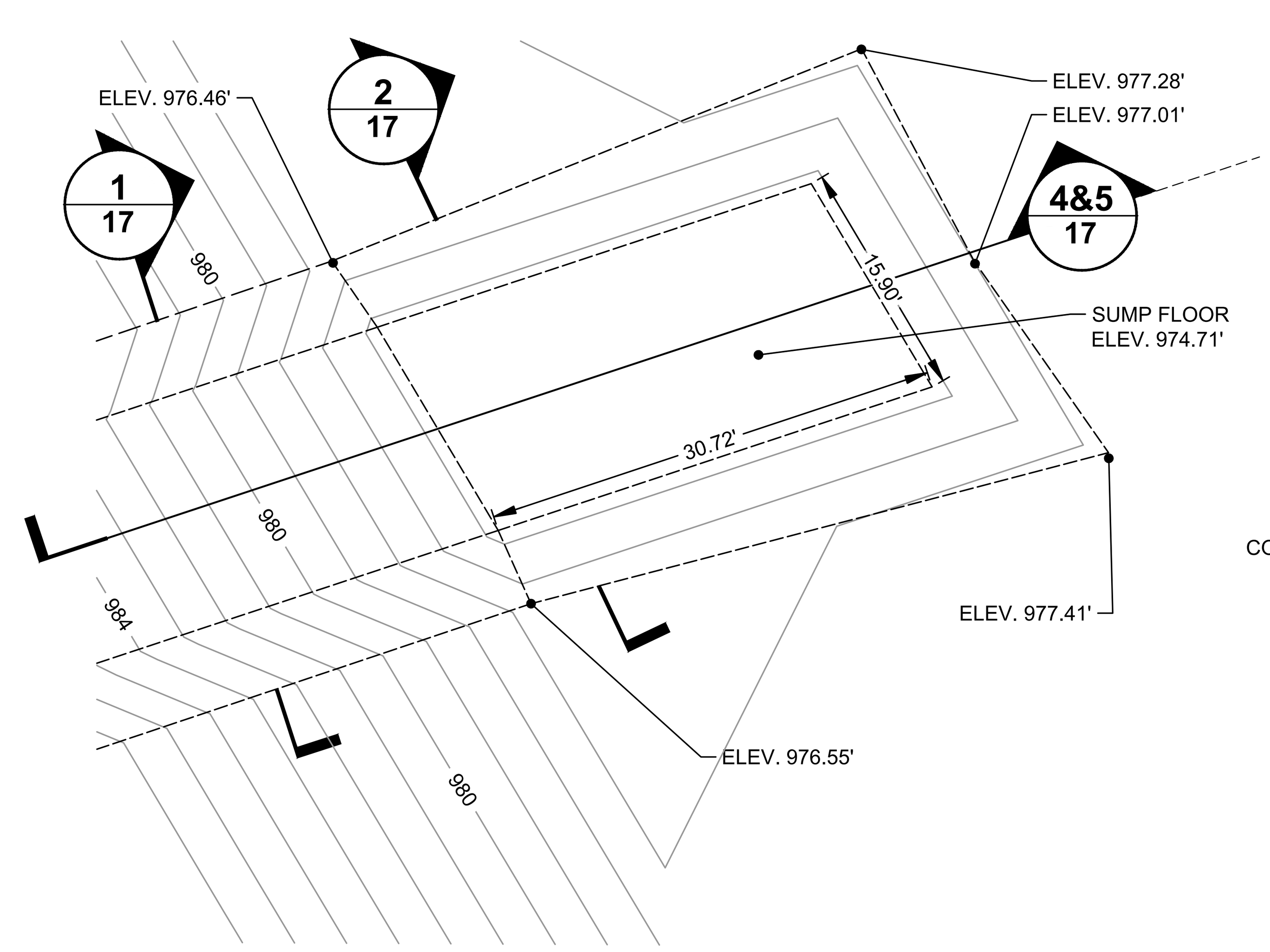
CELL 1
SUBGRADE SUMP PLAN (1)
SCALE: 1" = 10'



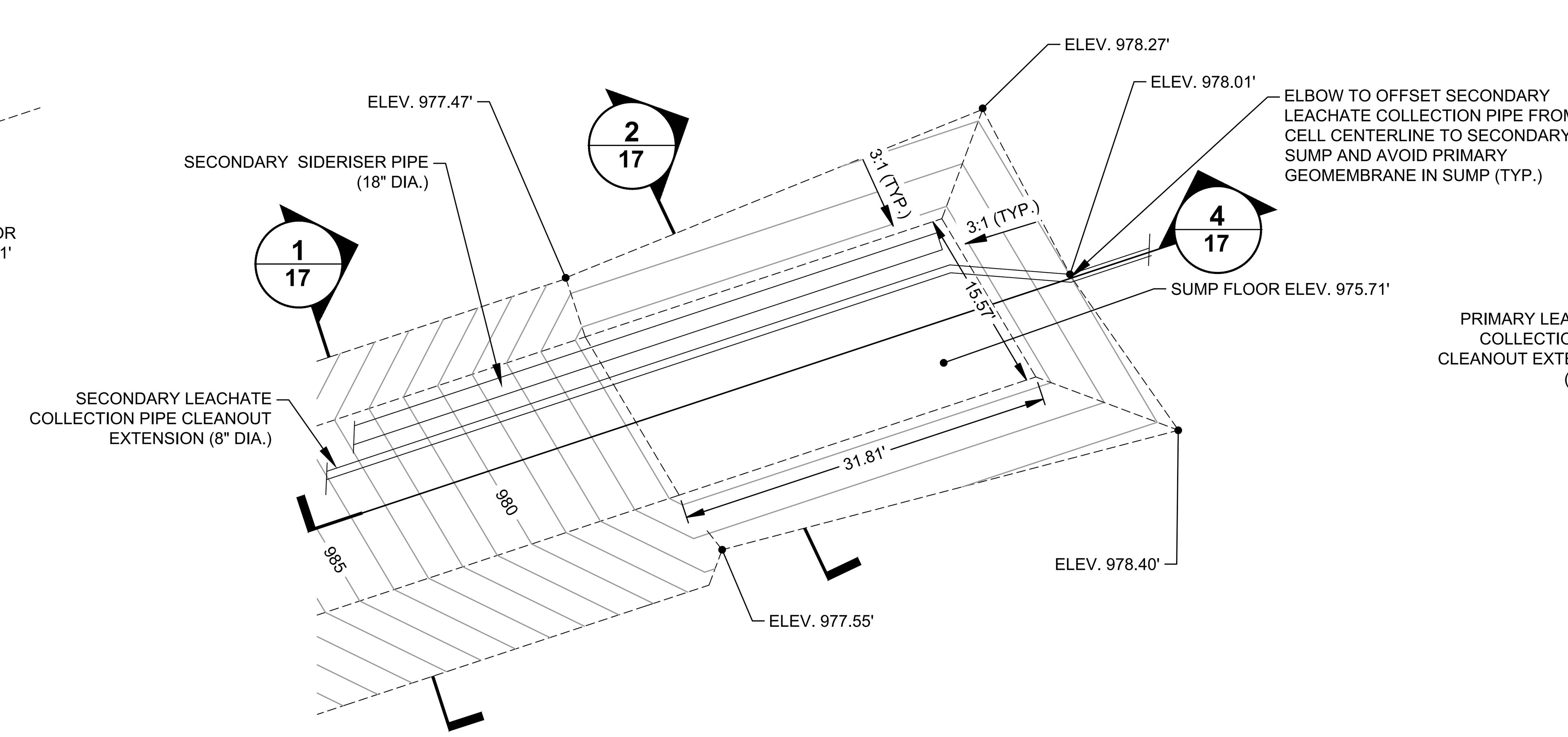
CELL 1
SECONDARY LEACHATE COLLECTION SUMP PLAN (2)
SCALE: 1" = 10'



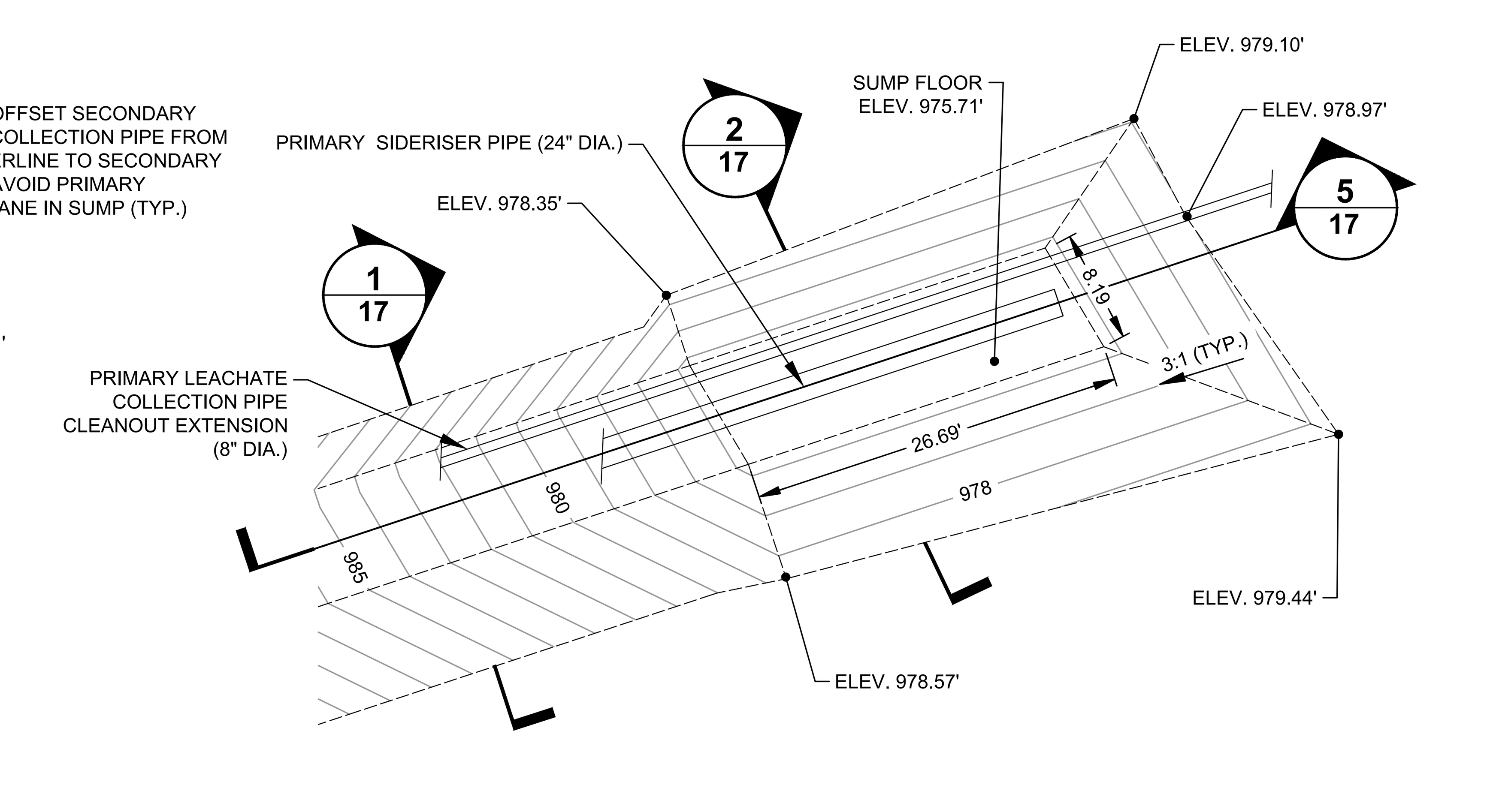
CELL 1
PRIMARY LEACHATE COLLECTION SUMP PLAN (3)
SCALE: 1" = 10'



CELL 2
SUBGRADE SUMP PLAN (4)
SCALE: 1" = 10'



CELL 2
SECONDARY LEACHATE COLLECTION SUMP PLAN (5)
SCALE: 1" = 10'



CELL 2
PRIMARY LEACHATE COLLECTION SUMP PLAN (6)
SCALE: 1" = 10'

GENERAL NOTES:

1. SUBGRADE ELEVATIONS REPRESENT TOP OF SITE SOIL FOLLOWING EXCAVATION FOR BASELINER SYSTEM.
2. SECONDARY SUMP ELEVATIONS REPRESENT TOP OF 1-FT-THICK COMPACTED SOIL CLAY LINER OF SECONDARY LINER SYSTEM AND IS THE SURFACE ON WHICH THE SECONDARY GEOSYNTHETICS WILL BE PLACED.
3. PRIMARY SUMP ELEVATIONS REPRESENT TOP OF SECONDARY GRANULAR LAYERS WHERE PRESENT OR SECONDARY SUMP ELEVATIONS WHERE SECONDARY GRANULAR LAYERS ARE ABSENT.
4. ELEVATIONS AND GRADES SHOWN FOR SUMP CONFIGURATIONS MAY VARY BASED ON CONSTRUCTION REQUIREMENTS.

XREFS: X-INT DRAFT-UDF-BDR-C-LD IMAGES: Arcadis Logo BW.PNG

1"=10' 10' 0 10' 20'

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed:	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

ARCADIS
ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LEACHATE SUMP PLANS

ARCADIS Project No. 30197838
Date FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
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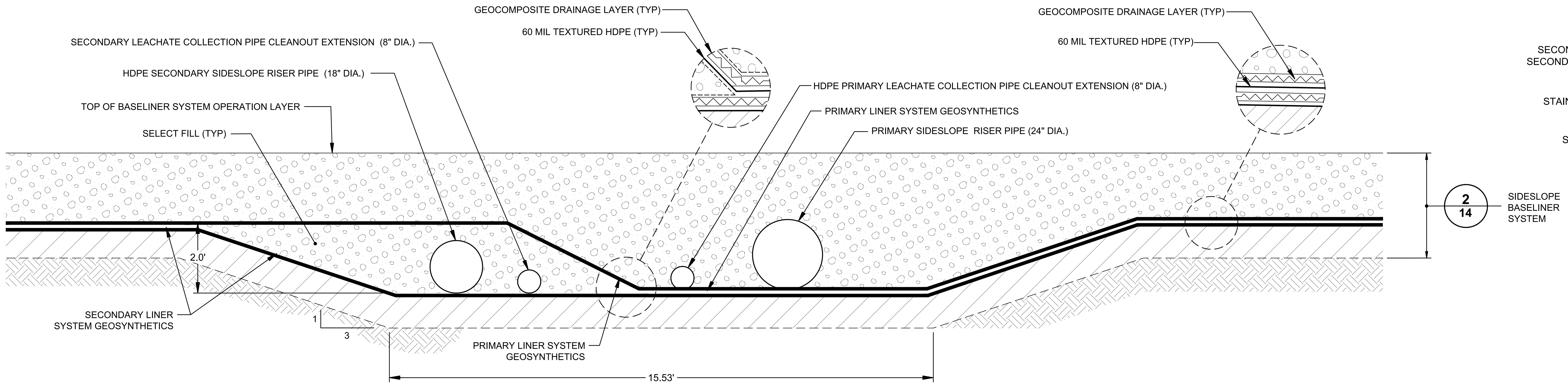
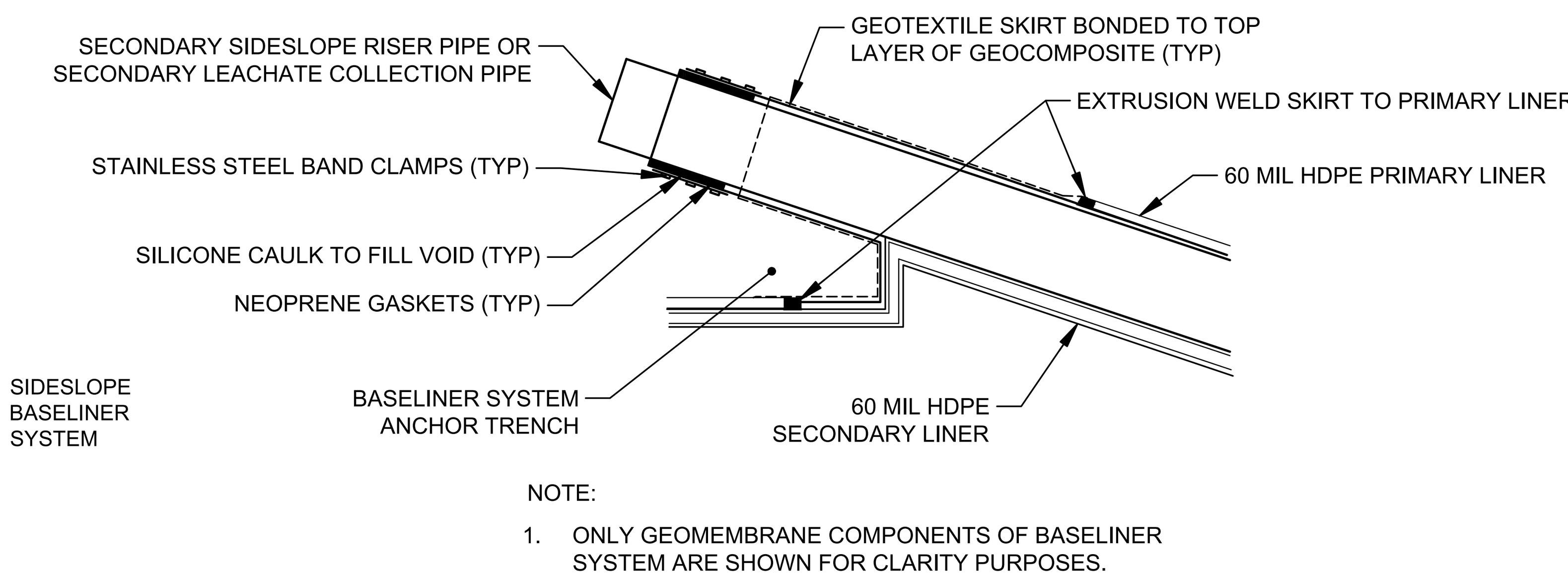
TEL. 315.446.9120



PRIMARY/SECONDARY SIDESLOPE RISER PIPE TRENCH (1)

0 2' 4'
SCALE: 1"=2'

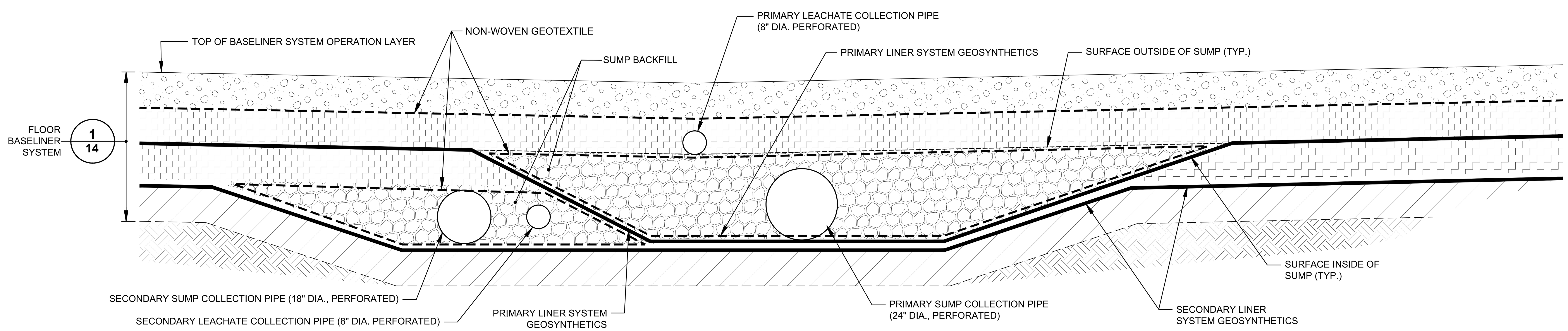


NOTE:

1. ONLY GEOMEMBRANE COMPONENTS OF BASELINER SYSTEM ARE SHOWN FOR CLARITY PURPOSES.

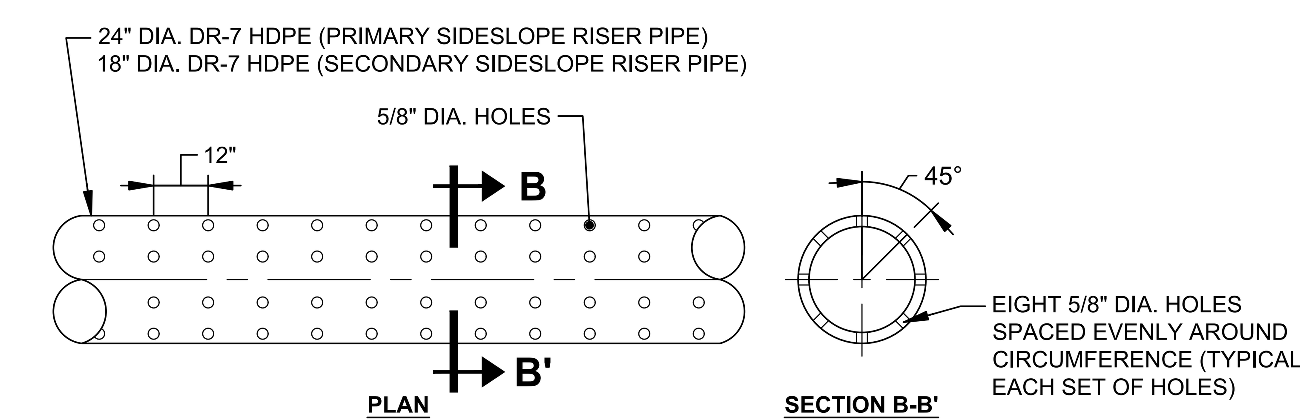
RISER PIPE-SIDESLOPE BASELINER SYSTEM PENETRATION (3)

NOT TO SCALE



SUMP CROSS SECTION (TYP.) (2)

0 2' 4'
SCALE: 1"=2'

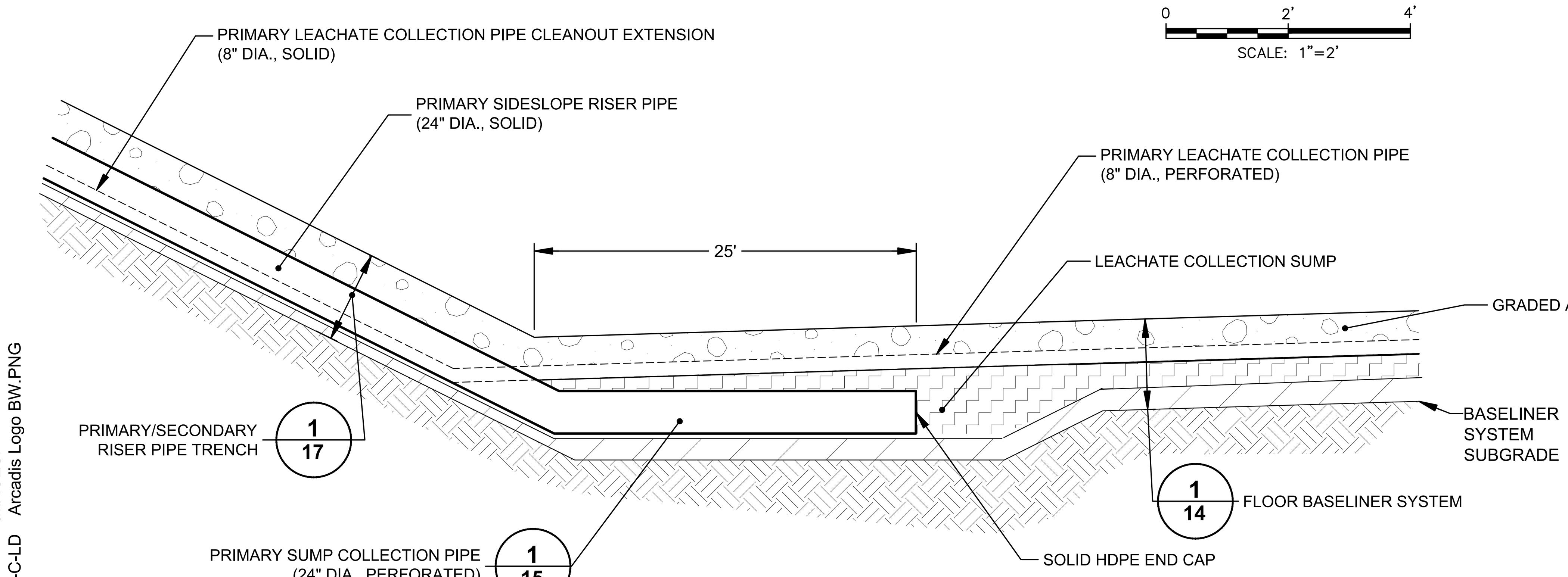


NOTE:

1. DETAIL APPLIES TO HORIZONTAL PORTIONS OF PRIMARY AND SECONDARY SUMP COLLECTION RISER PIPES.

PIPE PERFORATION DETAIL (6)

NOT TO SCALE

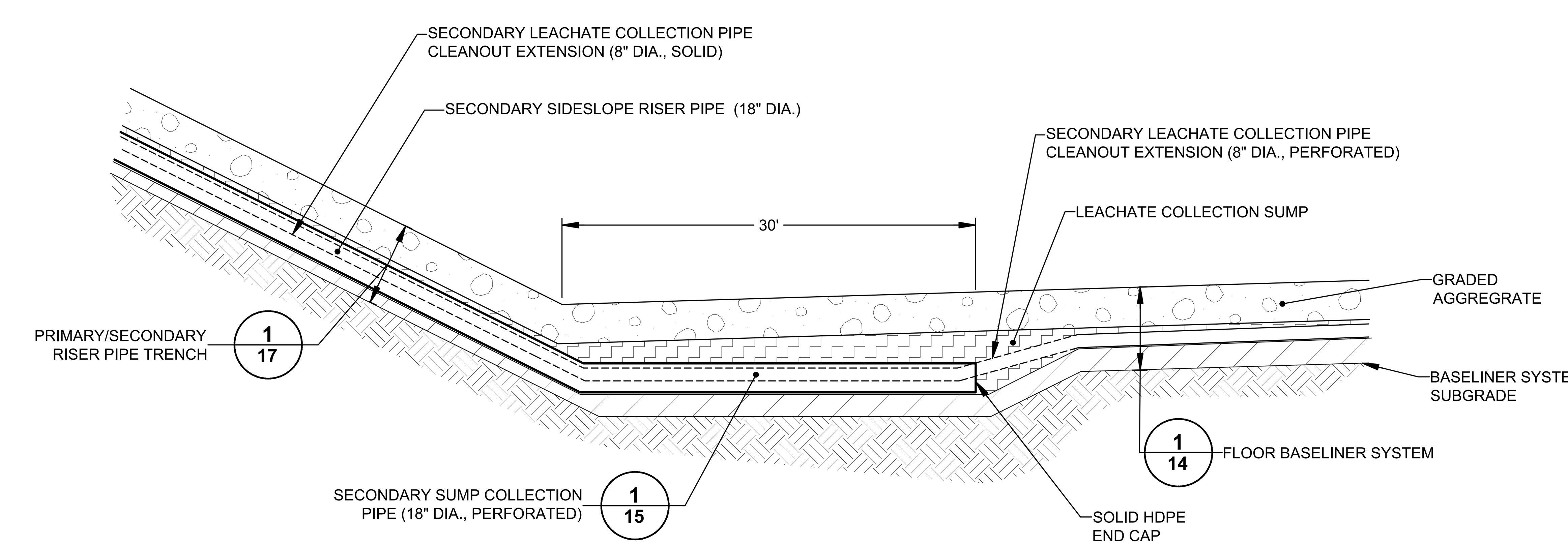


PRIMARY LEACHATE COLLECTION SUMP PROFILE (4)

0 8' 16'
SCALE: 1"=8'

GENERAL NOTES:

1. ELEVATIONS AND GRADES SHOWN FOR SUMP CONFIGURATIONS MAY VARY BASED ON CONSTRUCTION REQUIREMENTS.
2. GEOSYNTHETICS ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.



SECONDARY LEACHATE COLLECTION SUMP PROFILE (5)

0 8' 16'
SCALE: 1"=8'

SCALE(S) AS INDICATED

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No.	Date	Revisions	By	Ckd

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Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983
State: MA | Date Signed: | Project Mgr.: DK
Designed by: BMS | Drawn by: KLS | Checked by: PHB

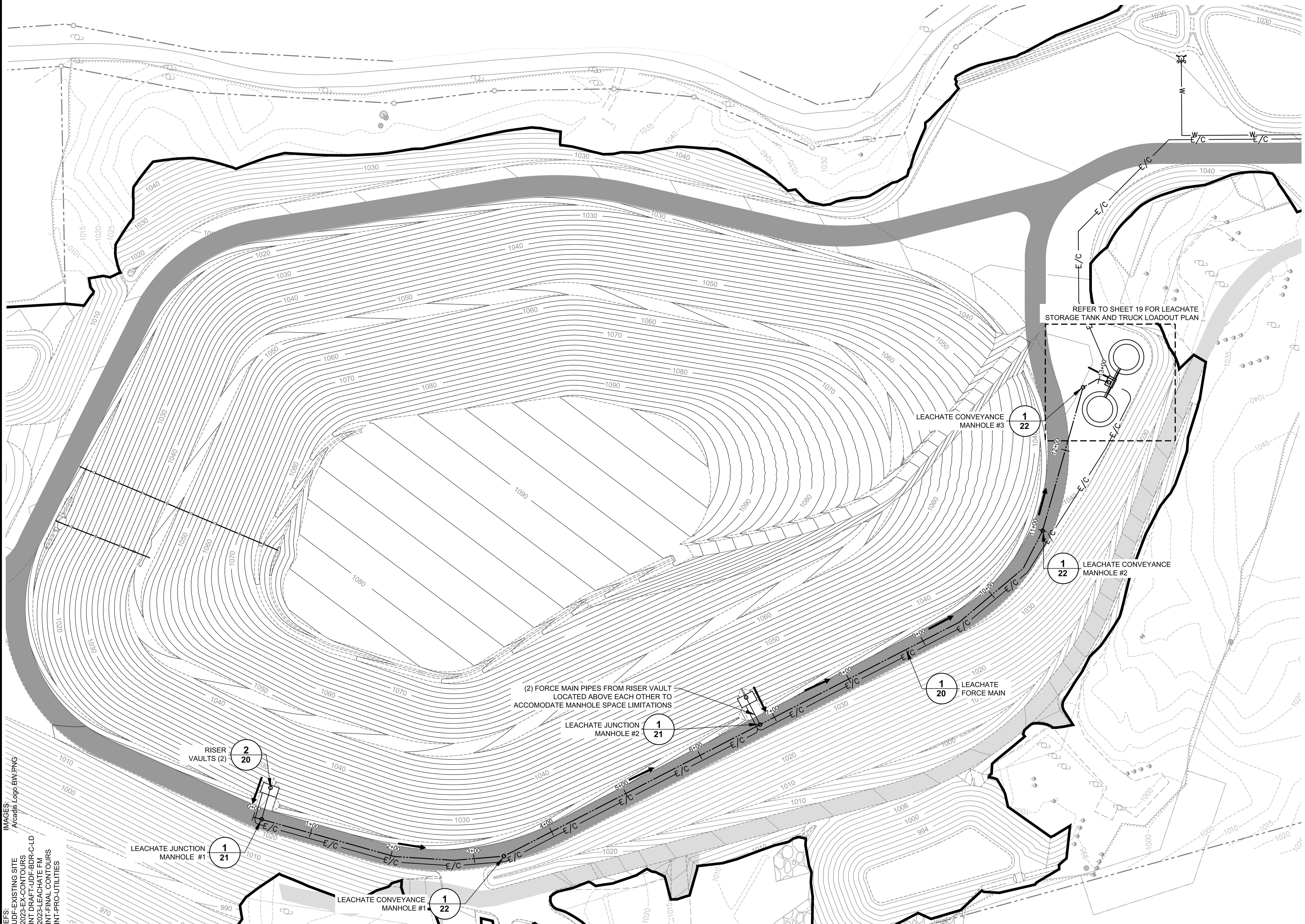
ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LEACHATE SUMP SECTIONS AND DETAILS

ARCADIS Project No. 30197838
Date FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120



EXISTING FEATURES LEGEND

- REBAR FOUND
- IRON PIN FOUND
- CONCRETE BOUND FOUND
- GRANITE BOUND FOUND
- BENCH MARK
- UTILITY POLE
- LAMP POST
- GUY WIRE
- MW 2022-2 — MONITORING WELL
- PZ 2022-8 — PIEZOMETER
- B 2022-8 — SOIL BORING
- WET AREA
- APPROXIMATE PROPERTY BOUNDARY
- EDGE OF GRAVEL
- EDGE OF BITUMINOUS
- EDGE OF WATER
- EDGE OF WETLAND
- STONEWALL
- OH — OVERHEAD WIRES
- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- 1010 — ELEVATION CONTOUR (5-FOOT INTERVAL)
- OVERHEAD LINE EASEMENT

DESIGN FEATURES LEGEND

- 1060 — INDEX ELEVATION CONTOUR (2-FOOT INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOUR (2-FOOT INTERVAL, SEE NOTE 2)
- ELEVATION GRADE BREAK
- APPROXIMATE LIMITS OF GRADING
- E/C — UNDERGROUND ELECTRIC AND COMMUNICATIONS CONDUITS
- W — WATER SERVICE LINE
- LEACHATE FORCE MAIN
- LEACHATE FORCE MAIN FLOW DRECTION

NOTES:

1. REFER TO DRAWINGS 2A AND 2B FOR BASEMAP INFORMATION.
2. DESIGN ELEVATION CONTOURS WITHIN UDF BASELINER LIMITS REPRESENT LINER SYSTEM SUBGRADE ELEVATIONS. DESIGN ELEVATION CONTOURS OUTSIDE UDF BASELINER LIMITS REPRESENT FINAL GRADE ELEVATIONS.

C:\Users\CSHill\DC\ACCDocs\Arcadis ACC US\AUS-99999999-GE_HOUSATONIC_PITTSFIELD_MA\Project Files\10_WIP\10T_ARC_ENV\202401-DWG\INT-UDF-DWG_18-LEACHATE TRANSFER &SSP.dwg LAYOUT: 18 SAVED: 2/27/2024 9:22 PM ACADVER: 24.2S (LMS TECH) PAGESETUP: ----
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XREFS: X-UDF-EXISTING SITE, X-2023-EX-CONTOURS, X-INT DRAFT-UDF-BDR-C-LD, X-2023-LEACHATE FM, X-INT-FINAL CONTOURS, X-INT-PRO-UTILITIES
IMAGES: Arcadis Logo BW.PNG

1"=60' — 60' 0 60' 120'

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Professional Engineer's Name: **MARK O. GRAVELDING**		
Professional Engineer's No.: 42983		
State: MA	Date Signed:	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

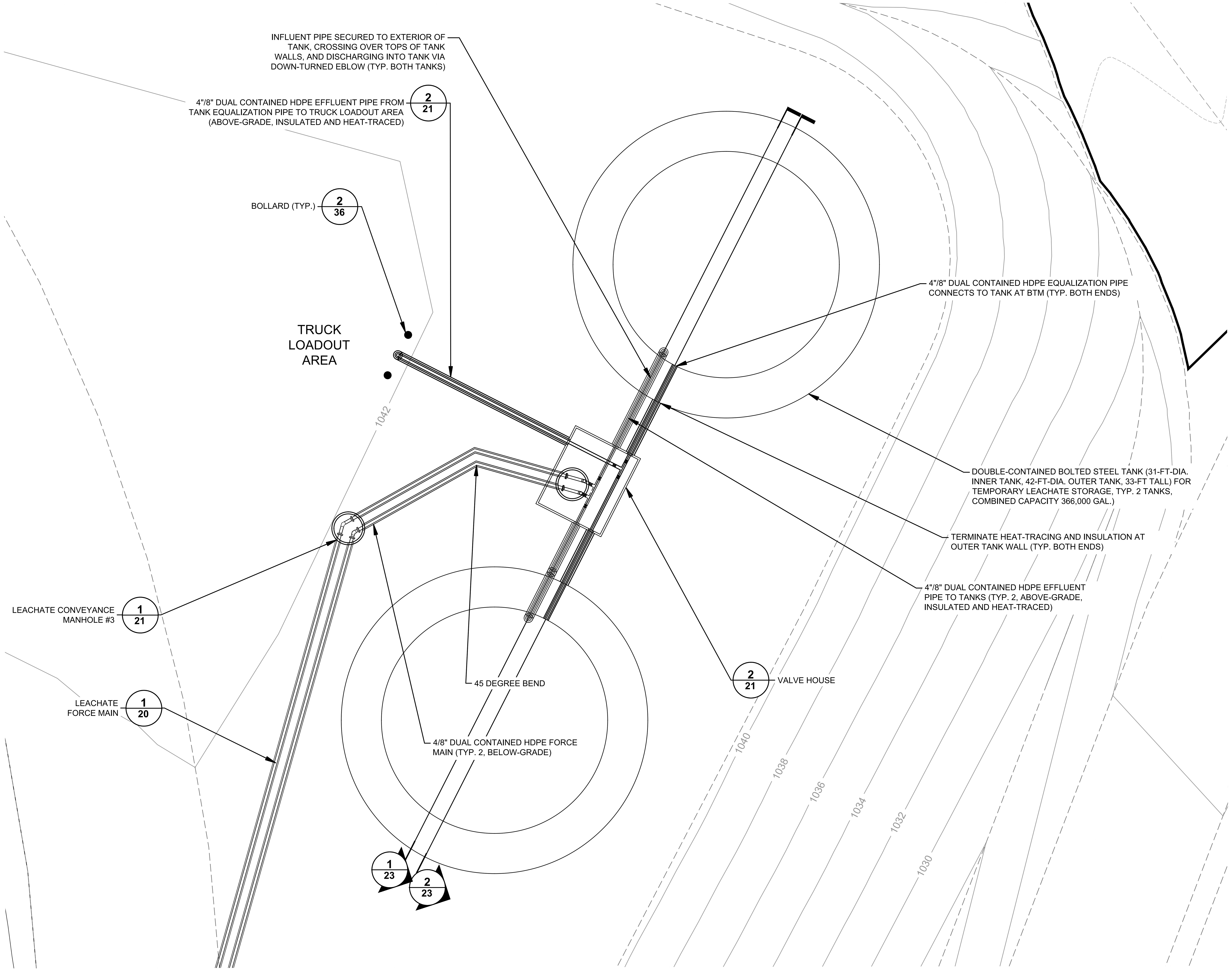
ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LEACHATE CONVEYANCE AND STORAGE SYSTEM PLAN

ARCADIS Project No. 30197838
Date: FEBRUARY 2024
ARCADIS, ONE LINCOLN CENTER, 110 WEST FAYETTE STREET, SYRACUSE, NEW YORK 13202, TEL. 315.446.9120

18



EXISTING FEATURES LEGEND

- REBAR FOUND
- IRON PIN FOUND
- CONCRETE BOUND FOUND
- GRANITE BOUND FOUND
- BENCH MARK
- UTILITY POLE
- LAMP POST
- GUY WIRE
- MW 2022-2 — MONITORING WELL
- PZ 2022-8 — PIEZOMETER
- B 2022-8 — SOIL BORING
- WET AREA
- APPROXIMATE PROPERTY BOUNDARY
- EDGE OF GRAVEL
- EDGE OF BITUMINOUS
- EDGE OF WATER
- EDGE OF WETLAND
- STONEWALL
- OH — OVERHEAD WIRES
- EDGE OF TREE/BRUSH LINE
- PHRAGMITES
- CONCRETE DEBRIS PILE
- GRAVEL PILE
- 1010 — ELEVATION CONTOUR (5-FOOT INTERVAL)
- OVERHEAD LINE EASEMENT

DESIGN FEATURES LEGEND

- 1060 — INDEX ELEVATION CONTOUR (2-FOOT INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOUR (2-FOOT INTERVAL, SEE NOTE 2)
- ELEVATION GRADE BREAK
- APPROXIMATE LIMITS OF GRADING

NOTES:

1. REFER TO DRAWINGS 2A AND 2B FOR BASEMAP INFORMATION.
2. DESIGN ELEVATION CONTOURS WITHIN UDF BASELINER LIMITS REPRESENT LINER SYSTEM SUBGRADE ELEVATIONS. DESIGN ELEVATION CONTOURS OUTSIDE UDF BASELINER LIMITS REPRESENT FINAL GRADE ELEVATIONS.

XREFS: X-UDF-EXISTING SITE; X-2023-EX-CONTOURS; X-INT DRAFT-UDF-BDR-C-LD; X-2023-LEACHATE FM; X-INT-FINAL CONTOURS
IMAGES: Arcadis Logo BW.PNG

C:\Users\CSHill\DC\ACCDocs\Arcadis ACC US\AUS-99999999-GE_HOUSATONIC_PITTSFIELD_MA\Project Files\10_WIP\10T_ARC_ENV\202401-DWG\INT-UDF-DWG_19-LEACHATE STORAGE TANK &TRUCK LOADOUT.dwg LAYOUT: 19 SAVED: 2/27/2024 9:23 PM ACADVER: 24.2S (LMS TECH)
PAGESETUP: ---- PLOTSTYLETABLE: ---- PLOTTED: 2/27/2024 10:36 PM BY: HILL, CHRISTIAN

1"=10' — 10' 0 10' 20'

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed:	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

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ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LEACHATE STORAGE TANK AND TRUCK LOADOUT PLAN

ARCADIS Project No. 30197838

Date FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
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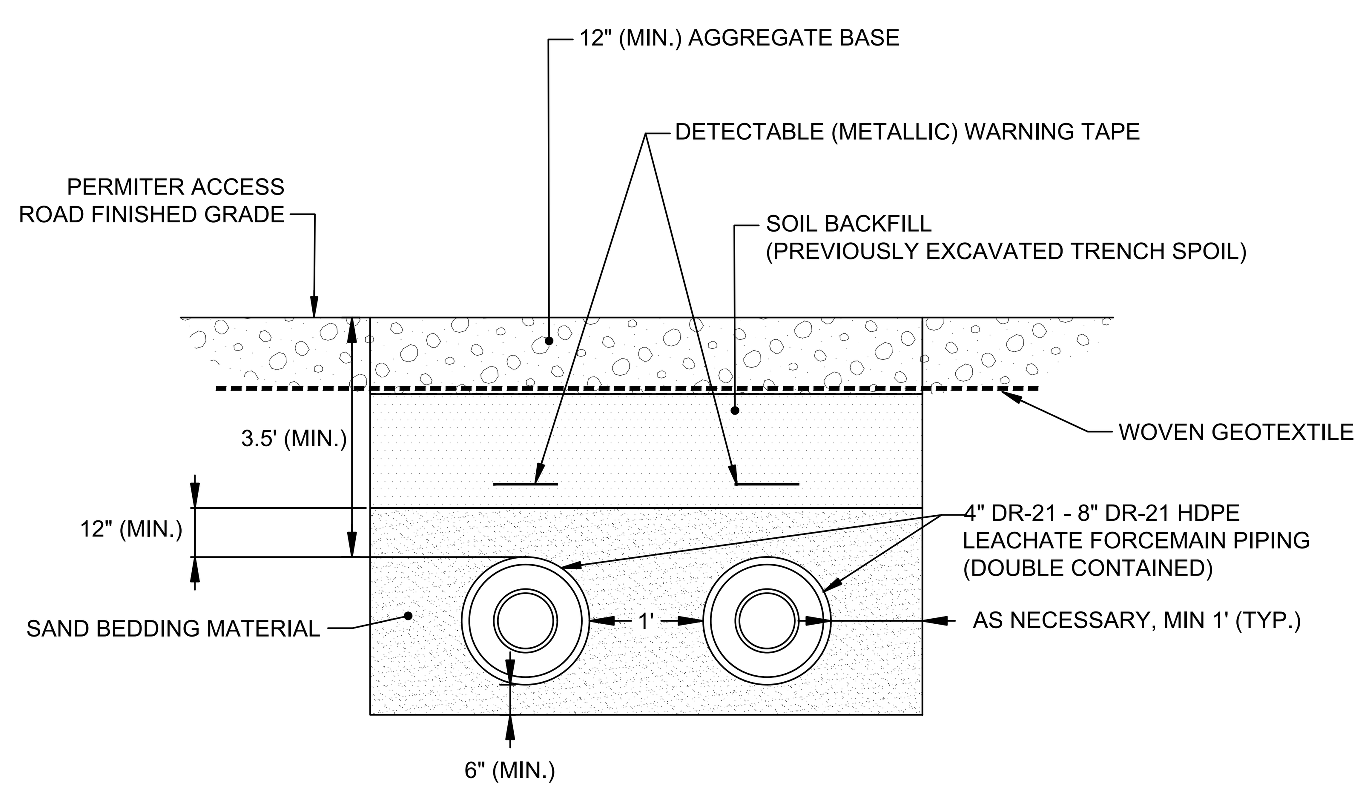
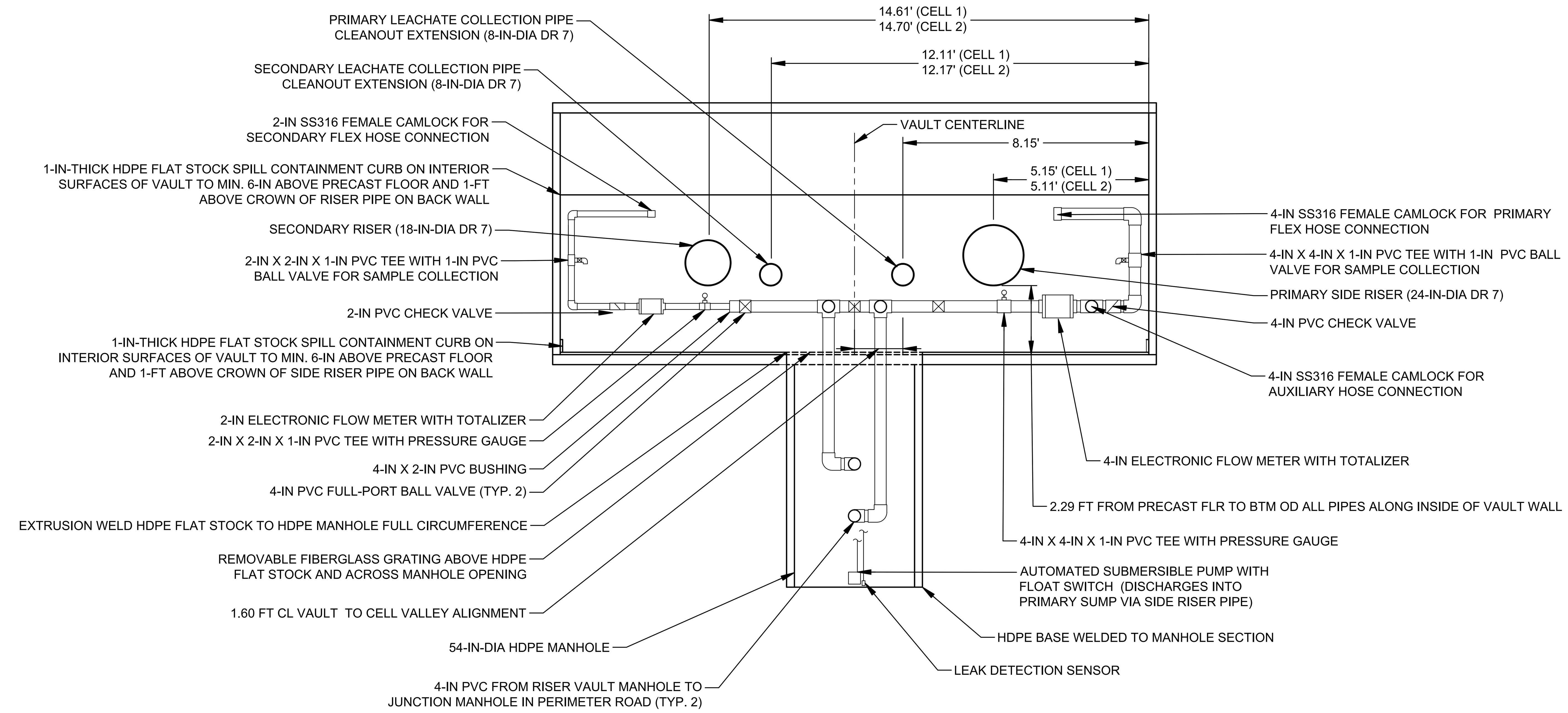
TEL. 315.446.9120

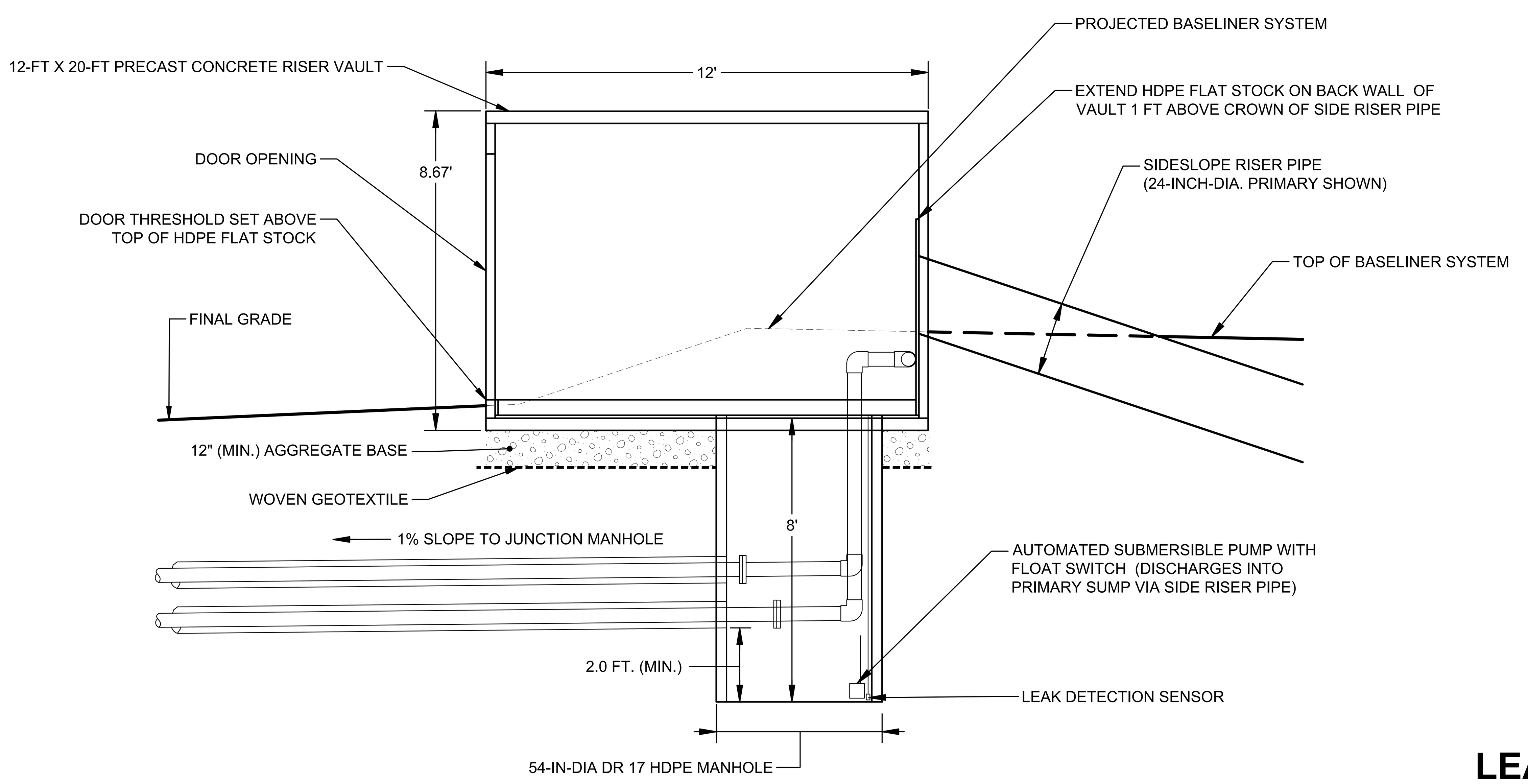


LEACHATE FORCE MAIN (1)

NOT TO SCALE



SECTION A-A'

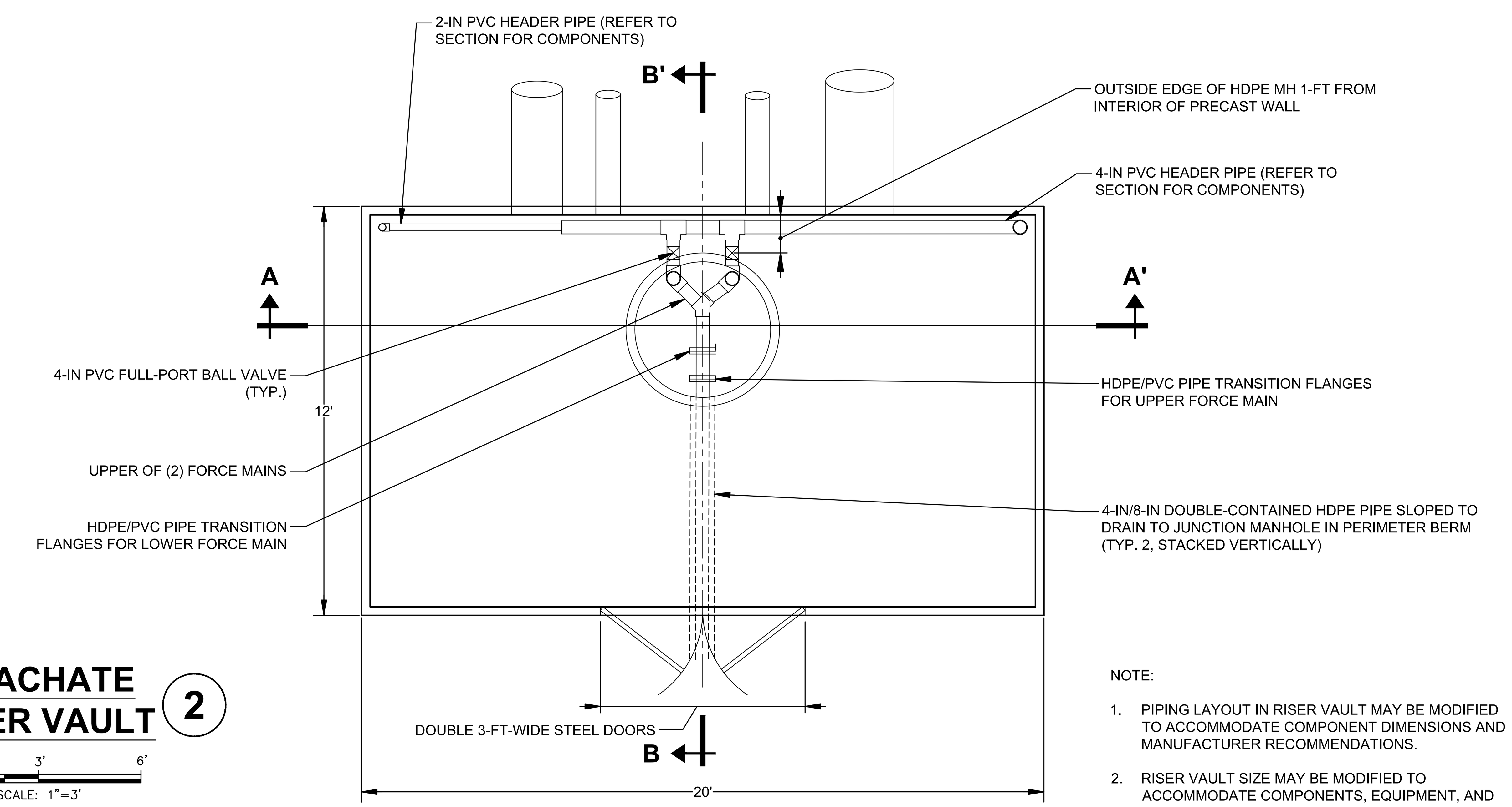


SECTION B-B'

LEACHATE RISER VAULT (2)

0 3' 6'

SCALE: 1"=3'



PLAN

NOTE:

1. PIPING LAYOUT IN RISER VAULT MAY BE MODIFIED TO ACCOMMODATE COMPONENT DIMENSIONS AND MANUFACTURER RECOMMENDATIONS.
2. RISER VAULT SIZE MAY BE MODIFIED TO ACCOMMODATE COMPONENTS, EQUIPMENT, AND ACCESS REQUIREMENTS.

SCALE(S) AS INDICATED

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

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GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS

UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LEACHATE CONVEYANCE AND STORAGE SYSTEM DETAILS - 1

ARCADIS Project No. 30197838

Date FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
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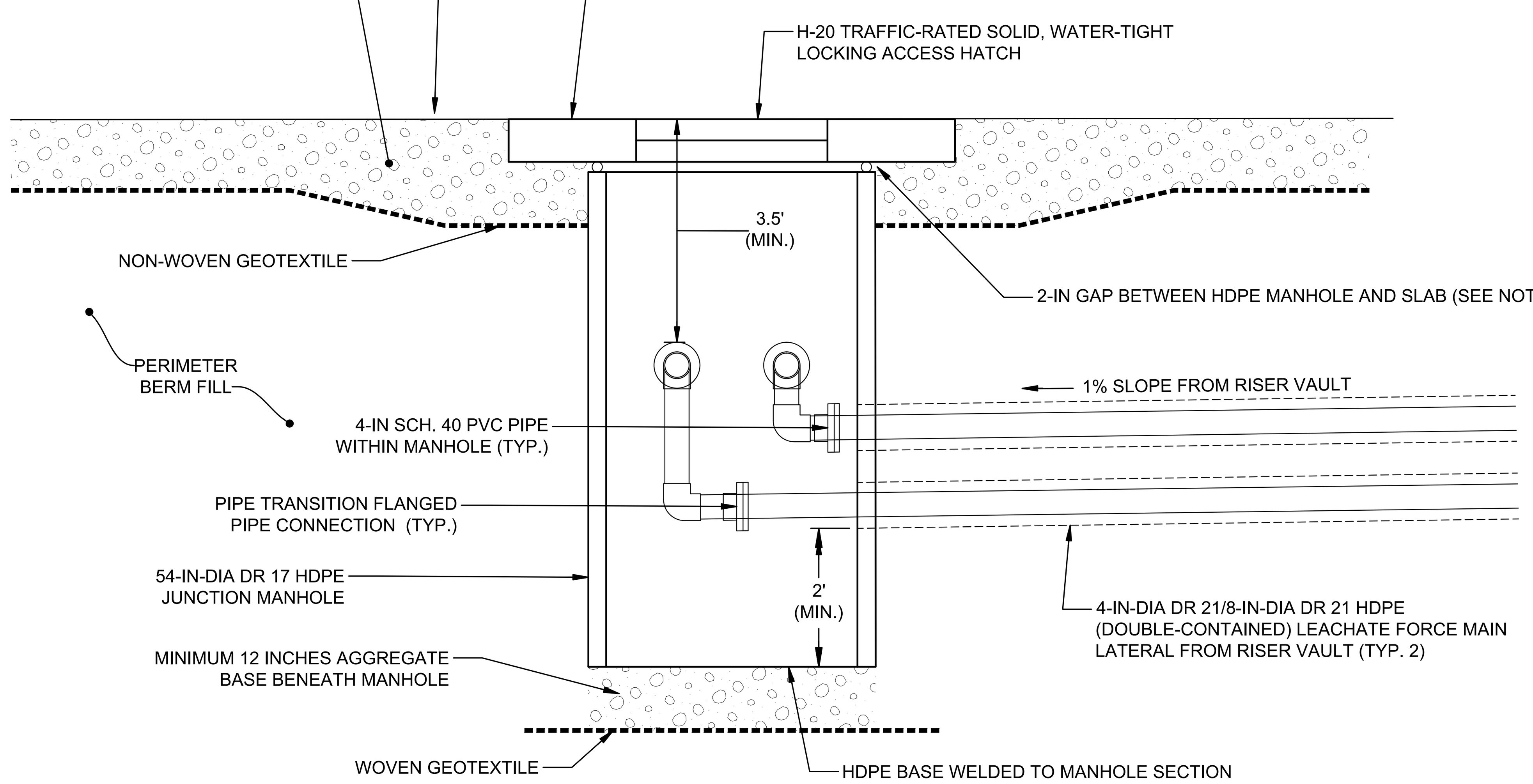
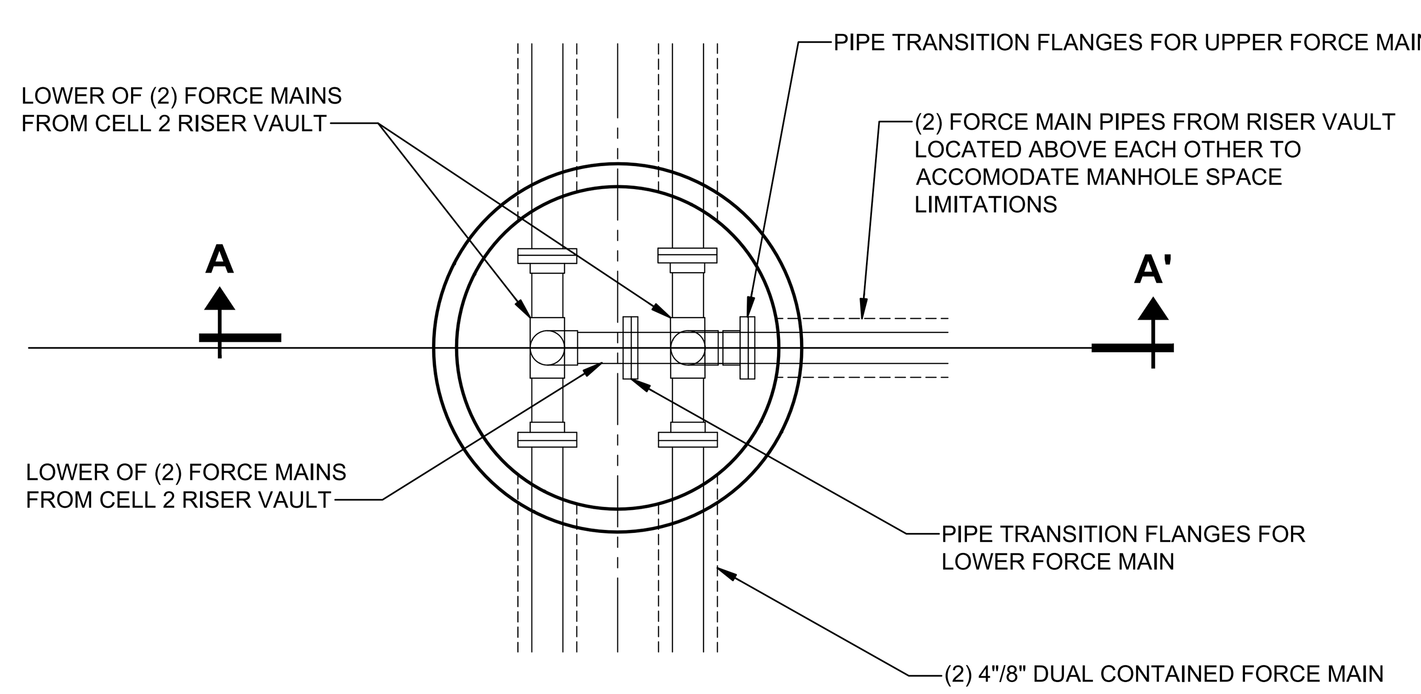
TEL. 315.446.9120

20



SECTION



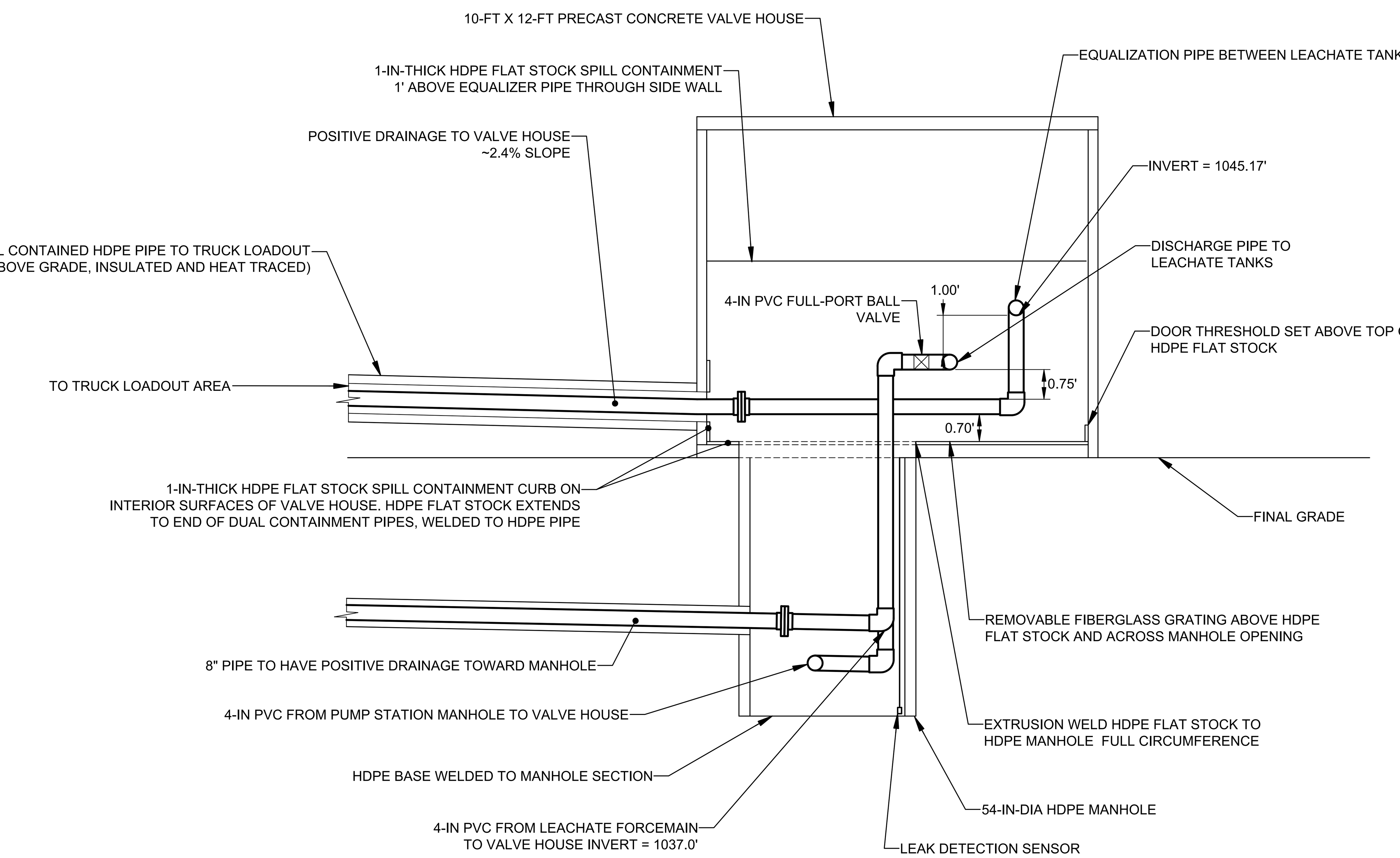
PLAN

NOTE:

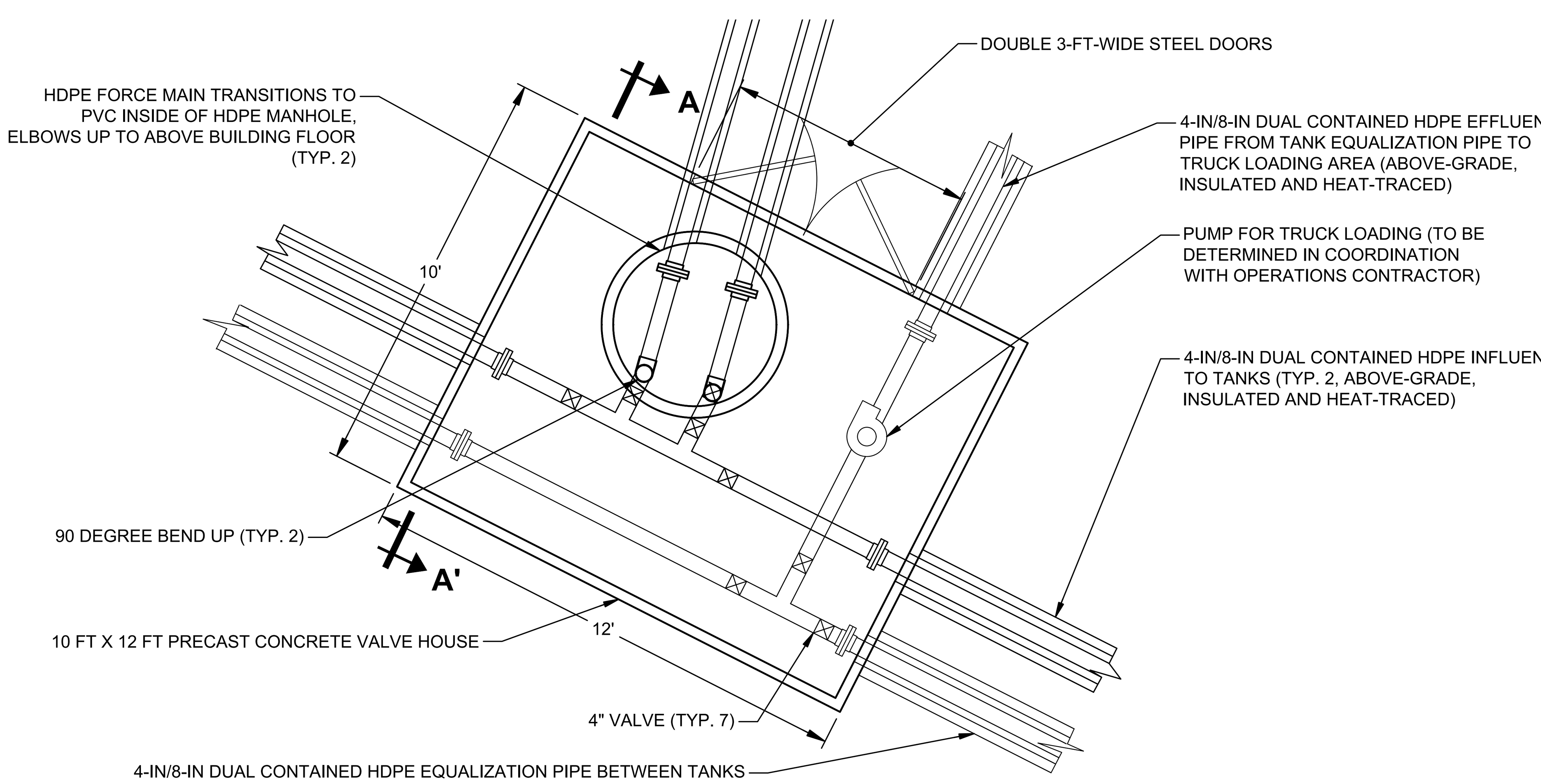
1. GAP BETWEEN TOP OF HDPE MANHOLE AND BOTTOM OF PRECAST CONCRETE SLAB PROVIDES ISOLATION OF VEHICLE LOADS FROM TRANSFERRING TO MANHOLE. POLY FOAM BACKER ROD OR SIMILAR INERT COMPRESSIBLE MATERIAL TO BE PLACED ON TOP OF MANHOLE WALL TO FILL GAP AND PREVENT AGGREGATE BASE FROM FALLING INTO MANHOLE INTERIOR.

LEACHATE JUNCTION MANHOLE (1)

0 2' 4'
SCALE: 1"=2'



SECTION



PLAN

VALVE HOUSE (2)

0 3' 6'
SCALE: 1"=3'

SCALE(S) AS INDICATED

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed:	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

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GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LEACHATE CONVEYANCE AND STORAGE SYSTEM DETAILS - 2

ARCADIS Project No. 30197838

Date FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
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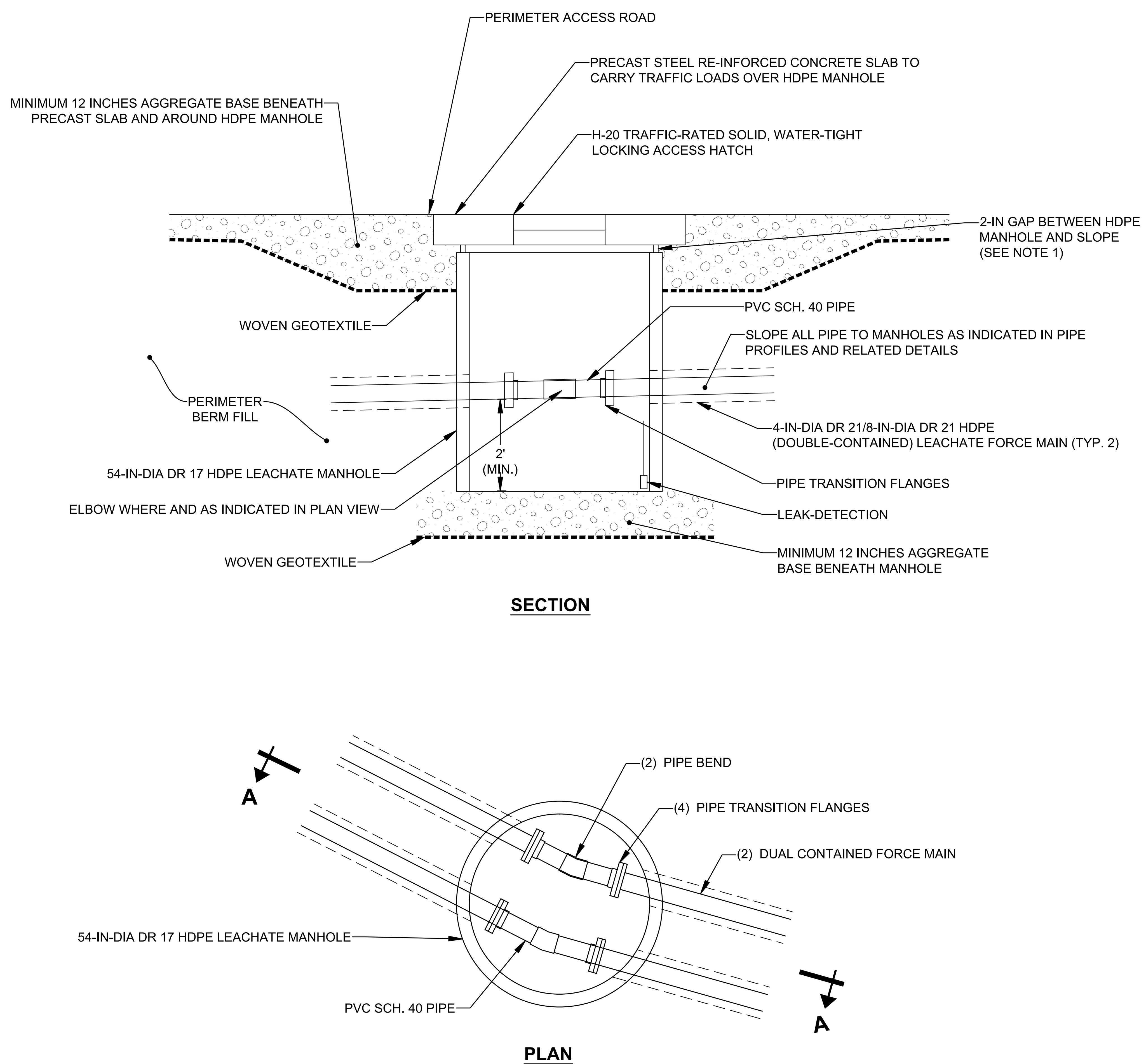
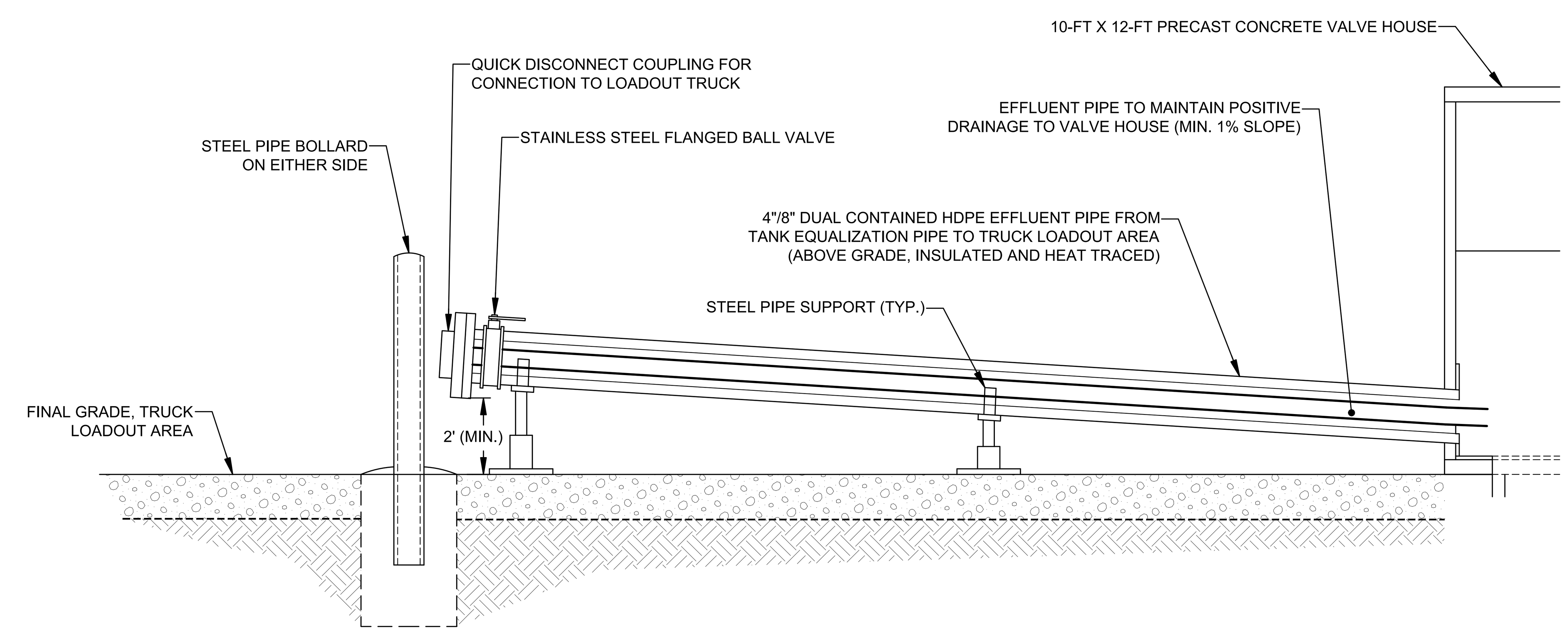


NOTE:

1. GAP BETWEEN TOP OF HDPE MANHOLE AND BOTTOM OF PRECAST CONCRETE SLAB PROVIDES ISOLATION OF VEHICLE LOADS FROM TRANSFERRING TO MANHOLE. POLY FOAM BACKER ROD OR SIMILAR INERT COMPRESSIBLE MATERIAL TO BE PLACED ON TOP OF MANHOLE WALL TO FILL GAP AND PREVENT AGGREGATE BASE FROM FALLING INTO MANHOLE INTERIOR.

LEACHATE CONVEYANCE MANHOLE (1)

0 2' 4'
SCALE: 1"=2'



TRUCK LOADOUT PIPE (2)

NOT TO SCALE

SCALE(S) AS INDICATED	Professional Engineer's Name: MARK O. GRAVELDING	Professional Engineer's No.: 42983	State: MA	Date Signed:
THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE	Project Mgr.: DK	Designed by: BMS	Drawn by: KLS	Checked by: PHB

No.	Date	Revisions	By	Ckd

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UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LEACHATE CONVEYANCE AND STORAGE SYSTEM DETAILS - 3

ARCADIS Project No. 30197838
Date FEBRUARY 2024

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SYRACUSE, NEW YORK 13202
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C:\Users\CSHill\DC\ACCDocs\Arcadis ACC US\AUS-99999999-GE_HOUSATONIC_PITTSFIELD_MA\Project Files\10_WIP\10T_ARC_ENV\202401-DWG\INT-UDF-DWG_22-LEACHATE TRANSFER DETAILS-3.dwg LAYOUT: 22 SAVED: 2/27/2024 9:24 PM ACADVER: 24.2S (LMS TECH) PAGESETUP: ----
PLOTSTYLETABLE: ---- PLOTTED: 2/27/2024 10:37 PM BY: HILL, CHRISTIAN
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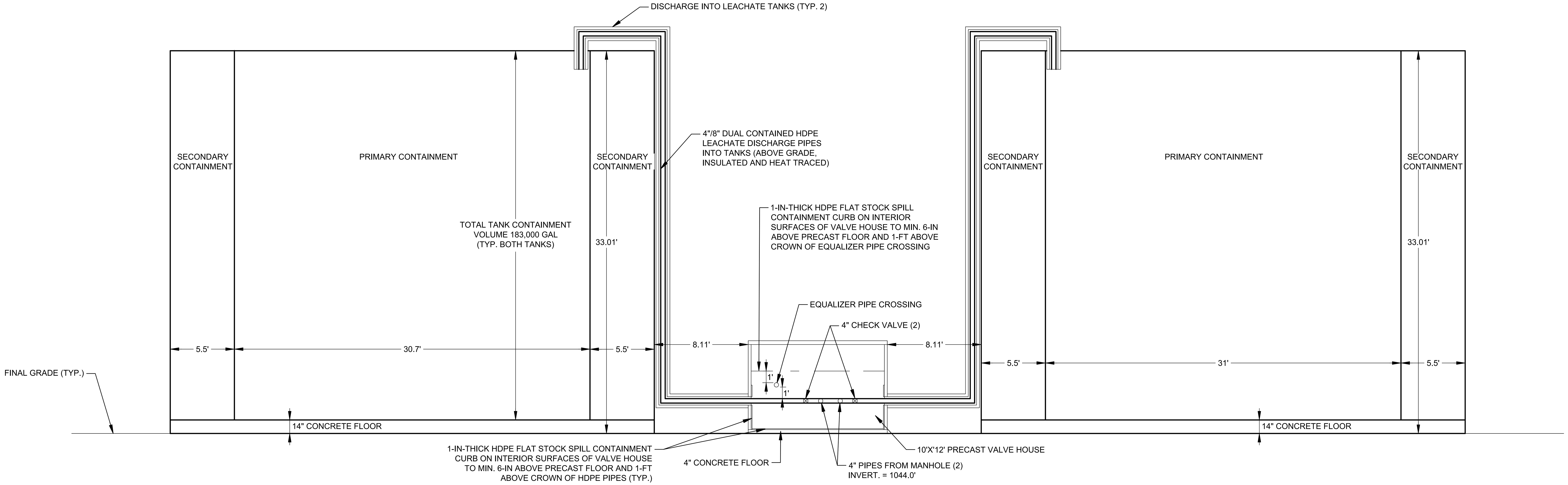
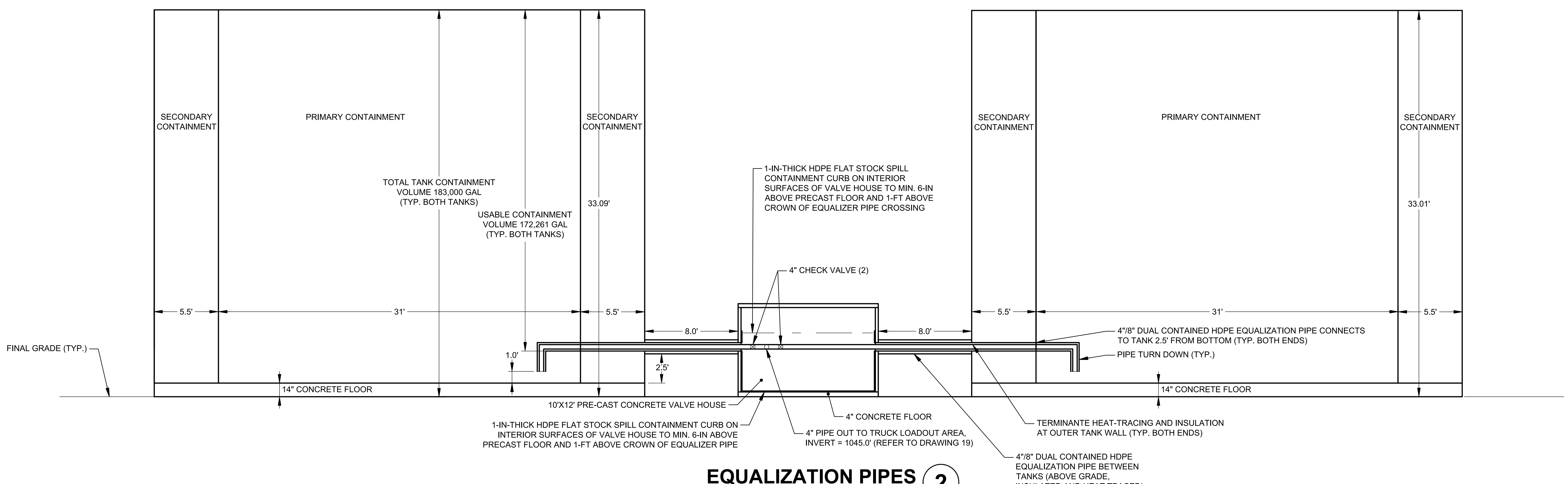


LEACHATE DISCHARGE PIPES (1)

SCALE: 1"=5'



EQUALIZATION PIPES (2)

SCALE: 1"=5'

C:\Users\CSHill\DC\ACCDocs\Arcadis ACC US\AUS-99999999-GE_HOUSATONIC_PITTSFIELD_MA\Project Files\10_WIP\10T_ARC_ENV\2024\01-DWG\INT-UDF-DWG_23-LEACHATE TRANSFER DETAILS-4.dwg LAYOUT: 23 SAVED: 2/27/2024 9:25 PM ACADVER: 24.2S (LMS TECH) PAGESETUP: ----
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XREFS: X-INT DRAFT-UDF-BDR-C-LD IMAGES: Arcadis Logo BW.PNG

1"=5' | 5' 0 5' 10'

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name: **MARK O. GRAVELDING**
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	**Drawn by**	**Checked by**
BMS	KLS	PHB

ARCADIS

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UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LEACHATE CONVEYANCE AND STORAGE SYSTEM DETAILS - 4

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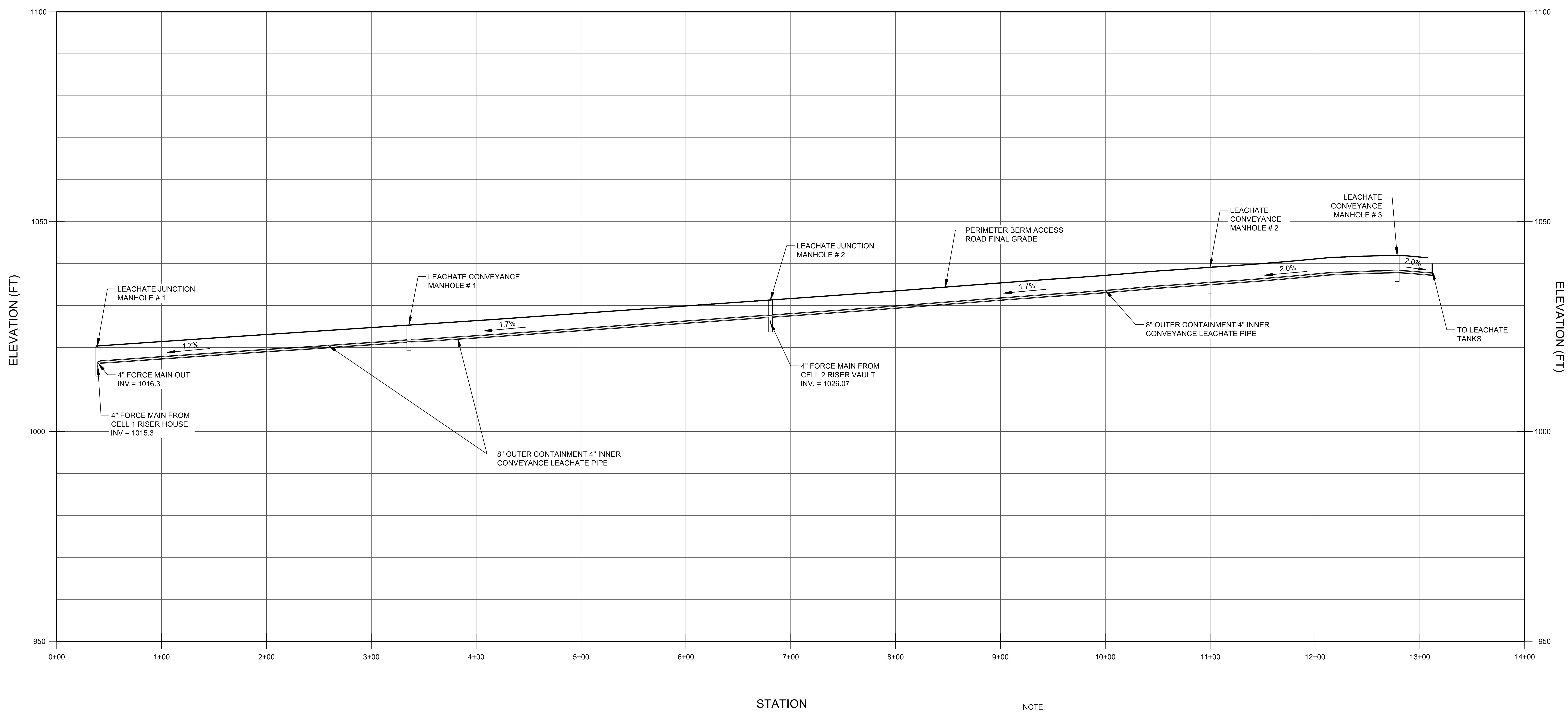
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120



LEACHATE FORCE MAIN PROFILE

0 50' 100'

HORIZONTAL SCALE: 1"=50'

VERTICAL SCALE: 5X EXAGGERATION

NOTE:

1. REFER TO DRAWING 18 FOR LEACHATE TRANSFER SYSTEM PLAN INFORMATION.

SCALE(S) AS INDICATED

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed:	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

ARCADIS

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS

UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

LEACHATE FORCE MAIN PROFILE

ARCADIS Project No. 30197838

Date FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
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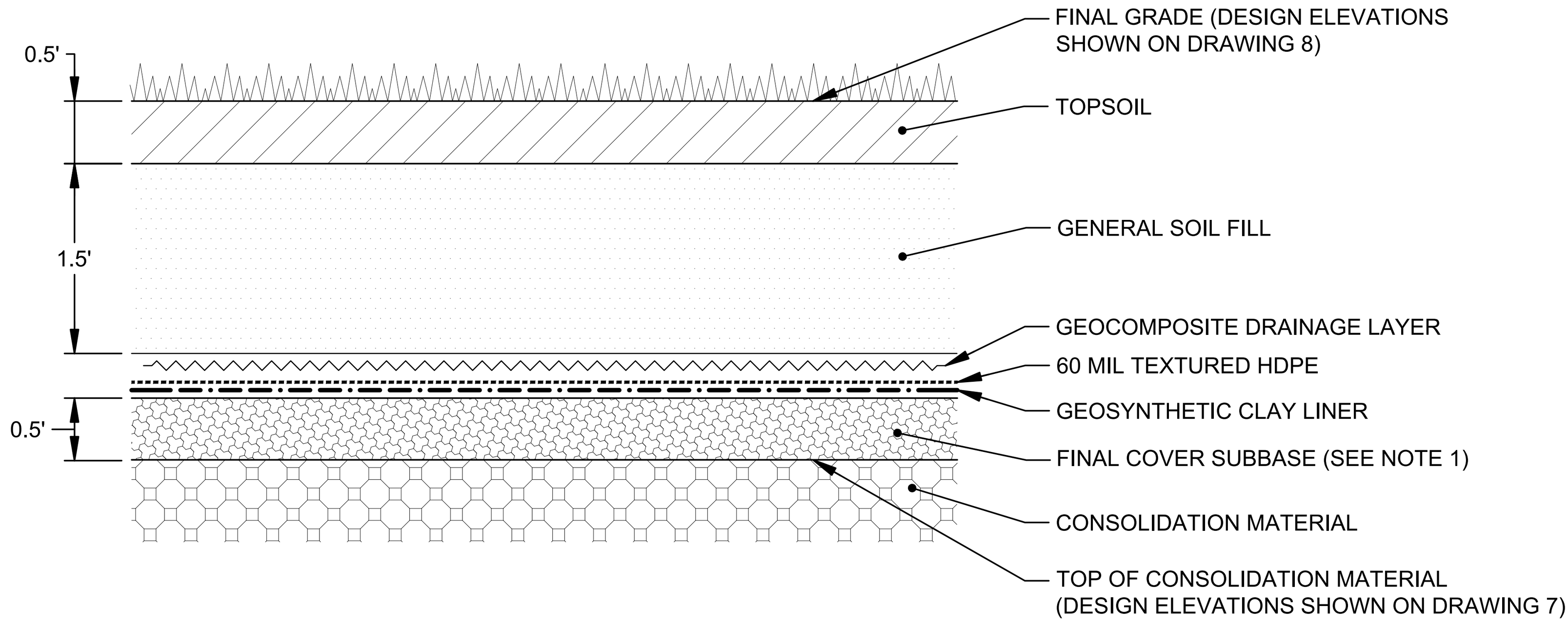
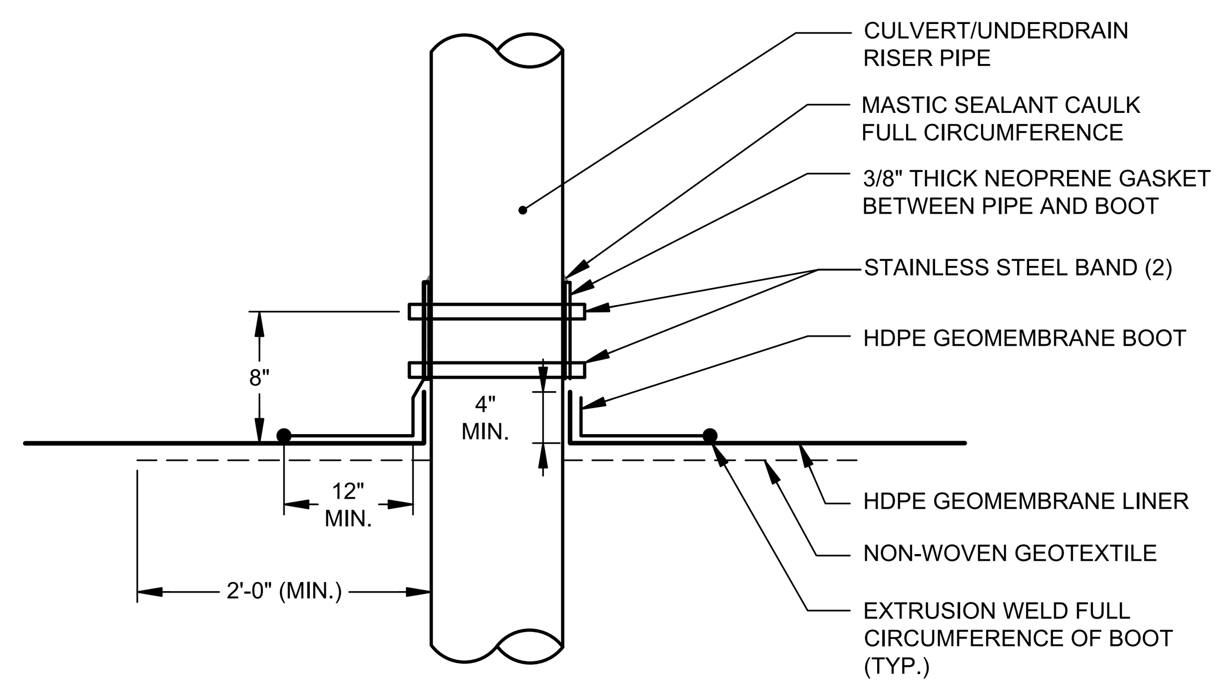


NOTES:

1. FINAL COVER SUBBASE TO BE COMPRISED OF MODERATELY PERMEABLE SANDY MATERIAL.

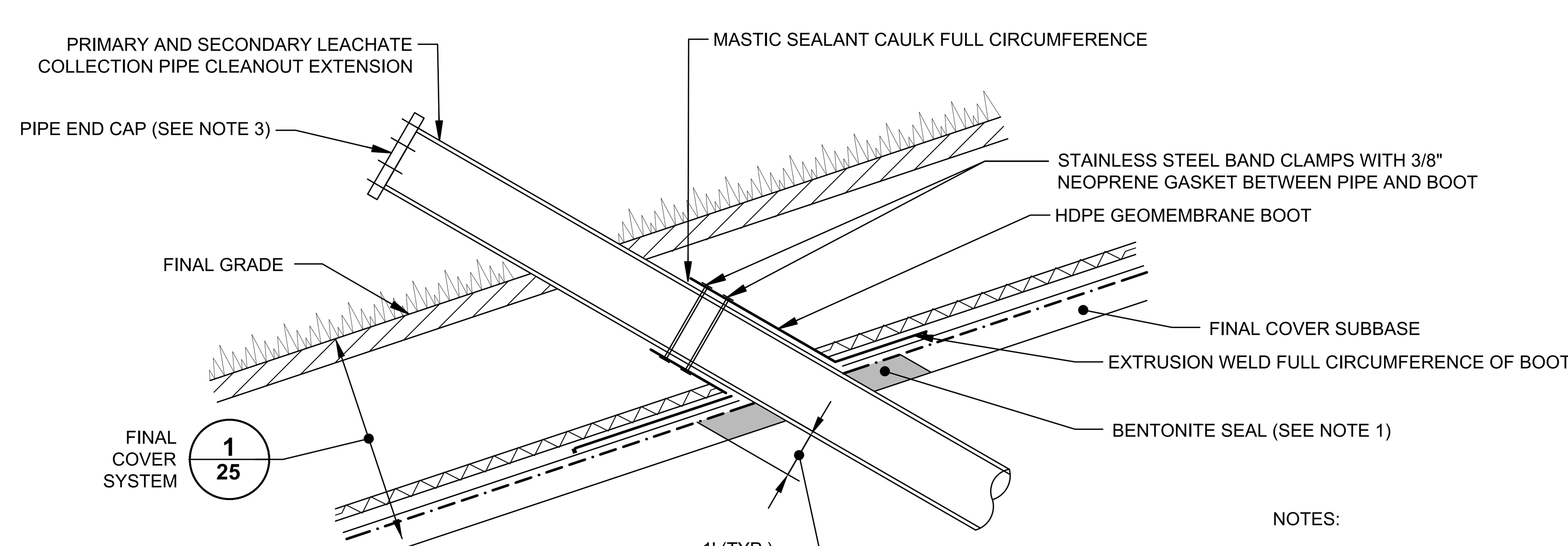
FINAL COVER SYSTEM (1)

NOT TO SCALE



GEOSYNTHETICS PENETRATION SEAL (3)

NOT TO SCALE

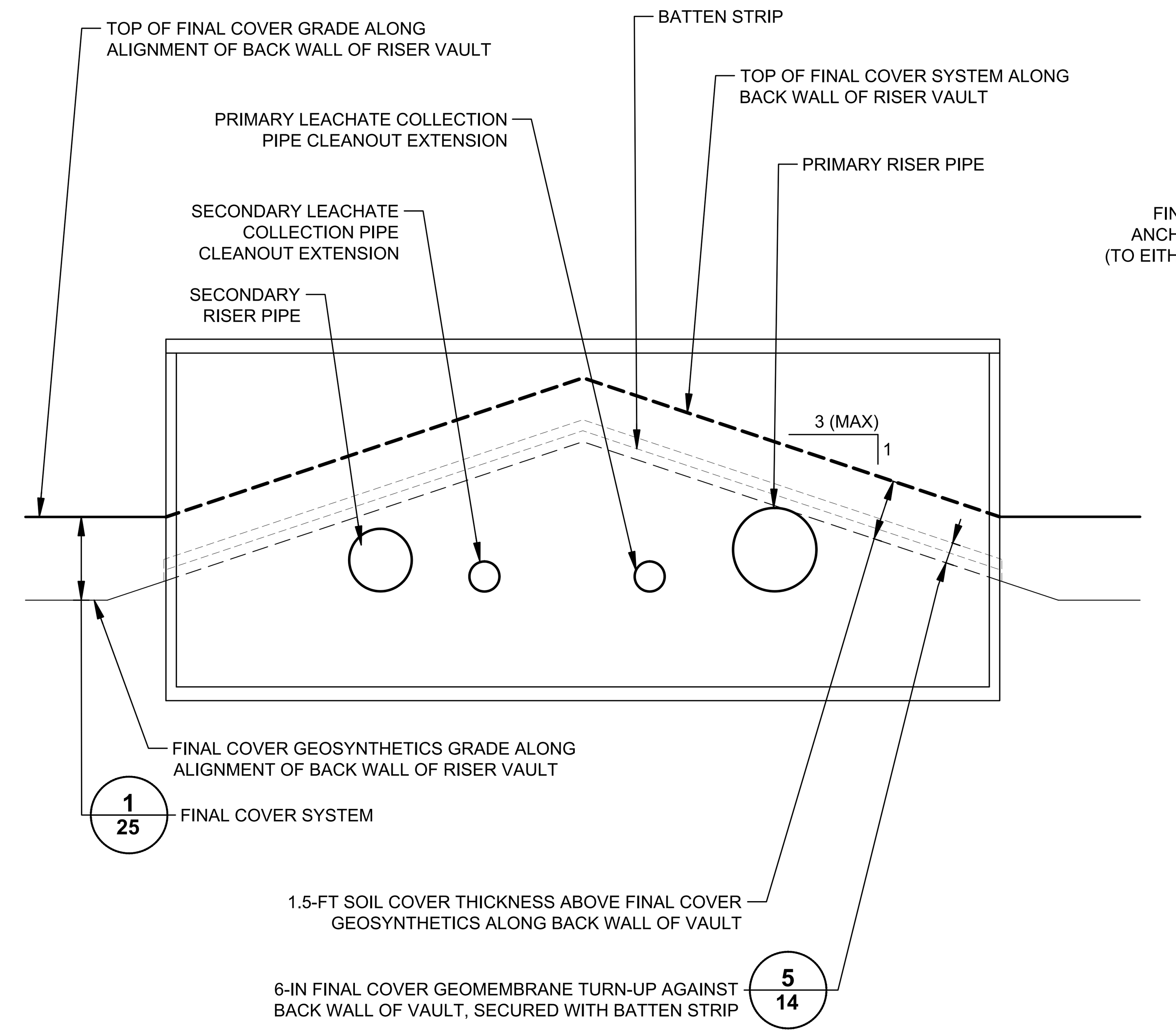


NOTES:

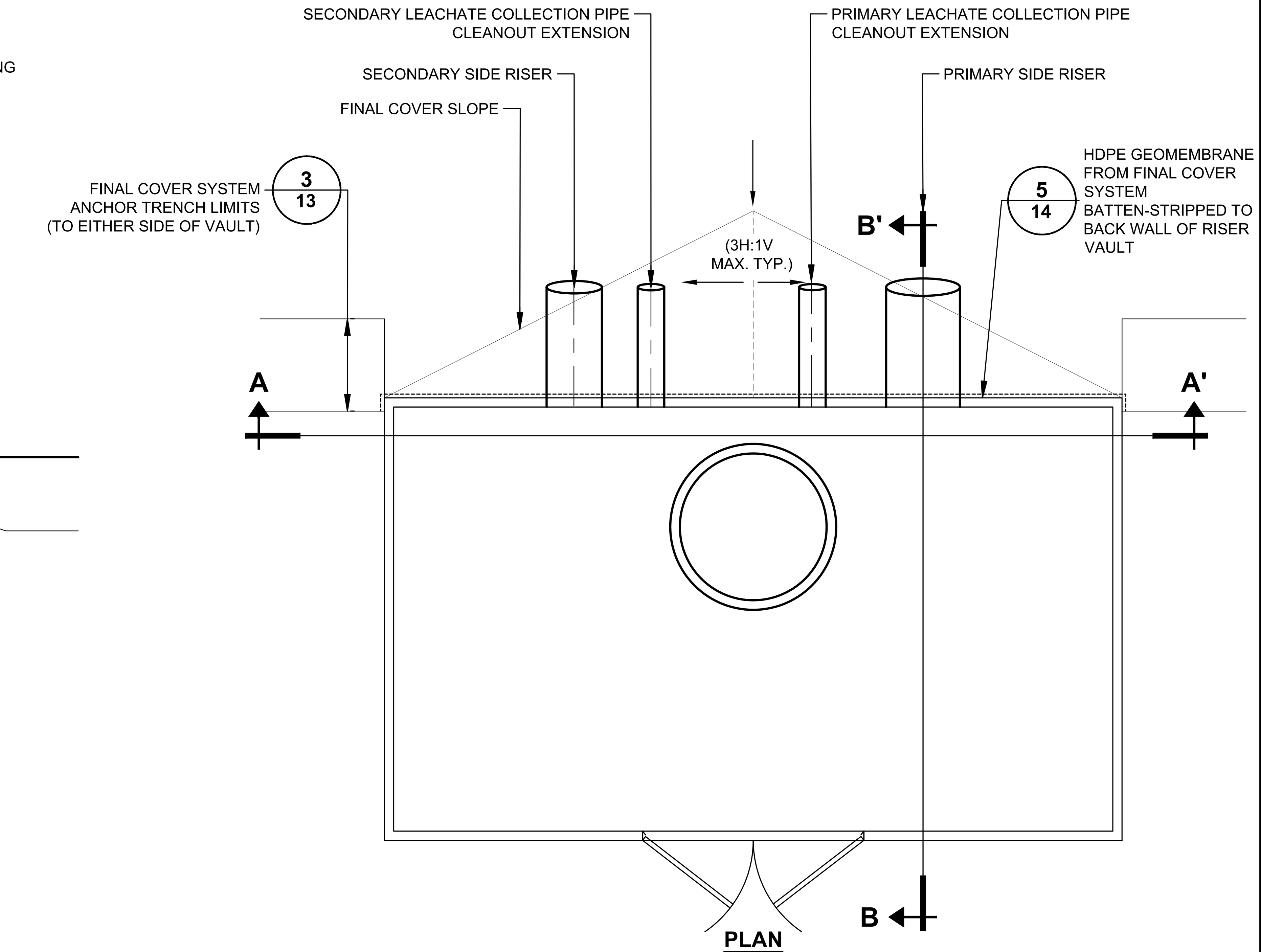
1. SEAL ANNULAR SPACE AROUND CLEANOUT EXTENSION WITH BENTONITE PRIOR TO FINAL COVER PLACEMENT.
2. DETAIL APPLIES TO UPGRADIENT ENDS OF PRIMARY AND SECONDARY LEACHATE COLLECTION PIPES.
3. PIPE END CAP SHALL BE AN HDPE FLANGE WITH NEOPRENE GASKET, HDPE COVER PLATE, AND STAINLESS STEEL BACKUP RING. SECURE COVER PLATE AND BACKUP RING TO FLANGE WITH STAINLESS STEEL NUTS, BOLTS, AND WASHERS.

LEACHATE COLLECTION PIPE CLEANOUT EXTENSION PENETRATION (4)

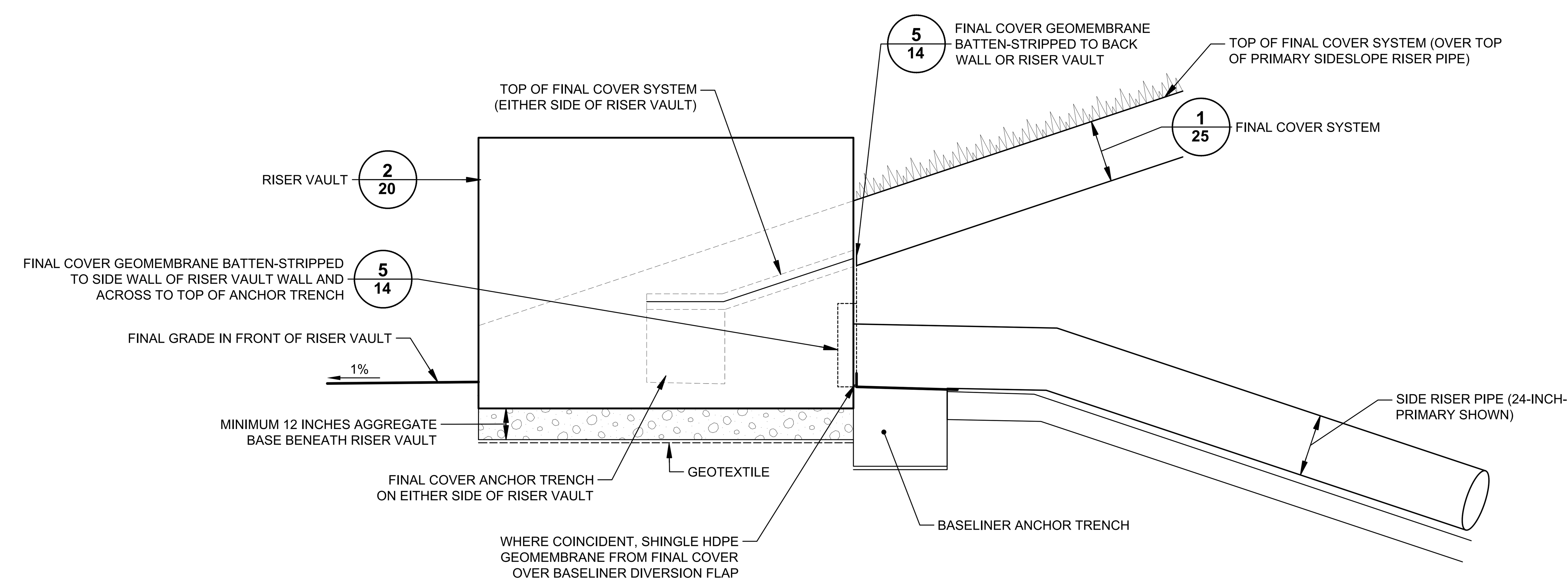
NOT TO SCALE



SECTION A-A'



PLAN



SECTION B-B'

NOTE:

1. INTERIOR DETAILS OF RISER VAULT OMITTED FOR CLARITY.

FINAL COVER TERMINATION AT RISER VAULT (2)

0 3' 6'
SCALE: 1"=3'

No.	Date	Revisions	By	Ckd

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SCALE(S) AS INDICATED

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

ARCADIS

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

FINAL COVER SYSTEM DETAILS

ARCADIS Project No. 30197838

Date FEBRUARY 2024

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ONE LINCOLN CENTER
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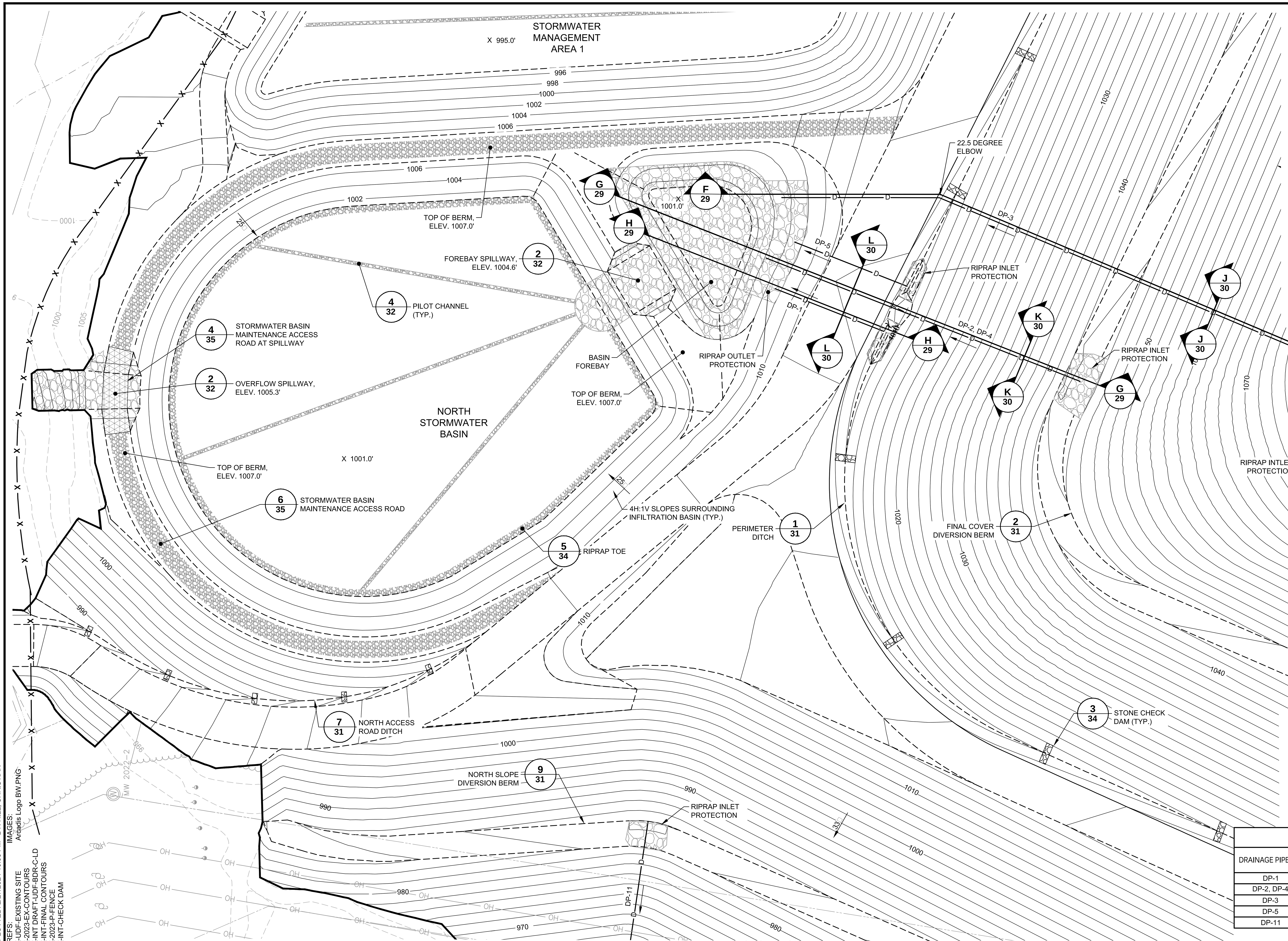

DESIGN FEATURES LEGEND

- ELEVATION GRADE BREAK
- 1010 — INDEX ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- APPROXIMATE LIMITS OF GRADING
- X 1101.7' DESIGN SPOT ELEVATIONS
- UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON SHEET 3A)
- DP-1 D DRAINAGE PIPE, FLOW DIRECTION, AND ID (SEE INVENTORY TABLE THIS DRAWING)
- STONE CHECK DAM
- DETAIL/SECTION REFERENCE NUMBER / DRAWING REFERENCE NUMBER
- RIPRAP
- CRUSHED STONE

NOTES:

1. REFER TO DRAWINGS 2A AND 2B FOR BASEMAP INFORMATION.
2. PROPOSED GRADING REPRESENTS TOP OF FINAL COVER AND FINISHED GRADE.
3. FINAL TOP OF COVER MAY BE ADJUSTED TO ACCOMODATE CONSTRUCTED TOP OF CONSOLIDATION MATERIAL GRADES.
4. ALL DRAIN PIPES TO BE CORRUGATED EXTERIOR HDPE.

DRAIN PIPE INVENTORY TABLE

DRAINAGE PIPE I.D.	QUANTITY/SIZE (IN.)	INTERIOR, WALL	INVERT ELEVATION (FT.)	
			IN	OUT
DP-1	2-24"	SMOOTH, DUAL-WALL	1008.5	1006.4
DP-2, DP-4	4-18"	CORRUGATED, SINGLE-WALL	1042.2	1004.1
DP-3	2-15"	CORRUGATED, SINGLE-WALL	1071.6	1004.1
DP-5	2-24"	SMOOTH, DUAL-WALL	1008.5	1006.4
DP-11	2-18"	CORRUGATED, SINGLE-WALL	982.0	954.0

XREFS:
X-UDF-EXISTING SITE
X-2023-EX-CONTOURS
X-INT DRAFT-UDF-BDR-C-LD
X-INT-FINAL CONTOURS
X-2023-P-FENCE
X-INT-CHECK DAM

IMAGES:
Arcadis Logo BW.PNG

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PLOTSTYLETABLE: ---- PLOTTED: 2/27/2024 10:38 PM BY: HILL, CHRISTIAN

30' 0 30' 60'
1"=30'

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983
State: MA | Date Signed: | Project Mgr.: DK
Designed by: BMS | Drawn by: KLS | Checked by: PHB

INTERNAL **DRAFT**

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UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

NORTH STORMWATER BASIN PLAN

ARCADIS Project No. 30197838
Date: FEBRUARY 2024
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ONE LINCOLN CENTER
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TEL. 315.446.9120

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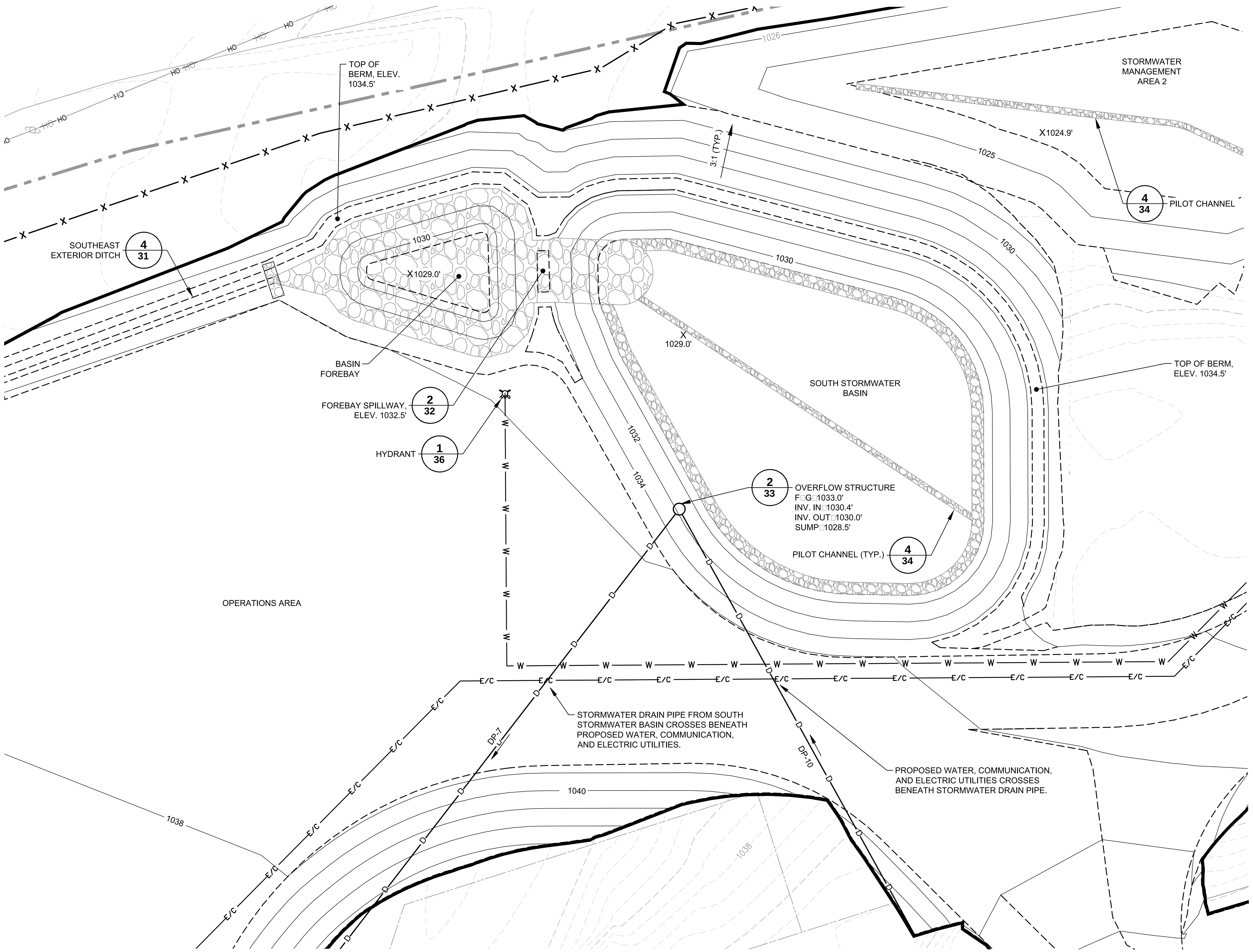

DESIGN FEATURES LEGEND

- ELEVATION GRADE BREAK
- INDEX ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- APPROXIMATE LIMITS OF GRADING
- x 1101.7' DESIGN SPOT ELEVATIONS
- UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON SHEET 3A)
- DP-7 DRAINAGE PIPE, FLOW DIRECTION, AND ID (SEE INVENTORY TABLE THIS DRAWING)
- WATER SERVICE LINE
- UNDERGROUND ELECTRIC AND COMMUNICATIONS CONDUIT
- DETAIL/SECTION REFERENCE NUMBER
- DRAWING REFERENCE NUMBER
- RIPRAP
- CRUSHED STONE

NOTES:

1. REFER TO DRAWINGS 2A AND 2B FOR BASEMAP INFORMATION.
2. PROPOSED GRADING REPRESENTS TOP OF FINISHED GRADE.
3. REFER TO DRAWING 8 FOR ADDITIONAL FINAL GRADE INFORMATION.
4. ALL DRAIN PIPES TO BE CORRUGATED EXTERIOR HDPE.

DRAIN PIPE INVENTORY TABLE

DRAINAGE PIPE I.D.	QUANTITY/SIZE (IN.)	INTERIOR, WALL	INVERT ELEVATION (FT.)	
			IN	OUT
DP-7	1-12"	SMOOTH, DUAL-WALL	1030.0	1024.2
DP-10	1-12"	SMOOTH, DUAL-WALL	1032.1	1030.4

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PLOTSTYLETABLE: ---- PLOTTED: 2/27/2024 10:38 PM BY: HILL, CHRISTIAN

XREFS: X-UDF-EXISTING SITE, X-2023-EX-CONTOURS, X-INT DRAFT-UDF-BDR-C-LD, X-INT-FINAL CONTOURS, X-2023-P-FENCE, X-INT-PRO-UTILITIES, X-INT-CHECK DAM
IMAGES: Arcadis Logo BW.PNG

20' 0 20' 40'
1"=20'

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983
State: MA | Date Signed: | Project Mgr.: DK
Designed by: BMS | Drawn by: KLS | Checked by: PHB

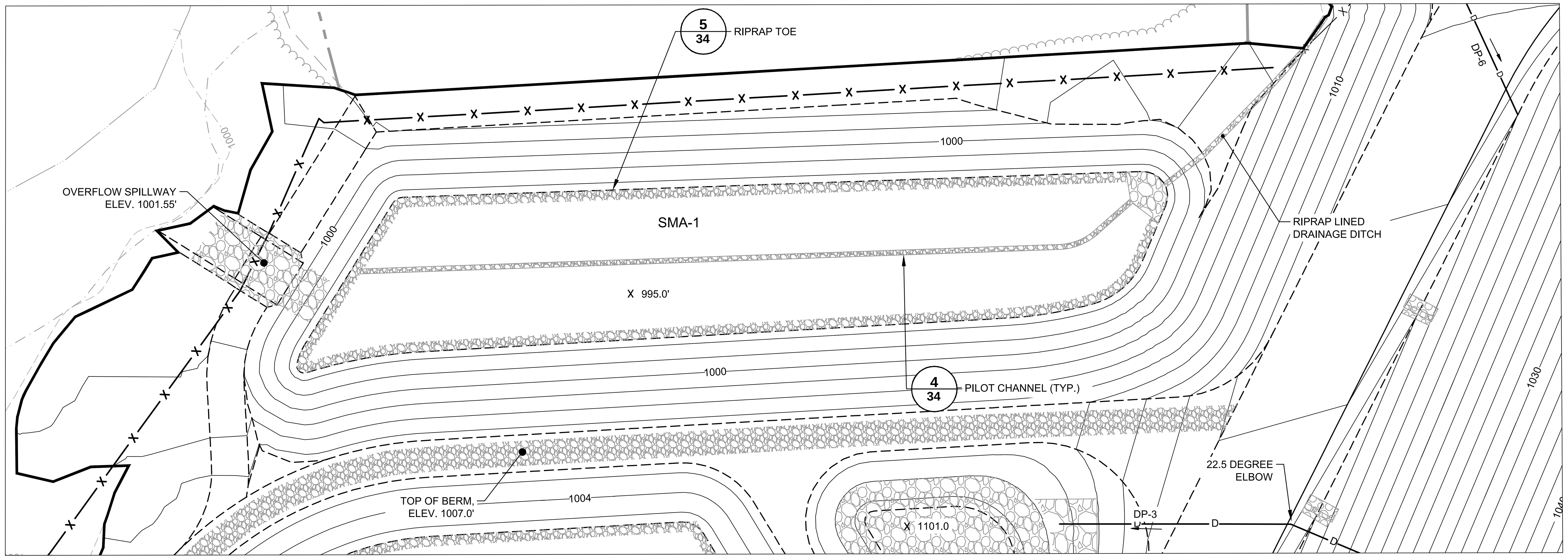
ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

SOUTH STORMWATER BASIN PLAN

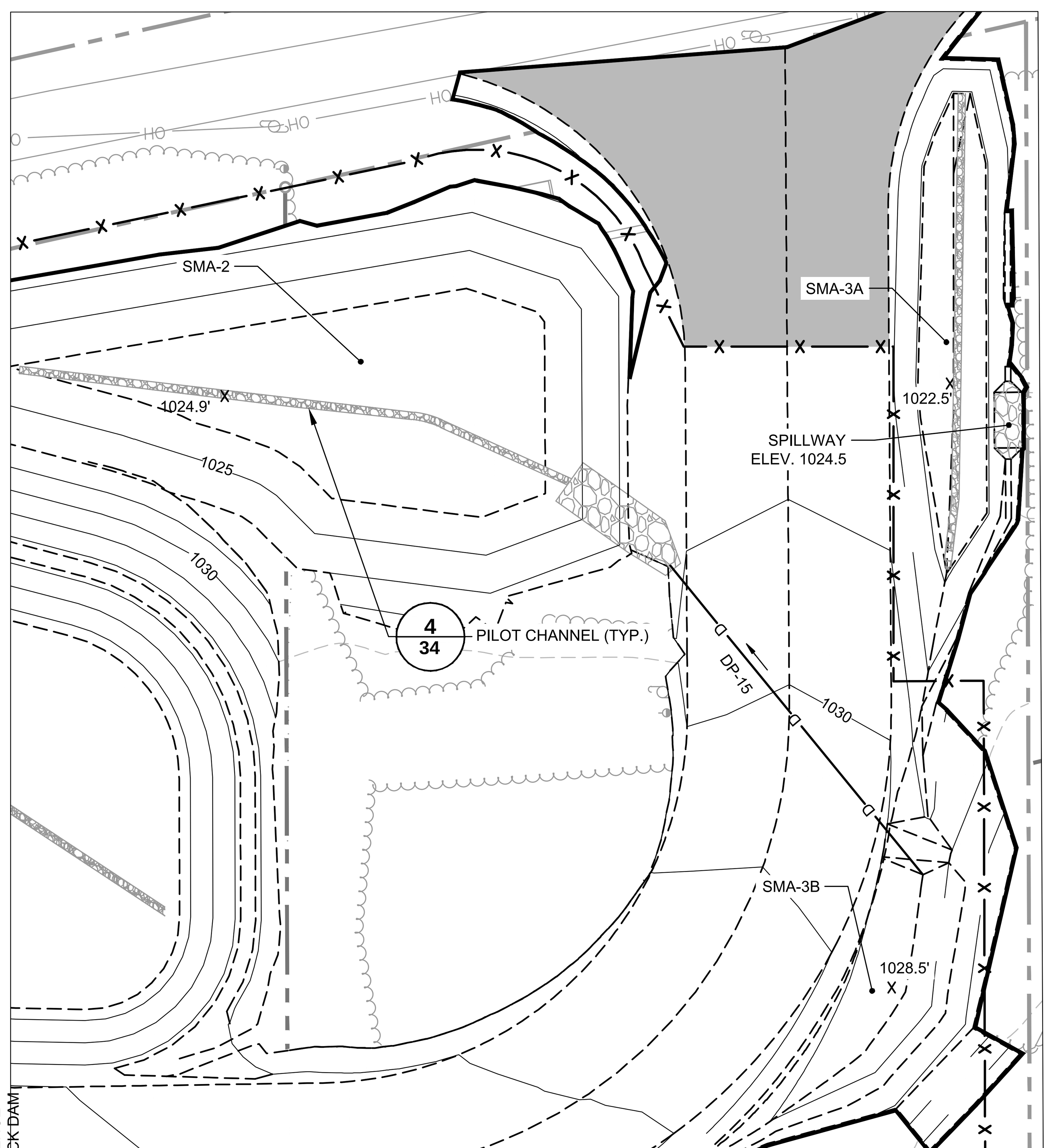
ARCADIS Project No. 30197838
Date FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120



SMA-1

SCALE: 1" = 30'

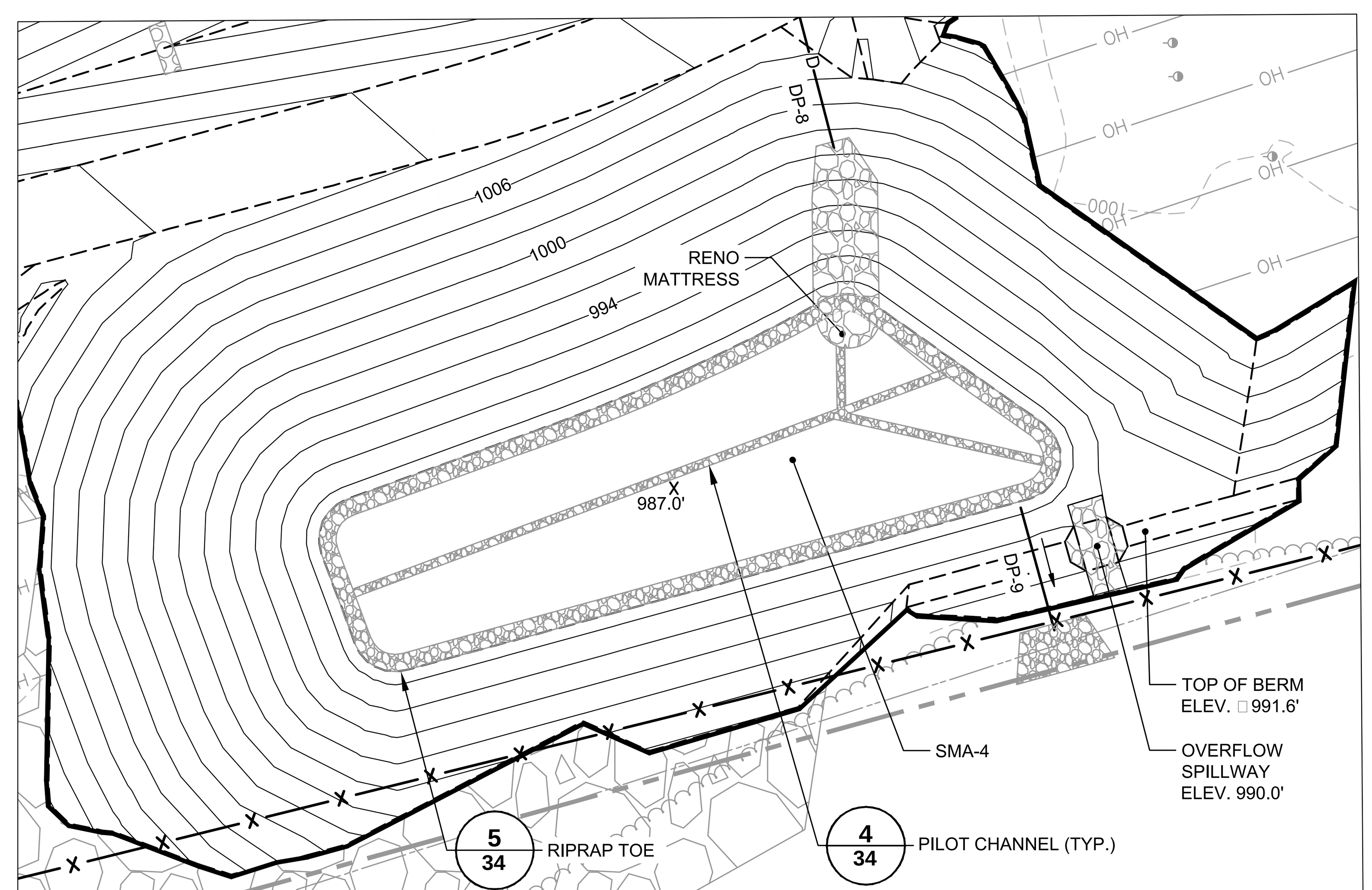


SMA-2

SCALE: 1" = 30'

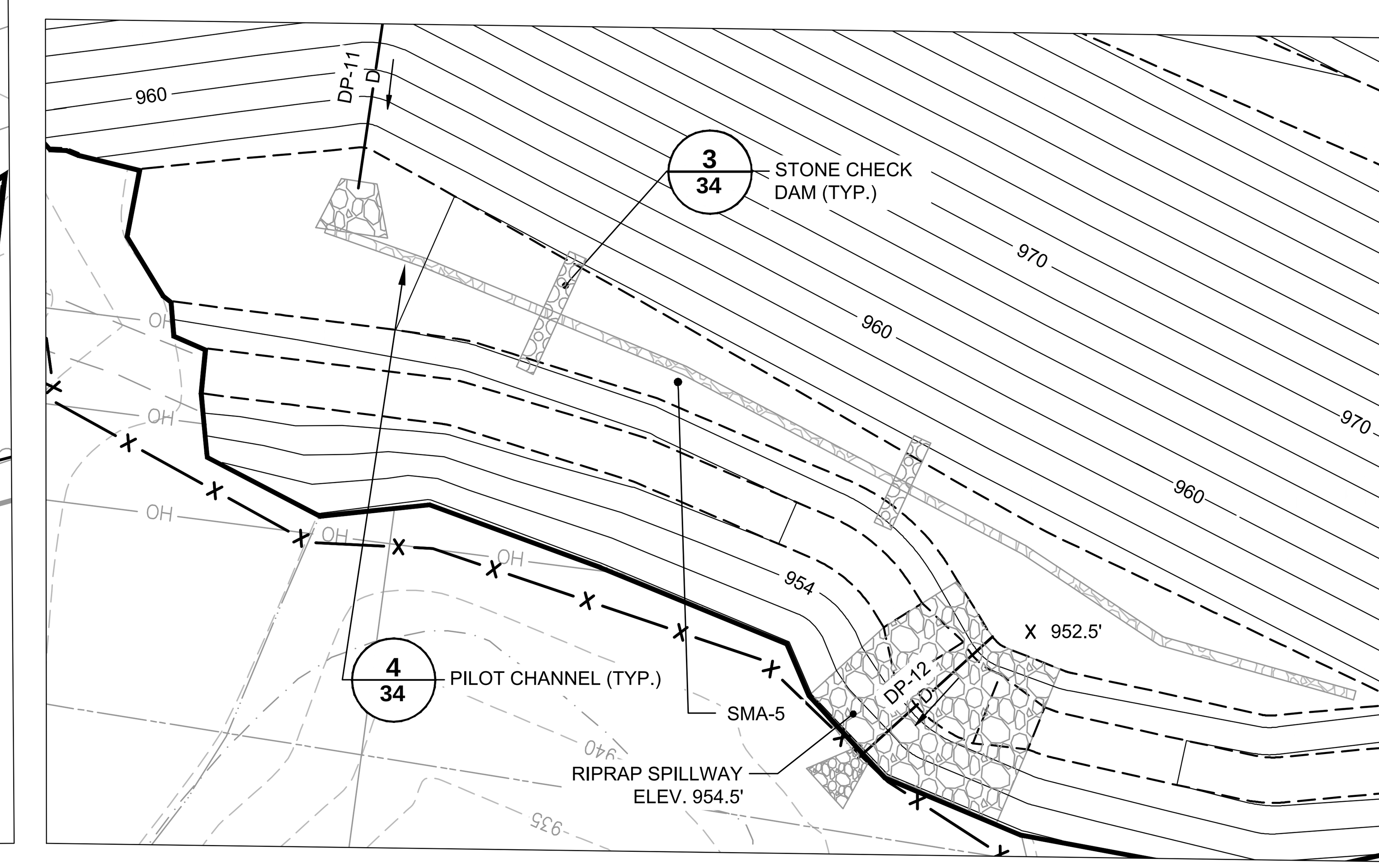
SMA-3A & 3B

SCALE: 1" = 30'



SMA-4

SCALE: 1" = 30'



SMA-5

SCALE: 1" = 30'

DESIGN FEATURES LEGEND

- ELEVATION GRADE BREAK
- INDEX ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- INTERMEDIATE ELEVATION CONTOURS (2-FOOT INTERVAL, SEE NOTE 2)
- APPROXIMATE LIMITS OF GRADING
- DESIGN SPOT ELEVATIONS (x 1101.7)
- UDF SECURITY FENCE AND GATE (MODIFIED AS SHOWN ON SHEET 3A)
- DRAINAGE PIPE, FLOW DIRECTION, AND ID (SEE INVENTORY TABLE THIS DRAWING) (DP-7)
- STONE CHECK DAM
- RIPRAP
- CRUSHED STONE
- DETAIL/SECTION REFERENCE NUMBER
- DRAWING REFERENCE NUMBER

NOTES:

1. REFER TO DRAWINGS 2A AND 2B FOR BASEMAP INFORMATION.
2. PROPOSED GRADING REPRESENTS TOP OF FINAL CONVER AND FINISHED GRADE.
3. FINAL TOP OF COVER MAY BE ADJUSTED TO ACCOMODATE CONSTRUCTED TOP OF CONSOLIDATION MATERIAL GRADES.
4. ALL DRAIN PIPES TO BE CORRUGATED EXTERIOR HDPE.

DRAIN PIPE INVENTORY TABLE

DRAINAGE PIPE I.D.	QUANTITY/SIZE (IN.)	INTERIOR, WALL	INVERT ELEVATION (FT.)	
			IN	OUT
DP-3	2-15"	CORRUGATED, SINGLE-WALL	1071.6	1004.1
DP-6	1-18"	SMOOTH, DUAL-WALL	1015.4'	1014.0'
DP-8	1-18"	CORRUGATED, SINGLE-WALL	999.4'	9970'
DP-9	4-4"	SMOOTH, DUAL-WALL	987.5'	987.1'
DP-11	2-18"	CORRUGATED, SINGLE-WALL	1028.7'	1026.6'
DP-12	2-18"	SMOOTH, DUAL-WALL	982.0	954.0
DP-15	2-8"	SMOOTH, DUAL-WALL	1028.7'	1026.6'

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PLOTSTYLETABLE: ---- PLOTTED: 2/27/2024 10:38 PM BY: HILL, CHRISTIAN

XREFS: X-UDF-EXISTING SITE X-2023-EX-CONTOURS X-INT DRAFT-UDF-BDR-C-LD X-INT-FINAL CONTOURS X-2023-P-FENCE X-INT-CHECK DAM
IMAGES: Arcadis Logo BW.PNG

1"=30' — 30' 0 30' 60'

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983
State: MA | Date Signed: | Project Mgr.: DK
Designed by: BMS | Drawn by: KLS | Checked by: PHB

ARCADIS

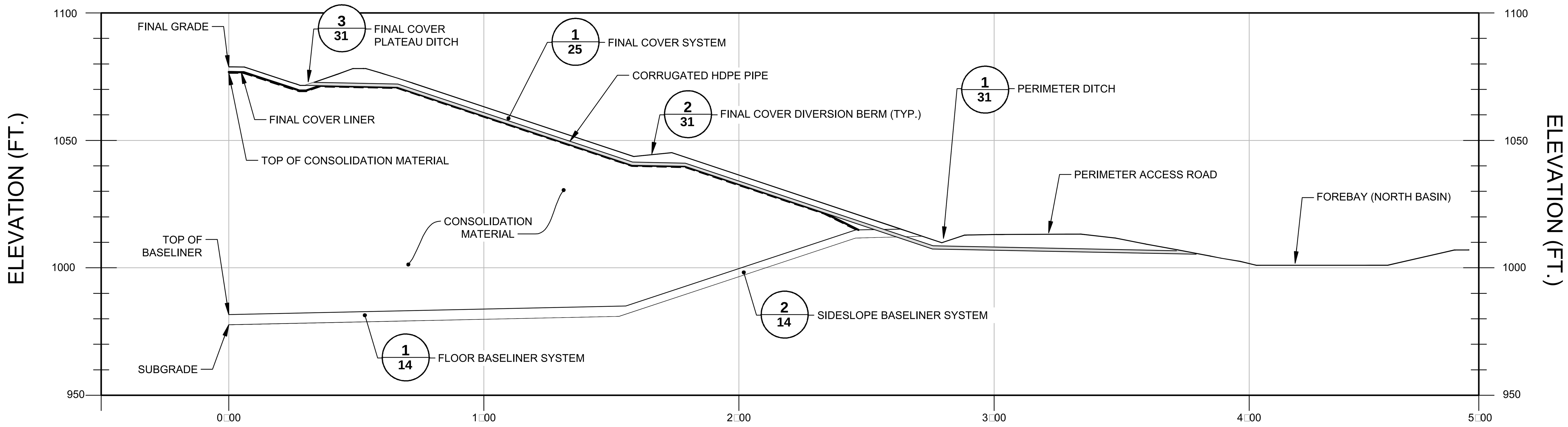
ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

STORMWATER MANAGEMENT AREA PLAN

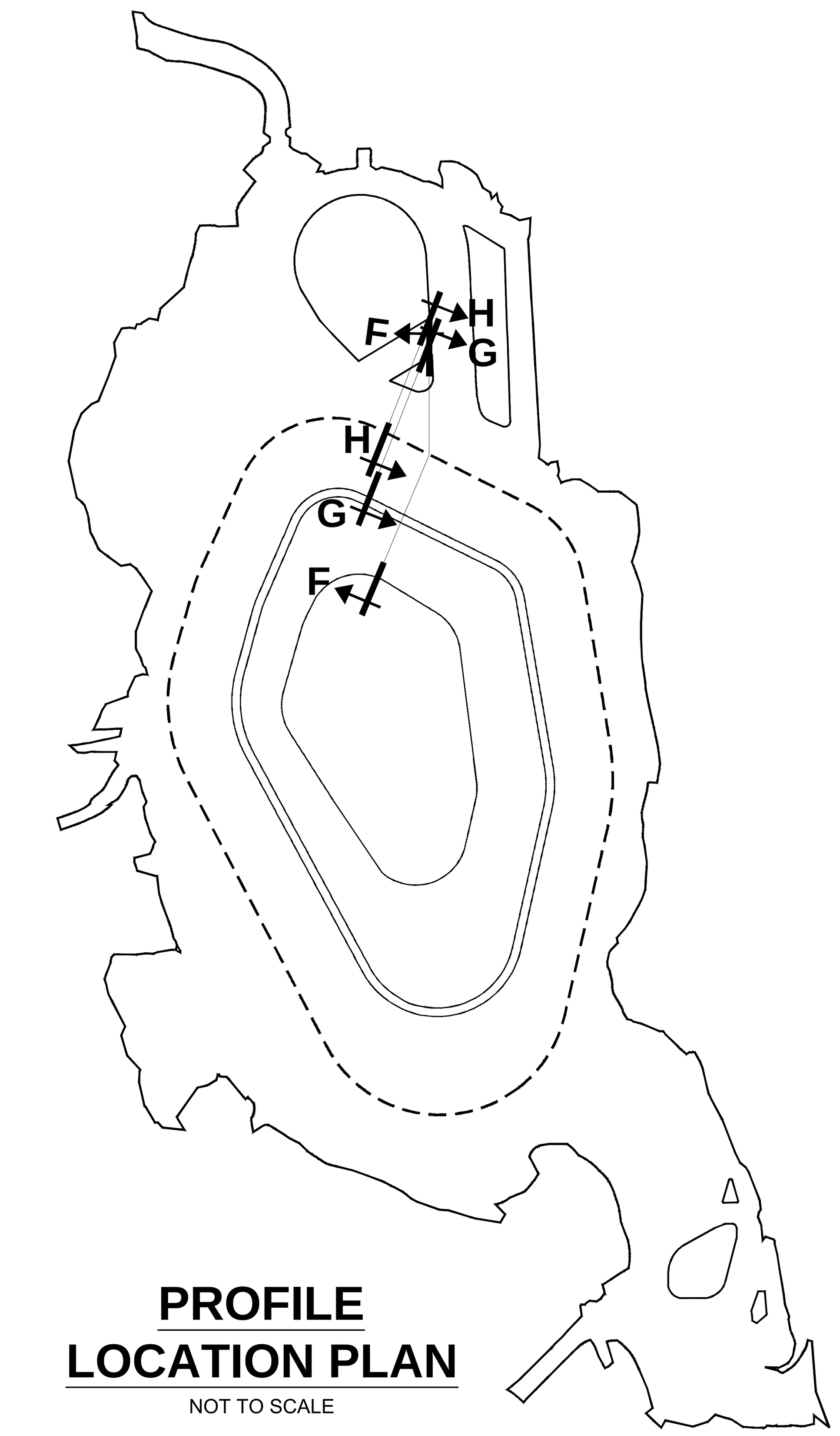
ARCADIS Project No. 30197838
Date: FEBRUARY 2024

ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120



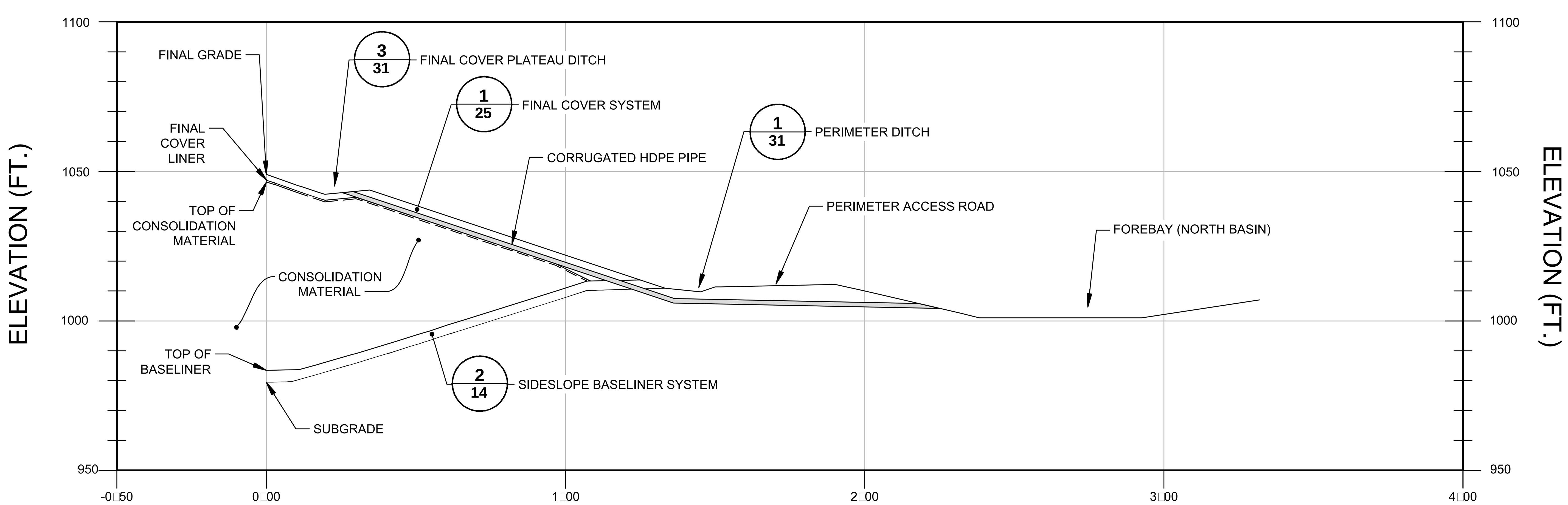
DRAIN PIPE PROFILE (F)

SCALE: 1" = 30'
(NO VERTICAL EXAGGERATION)



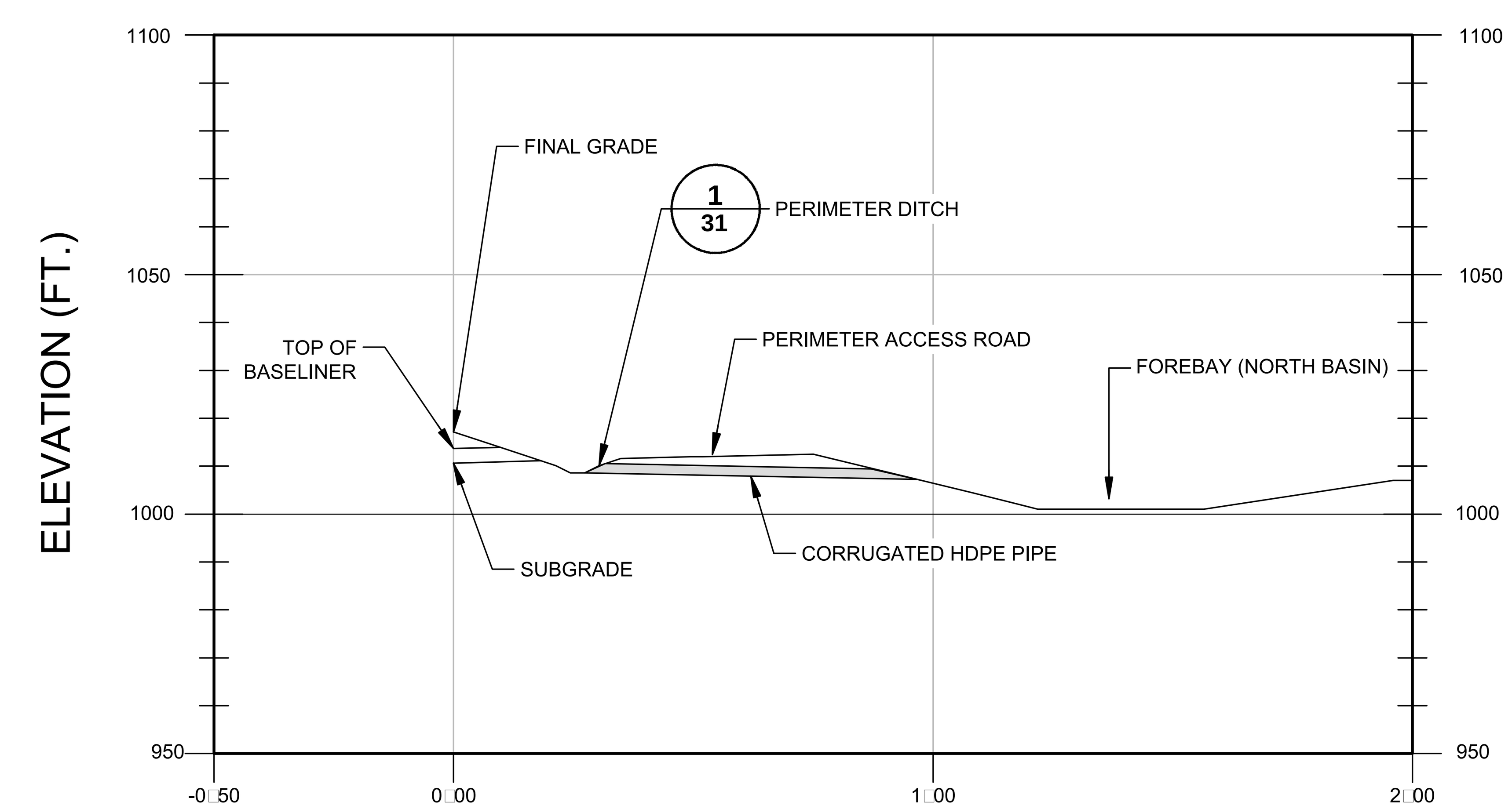
PROFILE LOCATION PLAN

NOT TO SCALE



DRAIN PIPE PROFILE (G)

SCALE: 1" = 30'
(NO VERTICAL EXAGGERATION)



DRAIN PIPE PROFILE (H)

SCALE: 1" = 30'
(NO VERTICAL EXAGGERATION)

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XREFS: X-INT DRAFT-UDF-BDR-C-LD IMAGES: Arcadis Logo BW.PNG

30' 0 30' 60'
1"=30'

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

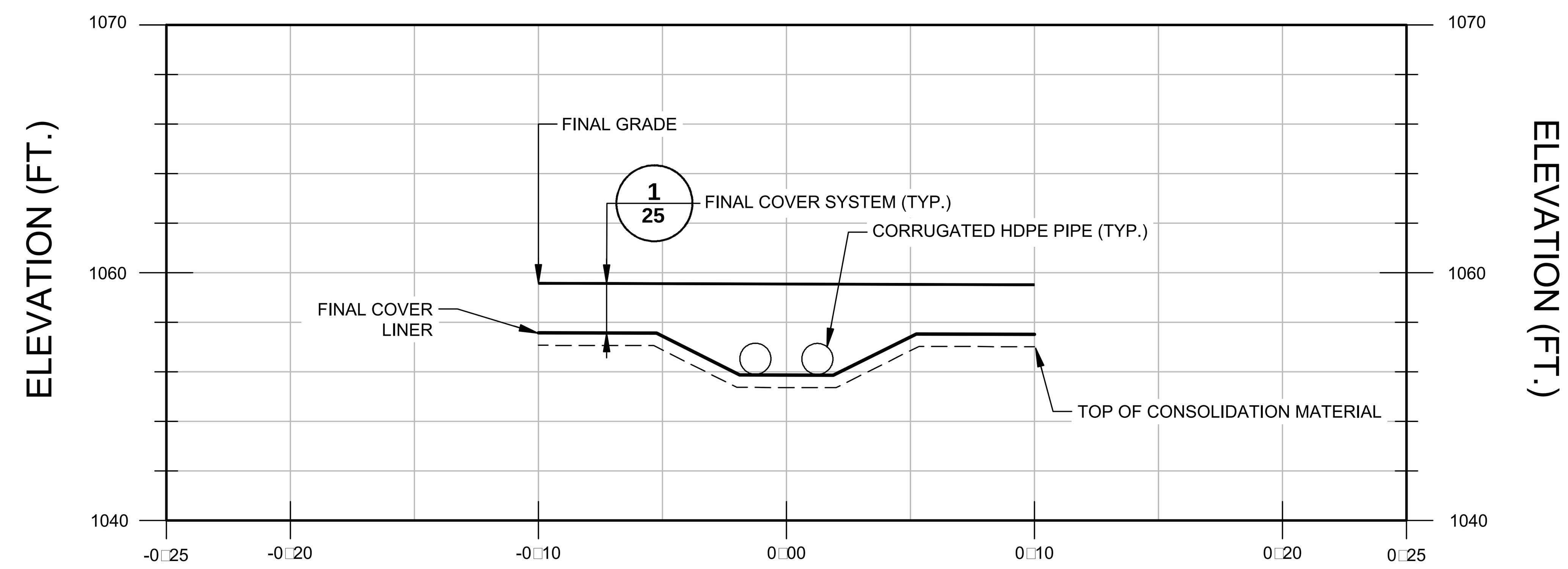
ARCADIS
ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

STORMWATER MANAGEMENT DETAILS - 1

ARCADIS Project No. 30197838
Date: FEBRUARY 2024

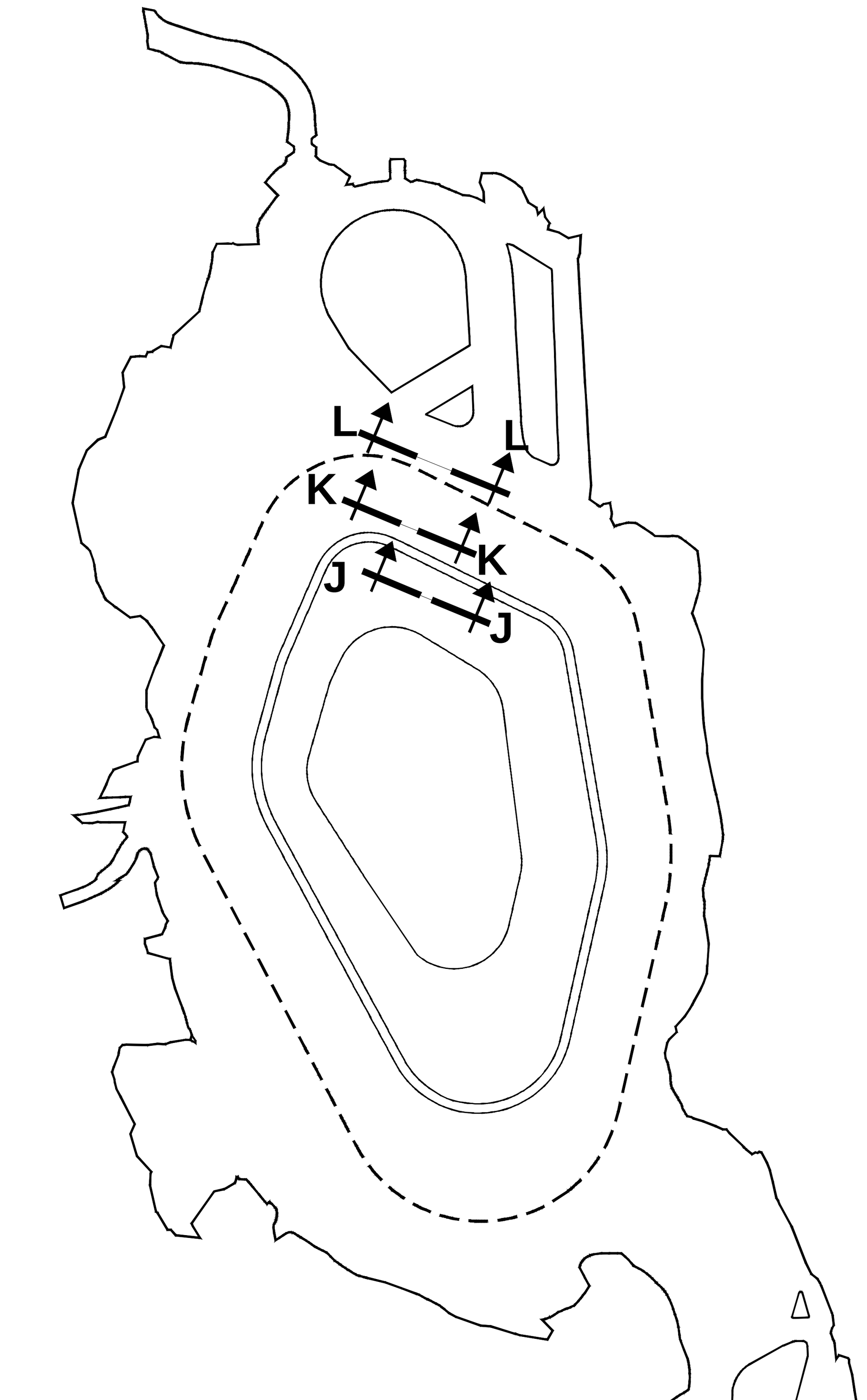
ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120



STATION

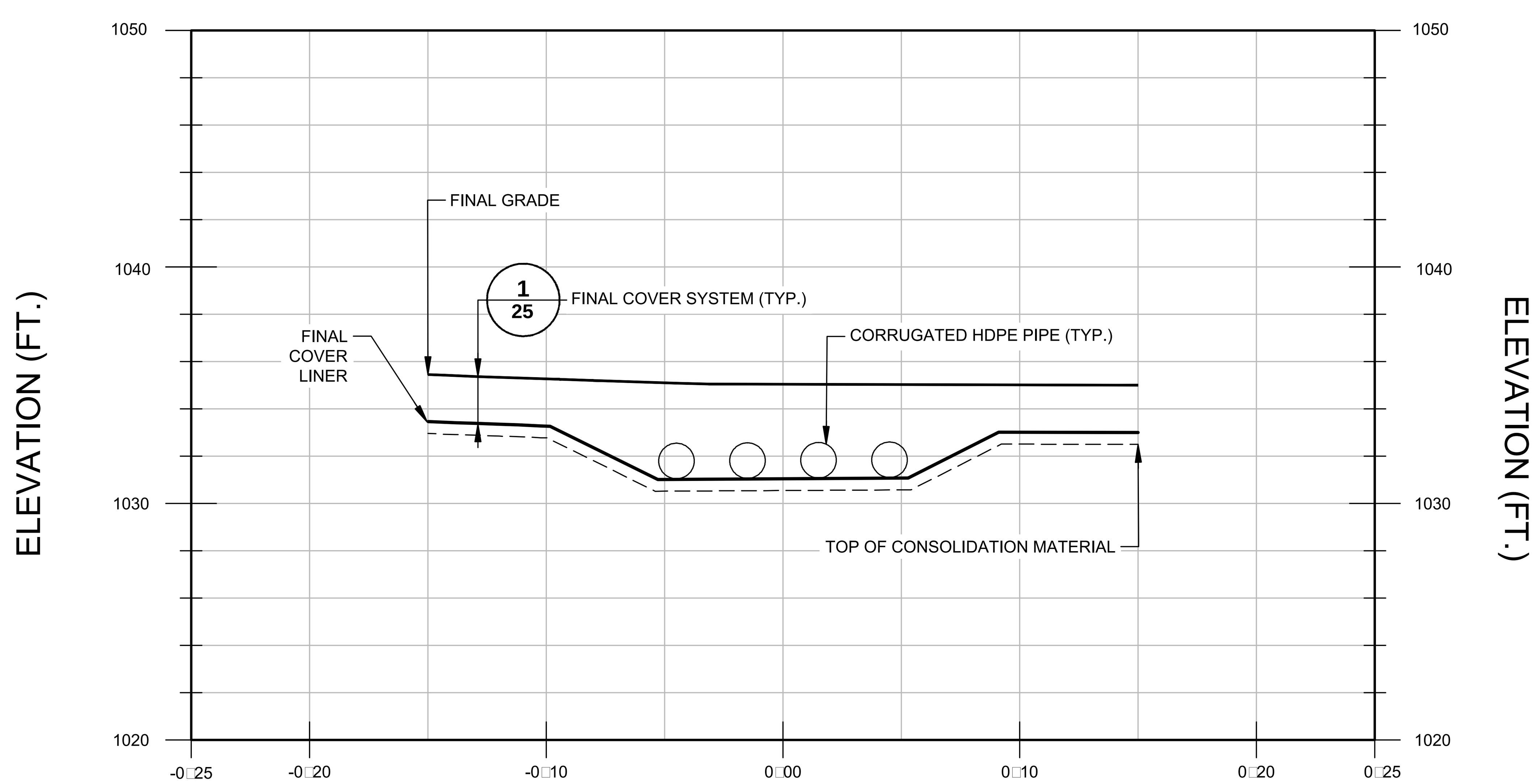
DRAIN PIPE SECTION (J)

SCALE: 1" = 5'
(NO VERTICAL EXAGGERATION)



CROSS SECTION LOCATION PLAN

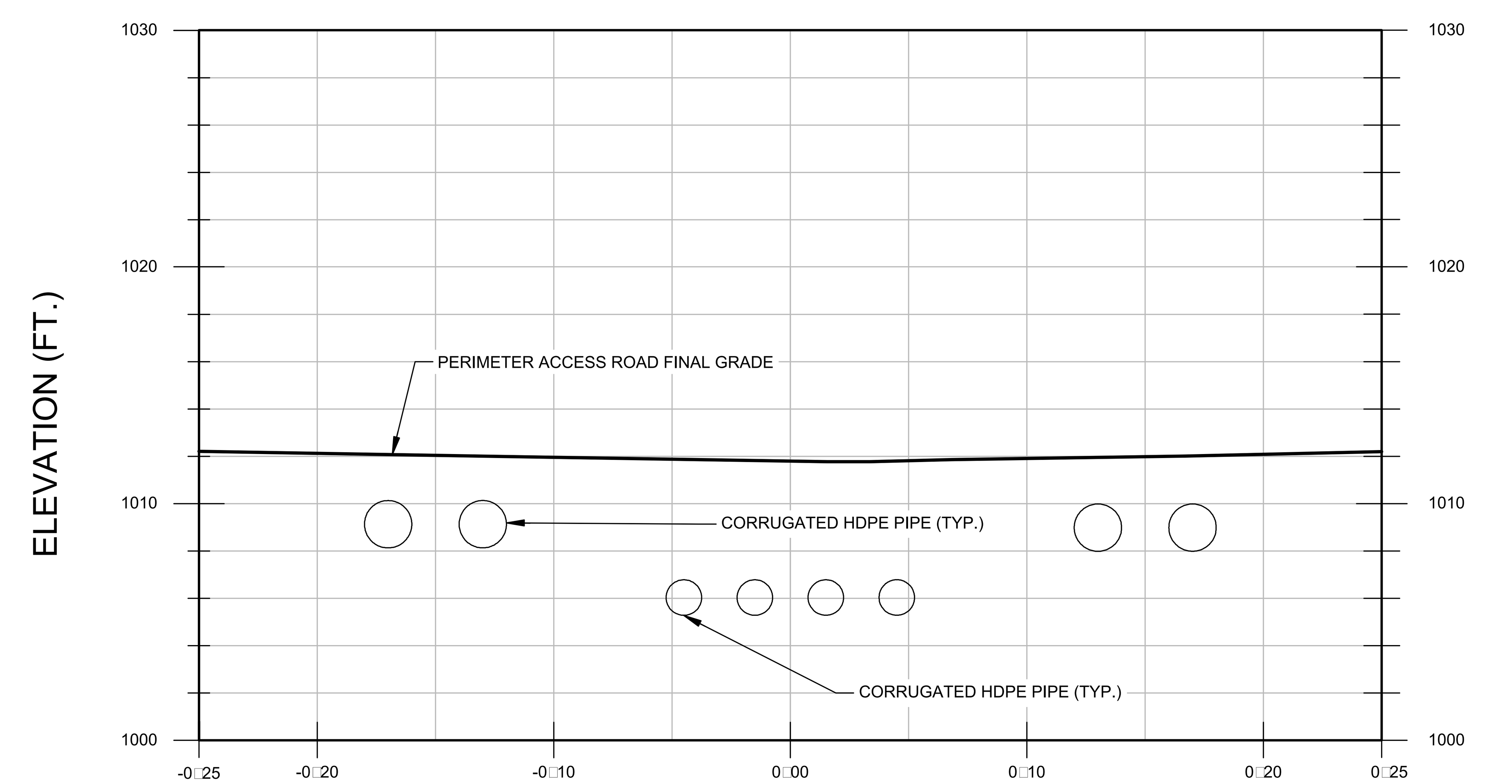
NOT TO SCALE



STATION

DRAIN PIPE SECTION (K)

SCALE: 1" = 5'
(NO VERTICAL EXAGGERATION)



STATION

DRAIN PIPE SECTION (L)

SCALE: 1" = 5'
(NO VERTICAL EXAGGERATION)

1"=10' 10' 0 10' 20'

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

ARCADIS
ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

STORMWATER MANAGEMENT DETAILS - 2

ARCADIS Project No. 30197838
Date FEBRUARY 2024
ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
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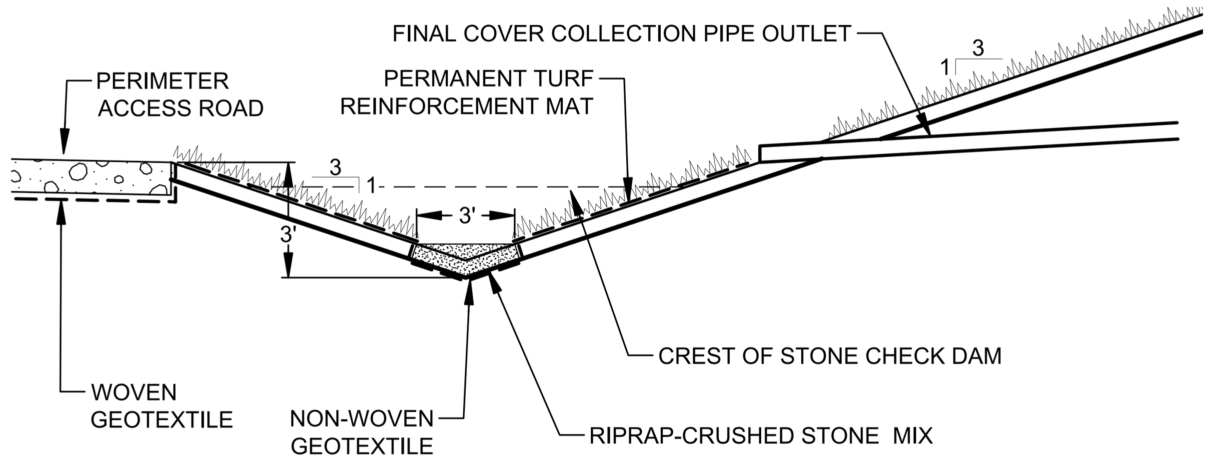
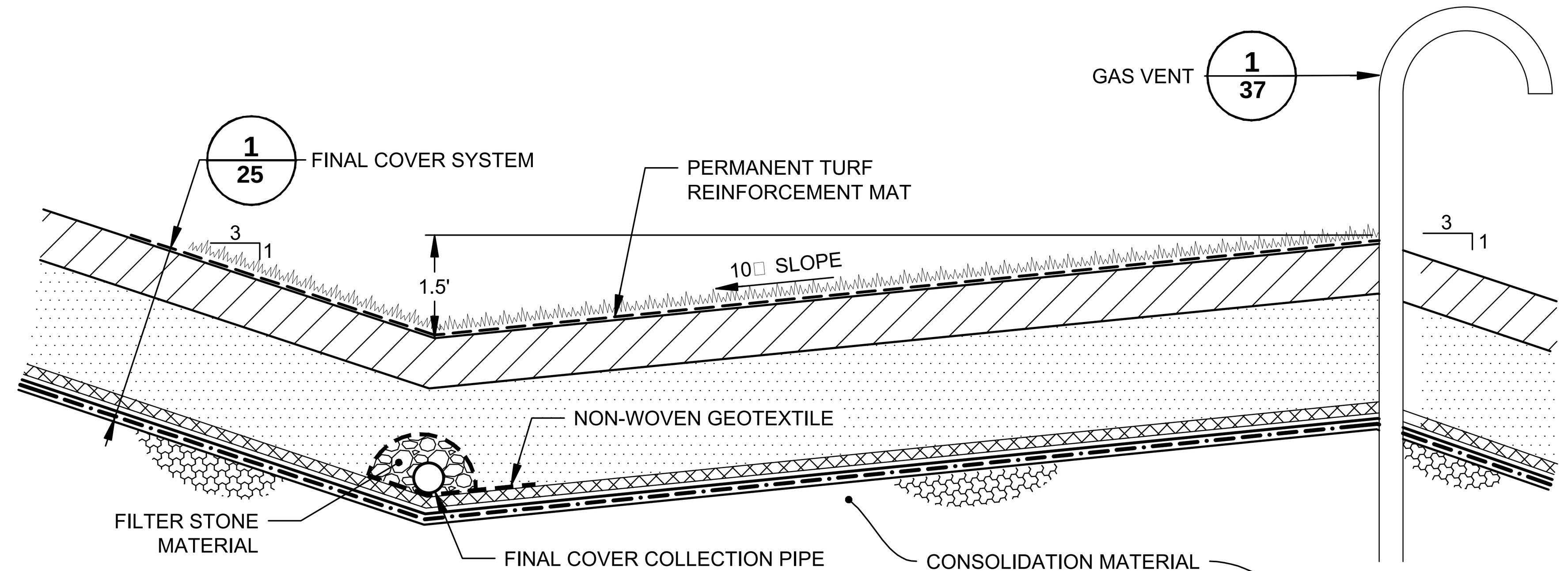


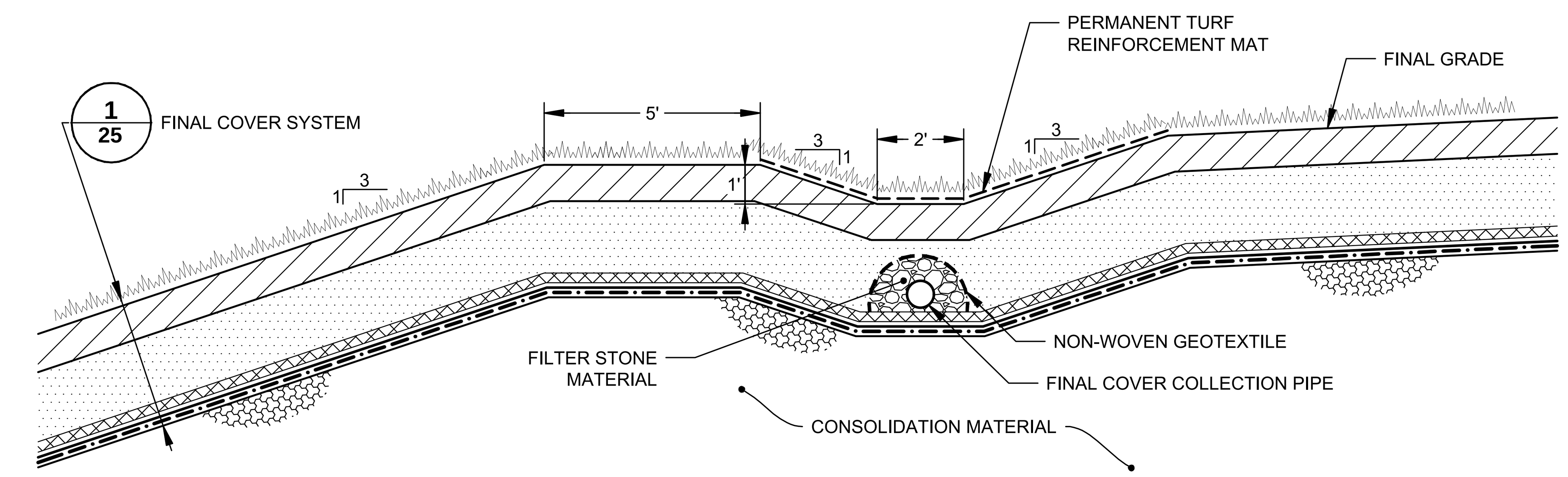
PERMITER DITCH SECTION (1)

SCALE: 1"=5'



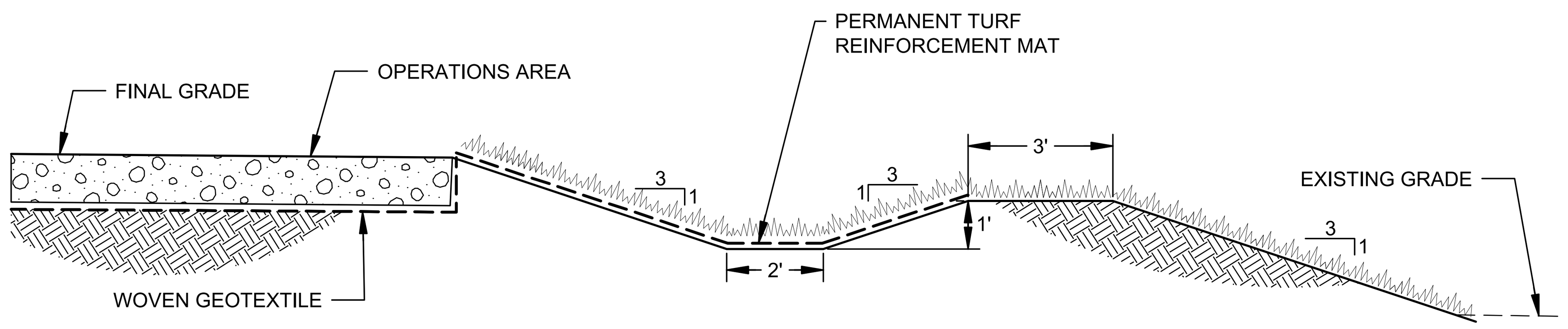
FINAL COVER DIVERSION BERM (2)

NOT TO SCALE



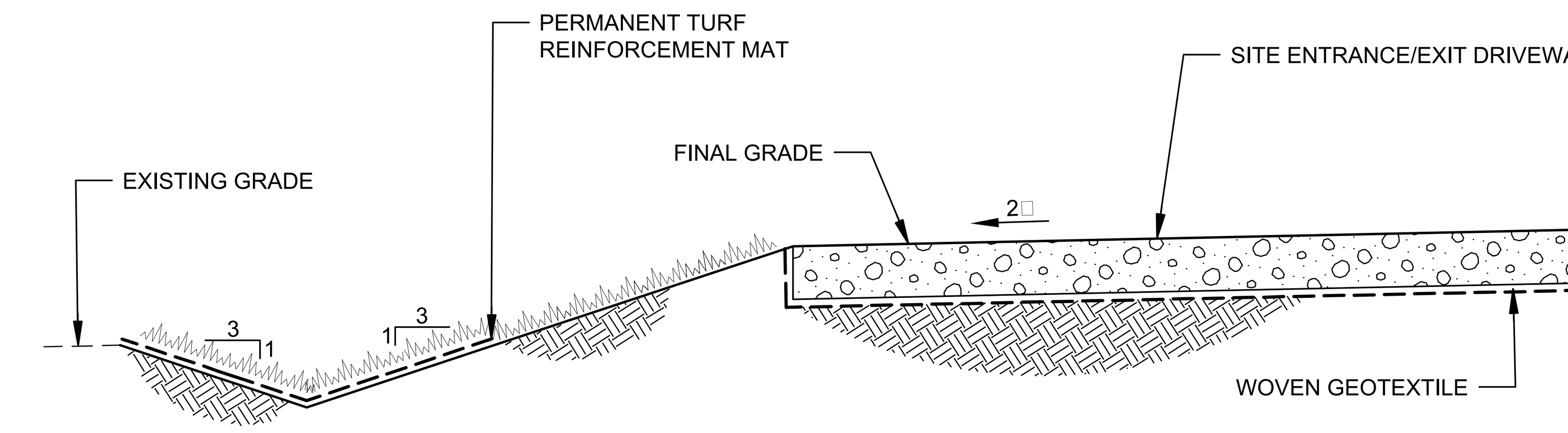
FINAL COVER PLATEAU DITCH (3)

NOT TO SCALE



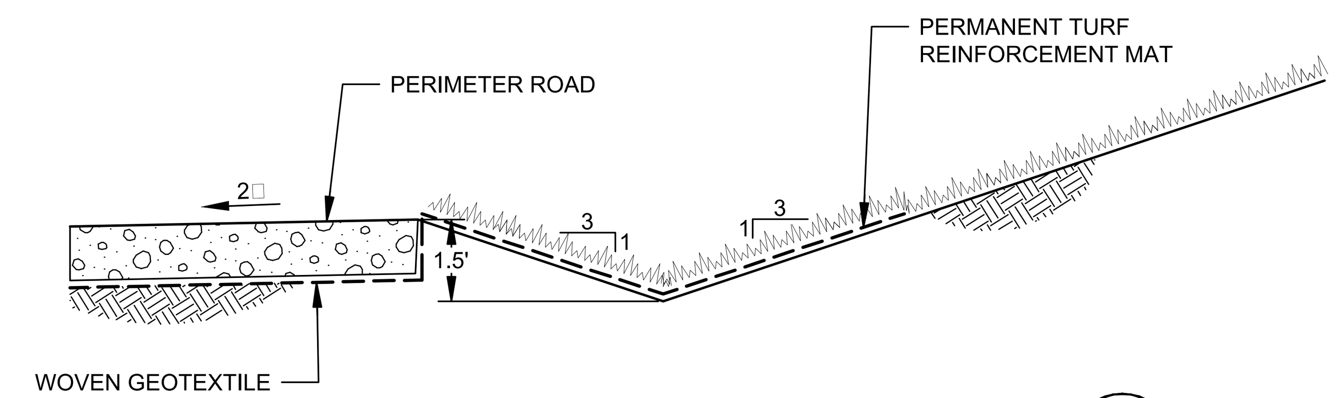
SOUTHEAST EXTERIOR DITCH (4)

NOT TO SCALE



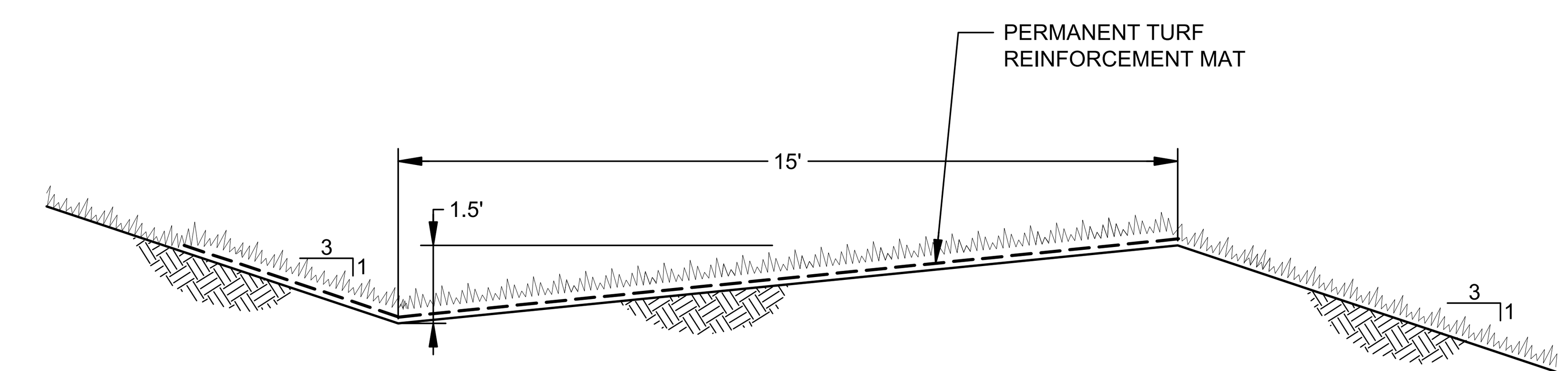
SOUTH ACCESS ROAD DITCH (6)

NOT TO SCALE



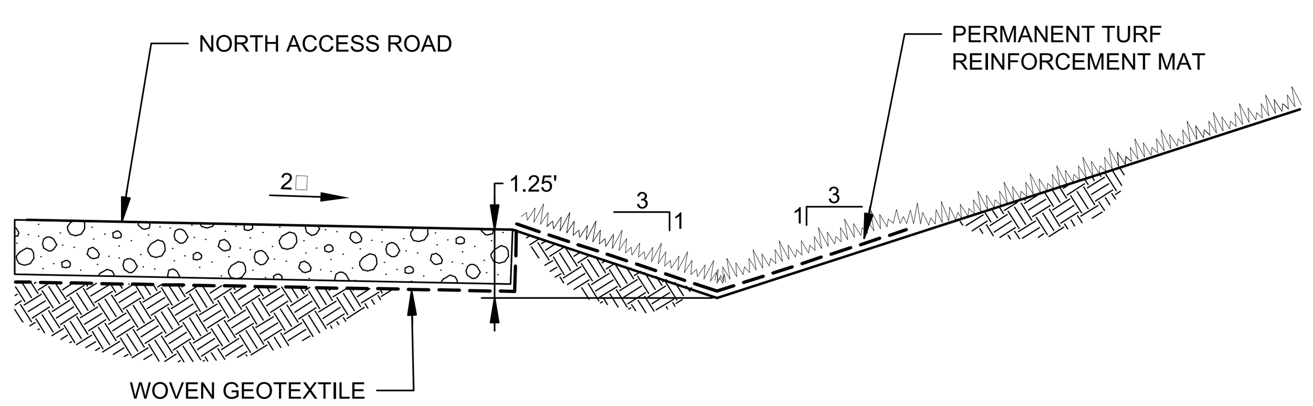
EAST EXTERIOR DITCH (5)

NOT TO SCALE



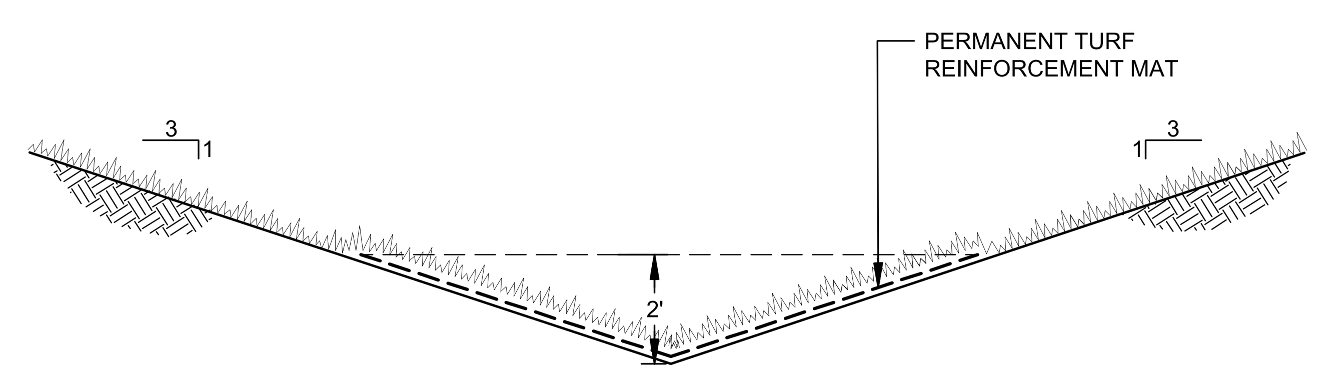
NORTH SLOPE DIVERSION BERM (9)

NOT TO SCALE



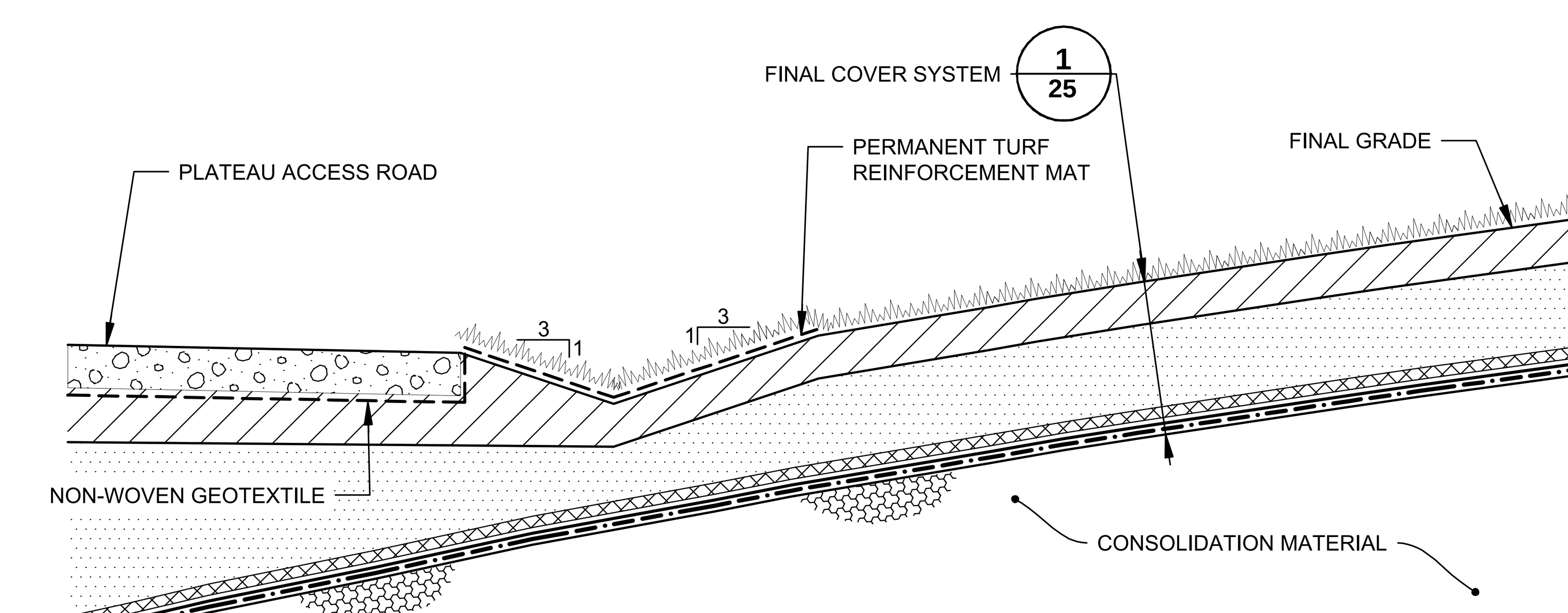
NORTH ACCESS ROAD DITCH (7)

NOT TO SCALE



SOUTHWEST EXTERIOR DITCH (8)

NOT TO SCALE



PLATEAU ACCESS ROAD DITCH (10)

NOT TO SCALE

NOTE:

1. REFER TO THE FINAL GRADING PLAN ON DRAWING 8 FOR LONGITUDINAL SLOPES OF DITCHES.

SCALE(S) AS INDICATED

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983
State: MA | Date Signed: | Project Mgr.: DK
Designed by: BMS | Drawn by: KLS | Checked by: PHB

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

STORMWATER MANAGEMENT DETAILS - 3

ARCADIS Project No. 30197838
Date FEBRUARY 2024

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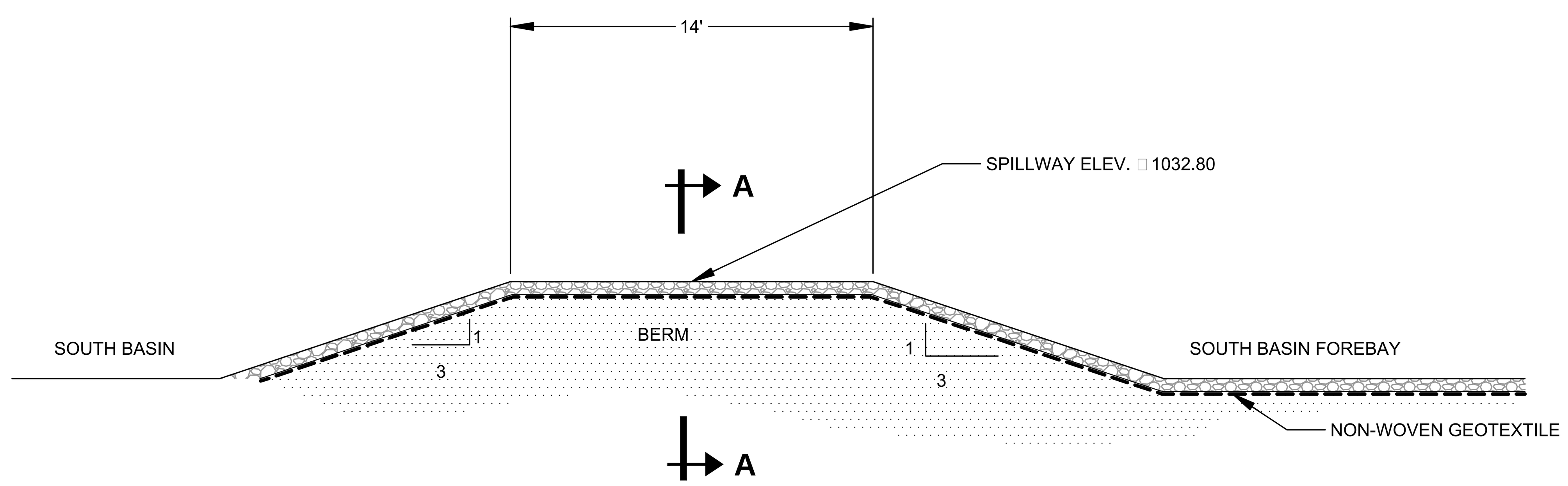
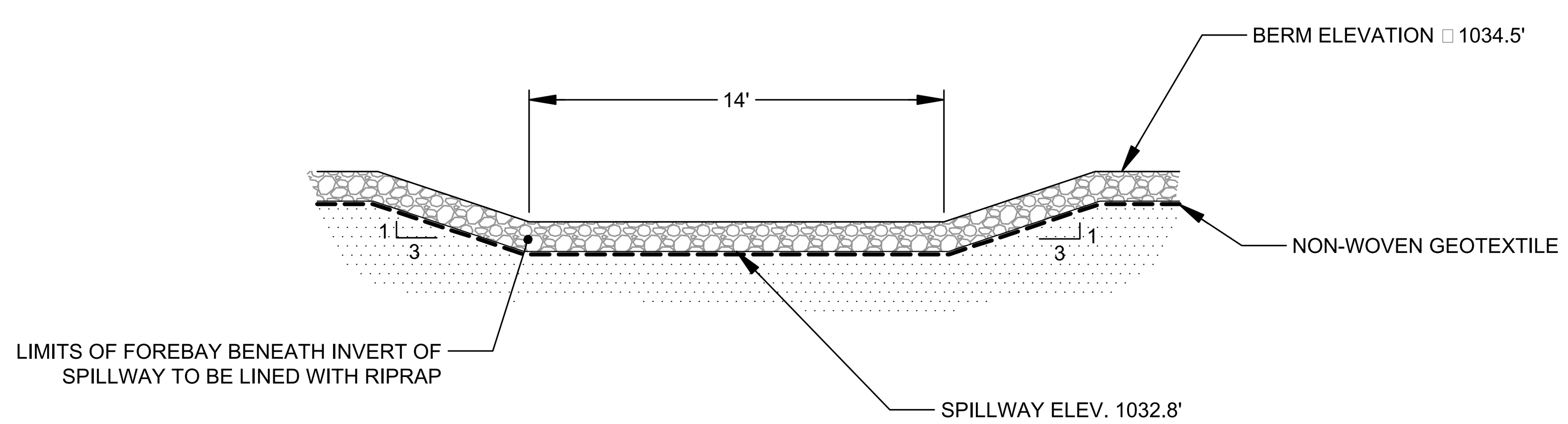
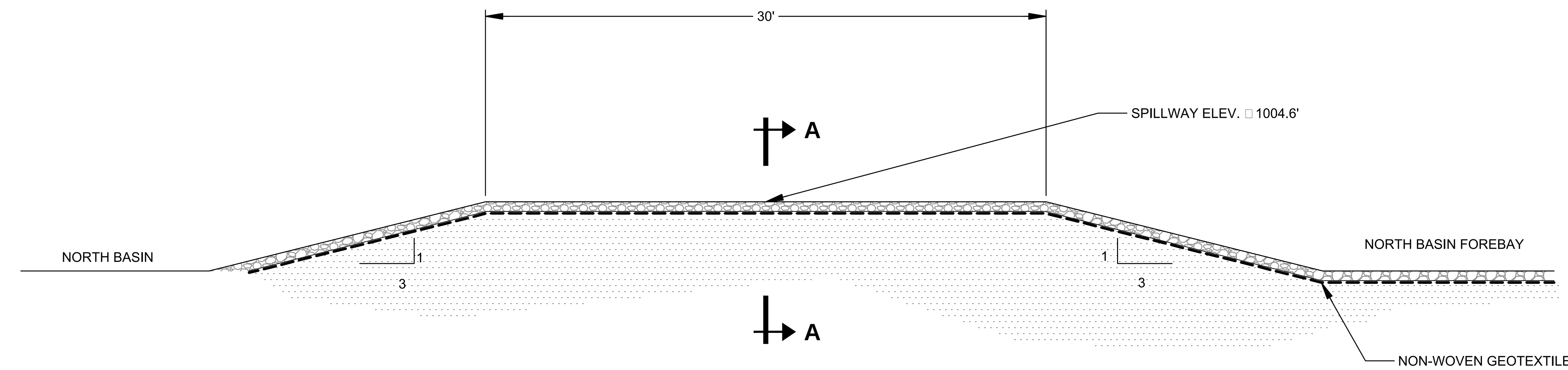


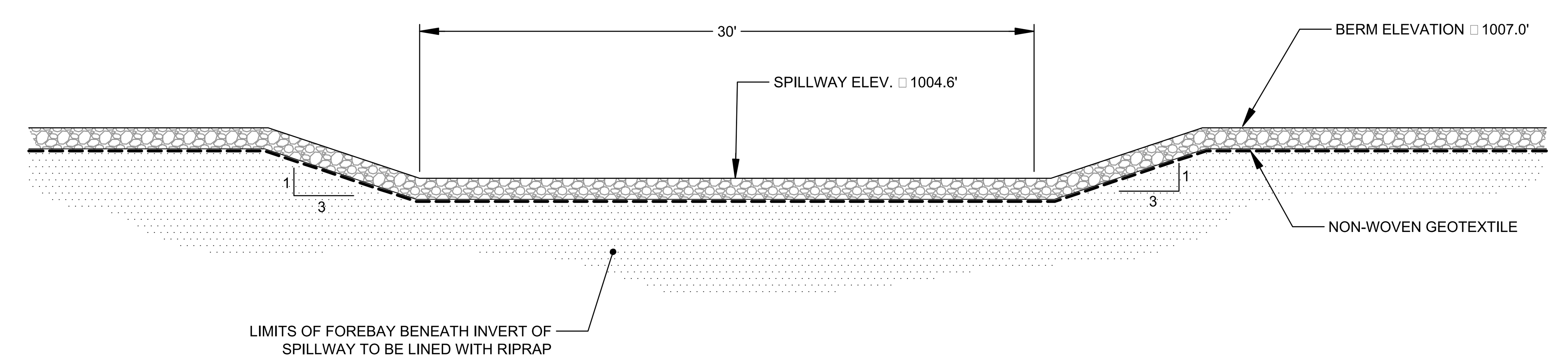


SECTION A-A

SOUTH BASIN FOREBAY SPILLWAY DETAIL 1

0 5' 10'
SCALE: 1"=5'





SECTION A-A

NORTH BASIN FOREBAY SPILLWAY DETAIL 2

0 5' 10'
SCALE: 1"=5'

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Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

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STORMWATER MANAGEMENT DETAILS - 4

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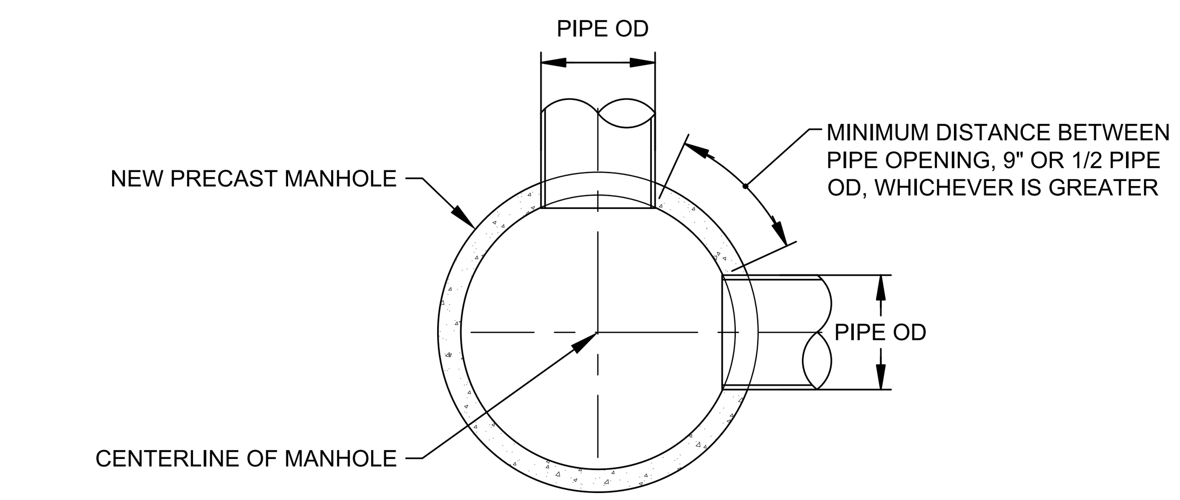
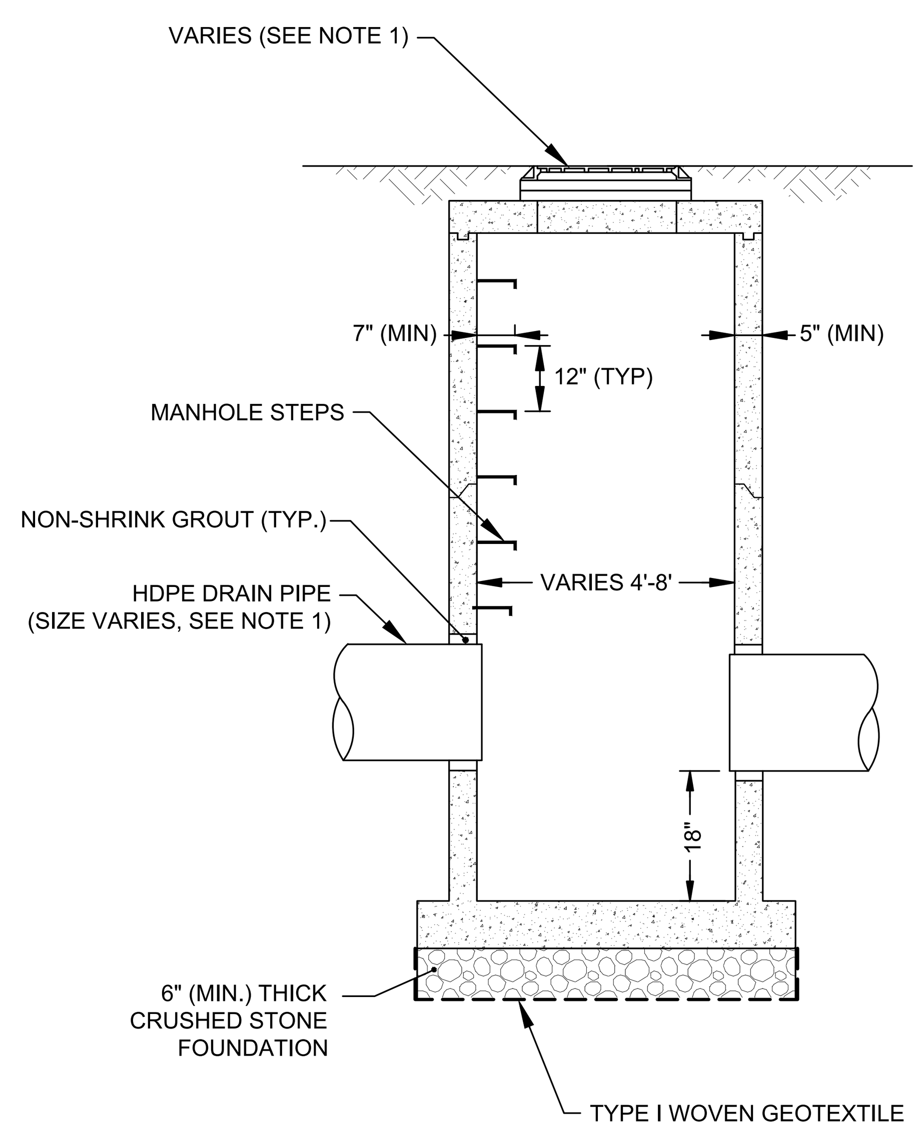


PLAN

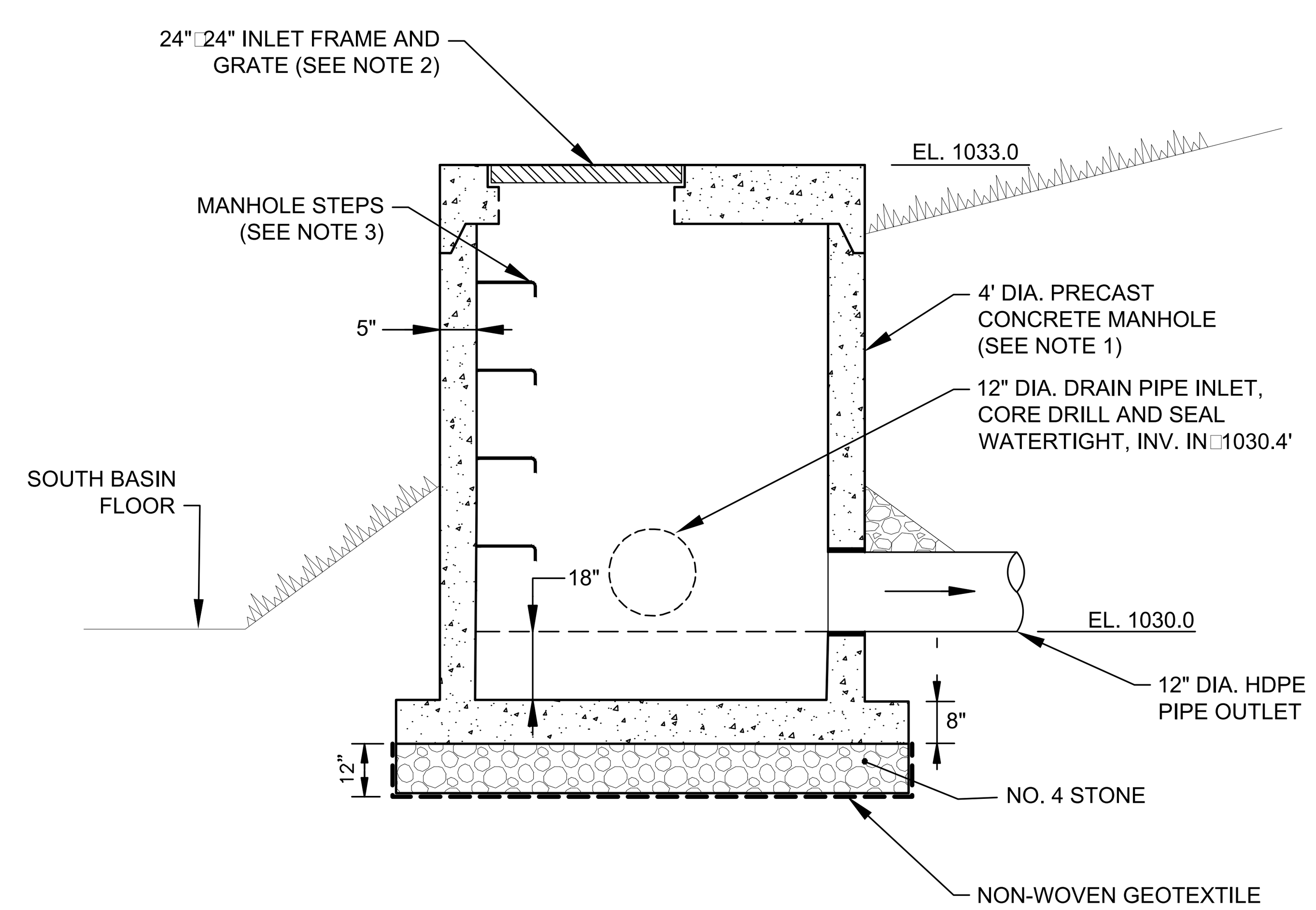


NOTES:

1. REFER TO DRAWINGS 26-28 FOR DRAIN PIPE ALIGNMENTS, SIZES, LID TYPES AND INVERT ELEVATIONS.
2. CONFORM PRECAST MANHOLES TO LATEST VERSION OF ASTM C139 INCLUDING WATER PROOFING OF ALL EXTERIOR SURFACES.
3. FRAME AND GRATE TO MEET OR EXCEED H-20 LOADING.
4. REFER TO THE TECHNICAL SPECIFICATIONS WITH REGARDS TO NON-SHRINK GROUT MATERIAL.

PRECAST CONCRETE DRAIN MANHOLE (TYP) (1)

NOT TO SCALE

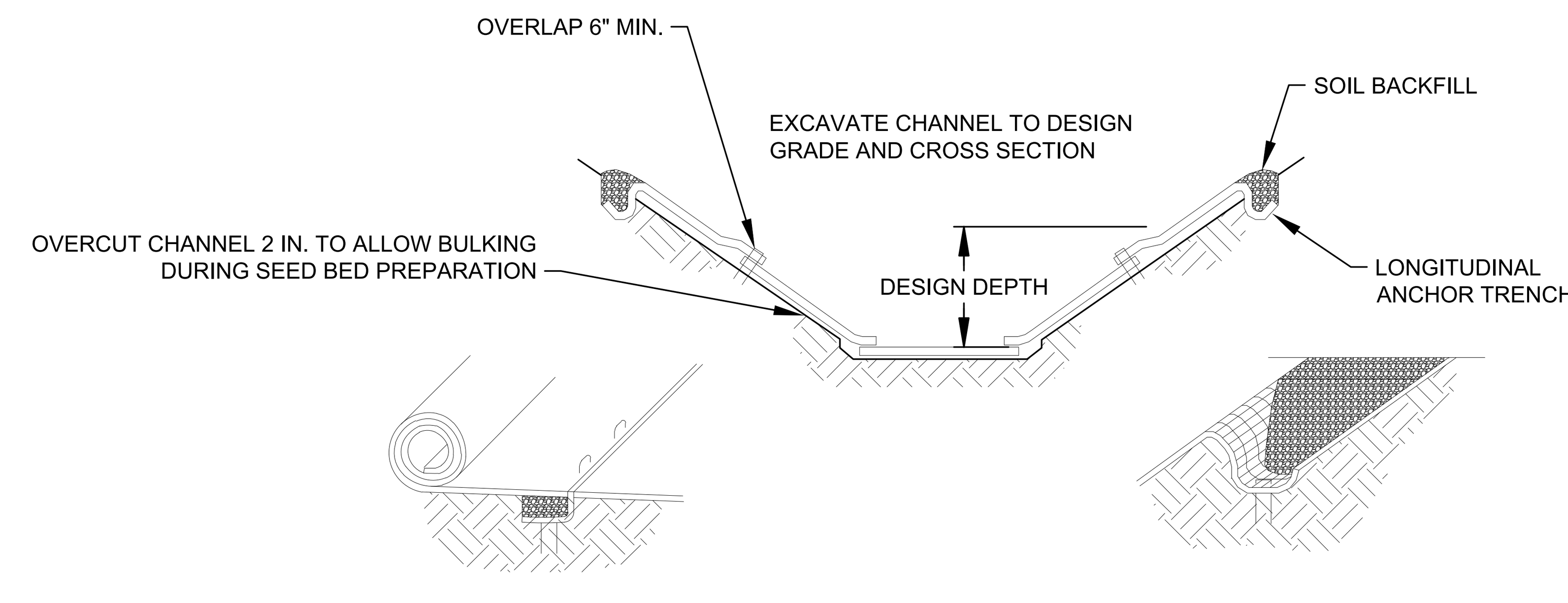


NOTES:

1. PRECAST REINFORCED CONCRETE MANHOLE SHALL CONFORM TO LATEST VERSION OF ASTM C478.
2. INLET FRAME AND GRATE SHALL BE MODEL R-3480 RECTANGULAR GRATE BY NEENAH FOUNDRY OR APPROVED EQUIVALENT.
3. MANHOLE STEPS SHALL BE PROVIDED FOR ALL MANHOLES EXCEEDING 3 FEET DEEP. MANHOLE STEPS SHALL MEET ASTM C478 AND OSHA STANDARDS.

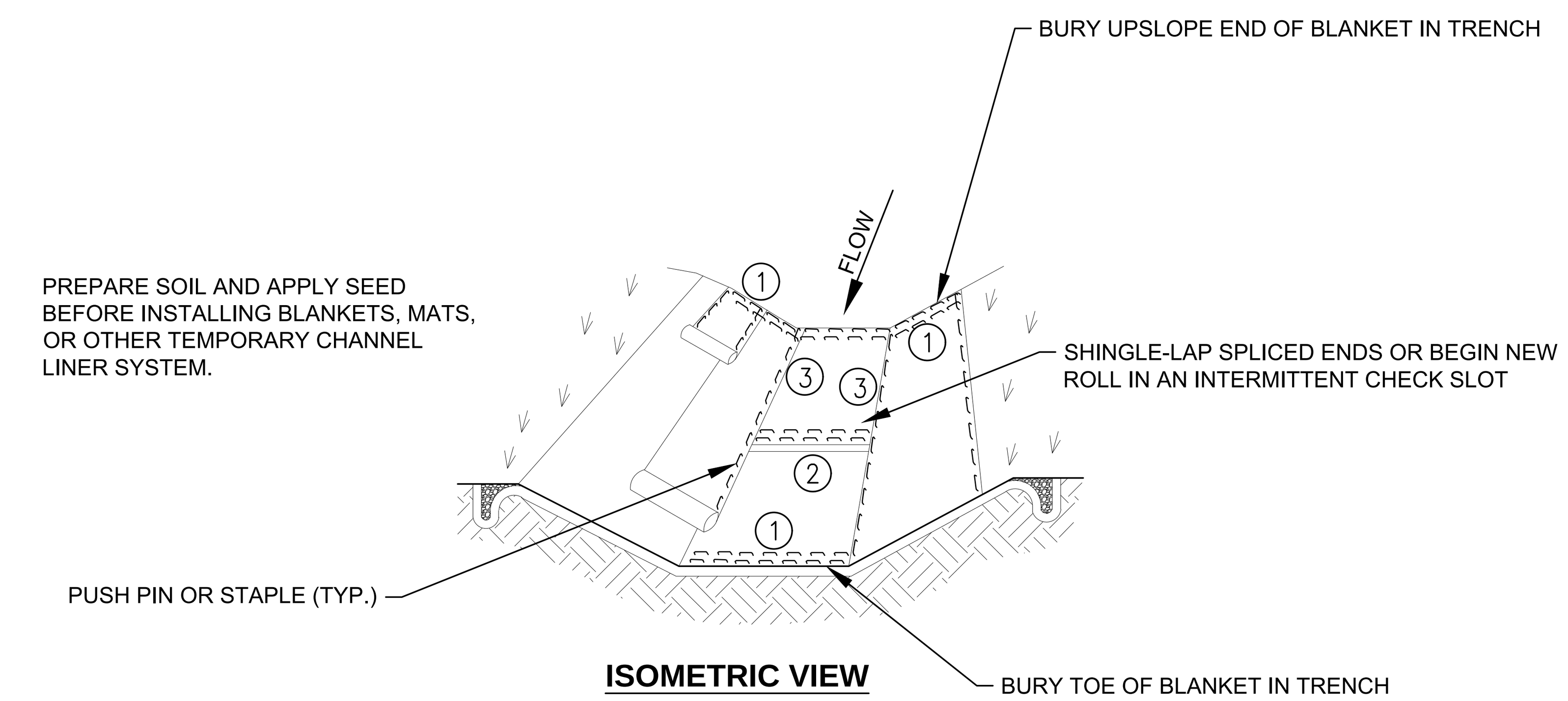
SOUTH BASIN OUTLET STRUCTURE (2)

NOT TO SCALE

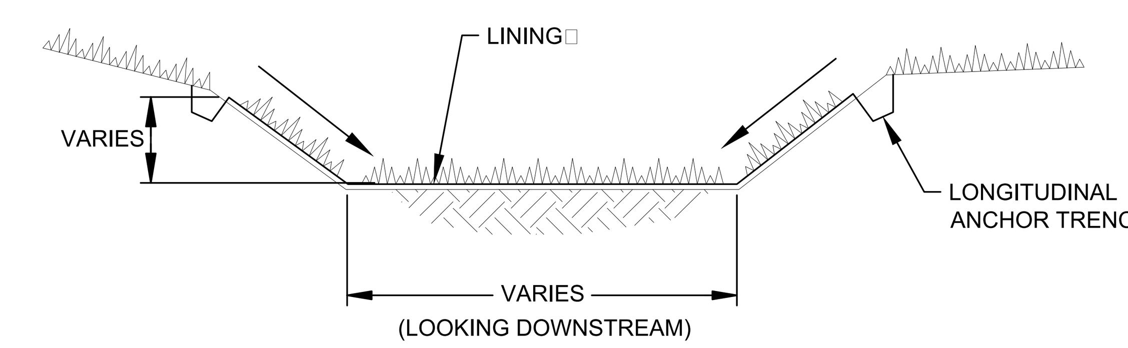


INTERMITTENT CHECK SLOT

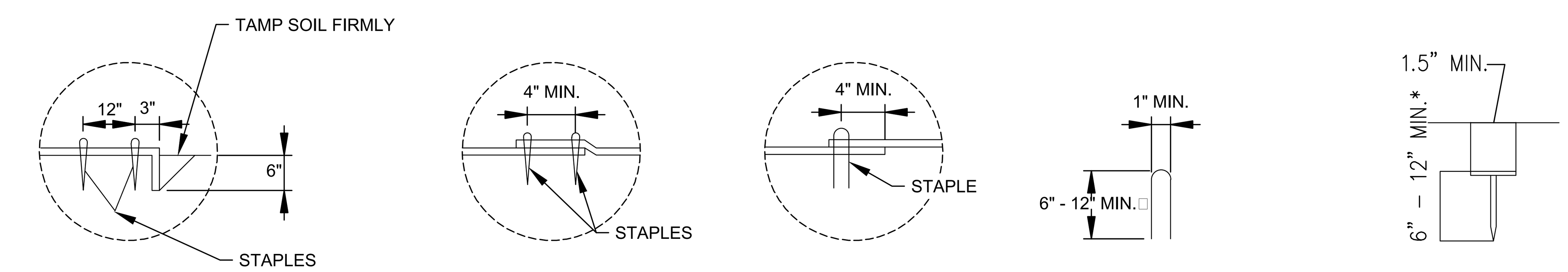
LONGITUDINAL ANCHOR TRENCH



ISOMETRIC VIEW



CHANNEL TRAPEZOIDAL CROSS-SECTION



ANCHOR SLOT | SINGLE JOINT | PARALLEL OVERLAPS | STAPLE DETAIL | PUSH PIN DETAIL

*SEE MANUFACTURER'S LINING INSTALLATION DETAIL FOR STAPLE PATTERNS, VEGETATIVE STABILIZATION FOR SOIL AMENDMENTS, SEED MIXTURES AND MULCHING INFORMATION

NOTES:

1. ANCHOR TRENCHES SHALL BE INSTALLED AT BEGINNING AND END OF CHANNEL IN THE SAME MANNER AS LONGITUDINAL ANCHOR TRENCHES.
2. CHANNEL DIMENSIONS SHALL BE CONSTANTLY MAINTAINED. CHANNEL SHALL BE CLEANED WHENEVER TOTAL CHANNEL DEPTH IS REDUCED BY 25% AT ANY LOCATION.
3. SEDIMENT DEPOSITS SHALL BE REMOVED WITHIN 24 HOURS OF DISCOVERY OR AS SOON AS SOIL CONDITIONS PERMIT ACCESS TO CHANNEL WITHOUT FURTHER DAMAGE. DAMAGED LINING SHALL BE REPAIRED OR REPLACED WITHIN 48 HOURS OF DISCOVERY.
4. NO MORE THAN ONE THIRD OF THE SHOOT (GRASS LEAF) SHALL BE REMOVED IN ANY MOWING. GRASS HEIGHT SHALL BE MAINTAINED BETWEEN 2 AND 3 INCHES UNLESS OTHERWISE SPECIFIED. EXCESS VEGETATION SHALL BE REMOVED FROM PERMANENT CHANNELS TO ENSURE SUFFICIENT CHANNEL CAPACITY.
5. AFTER CONSTRUCTION IS COMPLETE AND THE CHANNEL IS STABLE, INSPECT THE PERMANENT CHANNEL ANNUALLY AND AFTER EACH MAJOR RAINFALL FOR DAMAGE AND DETERIORATION. REPAIR DAMAGES IMMEDIATELY. ONGOING MAINTENANCE SHOULD INCLUDE THE REMOVAL OF ACCUMULATED SEDIMENT.
6. FOR SANDY SOIL CONDITIONS, STAPLE OR PUSH PIN SHALL BE A MINIMUM 8 INCHES.

TURF REINFORCEMENT MAT CHANNEL LINING (3)

NOT TO SCALE

NOT TO SCALE

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No.	Date	Revisions	By	Ckd

Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

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UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

STORMWATER MANAGEMENT DETAILS - 5

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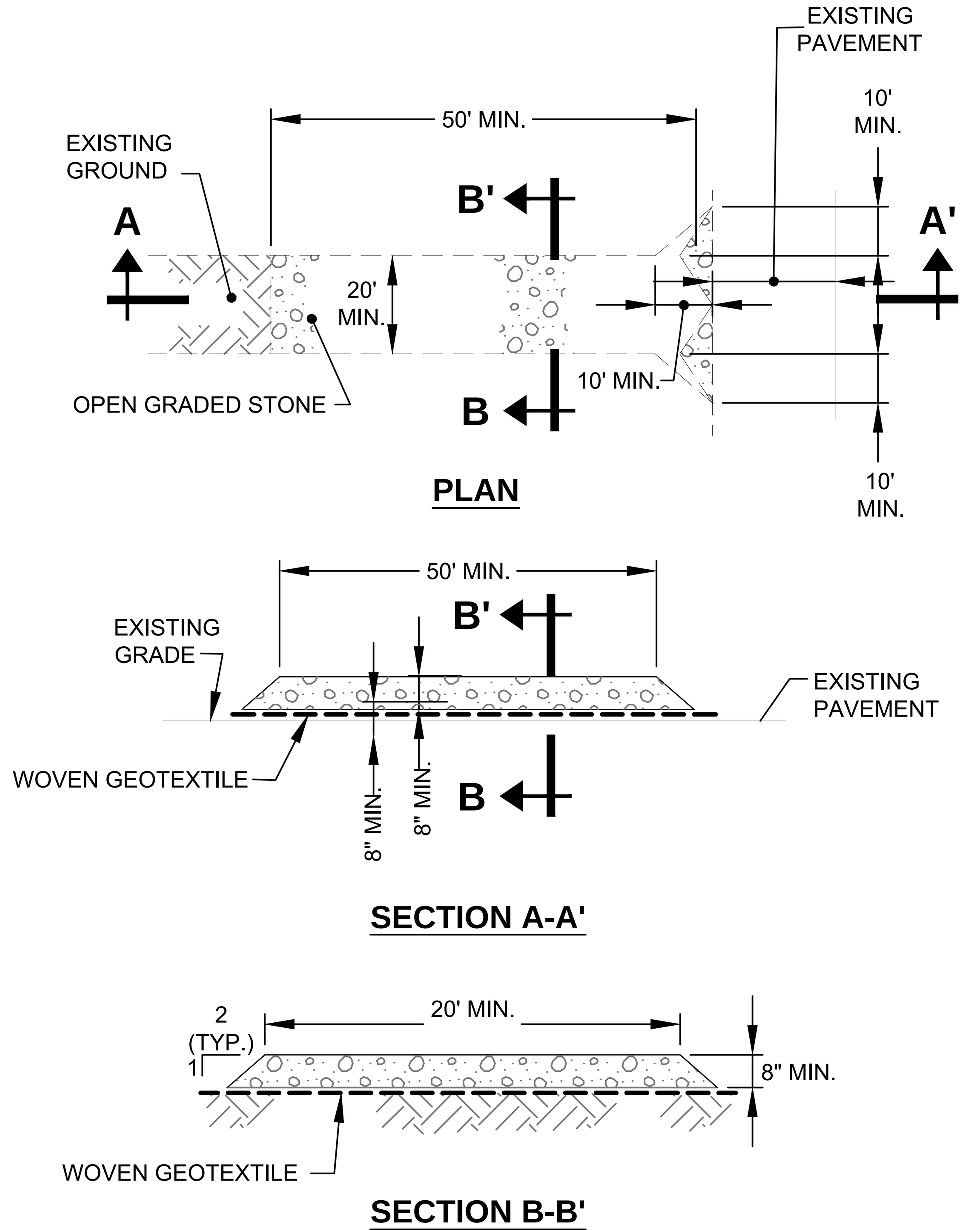
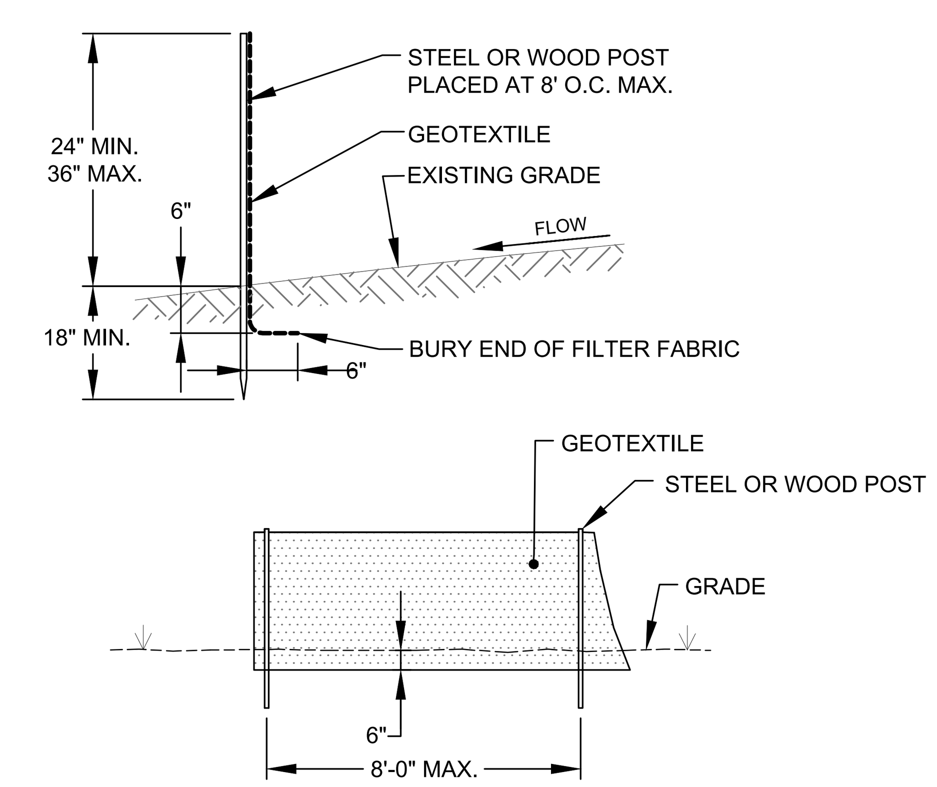


NOTE:

1. STABILIZED CONSTRUCTION ENTRANCES SHALL BE INSTALLED AT ALL WORK AREA ACCESS POINTS.

STABILIZED CONSTRUCTION ENTRANCE (1)

NOT TO SCALE

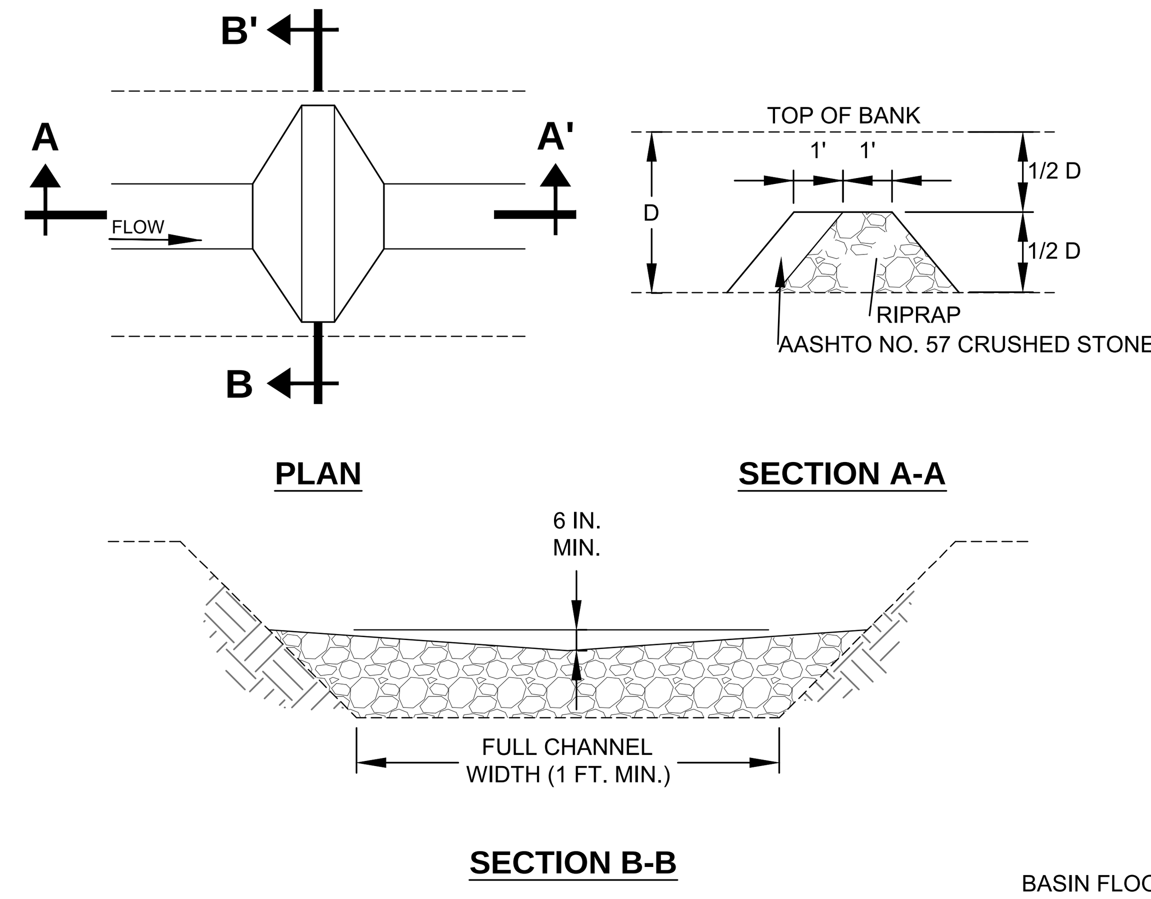


NOTES:

1. DEPOSITS SHALL BE REMOVED WHEN THEY REACH APPROXIMATELY 6 INCHES ABOVE GRADE ELEVATION.
2. THE SILT FENCE WILL REMAIN IN PLACE UNTIL A VEGETATIVE STAND IS ESTABLISHED.
3. THE SILT FENCE WILL BE USED FOR TEMPORARY EROSION AND SEDIMENTATION CONTROL ONLY.

SILT FENCE (2)

NOT TO SCALE

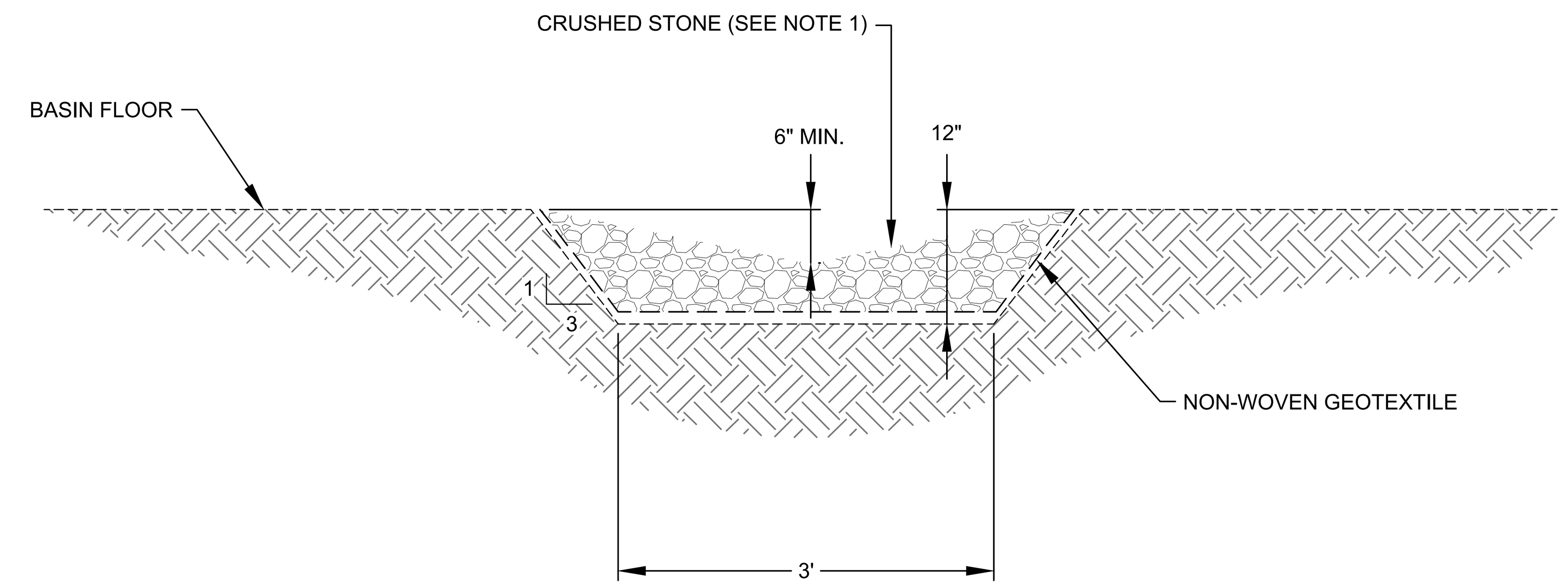


NOTES:

1. SEDIMENT MUST BE REMOVED WHEN ACCUMULATIONS REACH 1/2 THE HEIGHT OF THE DAMS.
2. DURING CONSTRUCTION, INSPECT STONE CHECK DAMS AT LEAST ONCE A WEEK AND WITHIN 24 HOURS OF THE END OF A STORM WITH A RAINFALL AMOUNT OF 0.5 INCH OR GREATER TO DETERMINE MAINTENANCE NEEDS.
3. REPLACE OR REPAIR THE CHECK DAM WITHIN 24 HOURS OF OBSERVED FAILURE.
4. IF STONE CHECK DAMS ARE USED IN GRASS-LINED CHANNELS WHICH WILL BE MOWED, CAREFULLY GRADE OUT THE STONE TO ENSURE IT DOES NOT INTERFERE WITH MOWING.
5. IMMEDIATELY UPON STABILIZATION OF EACH CHANNEL, REMOVE ACCUMULATED SEDIMENT AND STABILIZE DISTURBED AREAS.

STONE CHECK DAM (3)

NOT TO SCALE

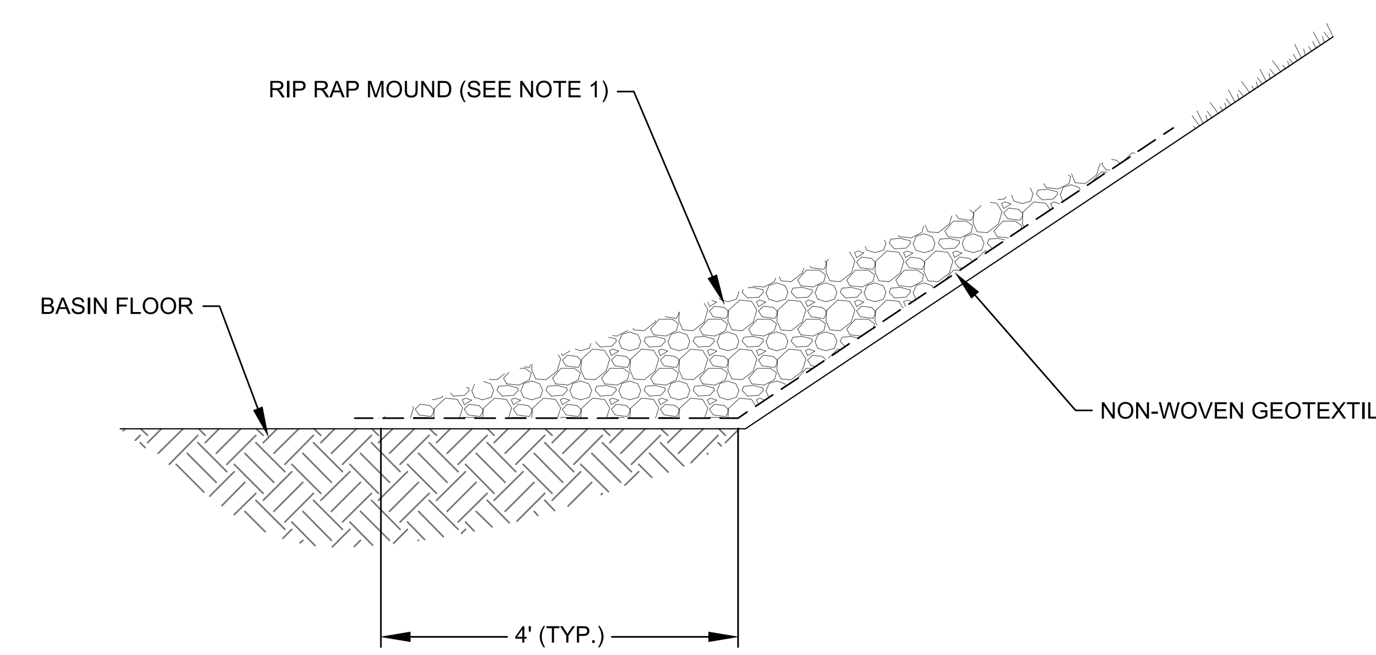


NOTE:

1. CRUSHED STONE TO BE CLEAN WASHED ANGULAR STONE WITH A D_{50} OF 2 INCHES.

INFILTRATION BASIN PILOT CHANNEL (4)

NOT TO SCALE

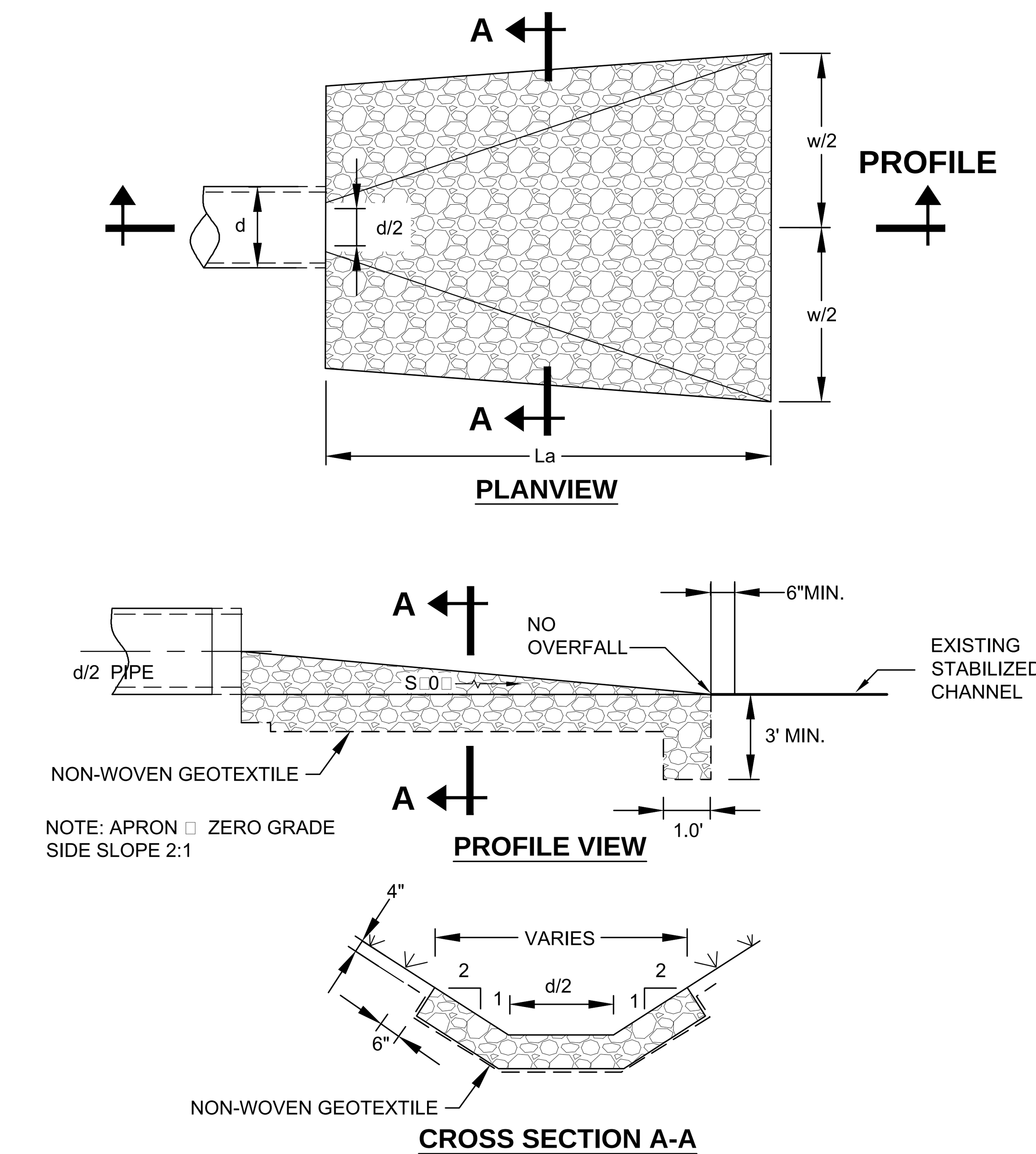


NOTE:

1. RIPRAP MOUND TO BE CONSTRUCTED ALONG INTERIOR TOE OF BASIN SIDE SLOPE (NORTH AND SOUTH STORMWATER BASINS).

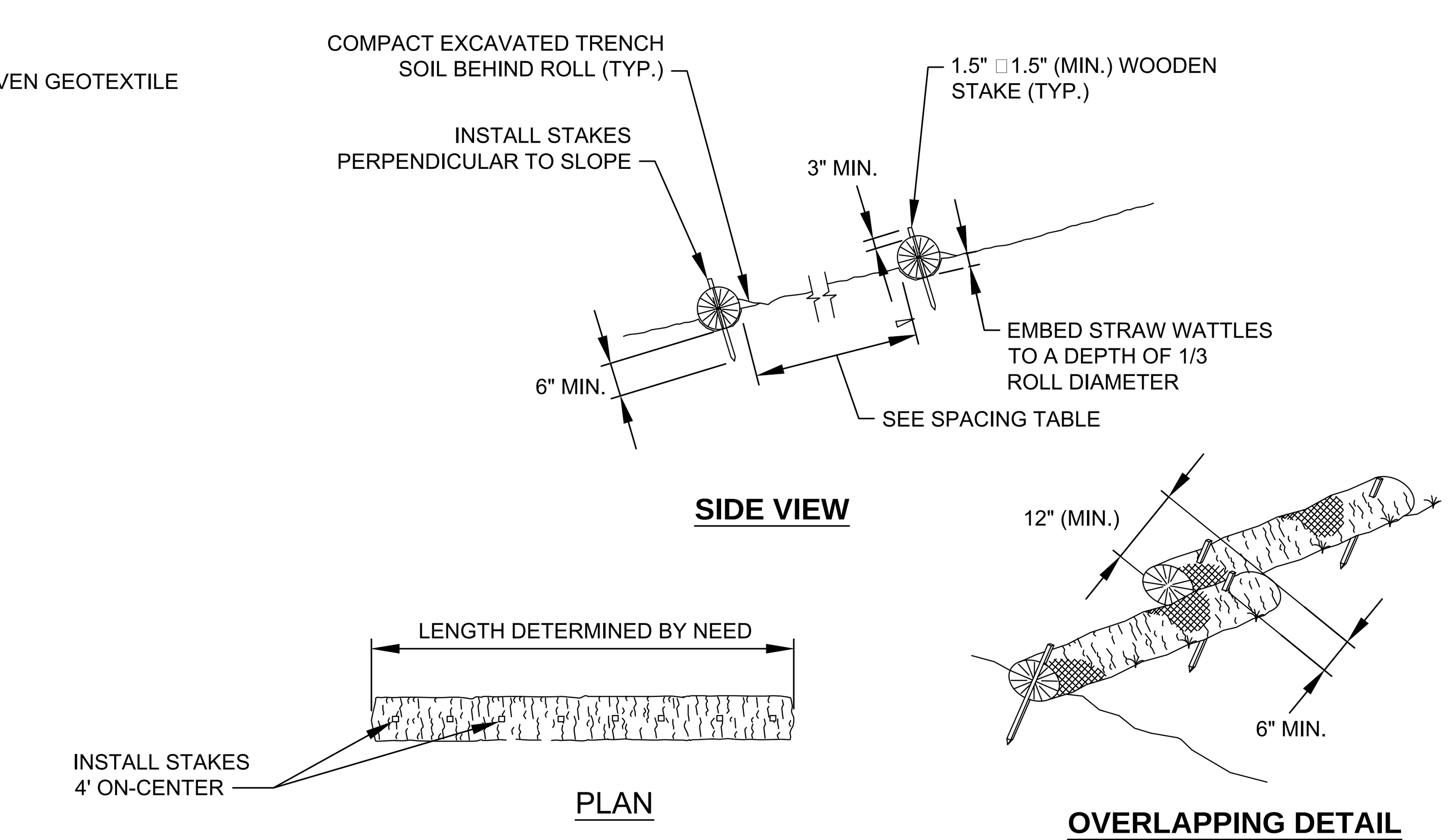
RIPRAP TOE OF BASIN (5)

NOT TO SCALE



RIPRAP OUTLET PROTECTION (6)

NOT TO SCALE



STRAW WATTLE MAX. SPACING TABLE

SLOPE	WATTLE SIZE		
	9"	12"	20"
1:1	10 FT	15 FT	20 FT
2:1	20 FT	30 FT	40 FT
3:1	30 FT	45 FT	60 FT
4:1 OR FLATTER	40 FT	60 FT	80 FT

NOTES:

1. PLACE WATTLES PARALLEL TO TOE OF SLOPE OR ALONG SLOPE CONTOUR. TURN THE ENDS OF EACH WATTLE UPSLOPE TO INHIBIT FLOW AROUND THE ROLL.
2. WHEN MULTIPLE WATTLES ARE RE UIRED ALONG AN ALIGNMENT, OVERLAP ADJOINING SEGMENTS BY A MINIMUM OF 12 INCHES.
3. REMOVE SEDIMENT FROM THE UPSLOPE SIDE OF WATTLES WHEN ACCUMULATION HAS REACHED 1/2 OF THE EFFECTIVE HEIGHT OF THE BARRIER.

STRAW WATTLE (7)

NOT TO SCALE

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Professional Engineer's No.: 42983
State: MA | Date Signed: | Project Mgr.: DK
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ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS

UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

EROSION AND SEDIMENT CONTROL DETAILS

ARCADIS Project No. 30197838

Date FEBRUARY 2024

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ONE LINCOLN CENTER
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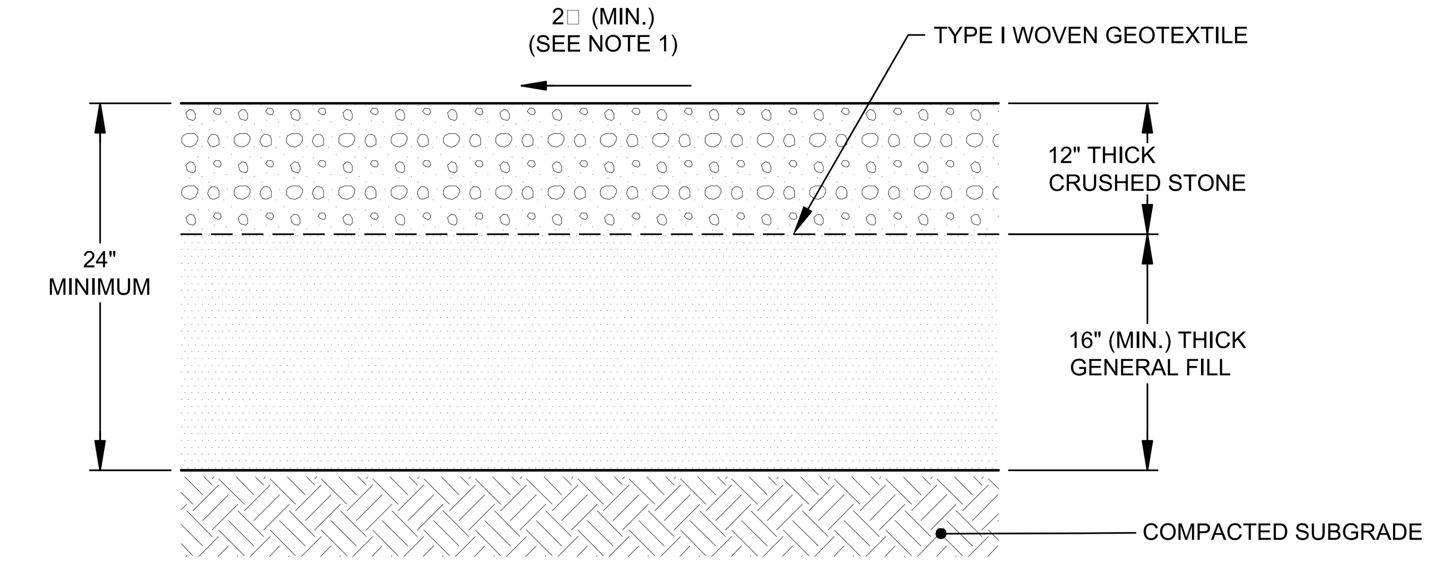
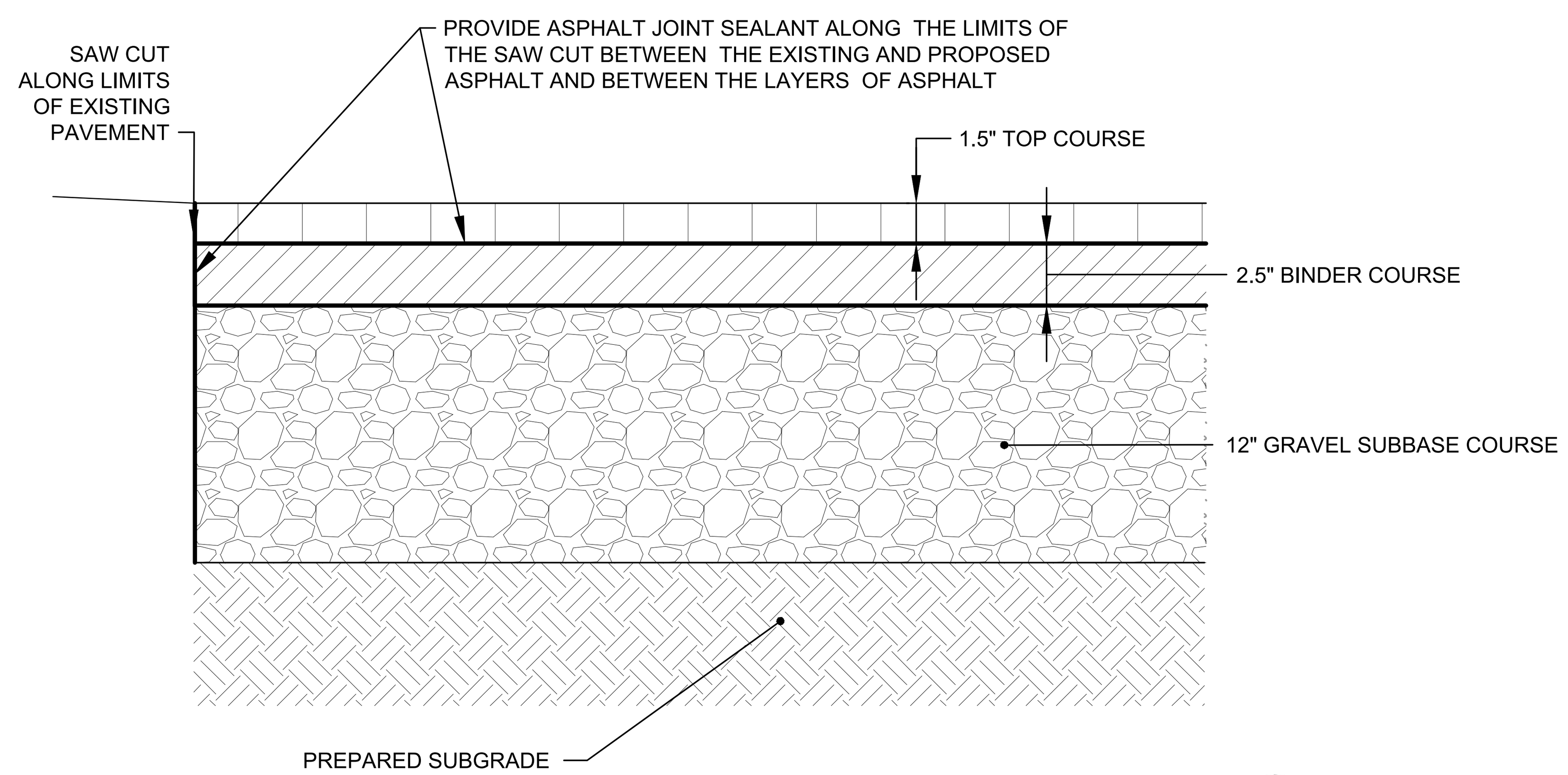


NOTES:

1. FINISHED GRADE OF ACCESS ROADS SHALL MAINTAIN A MINIMUM SLOPE OF 2□ TO MAINTAIN POSITIVE SURFACE RUNOFF DRAINAGE.

TYPICAL OPERATIONS AREA AND ACCESS ROAD SECTION (1)

NOT TO SCALE

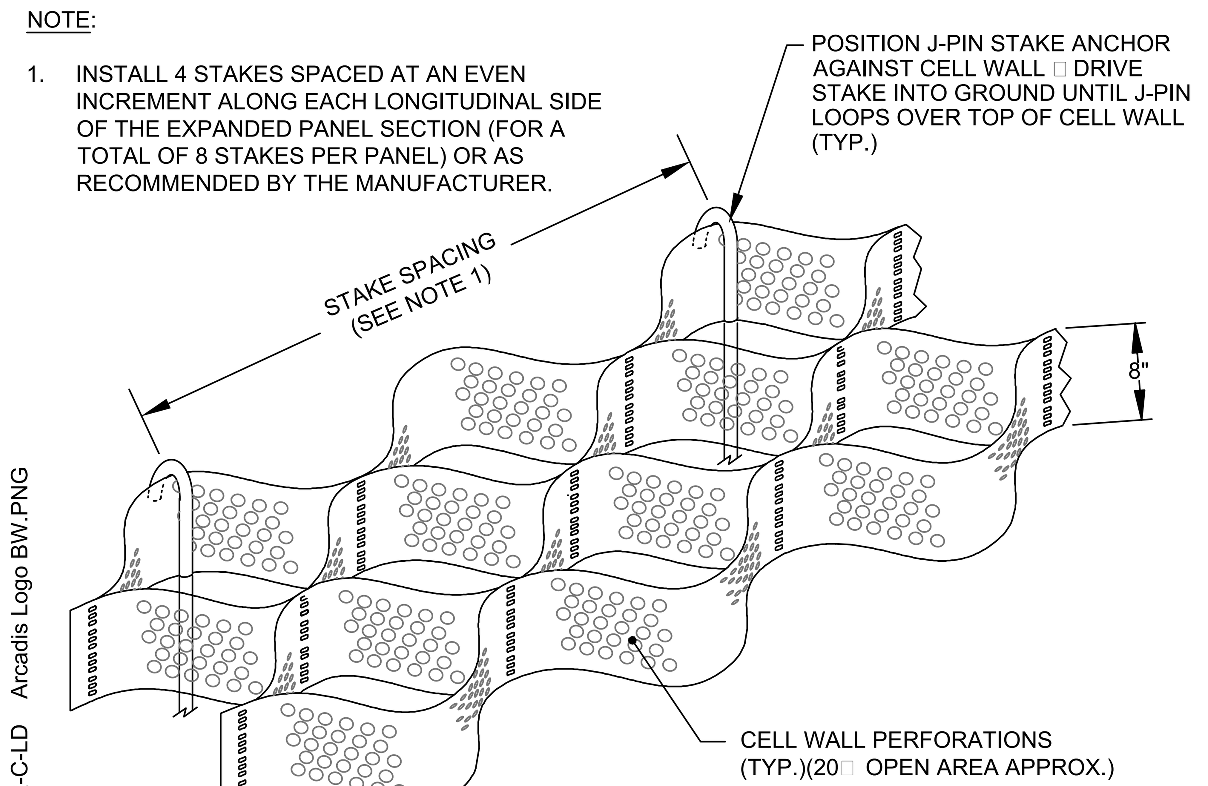


TYPICAL ASPHALT PAVEMENT SECTION (2)

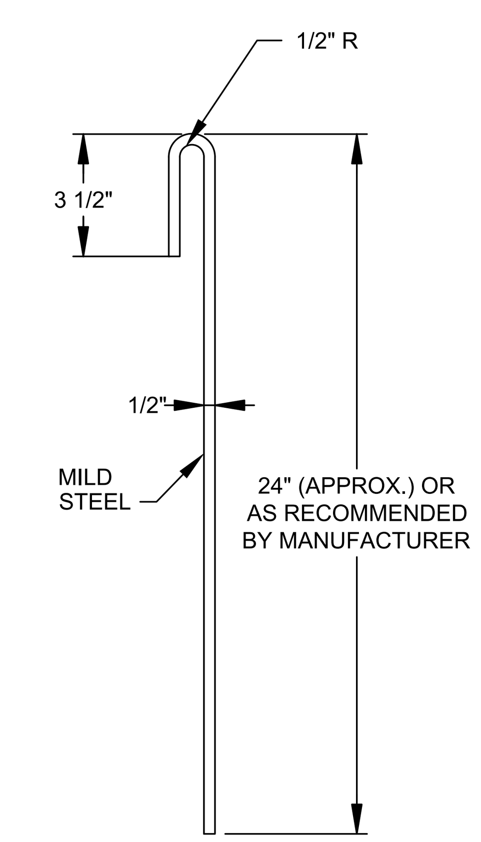
NOT TO SCALE

NOTE:

1. INSTALL 4 STAKES SPACED AT AN EVEN INCREMENT ALONG EACH LONGITUDINAL SIDE OF THE EXPANDED PANEL SECTION (FOR A TOTAL OF 8 STAKES PER PANEL) OR AS RECOMMENDED BY THE MANUFACTURER.



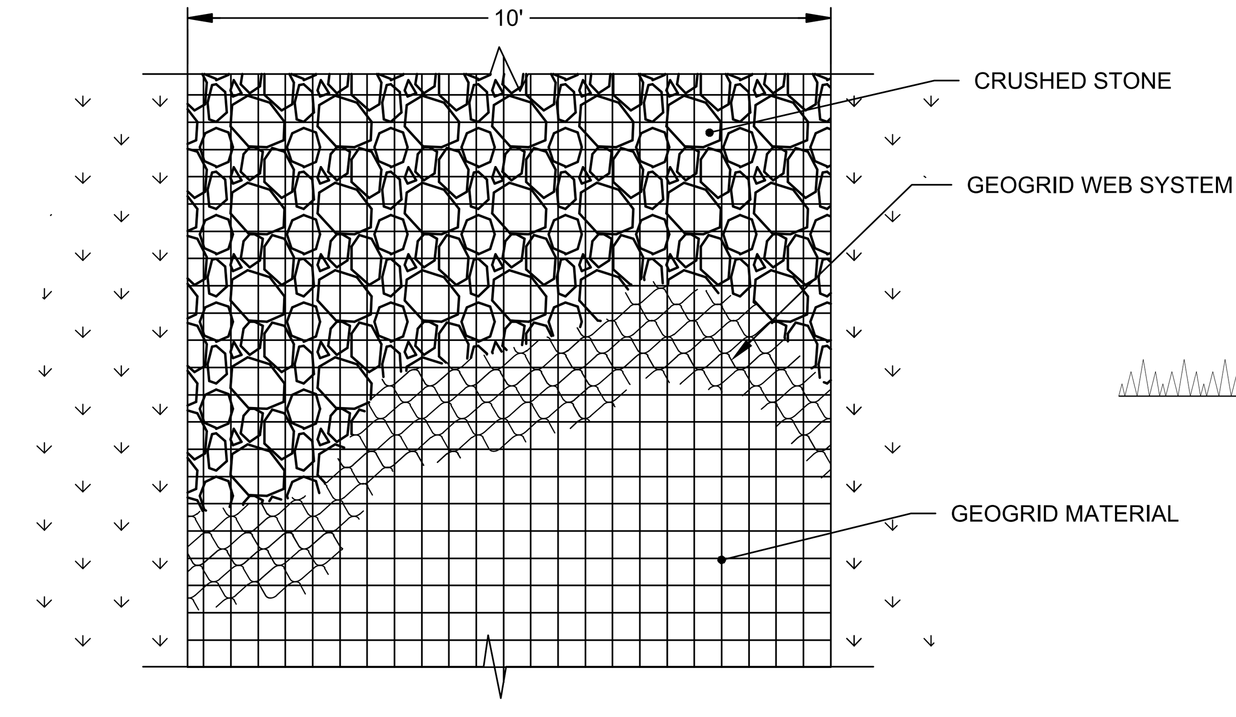
STAKING LAYOUT



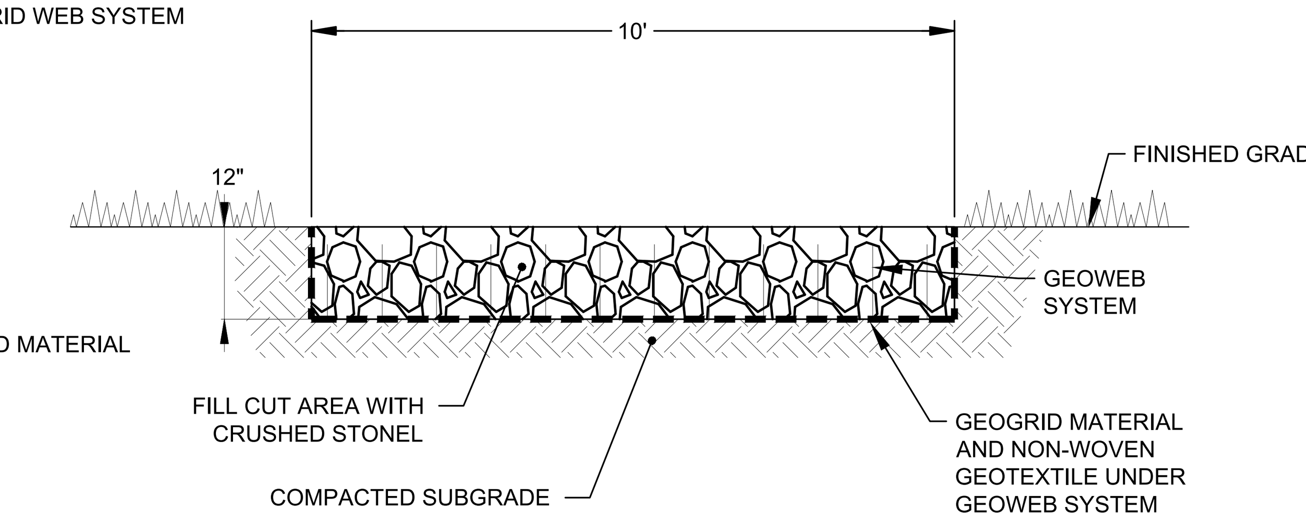
J-PIN STAKE ANCHOR

STAKED PANEL EDGE (3)

NOT TO SCALE



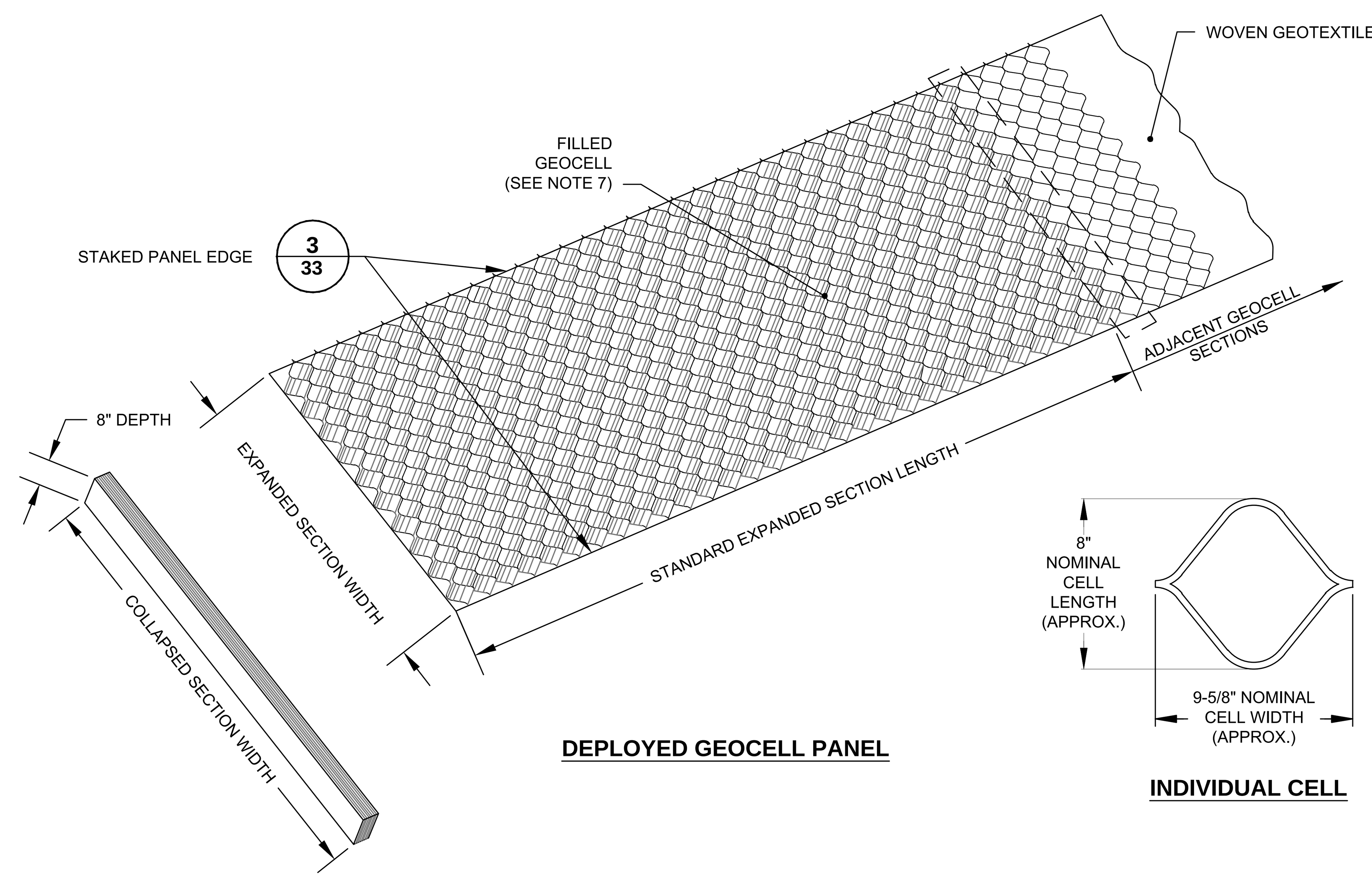
PLAN VIEW



SECTION VIEW

NORTH STORMWATER BASIN MAINTENANCE ACCESS ROAD (AT OVERFLOW SPILLWAY) (4)

NOT TO SCALE



DEPLOYED GEOCELL PANEL

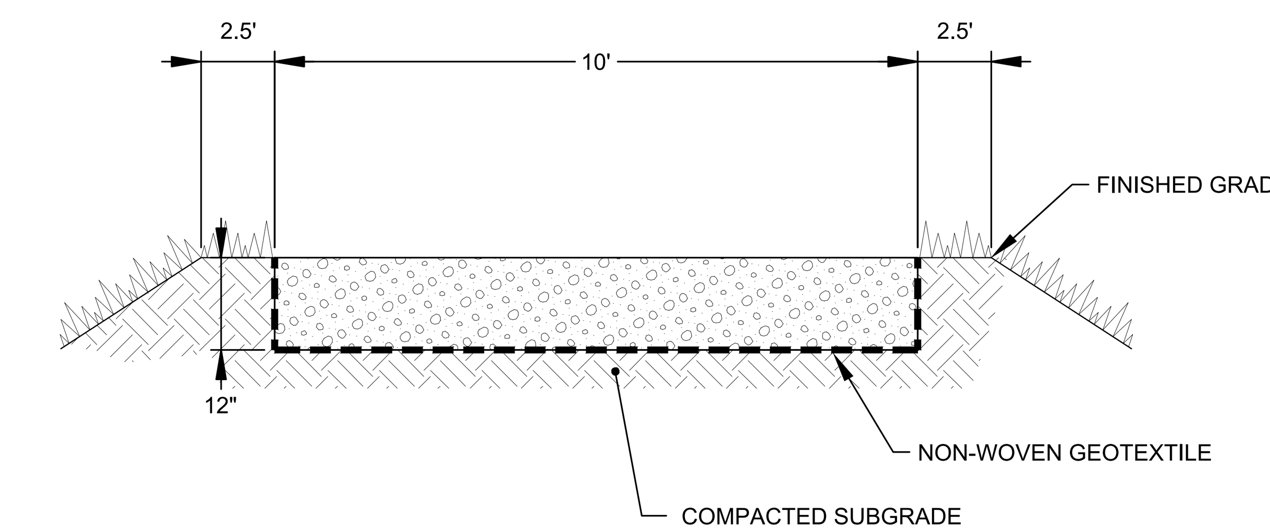
INDIVIDUAL CELL

GENERAL INSTALLATION NOTES:

1. SHAPE AND/OR SMOOTH SUBGRADE TO ACCEPT EXPANDED GEOCELL SECTIONS.
2. COMPACT SUBGRADE AND INSTALL GEOTEXTILE MATERIAL ALONG ALL GROUND INTERFACE AREAS. OVERLAP ADJACENT GEOTEXTILE PIECES A MINIMUM OF 2 FEET. PROVIDE ADE□UATE PINNING OF GEOTEXTILE FABRIC TO INHIBIT FABRIC MOVEMENT DURING GEOCELL INSTALLATION.
3. STAKE EDGES OF PROPOSED GEOCELL.
4. EXPAND GEOCELL. TOP OF GEOCELL SHALL BE FLUSH WITH FINAL GRADE.
5. PROPERLY ALIGN SECTIONS TO ENSURE ADJOINING PANELS ARE FLUSH AND MECHANICALLY CONNECT END SECTIONS.
6. BEING INFILLING ONLY AFTER ANCHORING IS IN PLACE. LIMIT DROP HEIGHT OF INFILL MATERIAL TO 3'.
7. ENSURE FILL IS FLUSH TO CELL TOP SURFACE AT COMPLETION OF WORK. AVOID EXCESSIVE OVERFILLING.

GEOCELL PANEL (5)

NOT TO SCALE



NORTH STORMWATER BASIN MAINTENANCE ACCESS ROAD (AT TOP OF BERM) (6)

NOT TO SCALE

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MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

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UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

ACCESS ROAD SECTIONS AND DETAILS

ARCADIS Project No. 30197838

Date FEBRUARY 2024

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SYRACUSE, NEW YORK 13202
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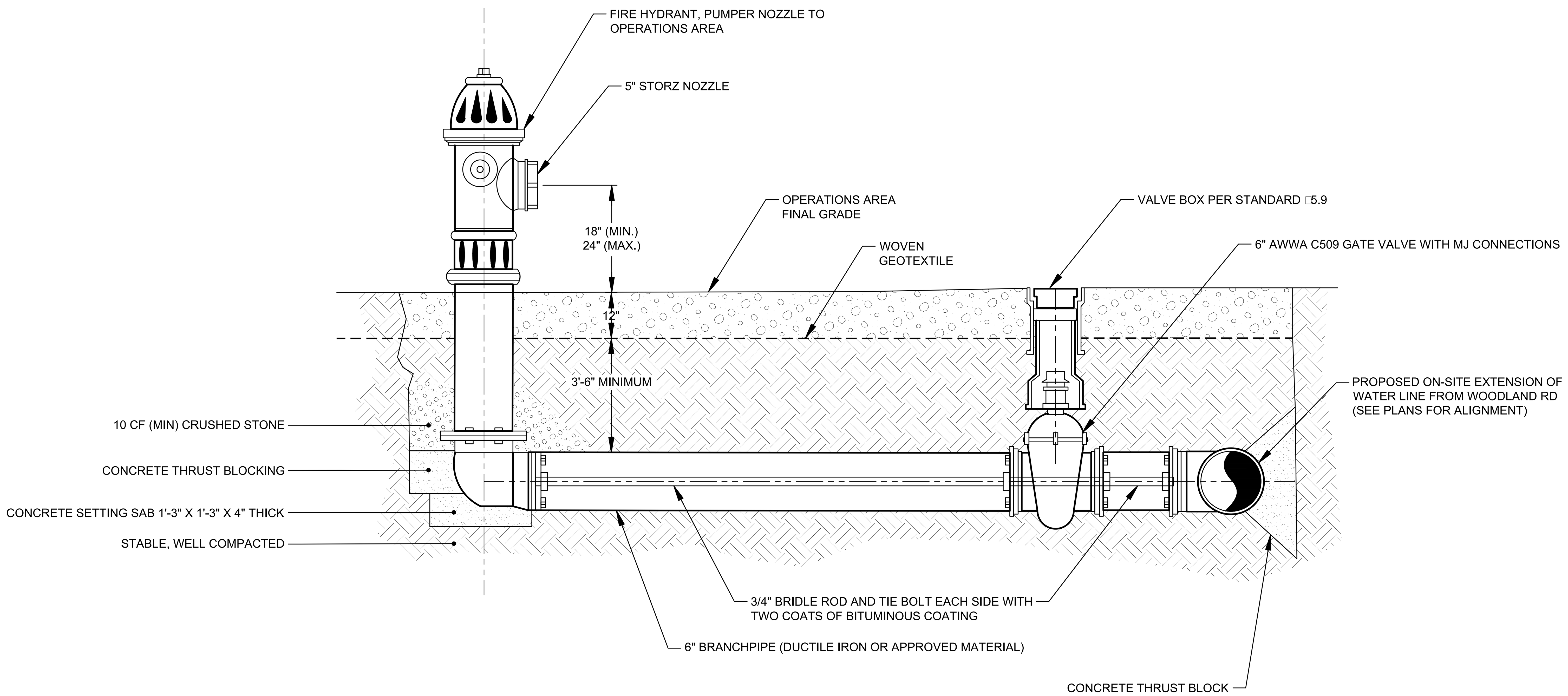
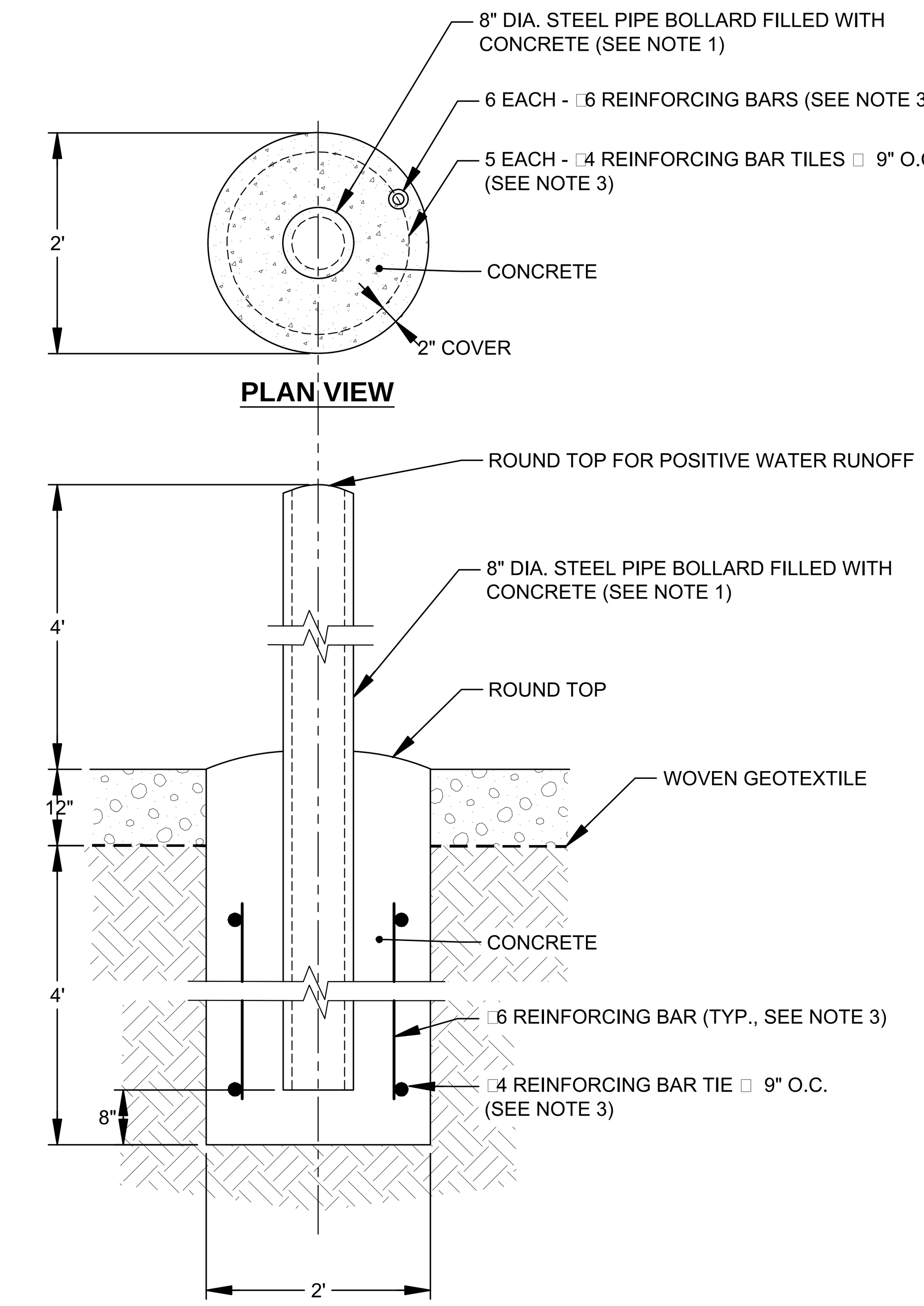


NOTES:

1. FOR HYDRANT INSTALLATION ON EXISTING MAIN, USE TAPPING SLEEVE AND VALVE.
2. RESTRAINING GLANDS MAY BE USED IN LIEU OF THREADED RODS IF APPROVED BY ENGINEER.

FIRE HYDRANT DETAIL 1

NOT TO SCALE



NOTES:

1. PIPE BOLLARD SHALL BE 8" DIAMETER (NOMINAL) SCHEDULE 40 STEEL PIPE (WALL THICKNESS APPROXIMATELY 0.32 INCHES) CONFORMING TOT THE RE□UIREMENTS OF ASTM A36 (STANDARD SPECIFICATION FOR CARBON STRUCTURAL STEEL).
2. PIPE BOLLARD SHALL BE PRIED AND PAINTED (MINIMUM TWO COATS) BY THE MANUFACTURER TO INHIBIT DEGRADATION. BOLLARD COLOR SHALL BE YELLOW UNLESS OTHERWISE DIRECTED BY THE OWNER OR ENGINEER.
3. REINFORCING BARS SHALL BE GRADE 60 DEFORMED BARS IN ACCORDANCE WITH ASTM A615 (STANDARD SPECIFICATION FOR DEFORMED AND PLAIN CARBON-STEEL BARS FOR CONCRETE REINFORCEMENT.

BOLLARD 2

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Professional Engineer's No.: 42983

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MA		DK
Designed by	Drawn by	Checked by
BMS	KLS	PHB

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UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

UTILITY DETAILS

ARCADIS Project No. 30197838
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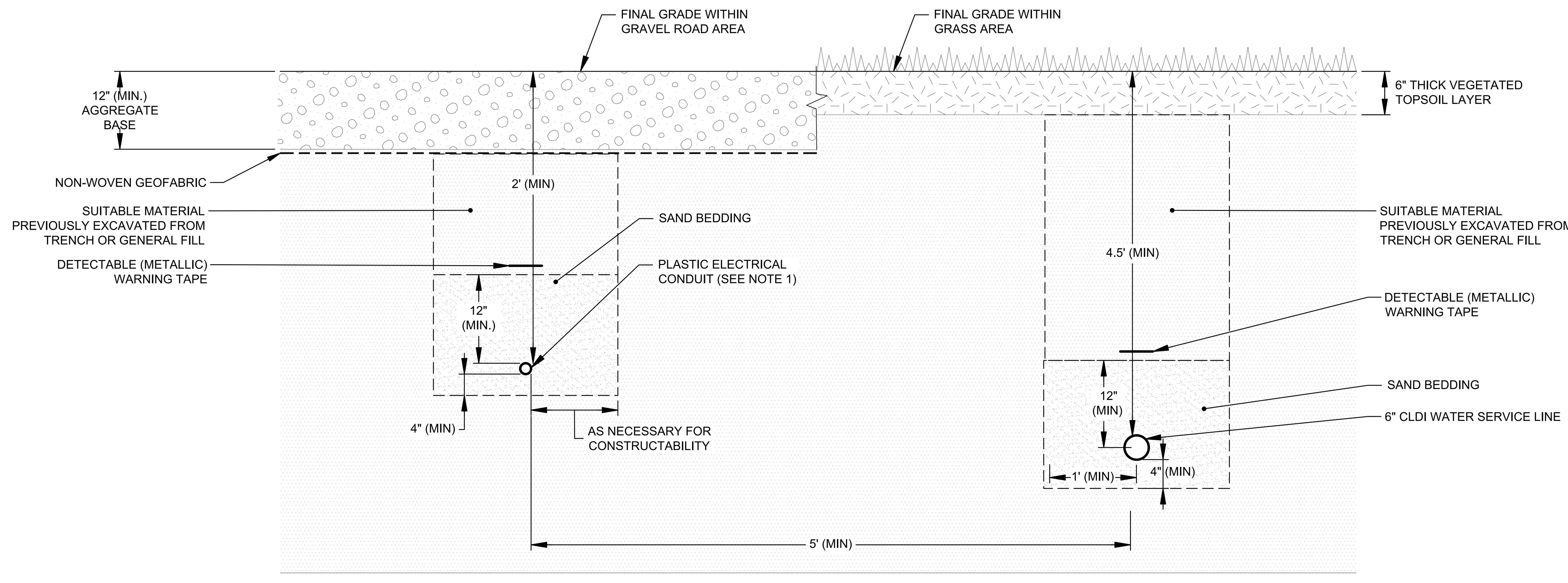
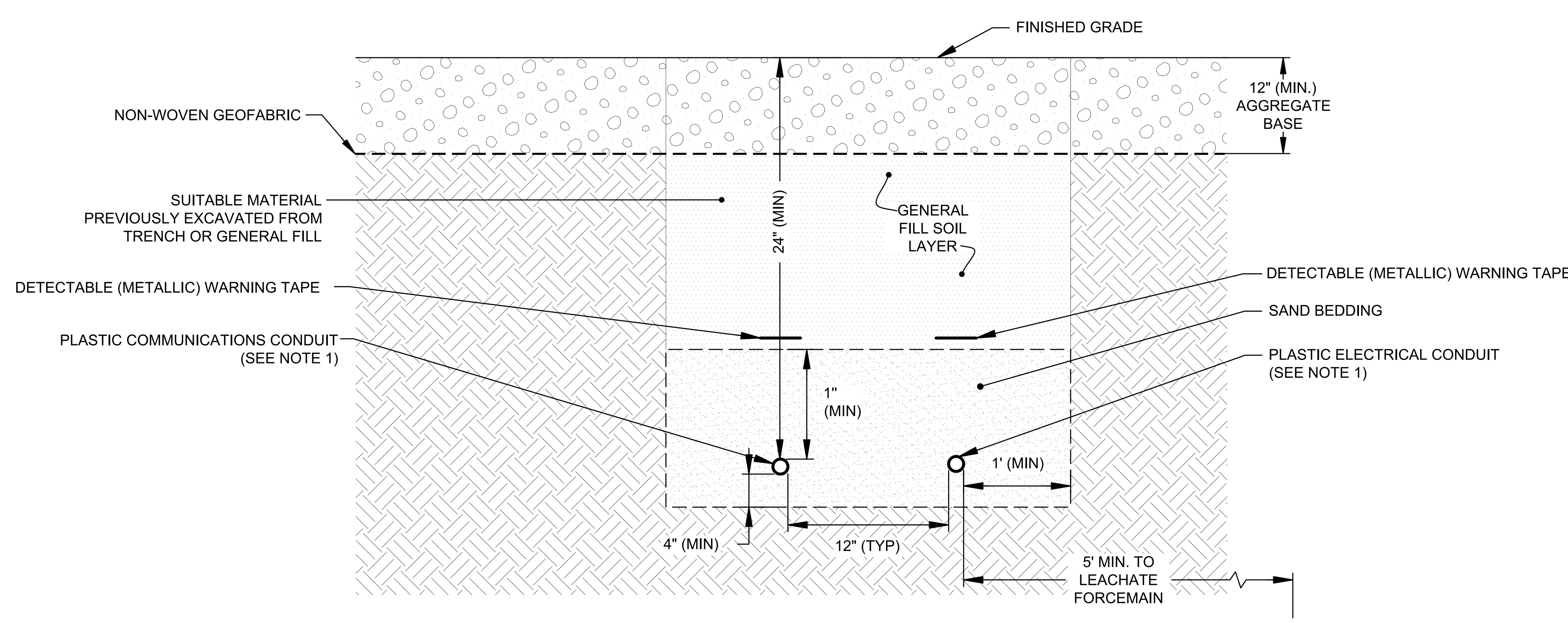


NOTES:

1. CONDUIT SIZES TO BE DETERMINED AT TIME OF CONSTRUCTION BASED ON NUMBER AND SIZE OF CONDUCTORS.
2. SITE SOIL MAY BE SUBMITTED FOR GEOTCHNICAL TESTING TO DETERMINE COMPLIANCE WITH SAND BEDDING MATERIAL REQUIREMENTS AND MAY BE USED AS SUBSTITUTE PENDING ACCEPTABLE EST RESULTS.

TYPICAL UTILITY TRENCHING WITH WATER SERVICE LINE (1)

NOT TO SCALE

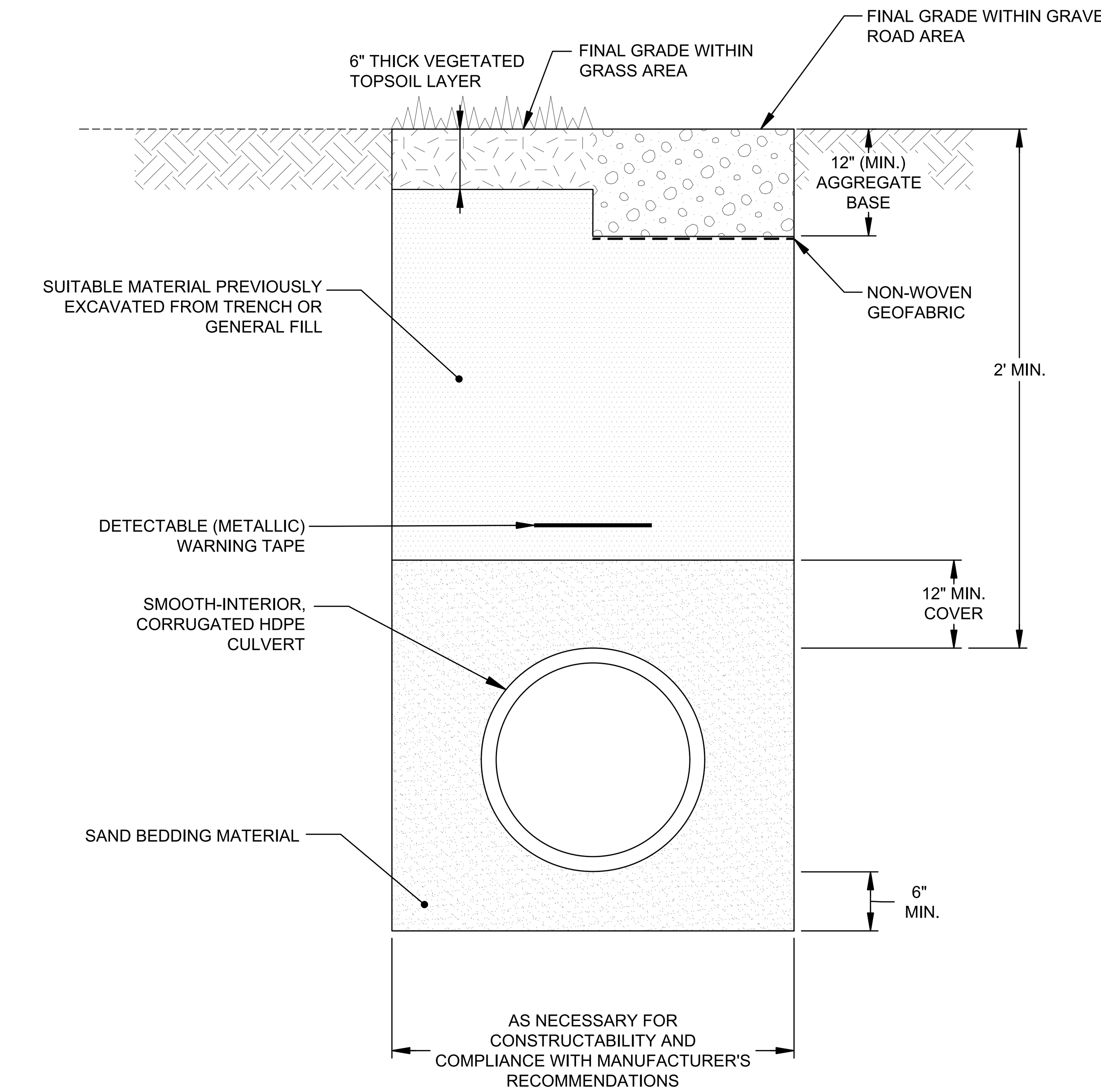


NOTE:

1. CONDUIT SIZES TO BE DETERMINED AT TIME OF CONSTRUCTION BASED ON NUMBER AND SIZE OF CONDUCTORS.

TYPICAL UTILITY TRENCH DETAIL WITHIN UDF PERIMETER ROAD (2)

NOT TO SCALE



NOTE:

1. COVER THICKNESS INDICATED IS TYPICAL EXCEPT AT CULVER INLET AND OUTLET.

TYPICAL CULVERT TRENCH DETAIL OUTSIDE LIMITS OF BASELINER (3)

NOT TO SCALE

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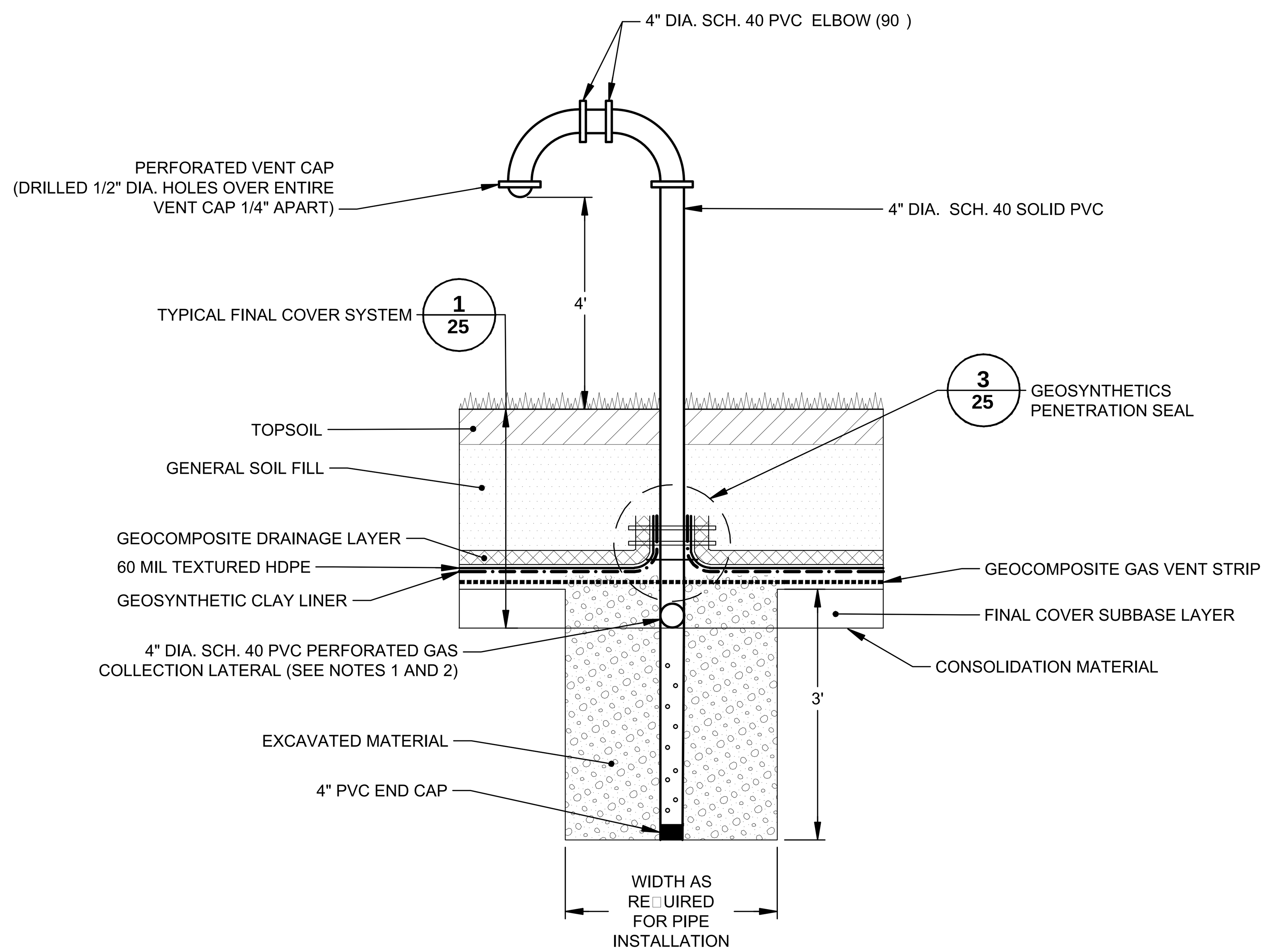
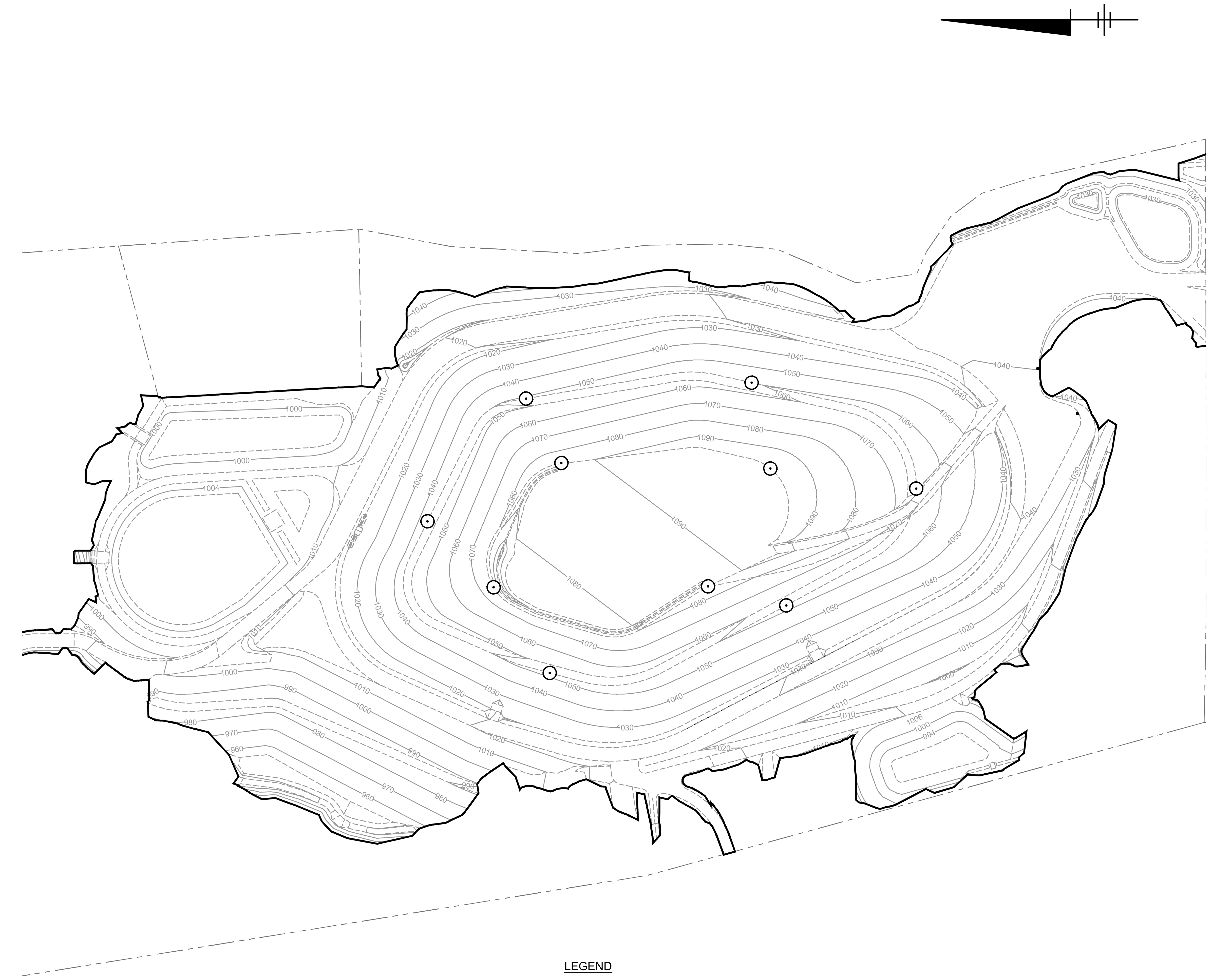


NOTES:

1. SEE DETAIL 2 THIS SHEET FOR GAS VENT LOCATIONS.
2. GAS COLLECTION LATERAL TO EXTEND 5' FROM GAS VENT ON BOTH SIDES.

GAS VENT (1)
NOT TO SCALE



LEGEND

⊙ GAS VENT

NOTE:

1. LOCATIONS AND NUMBER OF GAS VENTS SHOWN ARE FOR CONCEPTUAL PURPOSES ONLY.

GAS VENT LAYOUT (2)
0 150' 300'
SCALE: 1"=150'

SCALE(S) AS INDICATED	
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Professional Engineer's No. 42983		
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Designed by: BMS	Drawn by: KLS	Checked by: PHB

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GAS VENTING DETAILS

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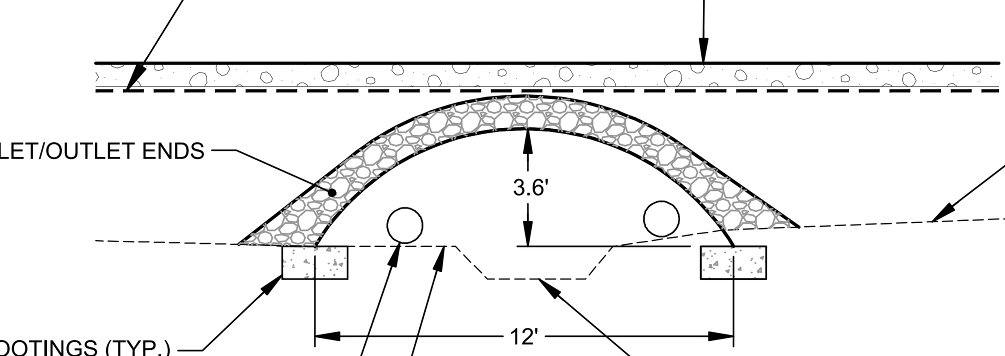
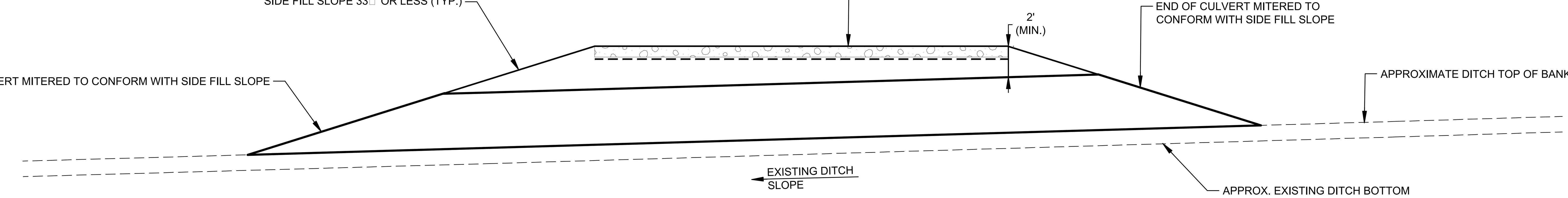


CROSS SECTION



PROFILE

NOTES:

1. EXISTING DITCH CHANNEL TO BE MAINTAINED DURING CULVERT INSTALLATION.
2. CULVERT FOOTING DESIGN TO BE PROVIDED BY CULVERT MANUFACTURER.

NORTH ACCESS ROAD OPEN ARCH CULVERTS (1)

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LEGEND:

- PIPING
- ELECTRIC SIGNAL
- CONTAINMENT BOUNDARY
- 4" PVC PIPING
- 4"/8" DOUBLE CONTAINMENT HDPE PIPING
- SUBMERSIBLE PUMP
- LOCAL INSTRUMENTATION
- PLC FUNCTION
- BALL VALVE
- CHECK VALVE
- CAMLOCK
- REDUCER BUSHING
- FLANGE CONNECTION
- PRESSURE INDICATOR
- FLOWMETER AND TOTALIZER

DESCRIPTION	PART #	41	CONDITION	ACTION
LOW LEVEL SWITCH	LSL-100	41	LOW LEVEL AT PRIMARY SUMP 1	STOP PUMP P-100
HIGH LEVEL SWITCH	LSH-100	41	HIGH LEVEL AT PRIMARY SUMP 1	START PUMP P-100
HIGH HIGH LEVEL SWITCH	LSHH-100	41	HIGH HIGH LEVEL AT PRIMARY SUMP 1	SIGNAL ALARM
LOW LEVEL SWITCH	LSL-110	41	LOW LEVEL AT SECONDARY SUMP 1	STOP PUMP P-110
HIGH LEVEL SWITCH	LSH-110	41	HIGH LEVEL AT SECONDARY SUMP 1	START PUMP P-110
HIGH HIGH LEVEL SWITCH	LSHH-110	41	HIGH HIGH LEVEL AT SECONDARY SUMP 1	SIGNAL ALARM
LOW LEVEL SWITCH	LSL-120	41	LOW LEVEL AT RISER VAULT 1	STOP PUMP P-120
HIGH LEVEL SWITCH	LSH-120	41	HIGH LEVEL AT RISER VAULT 1	"START PUMP P-120 SIGNAL ALARM"
LOW LEVEL SWITCH	LSL-200	41	LOW LEVEL AT PRIMARY SUMP 2	STOP PUMP P-200
HIGH LEVEL SWITCH	LSH-200	41	HIGH LEVEL AT PRIMARY SUMP 2	START PUMP P-200
HIGH HIGH LEVEL SWITCH	LSHH-200	41	HIGH HIGH LEVEL AT PRIMARY SUMP 2	SIGNAL ALARM
LOW LEVEL SWITCH	LSL-210	41	LOW LEVEL AT SECONDARY SUMP 2	STOP PUMP P-210
HIGH LEVEL SWITCH	LSH-210	41	HIGH LEVEL AT SECONDARY SUMP 2	START PUMP P-210
HIGH HIGH LEVEL SWITCH	LSHH-210	41	HIGH HIGH LEVEL AT SECONDARY SUMP 2	SIGNAL ALARM
LOW LEVEL SWITCH	LSL-220	41	LOW LEVEL AT RISER VAULT 2	STOP PUMP P-220
HIGH LEVEL SWITCH	LSH-220	42	HIGH LEVEL AT RISER VAULT 2	"START PUMP P-220 SIGNAL ALARM"
HIGH LEVEL SWITCH	LSH-001	42	HIGH LEVEL AT LEACHATE JUNCTION MANHOLE 1	SIGNAL ALARM
HIGH LEVEL SWITCH	LSH-002	42	HIGH LEVEL AT LEACHATE CONVEYANCE MANHOLE 1	SIGNAL ALARM
HIGH LEVEL SWITCH	LSH-003	42	HIGH LEVEL AT LEACHATE JUNCTION MANHOLE 2	SIGNAL ALARM
HIGH LEVEL SWITCH	LSH-004	42	HIGH LEVEL AT LEACHATE CONVEYANCE MANHOLE 2	SIGNAL ALARM
HIGH LEVEL SWITCH	LSH-005	43	HIGH LEVEL AT LEACHATE CONVEYANCE MANHOLE 3	SIGNAL ALARM
HIGH LEVEL SWITCH	LSH-300	43	HIGH LEVEL AT VALVE HOUSE	SIGNAL ALARM
HIGH LEVEL SWITCH	LSH-400	43	HIGH LEVEL AT TANK T-400	"STOP PUMPS P-100, P-110, P-200, P-210 SIGNAL ALARM"

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PROCESS & INSTRUMENTATION LEGEND AND TABLE

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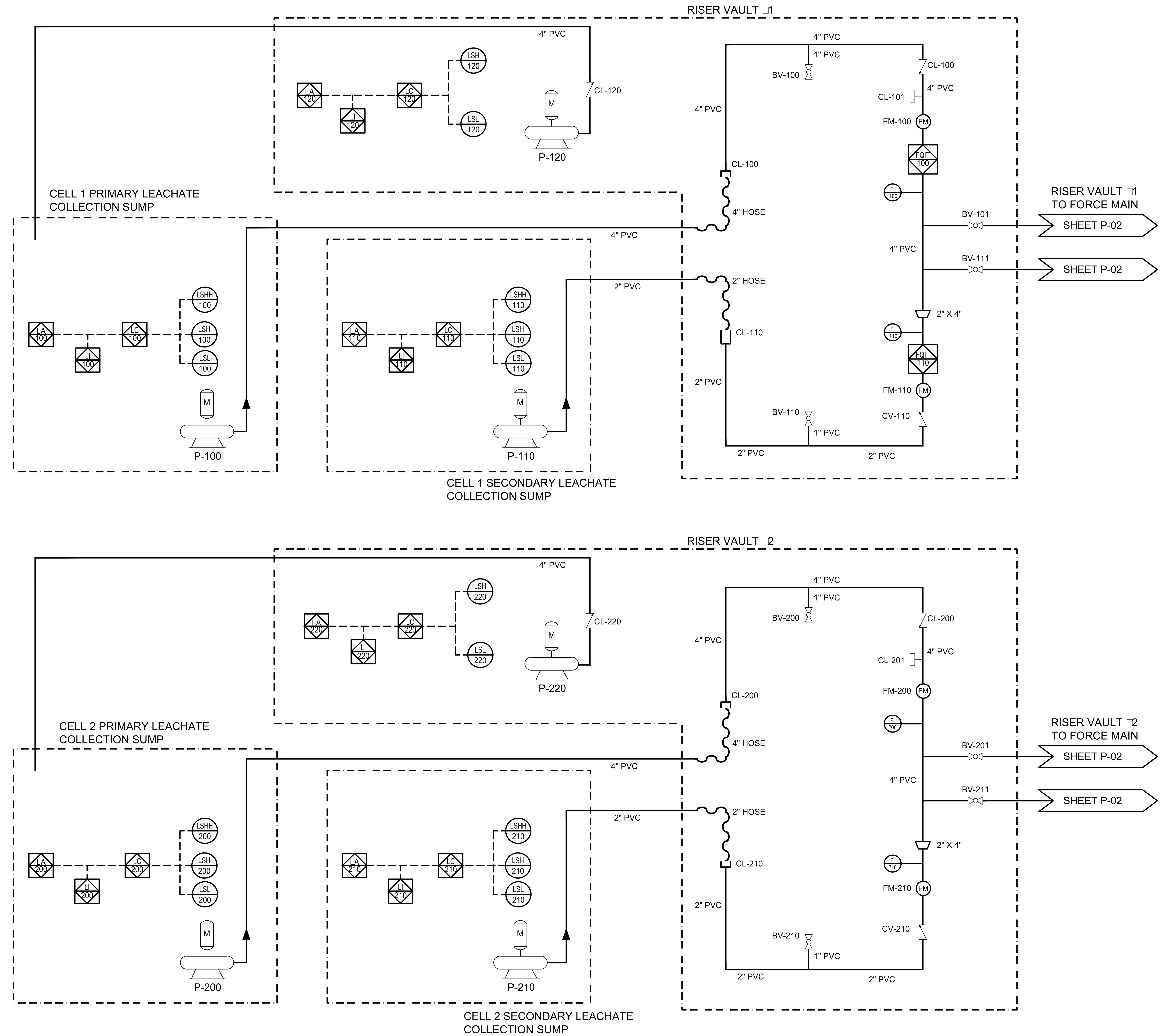

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PROCESS & INSTRUMENTATION DIAGRAM (1 of 3)

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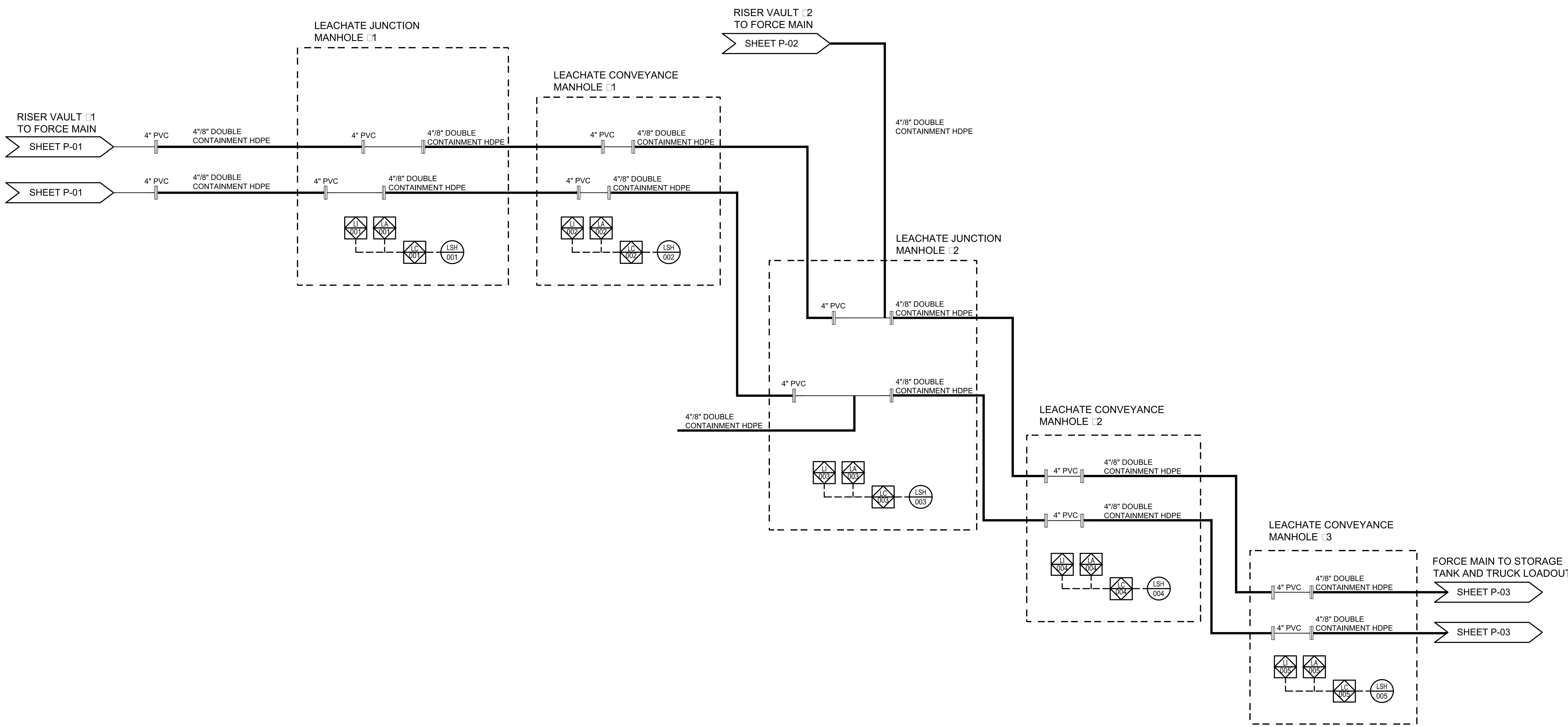

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Professional Engineer's No.: 42983

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Designed by	Drawn by	Checked by
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PROCESS & INSTRUMENTATION DIAGRAM (2 of 3)

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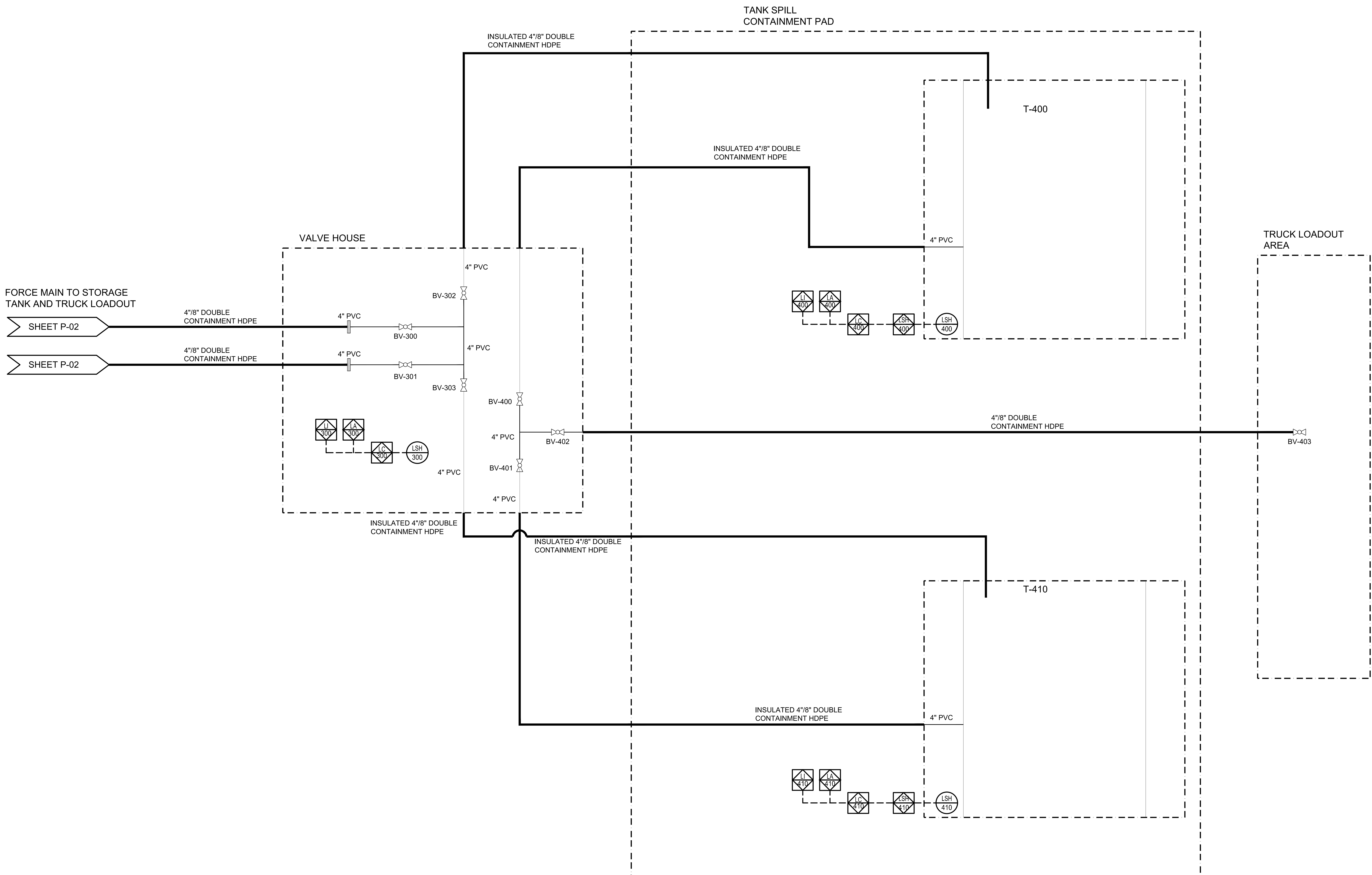

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PROCESS & INSTRUMENTATION DIAGRAM (3 of 3)

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Date FEBRUARY 2024

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Appendix B

Upland Disposal Facility Leachate Detection Response Action Plan

General Electric Company

Upland Disposal Facility Leachate Detection and Response Action Plan

GE-Pittsfield/Housatonic River Site

February 2024

Upland Disposal Facility Leachate Detection Response Action Plan

GE-Pittsfield/Housatonic River Site

February 2024

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Arcadis U.S., Inc.
One Lincoln Center, 110 West Fayette Street, Suite 300
Syracuse
New York 13202
Phone: 315 446 9120
Fax: 315 449 0017

Prepared For:
General Electric Company
1 Plastics Avenue
Pittsfield, Massachusetts 01201

Our Ref:
30197838

Table of Contents

Abbreviations

AR	Action Rate
CMR	Code of Massachusetts Regulations
EPA	U.S. Environmental Protection Agency
GCL	Geosynthetic clay liner
GDC	Geosynthetic drainage composite
GE	General Electric Company
GPAD	Gallons per acre per day
PLCS	Primary Leachate Collection System
RAP	Response Action Plan
ROR	Rest of River
SLCS	Secondary Leachate Collection System
UDF	Upland Disposal Facility

1 Introduction

1.1 General

This Response Action Plan has been prepared on behalf of the General Electric Company (GE) to present the monitoring conditions and response actions associated with the secondary leachate detection system for the Upland Disposal Facility (UDF) in Lee, Massachusetts. The UDF will be constructed and operated in accordance with the Revised Final Permit issued by the U.S. Environmental Protection Agency (EPA) on December 16, 2020 for the Rest of River (ROR) Remedial Action. The ROR consists of the portion of the Housatonic River and its backwaters and floodplain (excluding portions of certain residential properties) downstream of the confluence of the East and West Branches of the Housatonic River, which is located approximately two miles downstream from GE's former manufacturing facility in Pittsfield, Massachusetts. The Revised Final Permit requires GE to construct and utilize a UDF for the disposal of certain of the sediments and soils to be removed from the ROR area as part of the Remedial Action. The design intent of the UDF is to contain the removed sediments and soils within a low-permeability baseliner and cover system and to collect and treat leachate from the UDF.

On April 18, 2023, EPA issued a conditional approval letter for GE's December 2022 Conceptual Design Plan for the UDF. In that conditional approval letter, EPA required that GE prepare a Response Action Plan (RAP) to address the presence of leachate in the secondary liner system. This document constitutes that plan and specifies monitoring and (where necessary) actions for leachate that may be detected in the secondary liner system. The UDF RAP has also been prepared considering relevant components of 310 Code of Massachusetts Regulations (CMR) 19.110 related to leachate detection and secondary collection systems constructed between the primary and secondary liner systems.

1.2 Action Rate

This RAP presents a proposed Action Rate (AR) related to the presence of leachate within the secondary liner system for the UDF, which will be the trigger for implementation of actions as outlined herein. This proposed AR is based on the performance and design standards found in 310 CMR § 19.110(9) and the action rate described in that section. The proposed AR represents a rate that considers typical landfill operating conditions during the initial stages of filling within in a cell, which can result in a high inflow rate to the cell secondary leachate collection system (SLCS). Such higher inflow rates are expected to decrease in the later stages of filling operations and during closure of the UDF, as described in Section 2.

1.3 UDF Overview

The UDF area subject to the RAP includes the area designated for baseliner construction and consolidated material placement. The UDF baseliner area will be divided into two cells that are separated hydraulically by an intercell berm. Each cell will be approximately seven acres in size and are distinguished as Cell 1 (northern-most cell) and Cell 2 (southern-most cell).

1.3.1 UDF Liner System Description

As shown on Design Drawing 14, the UDF baseliner system will consist of the following components (in descending order):

- *Operations Layer*
  - One foot of graded aggregate underlain with a non-woven geotextile on the baseliner floor areas; and
  - Two feet of graded aggregate underlain with a non-woven geotextile on the baseliner sideslope areas.

- *Primary Leachate Collection System (PLCS)*
  - One foot of a granular drainage stone underlain with a geosynthetic drainage composite (GDC) on the baseliner floor areas; and
  - GDC on the baseliner side-slope areas.

- *Primary Liner System (includes two liners)*
  - A 60-mil textured HDPE geomembrane liner; and
  - A geosynthetic clay liner (GCL),

- *Secondary Leachate Collection System (SLCS)*
  - One foot of granular drainage stone underlain with a GDC on the baseliner floor areas; and
  - GDC on the baseliner side-slope areas.

- *Secondary Liner System (includes three liners)*
  - A 60-mil textured HDPE geomembrane liner;
  - A GCL; and
  - One foot of compacted soil clay liner.

1.3.2 Baseliner Leachate Collection and Removal

Each cell will include a PLCS and a SLCS, as well as separate riser pipes for leachate removal. The PLCS and SLCSs are being designed to collect and convey leachate to sump structures located at low points within each cell. Leachate accumulated in the primary and secondary sumps will be removed via pumping through side-slope riser pipes which will extend up from the cell sumps to the crest of the baseliner side slope, where the riser pipes will enter a vault structure that houses pumping equipment and controls. The process for removal of leachate from the sumps will be automated to provide removal at intervals needed to efficiently remove accumulated leachate and minimize hydrostatic head on the baseliner geomembranes. The leachate removal system will be monitored and provide data on liquid volumes removed from each cell. Further description of the UDF baseliner and leachate management systems is provided in Section 3 of the UDF Final Design Plan.

2 Action Rate

2.1 General

The purpose of this section is to quantify the AR related to leachate potentially encountered in the SLCS for each cell of the UDF. The AR will be defined as the quantity of liquid collected from the SLCS over a specified period, which when exceeded, will require certain actions to be taken as described in this RAP.

2.2 Inflow from the Primary Leachate Collection System

Inflow from the PLCS to the underlying SLCS can potentially occur through manufacturing and/or installation defects in the primary liner system geomembrane. The quantity of flow entering the SLCS from the PLCS, is a function of the liquid conditions within the PLCS. Additionally, other conditions such as the higher moisture content resident in the drainage layer materials at the time of placement, and filling operations can increase inflow rates to the SLCS.

During initial UDF operations, the cells will be uncapped and subject to water accumulation from precipitation events and to a lesser extent, moisture (water) within delivered consolidation material. With limited amounts of consolidated material available to absorb (within soil pore space) precipitation infiltration water, this infiltration water will enter the PLCS more rapidly than will be the case in later stages of filling and will result in a greater frequency of higher head conditions (and removal rates) on the primary liner geomembrane. In later stages of filling, the consolidated material (depending on delivered moisture content) will act to slow the progress of precipitation-based water inflows to the PLCS which will result in a lesser frequency of higher head conditions (and removal rates) on the primary liner geomembrane. In short, flows entering the SLCS are anticipated to decrease during the later stages of operations due to the reduced head conditions in the PLCS until capping of the UDF cells occur. Once capping of the cells is complete, the rate of inflow into the PLCS will decrease substantially which will minimize the source of inflow to the SLCS.

2.3 Action Rate Determination

For the purposes of this RAP, the AR for each of the UDF cells will be 100 gallons per acre per day (GPAD). This AR is based on the action rate specified in 310 CMR 19.110(9)(c) for leachate detected in the SLCS; it reflects the performance and design standards stated in 310 CMR 19.110(9)(a) and (b) and represents a 30-day rolling average (for any consecutive 30-day period).

3 Monitoring and Testing

Each SLCS sump will be electronically monitored for the presence of leachate. Leachate accumulated in the sumps will be pumped from the sumps via the side-slope riser pipes. The quantity of liquid removed from each sump will be measured and recorded for each pump cycle. The total daily inflow amount to each cell will be determined by adding the liquid quantities measured during each pump cycle over a 24-hour period. The daily inflow rate to each cell in gallons per acre per day can then be calculated by dividing the total daily removal amount by the constructed cell acreage.

After the initial 30 days of UDF operation (i.e., once consolidated material placement has commenced), the daily inflow rate to each cell will be determined each day on a 30-day rolling average basis (for 30 consecutive days). The calculated 30-day rolling average inflow rate will serve as a comparison metric to the AR specified in Section 2.3. Further discussion on comparison of the calculated cell daily inflow rates with the of the AR and associated monitoring thresholds is provided Section 4.

4 Response Actions

4.1 General

The purpose of this section is to outline the response actions corresponding to certain (trigger) inflow rates in comparison to the AR described in Section 2.3. Below those trigger inflow rates; no actions will be necessary beyond daily monitoring.

4.2 Inflow Rates Equal to or Above One-Half the Action Rate

For an inflow rate greater than or equal to 50 GPAD and less than 100 GPAD observed on a 30-day average rolling basis, GE will notify EPA within 72 hours of the occurrence and routine monitoring and operations will continue. One notification will be made for each 30-day period if inflow rates persist for greater than 30 days.

4.3 Inflow Rates Equal to or Above the Action Rate

For an inflow rate equal to or above 100 GPAD observed on a 30-day average rolling basis, GE will notify EPA within 24 hours of the occurrence and will perform a desktop review of available data for the UDF and report the findings of that review to EPA within 15 days following the initial notification to EPA. This review may include evaluation of weather conditions, construction work completed at the UDF, and UDF operations (consolidated material filling, leachate management). If the subject inflow rate can be attributed to temporary conditions (e.g., large or prolonged precipitation events, changing operational activities), then routine monitoring and operation will continue without the need for further action. If, however, the increased inflow rate is determined to be attributed to a condition that can be mitigated, an appropriate response action will be proposed to EPA for review and approval.

Potential response actions will be dependent on operational conditions and the results of the desktop review described above, but may include actions such as adjustment to consolidated material filling operations, changes to runoff water management within the cells, and leachate system equipment modifications. Upon EPA review and approval, the agreed-upon response action(s) will be implemented and monitoring and operation of the UDF will continue.

4.4 Single Day Inflow Rate Greater Than Twice the Action Rate

If the cell SLCS inflow rate from a single day is greater than twice the AR (i.e., 200 GPAD), GE will notify EPA within 24 hours and issue a stop-work directive for any operational activities. GE will also then immediately begin performing the above-described desktop review and initiate potential response actions as described in Section 4.3.

5 Documenting and Reporting

As mentioned in Section 1.3.2, removal of leachate from the cells will be automated to provide efficient leachate removal at intervals needed to minimize hydrostatic head on the baseliner geomembranes. This automation will include electronic monitoring of the SLCS with documentation of data collected for the frequency and liquid quantities pumped. The collected data will be processed daily through automated computation to determine the inflow rate to the SLCS that will be used for comparison to the AR.

GE will maintain records of the recorded inflow rates, any exceedances of the AR and response actions performed, and general operation of the SLCS (i.e., leachate quantities removed, inflow and leachate removal trends, maintenance performed).

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Appendix C

Technical Specifications

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SECTION 01 57 00 - TEMPORARY CONTROLS

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. The Contractor shall provide and maintain methods, materials, equipment, and temporary construction as required for controlling environmental conditions at the Site and adjacent areas during construction.

2. Maintain temporary controls until no longer required. Provide temporary controls at all times when The Contractor is working at the Site.

3. Temporary controls include, but are not limited to, the following:
   1) Dust controls.
   2) Odor controls.
   3) Noise controls.
   4) Lighting controls.
   5) Pollution controls.

B. Related sections

1. Section 31 25 00 Soil Erosion and Sediment Controls

1.02 SUBMITTALS

A. PROCEDURAL SUBMITTALS: SUBMIT THE FOLLOWING PLANS (SEPARATE OR AS PART OF CONTRACTOR'S OPERATIONS PLAN:

1. Dust Control Plan.

2. Odor Control Plan.

3. Noise Control Plan.

4. Lighting Control Plan

5. Pollution Control Plan.

B. PRODUCT DATA: SUBMIT MANUFACTURER'S PRODUCT DATA, SPECIFICATIONS, AND INSTALLATION INSTRUCTIONS FOR THE FOLLOWING:

1. Odor mitigation agents and proposed application and storage equipment for each.

2. Pollution control products and proposed application for each.

3. Monitoring equipment.

PART 2 – PRODUCTS

2.01 DUST CONTROLS

A. Water: Clean, potable

B. Source:

1. Identify water sources to be used by Contractor for Site dust control.

2. Provide water application measures and equipment for dust control.

2.02 ODOR CONTROLS

A. Odor Mitigation Agents, provide the following:

1. Short-Duration Mitigation Agent:
   a. BioSolve® Pinkwater®, by The BioSolve Company.
   b. Or equal.
2. Long-Duration Mitigation Agent:
   a. AC-645 Long-Duration Foam, by Rusmar, Inc.
   b. Or equal.

B. Water: Clean, potable.

C. Provide pressure washers, pneumatic foam unit, portable tanks, hoses, and other equipment required for the mixing, storage, and application of odor mitigation agents and water.

2.03 POLLUTION CONTROLS

A. Provide spill kits and oil-absorbent pads, rolls, and booms (and john boat for measure deployment) as required to contain spills, should they occur, and prevent the potential migration of pollutants in accordance with all applicable Laws and Regulations. Spill kits shall be located near to active work areas and dispersed around the Site at equipment and petroleum filling/storage areas.

PART 3– EXECUTION

3.01 DUST CONTROL

A. Construction Techniques and Best Management Practices (BMPs):

1. Remove, place, load, handle, and unload soil materials and clean backfill materials, in manner that minimizes the generation of dust.

2. To minimize airborne dust, apply water or use other methods subject to acceptance of Engineer.

3. The Contractor shall prevent blowing and movement of dust from exposed soil surfaces and access roads to reduce on- and off-Site damage, nuisances, and health hazards associated with dust emissions. Control may be achieved by irrigation in which the Site shall be sprinkled with water until the surface is moist. Apply dust controls as frequently as required without creating nuisances such as excessive mud and ponding of water at the Site.

4. Temporarily covering stockpiles with polyethylene liners or mulch before extended work breaks and at the end of each workday. Anchor liners to resist wind forces; slope to prevent accumulation of water.

5. For disturbed soil areas and where practicable, use temporary vegetation cover to control dust.

6. The Contractor shall implement measures such as reducing construction vehicle speeds on and near to the site to mitigate the generation of dust.

7. If deemed beneficial for use in certain Site roadway areas, the Contractor may place additional road cover materials, such as aggregates or pavements, to control and reduce dust generation.

8. Assessing wind conditions to determine if vehicle routes could be adjusted to minimize dust generation.

B. Dust standards for particulate matter associated with construction activities shall comply with the provisions described in Section 4.3 of the Quality of Life Compliance Plan (Anchor-QEA and Arcadis, 2023).

3.02 ODOR CONTROL

A. General:

1. Provide means, methods, and facilities required to control odors generated by the Work.

2. Proactively employ odor controls during the Work and evaluate and modify construction techniques and site management practices, as necessary and appropriate, to control objectionable odor caused by the Contractor's operation of vehicles and equipment, and other actions.

3. If the Contractor's means, methods, and facilities are unsuccessful in controlling Work-related odors as specified in this Section, based on the results of air monitoring, Work shall be suspended until appropriate corrective actions are taken by the Contractor to remedy the situation to Engineer's satisfaction. The Owner will not be liable for any expense or delay resulting from the Contractor's failure to control odors in accordance with this Section.

B. Odor Mitigation Agents:

1. Mobilize odor mitigation agents and means of storage and dispersion at the Work Area before initiating any ground-intrusive Work or dust-generating Work.

2. Application of odor mitigation agents shall be as follows:
   a. BioSolve Pinkwater:
      1) Prepare three-percent solution of BioSolve® Pinkwater® concentrate and water. Apply to exposed consolidation materials using backpack sprayers, power washers, or misters.
      2) When odors encountered, apply when actively managing consolidation materials within the UDF cells, and as required by the Owner or Engineer.
   b. AC-645 Long-Duration Foam:
      1) Prepare 13-percent solution of AC-645 Long-Duration Foam concentrate and water. Apply to excavation faces and uncovered stockpiles of staged remediation materials using pneumatic foam unit. Completely and uniformly cover exposed sediment surfaces with minimum three inches of foam.
      2) When odors encountered, apply before each work break, at the end of each workday, and as required by the Owner or Engineer.

C. Odor standards associated with construction activities shall comply with the provisions described in Section 4.4 of the Quality of Life Compliance Plan (Anchor-QEA and Arcadis, 2023).

3.01 NOISE CONTROL

A. The Contractor’s activities shall minimize noise emissions to greatest degree practicable. Measures employed by the Contractor to control and mitigate noise emissions include, but are not limited to, the following:

1. Use of properly muffled motorized equipment.
2. Scheduling of sitework activities to minimize heavy concentrations of equipment use that might result in prolonged or excessive elevated noise levels to avoid early morning or nighttime hours.
3. Use of sound-attenuating barriers around stationary equipment.
4. Controlling the speed at which equipment is operated.
5. Use of quieter backup alarms on certain construction equipment that frequently operates in reverse (e.g., front-end loaders and dump trucks).

B. Noise levels associated with construction activities shall comply with the provisions described in Section 4.4 of the Quality of Life Compliance Plan (Anchor-QEA and Arcadis, 2023).

3.02 LIGHTING CONTROL

A. Lighting Control Measures:

1. Supply lighting sufficient to provide safe conditions during low-light and nighttime operations, including compliance with applicable regulations of the Occupational Safety and Health Administration.
2. Provide fixed lighting where necessary for safe illumination of certain work areas (e.g., equipment and material staging areas, access ways, contractor facilities).

B. Employ light control BMPs to minimize or limit the potential off-site nuisance impacts generated by lighting during construction activities:

a. Proper positioning of lights.
b. Adjusting the brightness of lights used.
c. Proper setting of beam direction for fixed lighting.
d. Limiting height of light masts to extent practicable.
e. Shielding of lights to the extent practicable

C. Lighting standards associated with construction activities shall comply with the provisions described in Section 4.6 of the Quality of Life Compliance Plan (Anchor-QEA and Arcadis, 2023).

3.03 POLLUTION CONTROL

A. Pollution Control – General:

1. Provide means, methods, and facilities required to prevent contamination of soil, water, and atmosphere caused by discharge of noxious substances from construction operations.
2. Equipment used during construction shall comply with Laws and Regulations.

3. Hazardous Materials brought to the Site by the Contractor shall be identified in the Contractor's Health and Safety Plan.

4. Provide equipment and personnel to perform emergency measures required to contain spills and to remove contaminated soils and liquids caused by the Contractor's operations.

B. Protection of Surface Waters: Implement special measures to prevent harmful substances from entering surface waters. Prevent disposal of wastes, effluents, chemicals, and other such substances in or adjacent to surface waters and open drainage routes, in sanitary sewers, or in storm sewers.

C. Atmospheric Pollutants:

1. Provide systems for controlling atmospheric pollutants related to the Work.

2. Prevent toxic concentrations of chemicals and vapors.

3. Prevent harmful dispersal of pollutants into atmosphere.

D. Solid Waste:

1. Provide systems for controlling and managing solid waste related to the Work.

2. Prevent solid waste from becoming airborne, and from discharging to surface waters and drainage routes.

3. Properly handle and dispose solid waste.

4. Perform Regular Cleaning:
   a. The Contractor must remove all scrap or removed material, debris or rubbish from the Project work site at the end of each working day and more frequently whenever the Owner Field Representative deems such material to be a hazard.
   b. The Contractor cannot discard materials on the grounds of the Owner without the express permission of the Project Director.
   c. No salvage or surplus material may be sold on the premises of the Owner.
   d. No burning of debris or rubbish is allowed.
   e. Any recycled materials must be recycled, and the Contractor will be required to provide recycling plan.

3.04 PROHIBITED CONSTRUCTION PROCEDURES

A. Prohibited construction procedures include, but are not limited to, the following:

1. Dumping or disposing of spoil material, cleared vegetation, debris, or other waste material in any surface waters, drainage ways, or other unauthorized locations.

2. Indiscriminate, arbitrary, or capricious operation of equipment in any surface waters, drainage ways, or other unauthorized locations.

3.05 REMOVAL OF TEMPORARY CONTROLS

A. Remove temporary controls only when directed by the Owner or Engineer.

END OF SECTION

SECTION 01 73 30 - WASTE MANAGEMENT

PART 1 - GENERAL

1.01 WORK SPECIFIED

A. Contractor management and disposal of wastes generated during performance of the Work.

B. Submittals for Waste Management.

1.03 SUBMITTALS

A. Prepare and submit a Waste Management Plan (WMP) to the CM 30 days prior to mobilization to the Site.

B. The WMP shall contain the following:

1. Analysis of the proposed Site waste to be generated by Contractor, including types and anticipated quantities of each. The list of waste materials shall include, at a minimum, the following materials:
   a. Cardboard
   b. Clean dimensional wood
   c. Excess soil
   d. Wood pallets
   e. Demolition debris
   f. Fencing materials
   g. Concrete curing water
   h. Clean-up water
   i. Water used in operations, and similar activities (excludes water used for dust control)

2. Materials Handling Procedures: Description of how waste materials identified in Section 1.03 B.1 above will be managed on-site and a description of the means to be employed in disposal or recycling the materials.

3. Transportation: Describe the means of transportation of the recyclable materials (whether materials will be site-separated and self-hauled to designated centers, or whether mixed materials will be collected by a waste hauler and removed from the Site) and destination of such materials.

4. Hazardous Wastes: Identify potentially hazardous materials (if any) that may occur at the Site and describe the method for management and disposal of those hazardous waste materials.

5. Describe the method of recycling office materials such as clean white paper, mixed paper, toner cartridges for laser printers, copiers, and fax machines. Each item shall be recycled in accordance with the manufacturer's instructions.

6. List haulers, transfer stations and recyclers (with addresses and phone numbers) which the Contractor intends to utilize.

7. Note the coordination of product deliveries to designated prepared areas to minimize storage time on the Site and potential damage to stored materials and the return of packing materials, e.g., wood pallets, 55-gallon drums, where economically feasible.

C. Submit to the CM a record of each material recycled, reused, or salvaged and each construction waste dumpster removed from the Site on a monthly basis. The record shall include the amount of the material removed (in tons or cubic yards), the date on which it was removed and the receiving party. This record shall include copies of manifests, weight tickets, receipts, or invoices for each item disposed.

PART 2 - RODUCTS (NOT USED)

PART 3 - EXECUTION

Dispose of wastes as specified below, and in accordance with the Contract Documents.

3.01 SOLID WASTES

A. Contractor will provide waste containers at the Site for solid waste generated from the work. Locate containers in an area approved by the CM. The Contractor shall transport solid waste off of the Site and dispose of it in compliance with federal, state, and local requirements for solid waste disposal. A Subtitle D RCRA-permitted landfill shall be the minimum acceptable solid waste disposal option. The Contractor shall verify that the selected transporters and disposal facilities have the necessary permits and licenses to operate.

3.02 CHEMICALS AND CHEMICAL WASTES

A. Provide for containers and the disposal of chemicals and chemical wastes generated by Contractor off of the Site. Waste storage shall be in compliance with applicable RCRA regulations and stored in an area approved by the CM. Chemicals shall be dispensed ensuring no spillage to the ground or water. Periodic inspections of dispensing areas to identify leakage and initiate corrective action shall be performed and documented. This documentation will be periodically reviewed by the CM. Chemical waste shall be collected in corrosion-resistant, compatible containers. Collection drums shall be monitored and removed to a staging or storage area when contents are within 6 inches of the top. Wastes shall be classified, managed, stored, labeled, and disposed of in accordance with federal, state, and local laws and regulations.

3.03 CONTRACTOR-GENERATED HAZARDOUS WASTES

A. Contractor shall provide for containers and the disposal of contractor-generated hazardous wastes/excess hazardous materials (i.e., non-remediation related waste materials) off Site. Hazardous wastes are defined in 40 CFR 261 or are as defined by applicable state and local regulations. Hazardous materials are defined in 49 CFR 171 - 178. The Contractor shall, at a minimum, manage and store hazardous waste in compliance with 40 CFR 262. Waste storage shall be in compliance with RCRA regulations and in an area approved by the CM. The Contractor shall take sufficient measures to prevent spillage of hazardous and toxic materials during dispensing. The Contractor shall segregate hazardous waste from other materials and wastes; protect it from the weather by placing it in a safe covered location; and take precautionary measures such as providing secondary containment, berming, and other appropriate measures against accidental spillage. The Contractor shall be responsible for storage, describing, packaging, labeling, marking, and placarding of hazardous waste and hazardous material in accordance with 49 CFR 171 - 178, state, and local laws and regulations.

B. The Contractor shall transport Contractor-generated hazardous waste off Site in accordance with the Environmental Protection Agency and the Department of Transportation laws and regulations. The Contractor shall dispose of hazardous waste in compliance with federal, state and local laws and regulations. Spills of hazardous or toxic materials shall be immediately reported to the CM. Cleanup and cleanup costs due to spills shall be the Contractor's responsibility. The disposition of Contractor-generated hazardous waste and excess hazardous materials are the Contractor's responsibility.

3.05 RECYCLING AND WASTE MINIMIZATION

A. The Contractor shall participate in state and local government-sponsored recycling programs. The Contractor is further encouraged to minimize solid waste and hazardous waste generation throughout the duration of the Project.

3.06 PERSONAL PROTECTIVE EQUIPMENT (PPE) DISPOSAL

A. During operations, Contractor shall place into bags its own PPE that may potentially be contaminated. PPE and bagged PPE shall not be mixed with or mingled with remediation soils or debris. The Contractor shall be responsible for securing and controlling its bagged PPE.

3.07 CONTAMINATED WASTES

A. Potentially contaminated waste debris will be segregated/containerized and waste characterization sampling will be conducted. Once the waste has been characterized, the waste will be disposed of off-Site at a Owner-approved disposal facility.

END OF SECTION

SECTION 02 21 00 - SURVEYS

PART 1 – GENERAL

1.01 DESCRIPTION

A. The Contractor shall provide survey control sufficient to support the overall Project and document the performance of the work.

B. The Contractor will employ a licensed Surveyor to provide the surveying functions necessary for the proper construction and documentation of the work. All survey related work products will be sealed and signed by a registered Massachusetts Professional Engineer or Licensed Surveyor.

C. Survey control for construction and documentation purposes will be the responsibility of the Contractor. The Contractor will safeguard all survey points and benchmarks. Should any of these points be destroyed, the replacement cost will be borne by the Contractor. The Contractor will assume the entire expense of rectifying work improperly constructed due to failure to maintain and protect such established survey points and benchmarks.

D. Contractor shall furnish and/or provide all supervision, labor, tools, materials, equipment, services, and appurtenances necessary for, or incidental to, completing all work necessary for performing the surveying activities described herein and preparing required as-built survey data and drawings of pre-construction, interim, and post-construction grades.

1. The Contractor will perform topographic surveys to verify the design grades (i.e., subgrades and final grades) are met. The Contractor will prepare topographic drawings to document the constructed design conditions (i.e., alignments, elevations slopes).
2. During operation of the Upland Disposal Facility (UDF), the Contractor will perform surveying to track and document fill conditions and progress of remedial consolidation materials placed in the UDF cells.
3. All contingency surveying will be conducted at the Contractor's sole expense with no additional cost to the Owner.

1.02 APPLICABLE CODES, STANDARDS, AND SPECIFICATIONS (NOT USED)

1.03 SUBMITTALS

A. Survey Plan: The Contractor will submit a Survey Plan for review and approval by the Owner and Engineer 3 weeks prior to the start of any survey related field work. The Plan will include the following:

1. Survey Schedules and Crew
    a. The Plan will include all milestone and other field survey activities for the project.

b. The Plan will include name, address, telephone number, and qualifications, including licensure and/or certification, of the surveyor, crew chief, superintendent, and all other persons who are proposed to perform surveys or survey related duties to the Owner for review and approval.

B. Survey Data Records

1. The Contractor will furnish the Owner and Engineer with copies of project field notes, computations, any records relating to the layout of the work and information on any computer software required to interpret the finished data and records for review and approval prior to the final progress payment. The Owner and Engineer will use them as necessary to verify completion of the project work prior to submittal of the final payment. The Contractor will retain copies of all such material furnished to the Owner and Engineer.

2. Survey data will be provided in x, y, z, d (easting, northing, elevation, description) format. Each data file must include a descriptive header including, but not limited to: software and equipment information, project name and client, horizontal and vertical datum, units, survey type, alignment, and stations surveyed.

3. The Contractor will maintain a complete, accurate log of survey work as it progresses at the Site.

4. The accuracy of the Contractor's survey and other furnishing of data to the Engineer do not constitute a transfer of responsibility for verifying accuracy.

C. As-Built Drawings. Upon completion of major phases of Work, Contractor shall submit a copy of the associated survey drawing with contour data in a format compatible with AutoCAD Civil 3D 2023 and in PDF.

1. Drawings shall include the surveyed surface elevation contours (1 foot resolution), alignments and limits of surveyed conditions, and survey points for constructed features.

1.04 PERFORMANCE CRITERIA/QUALITY ASSURANCE

A. The Contractor must have a minimum of 5 years' experience completing the type of work specified herein.

B. All survey data acquisition, layout, and related work will be performed and signed by a licensed Surveyor.

C. The Contractor will conduct and document the quality control procedures recommended by the survey equipment manufacturer for the equipment used.

D. Survey will be conducted to meet the requirements specified herein; including, but not limited to, documenting the completed construction work with accuracy sufficient to allow for evaluation and confirmation the project work is being completed in conformance with the Contract Documents.

E. When applicable, the Contractor will regularly resurvey benchmarks for comparison with original elevations and positions. Where the Contractor uses the laser for control, he will periodically check the grade and alignment during each day's operation. The Contractor will promptly notify the Engineer if changes in elevations or positions occur to be reviewed for consistency with Design Drawings.

PART 2 – PRODUCTS (NOT USED)

PART 3– EXECUTION

3.01 GENERAL

A. The Contractor will exercise care during the execution of the work activities specified herein to minimize any disturbance to existing property and to the landscape and waters in the areas surrounding the work areas. Survey crews will not traverse into controlled areas or private property without first obtaining approval by the Owner or Engineer.

B. The Contractor will reference survey points to the provided survey control points and record all survey locations, with horizontal and vertical data, on project record documents.

C. Unless otherwise approved by the Engineer, topographic survey data shall be collected on a 10-foot by 10-foot grid or wherever the elevation changes more than 1 foot. Survey shall document location of grade breaks and edges of construction areas as appropriate. Structures and features exiting within the survey limits shall be surveyed and identified on the survey drawings.

3.02 PRE-CONSTRUCTION SURVEY

A. Contractor shall perform pre-construction surveys of Site construction areas, as needed, to document existing site conditions.

B. Pre-construction survey data and drawings shall be submitted to the Engineer at least one week prior to the start of earthwork activities in the surveyed areas, unless otherwise allowed by the Engineer.

3.03 UDF OPERATIONS FILL PROGRESSION SURVEYING

A. During UDF operations, fill progression surveys shall be conducted at least on an annual basis throughout the operation of the UDF. The annual fill progression survey will be completed at the end of consolidation material placement for the year.

B. Surveys shall verify that the maximum slopes within the cell consolidation areas are not exceeded.

C. Surveys shall be of sufficient detail and definition to allow for evaluation of constructed consolidation material grades with the design grades shown on the Design Drawings.

D. Surveys shall be of sufficient detail and definition to allow for volumetric computations of consolidation material placed.

3.04 POST-CONSTRUCTION SURVEY

A. The Contractor shall perform post-construction topographic and feature surveys to document the completed work and to confirm restoration to pre-construction conditions or other elevations as required. At a minimum, these surveys shall obtain the following information:

1. Location and identification of structures and features (e.g., building walls and structures, hydrants and shutoff valves, roads, fences, poles, equipment, etc.). For building walls and structures, include top and bottom elevations.
2. Surface topography and slope break lines for prominent grade changes.
3. Location and identification of drainage features (e.g., culvert pipes, subsurface pipes, manholes, catch basins, ditches, swales, pipe inlets/outlets, riprap protection, check dams, berms, etc.). Include descriptions of material types, pipes and sizes, manholes, catch basins, etc.).
4. Elevation of drainage systems (i.e., pipe and channel inverts, manhole and catch basin rim and sump, check dams and berm toes and crests).

3.05 CONTROL OF WORK

A. Reference Points

1. Established reference points damaged or destroyed by Contractor will be re-established by Contractor at no cost to Owner.
2. From established reference points, establish lines, grades, and elevations necessary to control the Work. Obtain measurements required for executing the Work to tolerances specified.
3. Establish, place, and replace as required, such additional stakes, markers, and other reference points necessary for control, intermediate checks, and guidance of construction operations.

B. Procedures

1. Accuracy:
   a. For topographic land surveys:
      1) Horizontal accuracy shall be plus or minus 0.1 feet.
      2) Vertical accuracy shall be plus or minus 0.05 feet for general site grading and 0.02 feet for structural features (e.g. pipes, manholes) unless otherwise specified or approved by the Engineer.
   b. Survey calculations shall include an error analysis sufficient to demonstrate required accuracy.

END OF SECTION

SECTION 02 51 00 - DECONTAMINATION

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Furnish all materials, equipment, and labor necessary to construct and maintain decontamination areas associated with UDF consolidation material placement operations and decontaminate vehicles, equipment, and personnel.
2. Construct and maintain decontamination areas within UDF cells.
3. Decontaminate all vehicles, equipment, and personnel that come into contact with consolidation materials at the site.

1.02 APPLICABLE CODES, STANDARDS, AND SPECIFICATIONS

A. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities (October 1985), as prepared by the National Institute of Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), United States Coast Guard (USCG), and United States Environmental Protection Agency (USEPA).

1.03 SUBMITTALS

A. Safety Data Sheets (SDS) for all cleaning/decontamination solutions shall be included in the Contractor’s Health and Safety Plan. SDS forms must be provided for review by the Owner and the Construction Manager (CM) prior to being brought on site.

PART 2 – PRODUCTS (NOT USED)

PART 3 – EXECUTION

1.01 GENERAL REQUIREMENTS

A. Decontaminate all construction vehicles leaving the UDF cells to prevent the tracking of soil material outside of the limits of the consolidation area. Visually inspect and decontaminate vehicles and equipment that come into contact with impacted materials (to the satisfaction of the Owner and/or CM) within the equipment decontamination area prior to leaving the cells. Promptly remove and dispose of any visible soil or other debris promptly within the cells in a manner consistent with consolidation material management.

B. Non-disposable equipment that has been used during implementation of the Project and has come in contact with impacted materials, or has otherwise become soiled (e.g., mud, dust) shall be cleaned before being removed from the Site. For equipment that has been in contact with impacted materials, Contractor will conduct post-cleaning wipe sampling of representative equipment surfaces for laboratory analysis for PCBs. The turnaround time for receipt of sampling results will be 5 to 7 days, during which the time, the equipment will not be allowed to leave the Site. PCB results greater than 10 ug/100 sq. cm. will require additional cleaning by the Contractor (at no cost to the Owner), and re-sampling and analysis until acceptable results are achieved.

C. Take precautions to limit contact between the vehicle/equipment, personnel performing the decontamination activities, and any decontamination liquids that may accumulate in the decontamination area. Use personal protective equipment, including disposable clothing for personnel engaged in decontamination activities, as required by the Contractor's Health and Safety Plan (HASP).

1.02 DECONTAMINATION AREAS

A. Construct and maintain decontamination area(s) in accordance with the Contract Documents to accommodate all loads, vehicles, equipment, and migration scenarios.

B. Construct the decontamination area at locations approved by the Owner and/or CM prior to construction.

C. Construct and maintain appropriately-sized decontamination areas for personnel. Locate personnel decontamination areas within the contamination reduction zone and include those facilities necessary to decontaminate personnel upon exiting the work area (exclusion zone), in accordance with the Contractor's HASP, and in accordance with local, state, and federal laws and regulations.

END OF SECTION

SECTION 03 00 05 - CONCRETE

PART 1 – GENERAL

1.1 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, equipment, and incidentals as shown, specified, and required to furnish and install concrete, reinforcing, and related materials.

2. The Work includes:
   a. Providing concrete consisting of Portland cement, fine and coarse aggregates, water, and approved admixtures; combined, mixed, transported, placed, finished, and cured.
   b. Fabricating and placing reinforcing, including ties and supports.
   c. Design, erection, and removal of formwork.
   d. Building into the concrete all sleeves, frames, anchorage devices, inserts, and other items required to be embedded in concrete.

B. Coordination:

1. Review installation procedures under other Sections and coordinate installation of items to be installed in the concrete Work.

C. Classifications of Concrete:

1. Class “A” concrete shall be steel-reinforced and includes all concrete unless otherwise shown or indicated.

2. Class “B” concrete shall be placed without forms or with simple forms, with little or no reinforcing and includes the following:
   a. Concrete fill.
   b. Duct banks.
   c. Unreinforced encasements.
   d. Curbs and gutters.
   e. Sidewalks.
   f. Thrust blocks.

1.2 REFERENCES

A. Standards referenced in this Section are:

1. ACI 224R, Control of Cracking in Concrete Structures.

2. ACI 301, Specifications for Structural Concrete for Buildings.

3. ACI 304R, Guide for Measuring, Mixing, Transporting and Placing Concrete.

4. ACI 305R, Specification for Hot Weather Concreting.

5. ACI 306R, Cold Weather Concreting.

6. ACI 309R, Guide for Consolidation of Concrete.

7. ACI 318, Building Code Requirements for Structural Concrete and Commentary.

8. ACI 347, Guide to Formwork for Concrete.

9. ACI SP-66, ACI Detailing Manual.
10. ASTM A82/A82M, Specification for Steel Wire, Plain, for Concrete Reinforcement.
11. ASTM A185/A185M, Specification for Steel Welded Wire Reinforcement, Plain, for Concrete.
12. ASTM A615/A615M, Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.
13. ASTM C31/C31M, Practice for Making and Curing Concrete Test Specimens in the Field.
14. ASTM C33/C33M, Specification for Concrete Aggregates.
15. ASTM C39/C39M, Test Method for Compressive Strength of Cylindrical Concrete Specimens.
16. ASTM C42/C42M, Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.
17. ASTM C94/C94M, Specification for Ready-Mixed Concrete.
18. ASTM C138/C138M, Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete.
19. ASTM C143/C143M, Test Method for Slump of Hydraulic-Cement Concrete.
20. ASTM C150/C150M, Specification for Portland Cement.
21. ASTM C172, Practice for Sampling Freshly Mixed Concrete.
22. ASTM C231, Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.
23. ASTM C260, Specification for Air-Entraining Admixtures for Concrete.
24. ASTM C309, Specification for Liquid Membrane-Forming Compounds for Curing Concrete.
25. ASTM C494/C494M, Specification for Chemical Admixtures for Concrete.
26. ASTM C579, Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes.
27. ASTM C1064/C1064M, Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete.
28. ASTM D1752, Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction.
29. ASTM E96/E96M, Test Methods for Water Vapor Transmission of Materials
30. ASTM E154, Test Methods for Water Vapor Retarders Used in Contact with Earth Under Concrete Slabs, on Walls, or as Ground Cover.
31. CRD-C 572, U. S. Army Corps of Engineers Specification for Polyvinylchloride Waterstops.
32. CRSI 1MSP, Manual of Standard Practice.

1.3 QUALITY ASSURANCE

A. Laboratory Trial Batch:

1. Employ independent testing laboratory experienced in design and testing of concrete materials and mixes to perform material evaluation tests and to design concrete mixes.

2. Each concrete mix design specified shall be verified by laboratory trial batch, unless indicated otherwise.

3. Perform the following testing on each trial batch:
   a. Aggregate gradation for fine and coarse aggregates.
   b. Slump.
   c. Air content.
   d. Compressive strength based on three cylinders each tested at seven days and at 28 days.

4. Submit for each trial batch the following information:
   a. Project identification name and number (if applicable).
   b. Date of test report.
   c. Complete identification of aggregate source of supply.
   d. Tests of aggregates for compliance with the Contract Documents.
   e. Scale weight of each aggregate.
   f. Absorbed water in each aggregate.
   g. Brand, type, and composition of cementitious materials.
   h. Brand, type, and amount of each admixture.
   i. Amounts of water used in trial mixes.
   j. Proportions of each material per cubic yard.
   k. Gross weight and yield per cubic yard of trial mixtures.
   l. Measured slump.
   m. Measured air content.
   n. Compressive strength developed at seven days and 28 days, from not less than three test cylinders cast for each seven day and 28-day test, and for each design mix.

1.4 SUBMITTALS

A. Action Submittals: Submit the following:

1. Shop Drawings:
   a. List of concrete materials and concrete mix designs proposed for use. Include results of tests performed to qualify the materials and to establish the mix designs. Do not start laboratory trial batch testing until this submittal is approved by the Engineer.
   b. Laboratory Trial Batch Reports: Submit laboratory test reports for concrete cylinders, materials, and mix design tests.
   c. Concrete placement drawings showing the location and type of all joints.
   d. Drawings for fabricating, bending, and placing concrete reinforcing. Comply with ACI SP-66. For walls and masonry construction, provide elevations to a minimum scale of 1/4-inch to one foot. Show bar schedules, stirrup spacing, adhesive dowels, splice lengths, diagrams of bent bars, arrangements, and assemblies, as required for fabricating and placing concrete reinforcing.

2. Product Data:
   a. Manufacturer’s specifications with application and installation instructions for proprietary materials and items, including admixtures and bonding agents.

3. Samples:
   a. Samples: Submit samples of materials as specified and as otherwise requested by Engineer, including names, sources, and descriptions.

B. Informational Submittals: Submit the following:

1. Delivery Tickets: Copies of all delivery tickets for each load of concrete delivered to or mixed at the Site. Each delivery ticket shall contain the information in accordance with ASTM C94/C94M along with project identification name and number (if any), date, mix type, mix time, quantity and amount of water introduced.

2. Site Quality Control Submittals:
   a. Report of testing results for testing of field concrete cylinders for each required time period. Submit within 24 hours after completion of associated test. Test report shall include results of all testing required at time of sampling.

1.5 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Transportation, Delivery, and Handling:

1. Deliver concrete reinforcing products to Site bundled, tagged, and marked. Use metal tags indicating bar size, lengths, and other information corresponding to markings on approved Shop Drawings.

2. Materials used for concrete shall be clean and free from foreign matter during transportation and handling and kept separate until measured and placed into concrete mixer.

3. Implement suitable measures during hauling, piling, and handling to ensure that segregation of coarse and fine aggregate particles does not occur and grading is not affected.

4. Deliver grout materials from manufacturers in unopened containers that bear intact manufacturer labeling.

B. Storage:

1. Store formwork materials above ground on framework or blocking. Cover wood for forms and other accessory materials with protective, waterproof covering. Provide for adequate air circulation or ventilation under cover.

2. Store concrete reinforcing materials to prevent damage and accumulation of dirt and excessive rust. Store on heavy wood blocking so that reinforcing does not come into contact with the ground. Space framework or blocking supports to prevent excessive deformation of stored materials.

3. Store concrete joint materials on platforms or in enclosures or covered to prevent contact with ground and exposure to weather and direct sunlight.

4. For storage of concrete materials, provide bins or platforms with hard, clean surfaces.

PART 2 – PRODUCTS

2.1 CONCRETE MATERIALS

A. Portland Cement: ASTM C150/C150M, Type II.

B. Aggregates: ASTM C33/C33M.

1. Fine Aggregate: Clean, sharp, natural sand free of loam, clay, lumps, and other deleterious substances. Dune sand, bank run sand, and manufactured sand are unacceptable.

2. Coarse Aggregate:
   a. Clean, uncoated, processed aggregate containing no clay, mud, loam, or foreign matter.
   b. Coarse aggregate shall comply with the following:
      1) Crushed stone, processed from natural rock or stone.
      2) Washed gravel, either natural or crushed. Slag, pit gravel, and bank-run gravel are not allowed.
   c. Coarse Aggregate Size: ASTM C33/C33M, Nos. 57 or 67, unless otherwise approved by Engineer.

C. Water: Clean, potable.

D. Admixtures:

1. Air-Entraining Admixture: ASTM C260.
2. Water-Reducing Admixture: ASTM C494/C494M, Type A.
3. Water Reducing and Set-Adjusting Admixtures: ASTM C494/C494M, Types D and E.
4. High Range Water-Reducing Admixture: ASTM C494/C494M, Type F/G.
5. Use only admixtures that have been tested and approved in the mix designs.
6. Do not use calcium chloride or admixtures containing chloride ions.

2.2 CONCRETE MIX

A. General:

1. Normal weight: 145 pounds per cubic foot.
2. Use air-entraining admixture in all concrete. Provide not less than four percent, nor more than eight percent, entrained air for concrete exposed to freezing and thawing, and provide from three to five percent entrained air for other concrete.

B. Proportioning and Design of Class “A” Concrete Mix:

1. Minimum compressive strength at 28 days: 4,500 psi.
2. Maximum water-cement ratio by weight: 0.42.
3. Minimum cement content: 564 pounds per cubic yard.

C. Proportioning and Design of Class “B” Concrete Mix:

1. Minimum compressive strength at 28 days: 3,000 psi.
2. Maximum water-cement ratio by weight: 0.50.
3. Minimum cement content: 517 pounds per cubic yard.

D. Slump Limits:

1. Proportion and design mixes to result in concrete slump at point of placement of not less than one inch and not more than four inches.
2. When using high-range water reducers, slump prior to addition of admixture shall not exceed three inches. Slump after adding admixture shall not exceed eight inches at point of placement.

E. Adjustment of Concrete Mixes:

1. Concrete mix design adjustments may be requested by Contractor when warranted by characteristics of materials, Site conditions, weather, test results, or other, similar circumstances.
2. Submit for Engineer's approval laboratory test data for adjusted concrete mix designs, including compressive strength test results.
3. Implement adjusted mix designs only after Engineer's approval.
4. Adjustments to concrete mix designs shall not result in additional costs to Owner.

2.3 FORM MATERIALS

A. Provide form materials with sufficient stability to withstand pressure of placed concrete without bow or deflection. Contractor shall be responsible for designing the formwork system to resist all applied loads including pressures from fluid concrete and construction loads.

B. Smooth Form Surfaces: Acceptable panel-type to provide continuous, straight, smooth, as-cast surfaces in accordance with ACI 301.

C. Unexposed Concrete Surfaces: Material to suit project conditions.

D. Provide 3/4-inch chamfer at all external corners. Chamfer is not required at re-entrant corners unless otherwise shown or indicated.

E. Form Ties:

1. Provide factory-fabricated, removable, or snap-off metal form ties, that prevent form deflection and prevent spalling of concrete surfaces upon removal. Materials used for tying forms are subject to approval of the Engineer.
2. Unless otherwise shown or indicated, provide ties so that portion remaining within concrete after removal of exterior parts is at least 1.5 inches from outer surface of concrete. Unless otherwise shown or indicated, provide form ties that, upon removal, will leave a uniform, circular hole not larger than one-inch diameter in the concrete surface.
3. Ties for exterior walls, below-grade walls, and walls subject to hydrostatic pressure shall be provided with waterstops.
4. Wire ties are unacceptable.

2.4 REINFORCING MATERIALS

A. Reinforcing Bars: ASTM A615/A615M, Grade 60 deformed bars.

B. Welded Wire Fabric: ASTM A185/A185M.

C. Steel Wire: ASTM A82/A82M.

D. Provide supports for reinforcing including bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcing in place.

1. Use wire bar-type supports complying with CRSI MSP1 recommendations, except as specified in this Section. Do not use wood, brick, or other unacceptable materials.

2. For slabs on grade, use precast concrete blocks, four inches square minimum with compressive strength equal to or greater than the surrounding concrete, or supports with sand plates or horizontal runners where base materials will not support chair legs.

3. For all concrete surfaces where legs of supports are in contact with forms, provide supports having either hot-dip galvanized, plastic-protected, or stainless-steel legs in accordance with CRSI MSP1.

4. Provide precast concrete supports over waterproof membranes.

2.5 RELATED MATERIALS

A. Waterstops:

1. PVC Waterstops:
   a. Manufacturers: Provide products of one of the following:
      1) W.R. Meadows, Inc.
      2) Greenstreak Plastic Products Company.
      3) Or equal.
   b. Waterstops shall comply with CRD-C 572. Do not use reclaimed or scrap material.
   c. Minimum Thickness: 3/8-inch.
   d. Provide waterstops with minimum of seven ribs equally spaced at each end on each side with the first rib located at the edge. Each rib shall be minimum 1/8-inch in height.
   e. Construction Joints: Waterstops shall be six-inch wide flat-strip type.
   f. Expansion Joints: Waterstops shall be nine-inch wide centerbulb type.

2. Hydrophilic Waterstops:
   a. Products and Manufacturers: Provide one of the following:
      1) Duroseal Gasket, by BBZ USA, Inc.
      2) Adeka Ultraseal MC-2010M, by Asahi Denka Kogyo K.K.
      3) Hydrotite, by Greenstreak Plastic Products Company.
      4) Or equal.
   b. Hydrophilic waterstop materials shall be bentonite-free and shall expand by minimum of 80 percent of dry volume in the presence of water to form a watertight joint seal without damaging the concrete in which it is cast.
   c. Waterstop material shall be composed of resins and polymers that absorb water and cause a completely reversible and repeatable increase in volume.
   d. Waterstop material shall be dimensionally stable after repeated wet-dry cycles with no deterioration of swelling potential.
   e. Select material in accordance with manufacturer’s recommendations for type of liquid to be contained.
   f. Minimum cross-sectional dimensions: 3/16-inch by 3/4-inch.
   g. Location of hydrophilic waterstops shall be as shown or indicated on the Drawings, or where approved by Engineer.
   h. Hydrophilic Sealant: Shall adhere firmly to concrete, metal, and PVC in dry or damp condition and be indefinitely elastic when cured.

1) Products and Manufacturers: Provide one of the following:
   a) Duroseal Paste, by BBZ USA, Inc.
   b) Adeka Ultraseal P-201, by Asahi Denka Kogyo K.K.
   c) Hydrotite, by Greenstreak Plastic Products Company.
   d) Or equal.

B. Vapor Retarder:

1. Products and Manufacturers: Provide one of the following:
   a. Stego Wrap 10-mil Vapor Retarder, by Stego Industries LLC.
   b. Griffolyn 10-mil, by Reef Industries.
   c. Moistop Ultra, by Fortifiber Industries.
   d. Or equal.

2. Vapor retarder membrane shall comply with the following.
   a. Water Vapor Transmission Rate, ASTM E96/E96M: 0.04 perms or lower.
   b. Water Vapor Retarder, ASTM E1745: Meets or exceeds Class C.
   c. Thickness of Retarder (plastic), ACI 302 1R: Not less than 10 mils.
   d. Provide accessories by same manufacturer as vapor retarder.

C. Membrane-Forming Curing Compound: ASTM C309, Type I.

D. Epoxy Bonding Agent:

1. Two-component epoxy resin bonding agent.

2. Products and Manufacturers: Provide one of the following:
   a. Sikadur 32, Hi-Mod LPL, by Sika Corporation.
   b. Eucopoxy LPL, by the Euclid Chemical Company.
   c. Or equal.

E. Epoxy-Cement Bonding Agent:

1. Three-component blended epoxy resin-cement bonding agent.

2. Products and Manufacturers: Provide one of the following:
   a. Sika Armatec 110 EpoCem, by Sika Corporation.
   b. Duralprep A.C., by Euclid Chemical Company.
   c. Or equal.

F. Preformed Expansion Joint Filler:

1. Provide preformed expansion joint filler complying with ASTM D1752, Type I (sponge rubber) or Type II (cork).

G. Joint Sealant and Accessories:

1. For joint sealants and accessories used on isolation joints, control joints, and expansion joints, refer to Section 07 92 00, Joint Sealants.

2.6 GROUT

A. Non-shrink Grout:

1. Pre-packaged, non-metallic, cementitious grout requiring only the addition of water at the Site.

2. Minimum 28-day Compressive Strength: 7,000 psi.

3. Products and Manufacturers: Provide one of the following:
   a. NS Grout by Euclid Chemical Company.
   b. Set Grout by Master Builders, Inc.
   c. NBEC Grout by Five Star Products, Inc.
   d. Or equal.

B. Epoxy Grout:

1. Pre-packaged, non-shrink, non-metallic, 100 percent solids, solvent-free, moisture-insensitive, three-component epoxy grouting system.

2. Minimum Seven-day Compressive Strength: 14,000 psi, when tested in accordance with ASTM C579.

3. Products and Manufacturers: Provide one of the following:
   a. Euco High Strength Grout, by Euclid Chemical Company.
   b. Sikadur 42, Grout Pak, by Sika Corporation.
   c. Five Star Epoxy Grout, by Five Star Products, Inc.
   d. Or equal.

C. Grout Fill:

1. Grout mix shall consist of cement, fine and coarse aggregates, water, and admixtures complying with requirements specified in this Section for similar materials in concrete.

2. Proportion and mix grout fill as follows:
   a. Minimum Cement Content: 564 pounds per cubic yard.
   b. Maximum Water-Cement Ratio: 0.45.
   c. Maximum Coarse Aggregate size: 1/2-inch, unless otherwise indicated.
   d. Minimum 28-day Compressive Strength: 4,000 psi.

PART 3 – EXECUTION

3.1 INSPECTION

A. Contractor shall examine the substrate and the conditions under which the Work will be performed and notify Engineer in writing of unsatisfactory conditions. Do not proceed with the Work until unsatisfactory conditions are corrected.

3.2 FORMWORK

A. Construct formwork in accordance with ACI 347 such that concrete members and structures are of correct size, shape, alignment, elevation, and position.

B. Provide openings in formwork to accommodate the Work of other trades. Accurately place and securely support items required to be built into formwork.

C. Clean and adjust forms prior to placing concrete. Apply form release agents or wet forms as required. Re-tighten forms during and after concrete placing, when required, to eliminate cement paste leaks.

D. Removing Formwork:

1. Comply with ACI 301 and ACI 347, except as otherwise indicated in the Contract Documents.

2. Do not remove formwork and shoring until supported concrete members have acquired minimum of 90 percent of specified compressive strength. Results of suitable quality control tests of field-cured specimens may be submitted to Engineer for review as evidence that concrete has attained sufficient strength for removal of supporting formwork and shoring prior to removal times indicated in the Contract Documents.

3. Removal time for formwork is subject to the Engineer's acceptance.

4. Repair form tie-holes following in accordance with ACI 301.

3.3 REINFORCING, JOINTS, AND EMBEDDED ITEMS

A. Comply with the applicable recommendations of Laws and Regulations and standards referenced in this Section, including CRSI MSP1, for details and methods of placing and supporting reinforcing.

B. Clean reinforcing to remove loose rust and mill scale, earth, ice, and other materials which act to reduce or destroy bond between reinforcing material and concrete.

C. Position, support, and secure reinforcing against displacement during formwork construction and concrete placing. Locate and support reinforcing by means of metal chairs, runners, bolsters, spacers, and hangers, as required.

1. Place reinforcing to obtain minimum concrete coverages as shown on the Drawings and as required in ACI 318. Arrange, space, and securely tie bars and bar supports together with 16-gage wire to hold reinforcing accurately in position during concrete placing. Set with ties so that twisted ends are directed away from exposed concrete surfaces.

2. Do not secure reinforcing to formwork using wire, nails or other ferrous metal. Metal supports subject to corrosion shall not be in contact with formed or exposed concrete surfaces.

D. Provide sufficient quantity of supports of strength required to carry reinforcing. Do not place reinforcing more than two inches beyond the last leg of continuous bar support. Do not use supports as bases for runways for concrete conveying equipment and similar construction loads.

E. Splices: Provide standard reinforcing splices by lapping ends, placing bars in contact, and tying tightly with wire. Comply with requirements shown or indicated for minimum lap of spliced bars, as shown on the Drawings.

F. Install welded wire fabric in lengths as long as practical, lapping adjoining sections a minimum of one full mesh.

G. Do not place concrete until reinforcing is inspected and Engineer indicates that conditions are acceptable for placing concrete. Concrete placed in violation of this paragraph will be rejected. Notify the Engineer in writing at least two working days prior to proposed concrete placement.

H. Joints:

1. Provide construction, isolation, expansion, and control joints as indicated or required. Locate construction joints so as to not impair the strength and appearance of the structure. Place isolation and control joints in slabs-on-grade to stabilize differential settlement and random cracking.

2. In walls, locate joints at a maximum spacing of 40 feet and approximately 12 feet from corners.

3. In foundation slabs and slabs-on-grade, locate joints at intervals of approximately 40 feet.

4. In mats and structural slabs and beams, locate joints in compliance with ACI 224R.

5. Locations of joints shall be in accordance with the Contract Documents and as approved by Engineer in the Shop Drawings.

6. Where construction joints are indicated to be roughened, intentionally roughen surfaces of previously placed concrete to amplitude of 1/4-inch.

I. Installation of Embedded Items: Set and build into the Work anchorage devices and embedded items required for other Work that is attached to, or supported by, cast-in-place concrete. Use setting diagrams, templates, and instructions provided under other Sections and, when applicable, other contracts for locating and setting. Refer to Paragraph 1.1.B of this Section. Do not embed in concrete uncoated aluminum items. Where aluminum items are in contact with concrete surfaces, coat aluminum to prevent direct contact with concrete.

J. Adhesive Dowels:

1. Adhesive dowels shall be reinforcing bar dowels set in an adhesive in hole drilled into hardened concrete. Comply with adhesive system manufacturer's installation instructions regarding hole diameter, drilling method, embedment depth required to fully develop required tensile strength, and hole cleaning and preparation instructions. Unless more-stringent standards are required by adhesive system manufacturer, comply with the following.

2. Drill holes to adhesive system manufacturer's recommended diameter and depth to develop required tensile strength. Holes shall not be more than 1/4-inch greater than nominal bar diameter, and hole depth shall not be less than twelve times nominal bar diameter. Hammer-drill holes. Cored holes are not allowed.

3. Embedment depths shall be based on concrete compressive strength of 2,000 psi when embedded in existing concrete, and 4,000 psi when embedded in new concrete.

4. Determine location of existing reinforcing steel in vicinity of proposed holes prior to drilling. Adjust location of holes to be drilled to avoid drilling through or damaging existing reinforcing bars only when approved by Engineer.

5. Before setting adhesive dowel, hole shall be free of dust and debris using method recommended by adhesive system manufacturer. Hole shall be brushed, with manufacturer-approved brush and blown clean with clean, dry, oil-free compressed air to remove dust and loose particles. Hole shall be dry as defined by adhesive system manufacturer.

6. Inject adhesive into hole through injection system mixing nozzle and necessary extension tubes, placed to bottom of hole. Withdraw discharge end as adhesive is placed but keep end of tube immersed to prevent forming air pockets. Fill hole to depth that ensures that excess material is expelled from hole during dowel placement.

7. Twist dowels during insertion into partially filled hole to guarantee full wetting of bar surface with adhesive. Insert bar slowly to avoid developing air pockets.

3.4 CONCRETE PLACING

A. Site Mixing: Use drum-type batch machine mixer, mixing not less than 1.5 minutes for one cubic yard or smaller capacity. Increase required mixing time by minimum of 15 seconds for each additional cubic yard or fraction thereof.

B. Ready-Mixed Concrete: Comply with ASTM C94/C94M.

C. Concrete Placing:

1. Place concrete in a continuous operation within planned joints or sections in accordance with ACI 304R.
2. Do not begin placing concrete until work of other trades affecting concrete is completed.
3. Wet concrete and subgrade surfaces to saturated surface dry condition immediately prior to placing concrete.
4. Deposit concrete as near its final location as practical to avoid segregation due to re-handling or flowing.
5. Avoid separation of the concrete mixture during transportation and placing. Concrete shall not free-fall for distance greater than four feet during placing.
6. Complete concrete placing within 90 minutes of addition of water to the dry ingredients.

D. Consolidate placed concrete in accordance with ACI 309R using mechanical vibrating equipment supplemented with hand rodding and tamping, such that concrete is worked around placing and other embedded items and into all parts of formwork. Insert and withdraw vibrators vertically at uniformly spaced locations. Do not use vibrators to transport concrete within the formwork. Vibration of formwork or placing is not allowed.

E. Protect concrete from physical damage or reduced strength due to weather extremes during mixing, placing, and curing.

1. In hot weather comply with ACI 305R.
2. In cold weather comply with ACI 306R.

3.5 QUALITY OF CONCRETE WORK

A. Make concrete solid, compact, smooth, and free of laitance, cracks, and cold joints.

B. Concrete for liquid-retaining structures and concrete in contact with earth, water, or exposed directly to the elements shall be watertight.

C. Cut out and properly replace to extent directed by Engineer, or repair to satisfaction of Engineer, surfaces that contain cracks or voids, are unduly rough, or are in defective in any way. Patches or plastering are unacceptable.

D. Repair, removal, and replacement of defective concrete directed by Engineer shall be at no additional cost to Owner.

3.6 CURING

A. Begin initial curing as soon as free water has disappeared from exposed surfaces. Where possible, keep continuously moist for not less than 72 hours. Continue curing by using moisture-retaining cover or membrane-forming curing compound. Cure formed surfaces by moist curing until formwork is removed. Provide protection, as required, to prevent damage to exposed concrete surfaces. Total curing period shall not be less than seven days. Curing methods and materials shall be compatible with scheduled finishes.

3.7 FINISHING

A. Slab Finish:

1. After placing concrete slabs, do not work the surface further until ready for floating. Begin floating when surface water has disappeared or when concrete has stiffened sufficiently. Use a wood float only. Check and level surface plane to a tolerance not exceeding 1/4-inch in ten feet when tested with a ten-foot straightedge placed on the surface at not less than two different angles. Cut down high spots and fill low spots. Uniformly slope surfaces to drains. Immediately after leveling, re-float the surface to a uniform, smooth, granular texture. Slab surfaces shall receive a float finish. Provide additional trowel finishing as required in this Section.

2. After floating, begin first trowel finish operation using power-driven trowel. Begin final troweling when surface produces a ringing sound as trowel is moved over the surface.

3. Consolidate concrete surface by the final hand troweling operation. Finish shall be free of trowel marks, uniform in texture and appearance, and with a surface plane tolerance not exceeding 1/8-inch in ten feet when tested with a ten-foot straightedge. Grind smooth surface defects that would telegraph through applied floor covering system.

4. Use trowel finish for the following:
   a. Interior exposed slabs, unless otherwise shown or indicated.
   b. Apply non-slip broom finish, after troweling, to exterior concrete slab and elsewhere as shown.

B. Apply chemical floor hardener to exposed interior concrete floor areas when cured and dry, in accordance with hardener manufacturer’s instructions.

C. Formed Finish:

1. Provide smooth form concrete finish at exposed surfaces. Use largest practical form panel sizes to minimize form joints. Exposed surfaces include interior water-contacting surfaces of tanks, whether or not directly visible. All surfaces shall be considered as exposed, unless buried or covered with permanent structural or architectural material. After removing forms, patch form tie holes and defects in accordance with ACI 301. Remove fins exceeding 1/8-inch in height. Where surface will be coated or will receive further treatment, remove all fins flush with concrete surface.

2. Provide rough form finish at all unexposed surfaces. After removing forms, patch form tie holes and defects in accordance with ACI 301. Remove fins exceeding 1/2-inch in height.

3.8 GROUT PLACING

A. Place grout as shown and indicated, and in accordance with grout manufacturer's instructions and recommendations. If grout manufacturer's instructions conflict with the Contract Documents, notify Engineer and not proceed until obtaining Engineer's clarification.

B. Dry packing is not allowed, unless otherwise indicated.

C. Manufacturers of proprietary grout materials shall make available upon 72 hours' notice the services of qualified, full-time, factory-trained employee to aid in ensuring proper use of grout materials at the Site.

D. Placing grout shall comply with temperature and weather limitations described in Article 3.4 of this Section.

3.9 FIELD QUALITY CONTROL

A. Site Testing Services:

1. Contractor shall employ independent testing laboratory to perform field quality control testing for concrete. Engineer will direct where samples are obtained.
2. Testing laboratory will provide all labor, material, and equipment required for sampling and testing concrete, including: scale, glass tray, cones, rods, molds, air tester, thermometer, and other incidentals required.
3. Contractor shall provide curing and necessary cylinder storage.

B. Quality Control Testing During Construction:

1. Perform sampling and testing for field quality control during concrete placing, as follows:
    a. Sampling Fresh Concrete: ASTM C172.
    b. Slump: ASTM C143/C143M; one test for each concrete load at point of discharge.
    c. Concrete Temperature: ASTM C1064/C1064M; one for every two concrete loads at point of discharge, and when a change in the concrete is observed. Test each load when time from batching to placement exceeds 75 minutes.
    d. Air Content: ASTM C231; one for every two concrete loads at point of discharge, and when a change in the concrete is observed.
    e. Unit Weight: ASTM C138/C138M; one for every two concrete loads at point of discharge, and when a change in the concrete is observed.
    f. Compression Test Specimens:
        1) In accordance with ASTM C31/C31M, make one set of compression cylinders for each 50 cubic yards of concrete, or fraction thereof, of each mix design placed each day. Each set shall be four standard cylinders, unless otherwise directed by Engineer.
        2) Cast, store, and cure specimens in accordance with ASTM C31/C31M.
    g. Compressive Strength Tests:
        1) In accordance with ASTM C39/C39M; one specimen tested at seven days, and three specimens tested at 28 days.
        2) Concrete that does not comply with strength requirements will be considered as defective Work.
    h. Submit test results from certified by testing laboratory to Engineer within 24 hours of completion of test.

i. When there is evidence that strength of in-place concrete does not comply with the Contract Documents, Contractor shall employ the services of concrete testing laboratory to obtain cores from hardened concrete for compressive strength determination. Cores and tests shall comply with ASTM C42/C42M and the following:

1) Testing of Adhesive Dowels: Contractor will employ testing agency to perform field quality control testing of drilled dowel installations. After adhesive system manufacturer's recommended curing period and prior to placing connecting reinforcing, proof-test for pullout ten percent of adhesive dowels installed. Adhesive dowels shall be tensioned to 60 percent of specified yield strength. Where dowels are located less than six bar diameters from edge of concrete, Engineer will determine tensile load required for test. If one or more dowels fail, retest all dowels installed for the Work. Dowels that fail shall be reinstalled and retested at Contractor's expense.

END OF SECTION

SECTION 22 10 00 - POLYVINYL CHLORIDE (PVC) PIPE AND FITTINGS

PART 1 GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary for installation of all polyvinyl chloride (PVC) pipe, fittings, and appurtenances as specified herein for the underdrain system and miscellaneous connections, as shown on the Drawings.

B. The Contractor shall be prepared to install PVC pipe and fittings in conjunction with the earthwork and other project components.

C. The work shall include procurement, installation, connection, and testing of all piping.

1.03 WARRANTY

A. The Contractor shall furnish the Owner written warranties obtained from the manufacturer and the installer against defects in materials and workmanship in accordance with ASTM D 1785 and ASTM D 2464. Warranty conditions proposed by the manufacturer or installer concerning limits of liability will be evaluated and must be acceptable to the Owner.

1.04 SUBMITTALS

A. The Contractor shall submit to the Owner for approval within 14 days prior to the start of pipe work, complete, detailed shop drawings of all PVC pipe and fittings, a list of materials to be furnished, and the name of the pipe manufacturer.

B. The Contractor shall submit to the CQA Consultant the PVC pipe manufacturer's certification of compliance with this Technical Specification.

C. In addition to the certification in Part 1.04 above, the Contractor shall submit to the CQA Consultant the following documentation from the PVC pipe manufacturer on the raw materials used to manufacture the PVC pipe and fittings:

1. Certificate stating the specific PVC compound, its source, and the information required by ASTM D 1248.
2. Certificate stating that no recycled resin was used in manufacturing the pipe except for a small percentage of resin generated in the pipe Manufacturer's own plant from production using the same new resin as the recycled resin.

PART 2 PRODUCTS

2.01 POLYVINYL CHLORIDE (PVC) COMPOUND

The PVC pipe and fittings shall be manufactured from Type I, Grade 1, PVC conforming to ASTM D 1784 and 1785.

2.02 PVC PIPES AND FITTINGS

A. PVC pipe shall be supplied in standard laying lengths not exceeding 40 feet.

B. PVC pipe shall be furnished perforated, as specified on the Drawings. If pipes are manufactured unperforated and are to be installed perforated, then perforations shall be drilled into the pipe prior to delivery to the site. Perforations shall consist of 0.020-inch width slots, made by the manufacturer. Other methods of perforating pipes may be proposed by the Contractor.

C. PVC pipes and fittings shall be homogeneous throughout and free of visible cracks, holes (other than intentional manufactured perforations), foreign inclusions, or other deleterious effects, and shall be uniform in color, density, melt index, and other physical properties.

D. Fittings at the ends of pipes shall consist of PVC end caps unless indicated otherwise on the Drawings.

F. PVC pipe shall be 4-inch diameter, Schedule 40.

2.03 IDENTIFICATION

The following shall be continuously indent printed on the pipe, or spaced at intervals not exceeding 5 feet:

1. Name and/or trademark of the pipe manufacturer;
2. Nominal pipe size;
3. Schedule;
4. Manufacturing Standard Reference (e.g., ASTM D 1785); and
5. A production code from which the date and place of manufacture can be determined.

2.04 TRANSPORTATION

Transportation of PVC pipe and fittings shall be the responsibility of the Contractor. The Contractor shall be liable for all damage to the PVC pipe and fittings incurred prior to and during transportation to the site.

PART 3 EXECUTION

3.01 HANDLING AND PLACEMENT

A. The Contractor shall exercise care when transporting, handling and placing PVC pipe and fittings, such that they will not be cut, kinked, twisted, or otherwise damaged.

B. Ropes and fabric or rubber-protected slings and straps shall be used as necessary when handling PVC pipe. Slings, straps, etc. shall not be positioned at joints. Chains, cables, or hooks shall not be inserted into the pipe ends as a means of handling pipe.

C. Pipe or fittings shall not be dropped onto rocky or unprepared ground. Under no circumstances shall pipe or fittings be dropped into trenches or dragged over sharp and cutting objects.

D. PVC pipe shall be stored on clean level ground, preferably turf or sand, free of sharp objects which could damage the pipe. Stacking shall be limited to a height that will not cause excessive deformation of the bottom layers of pipes under anticipated temperature conditions. Where necessary, due to ground conditions, the pipe shall be stored on wooden sleepers, spaced suitably and of such width as not to allow deformation of the pipe at the point of contact with the sleeper or between supports. The pipes should be stored out of direct sunlight.

E. The maximum allowable depth of cuts, gouges, or scratches on the exterior surface of PVC pipe or fittings is 10 percent of the wall thickness. The interior of the pipe and fittings shall be free of cuts, gouges, and scratches. Sections of pipe with excessive cuts, gouges, or scratches shall be removed and the ends of the pipe rejoined at no cost to the Owner.

F. Whenever pipe installation activities are not actively in progress, the open end of pipe that has been placed shall be closed using a watertight plug.

3.02 INSTALLATION

A. All PVC pipe and fittings shall be installed in accordance with the manufacturer's instructions.

B. The Contractor shall carefully examine all pipe and fittings for cracks, damage, or defects before installation. Defective materials shall be immediately removed from the site and replaced at no cost to the Owner.

C. The interior of all pipe and fittings shall be inspected, and any foreign material shall be completely removed from the pipe interior before it is moved into final position.

D. Field-cutting of pipes, where required, shall be made with a machine specifically designed for cutting pipe. Cuts shall be carefully made, without damage to pipe or lining, so as to leave a smooth end at right angles to the axis of pipe. Cut ends shall be tapered and sharp edges filed off smooth. Flame cutting will not be allowed.

E. All pipe and fittings shall be laid or placed to the lines and grades shown on the Drawings with bedding and backfill shown on the Drawings and as specified in this Section.

F. No pipe shall be laid until the CQA Consultant has approved the bedding conditions.

G. No pipe shall be brought into position until the preceding length has been bedded and secured in its final position.

H. Blocking under piping shall not be permitted unless specifically accepted by the Engineer for special conditions.

I. The Contractor shall provide all necessary adapters and/or connection pieces required when connecting different types and sizes of pipe or when connecting pipe made by different manufacturers.

3.03 JOINTS AND CONNECTIONS

A. Mechanical connections of PVC pipe to auxiliary equipment such as valves, flow meters, pumps, and tanks shall be as described in the section of the specifications that address the auxiliary equipment.

END OF SECTION

SECTION 31 05 13 - SOILS FOR EARTHWORK

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, tools, equipment, and incidentals as shown, specified, and required to furnish and install soils for construction of components indicated on the Design Drawings.

B. Related sections

1. Section 31 05 16 – Aggregates for Earthwork
2. Section 31 05 19.13 – Geotextiles for Earthwork
3. Section 32 91 19.13 – Topsoil Placement and Grading

1.02 REFERENCES

A. Reference Standards:

1. The following standards are referenced in this Section:
   a. ASTM D1140, Standard Test Methods for Amount of Material in Soils Finer than No. 200 (75 µm) Sieve.
   b. ASTM D1557, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort of 56,000 ft-lbf/ft3, also known as “Modified Proctor”
   c. ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).
   d. ASTM D4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
   e. ASTM D6913, Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis.
   f. ASTM 6938 Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
   g. USEPA SW-846 Method 6010, Inductively Coupled Plasma-Atomic Emission Spectrometry.
   h. USEPA SW-846 Method 7471, Mercury in Solid or Semisolid Waste (Manual Cold Vapor Technique).
   i. USEPA SW-846 Method 8081, Organochlorine Pesticides by Gas Chromatography.
   j. USEPA SW-846 Method 8082, Polychlorinated Biphenyls (PCBs) by Gas Chromatography.
   k. USEPA SW-846 Method 8151, Chlorinated Herbicides by GC Using Methylation or Pentafluorobenzylation Derivatization.
   l. USEPA SW-846 Method 8260, Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS).
   m. USEPA SW-846 Method 8270, Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS).
   n. USEPA SW-846 Method 9012, Total and Amenable Cyanide (Automated Colorimetric, with Off-Line Distillation).

1.03 QUALITY ASSURANCE

A. Use materials, procedures, operations, and methods in strict conformance with the Contract Documents. Materials will be subjected to strict quality control monitoring as detailed herein. Conform the placed granular materials exactly to the Contract Documents, except as otherwise authorized in writing by the Construction Manager (CM).

B. Sampling of soil materials used for construction shall be conducted in accordance with the Field Sampling Plan/Quality Assurance Project Plan (FSP/QAPP [Arcadis 2023]).

1.04 SUBMITTALS

A. Submit background information for each proposed borrow pit to the CM for review as part of the borrow pit's initial screening for acceptance. At a minimum, background information shall include the following:

1. The location of the borrow site(s) including state, county, municipality, address, block, and lot numbers.
2. The names, contact information, and relationship of persons involved with the borrow site preparation and transport of the fill from the borrow site to the receiving site.
3. A description of the borrow site including use history.
4. Identification of specific areas within the borrow site on a scaled site plan where material will be obtained for use at the project site.
5. Identification of specific areas within the borrow site on a scaled site plan where samples for analytical and geotechnical testing will be obtained.
6. A description of sampling methodology to be used to obtain geotechnical and analytical samples.
7. The results of geotechnical testing previously performed and description of the geotechnical properties of the fill material and indication that the material meets the projects' geotechnical specifications.

B. Submit results of laboratory chemical analysis of each material type from each borrow pit at the frequencies specified in Section 2.02 of this specification.

C. Submit results of laboratory geotechnical testing of each material type from each borrow pit at the frequencies specified in Section 2.02 of this specification.

1.05 DELIVERY

A. Notify the CM no less than one (1) week in advance of delivery of all soil fill materials.

PART 2 – PRODUCTS

2.01 MATERIALS

A. Imported General Fill - general fill will be used to backfill excavations, as subgrade material for construction of berms and embankments, in construction of the general fill soil layer component of the final cover system, as subgrade material in the vegetative surface restoration areas. Material shall be free of rock and gravel larger than three inches in any dimension, debris, waste, frozen materials, organic material, and other deleterious matter having a gradation in accordance with the following unless otherwise approved by the Engineer:

Sieve Size (Square Opening)	**Percentage by Weight Passing Sieve**
3–inch	100
No. 200	5-50

B. Imported general fill shall be classified as ASTM D2487 Soil Classification Groups GW, GP, GM, SW, SP, and SM, or a combination of these groups and have a liquid limit not greater than 45, and plasticity index not greater than 25.

C. Imported general fill used for construction of the general fill soil layer component of the final cover system shall have a permeability no greater than 1 x 10^{-4} cm/sec per ASTM D5084 unless otherwise approved by the Engineer.

2.02 SOURCE QUALITY CONTROL

A. Off-Site Materials: Contractor will coordinate, collect, and submit the sample, and pay for laboratory testing of each material to verify compliance with the Contract Documents.

1. Geotechnical Testing: Contractor will obtain representative samples of each material for the following:
   a. Gradation in accordance with ASTM D6913 and ASTM D1140
   b. Moisture/density relationship in accordance with ASTM D1557
   c. Atterberg limits in accordance with ASTM D4318
   d. Permeability in accordance with ASTM D5084

2. The above testing shall be completed prior to placement of the material and at a frequency of one per 5,000 CY of imported fill.

3. Chemical Testing: Contractor will obtain representative samples of each material for chemical testing for fill material with greater than 10 percent by weight passing the No. 80 sieve, as determined by gradation testing performed in accordance with Section 2.02.A.1 of this specification. Sampling will be performed as follows:
   a. The frequency of sampling/analysis for chemical contaminants is dependent on the source/location of the proposed off-site soil fill material:
      1) If the candidate material is from an undisturbed in-place source (e.g., an active gravel/borrow pit), the source will provide a letter certifying that the material is virgin, and one representative sample of the material will be collected and analyzed. The analytical data from this chemical characterization will be compared with the criteria described in Section 3.1 and submitted to EPA for approval prior to use as part of the response action. The results of this sample will be considered to represent the materials that originate from this virgin source up to 20,000 cubic yards of material from the borrow source, until such time as the physical characteristics of the source location significantly change.

2) For off-site materials that have not been certified as a virgin source, the frequency of initial borrow source characterization testing will involve the collection of one composite sample for each 2,000 cubic yards from the borrow source and for each distinct material type specified in the technical design documents. If the volume of material to be characterized is less than 2,000 cubic yards, one composite sample will still be collected from that material. Each composite sample will be composed of 10 discrete “grab” subsamples that will be collected at spatially distributed locations within the source material and composited into a single sample to be submitted to a laboratory for the appropriate chemical analyses listed above. The analytical data from this chemical characterization will be compared with the criteria described in Section 3.1 and submitted to EPA for approval prior to use as part of the response action. This initial sampling frequency will be used to characterize up to 20,000 cubic yards of material from the borrow source.

3) If more than one off-site source is proposed for the soil fill material, samples shall be collected and analyzed from each source at the appropriate frequency provided above.

b. Each sample will be collected and sampled in accordance with the Soil Cover/Backfill Characterization Plan; Arcadis 2023). tested for the following:

1) PCBs and the volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and metals listed in Appendix IX of 40 Code of Federal Regulation 264, plus benzidine, 2-chloroethyl vinyl ether, and 1,2-diphenylhydrazine (Appendix IX+3 VOCs, SVOCs, and metals)

c. Chemical testing shall be completed prior to shipment of fill. Fill material may not be accepted for import until results of chemical analysis are approved by the Construction Manager (CM).

4. The results of the soil chemical testing shall be compared with the EPA Region 9 Preliminary Remediation Goals (PRGs) for soil and the MCP Method 1 S-1/GW-1 soil standards to verify acceptability of the proposed soil materials for on-site use.

PART 3– EXECUTION

3.01 INSPECTION

A. Before applying soils, verify that the underlying geotextiles, if required, are free of tears, holes, wrinkles, and foreign objects, and are securely anchored.

B. Verify that subgrades, and final grades, slopes and elevations conform to specified requirements. Correct inaccurately graded work at no additional cost to the Owner. Notify the CM immediately if a specified grade, slope, or elevation appears inconsistent with the others specified.

C. At the beginning of each day's Work, the CM will inspect the previously placed soils and the Contractor shall institute whatever corrective action, if any, that the CM deems appropriate, at no extra cost to the Owner, unless the action requested is clearly beyond the scope of this Contract. This may include but is not limited to the removal of unsuitable granular materials. Do not proceed with the Work until unsatisfactory conditions are corrected.

3.02 SUBGRADE PREPARATION

A. Subgrades shall be firm, dense, and thoroughly compacted and consolidated; shall be free from mud, muck, and other soft or unsuitable materials; and shall remain firm and intact under all construction operations. Subgrades that are otherwise solid but become soft or mucky on top due to construction operations shall be reinforced with dense graded aggregate. Finished elevation of stabilized subgrades shall not be above subgrade elevations shown.

B. If, in CM’s opinion, subgrade becomes softened or mucky because of construction delays, failure to dewater properly, or other cause within Contractor’s control, subgrade shall be excavated to firm material, trimmed, and backfilled with dense graded aggregate material at Contractor’s expense.

3.03 PLACEMENT OF SOIL FILL MATERIAL

A. Do not allow heavy equipment to operate directly on exposed geotextile. Construct a platform of the granular material from which additional material can be spread.

B. Materials shall be placed, not dumped, to the limits and grades shown on Drawings.

C. Do not operate equipment in a manner that will cause equipment to dig into the geotextiles. If this occurs, even inadvertently, clear the area to demonstrate to the satisfaction of the CM that the geotextiles have not been damaged. Immediately repair any damage at the Contractor's expense.

D. Furnish and use equipment capable of adding measured amounts of water to the fill materials to bring fill materials to a condition within required moisture content range. Furnish and use equipment capable of discing, aerating, and mixing the fill materials to ensure reasonable uniformity of moisture content throughout the fill materials, and to reduce moisture content of borrow materials by air drying, when necessary. When subgrade or lift of fill materials requires moisture-conditioning before compaction, fill material shall be sufficiently mixed or worked on the subgrade to ensure uniform moisture content throughout the lift of material to be compacted. Materials at moisture content in excess of specified limit shall be dried by aeration or stockpiled for drying.

E. Select and use equipment capable of providing the compaction necessary to achieve the densities specified in specification Section 31 22 00 Table 1.

F. Furnish and use equipment capable of compacting in restricted areas next to structures and around piping and Underground Facilities. Effectiveness of the equipment selected by Contractor shall be tested at start of compacted fill Work by constructing a small section of fill within or adjacent to the area where fill will be placed. Record total number of coverages with selected compaction equipment and perform field moisture content and density tests to ensure that specified compaction of fill has been obtained. If tests on the test section of fill indicate that required compaction has not obtained, do one or more of the following:

1. Increase the amount of coverages.
2. Decrease the lift thicknesses.
3. Use different compaction equipment.

G. Place fill materials in horizontal, loose lifts, not exceeding specified uncompacted thickness. Place fill in a manner ensuring uniform lift thickness after placing. Mechanically compact each lift, by not less than two complete coverages of the compactor. One coverage is defined as the conditions reached when all portions of the fill lift have been subjected to the direct contact of compactor's compacting surface. Compaction of fill materials by inundation with water is unacceptable.

H. Do not place fill materials when standing water is present on surface of the area where fill will be placed. Do not compact fill when standing water is present on the fill to be compacted. Do not place or compact fill in a frozen condition or on top of frozen material. Fill containing organic materials or other unacceptable materials previously described shall be removed and replaced prior to compaction.

I. If required densities are not obtained because of improper control of placement or compaction procedures, or because of inadequate or improperly functioning compaction equipment, Contractor shall perform all work required to provide the required densities. Such work shall include, at no additional cost to Owner, complete removal of unacceptable fill areas and replacement and re-compaction until acceptable fill is provided.

J. Repair, at Contractor's expense, observed or measured settlement. Make repairs and replacements as required within five days after being so advised by CM.

3.04 FIELD QUALITY CONTROL

A. The Contractor will perform thickness measurements in the field to determine compliance with the Contract Documents.

B. Subcontract an independent third-party firm to test the in-place density and moisture content of the general fill material where required by Table 1 in Section 31 22 00 - Grading in accordance with ASTM D-6938.

END OF SECTION

SECTION 31 05 13.10 – LOW PERMEABILITY SOIL LINER

PART 1 GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary for the construction of the low permeability soil liner component of the liner system as specified herein, as shown on the Design Drawings and in accordance with the project Construction Quality Assurance Plan (CQAP) and this Section. The low permeability soil liner consists of 12 inches of low permeability clay overlain by a geosynthetic clay liner (GCL) on the UDF cell floor (floor baseliner) and the interior perimeter berm sideslope (sideslope baseliner).

B. The Contractor shall be prepared to construct the low permeability soil liner in conjunction with the earthworks and the installation and construction of the other components of the liner system.

C. Notwithstanding the prequalification of any material sources for the low permeability soil liner, the Contractor shall be entirely responsible for meeting the requirements of this Section.

D. The low permeability soil liner (low permeability soil) material will be furnished by the Owner from off-site sources. The low permeability soil liner material will be delivered by the Owner to the on-site stockpile area. The Contractor shall be responsible for loading and transporting the stockpiled material to the cell working area. The Contractor shall have full responsibility for scheduling and coordinating all material deliveries directly with the Owner’s supplier(s) and hauler(s).

1.02 RELATED SECTIONS

A. Section 31 23 00 – Excavation and Fill

B. Section 31 05 19.16 – Geosynthetic Clay Liner

C. Section 31 22 00 – Grading

D. Section 31 05 13 – Soil for Earthwork

1.03 SUBMITTALS

A. The Contractor shall submit the following information and samples to the Engineer a minimum of 21 days prior to the start of construction of the low permeability soil liner, unless material source has been prequalified by the Owner.

1. The proposed material source or sources.
2. Laboratory test data in conformance with the requirements of Part 2.01(B).
3. A 100-pound sample of material from each proposed source.

B. The Contractor shall notify the CM and Owner in writing a minimum of 7 days prior to starting construction of the low permeability soil liner. This notice shall state the material to be used, the equipment to be used, the date and time that placement operations will start, and the name of the person in the field who will be in charge of the constructing the low permeability soil liner, and the Engineers approval of the material.

C. If work is interrupted for reasons other than inclement weather, the Contractor shall notify the Owner a minimum of 24 hours prior to the stoppage and the resumption of work.

D. It is the responsibility of the Contractor to ensure that the material used for the low permeability soil liner construction meets the requirements of these Specifications. Any material that does not conform to these Specifications will be rejected by the Engineer and shall be replaced by the Contractor with new material at no cost to the Owner.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Construction of the low permeability soil liner will be monitored and tested by the Engineer as outlined in the CQAP and as shown on Tables 1 and 2 of this Section.

B. The Contractor shall be aware of the activities outlined in the CQAP and shall account for these activities in the construction schedule.

PART 2 PRODUCTS

2.01 MATERIALS

A. The low permeability soil liner shall consist of relatively homogeneous, fine grained, natural soils that are free of debris, foreign objects, and organics. No material larger than 1 inch in largest dimension, as determined by passing a standard 1-inch sieve, shall be allowed in the upper 6 inches of any low permeability soil layer that will be in contact with the primary or secondary geomembrane layers. The soil shall be classified according to the Unified Soil Classification System (USCS) as either CL or CH material, and have a maximum particle size of 1 inch and a maximum of 25 percent gravel size particles. The low permeability soil liner shall have, in accordance with ASTM D 4318, a liquid limit of greater than or equal to 30 and a plasticity index greater than or equal to 10. In addition, testing carried out by the Owner in conformance with the requirements of the Specifications shall demonstrate that the compacted low permeability soil liner material will exhibit an in-place hydraulic conductivity less than or equal to 1.0×10^{-7} centimeters per second (cm/sec).

B. The Owner shall employ an independent geotechnical testing laboratory to perform the following pre-qualification soil testing (a minimum of one set of tests per material source) on each proposed material source and shall submit the test data to the Engineer.

1. Mechanical Gradation ASTM D 422
2. Hydrometer Analysis ASTM D 422
3. Atterberg Limits ASTM D 4318
4. Natural Water Content ASTM D 2216
5. Modified Proctor ASTM D 1557
6. Standard Proctor ASTM D 698
7. Hydraulic Conductivity ASTM D 5084
    a. The hydraulic conductivity tests shall be performed using a flexible wall permeameter that can apply cell pressure and backpressure (e.g., triaxial cell).
    b. At a minimum, hydraulic conductivity tests shall be performed at a water content, dry density, and level of compaction corresponding to the following conditions:
        - 100% of the maximum modified Proctor dry density at the modified Proctor optimum moisture content;
        - 95% of the maximum modified Proctor dry density at the modified Proctor optimum moisture content;
        - 90% of the maximum modified Proctor dry density at the modified Proctor optimum moisture content;

- both 95% and 90% of the maximum modified Proctor dry density at moisture contents on the “line of optimum moisture contents,” which is formed by a line joining the peaks of the modified Proctor and standard Proctor compaction curves;
- 90% of the maximum modified Proctor dry density at a moisture content between the modified Proctor optimum moisture content and the line of optimum moisture contents; and
- additional points as necessary to adequately define and justify the range of moisture contents and dry densities to which the Contractor intends to compact the material to achieve a hydraulic conductivity of no more than 1 x 10^{-7} cm/sec.

c. Tests shall be performed at an effective confining pressure of 5 pounds per square inch (psi).

d. The results of the hydraulic conductivity tests shall be used by the Owner to identify a range of moisture contents and dry densities within which the compacted low permeability soil liner is likely to exhibit a hydraulic conductivity of 1 x 10^{-7} cm/sec. The Engineer will review the tests and range of acceptable moisture contents and dry densities defined by the Owner. In no event shall the range of acceptable dry densities be less than 90 percent of the maximum modified Proctor dry density. Upon approval by the Engineer, the range will become the basis for construction testing of the test fill described in Part 3.01. However, regardless of the approved range of compaction criteria, the final basis for acceptance of the low permeability soil liner shall be an in-place hydraulic conductivity of 1 x 10^{-7} cm/sec, as measured in the laboratory for shelby tubes taken from the liner.

C. The final approval of a source for low permeability soil liner will be at the sole discretion of the Engineer.

2.02 EQUIPMENT

A. The Contractor shall only use equipment that has been approved by the Engineer for this work. The Contractor shall submit details of proposed equipment to the Engineer for approval a minimum of 7 days in advance of the Contractor’s intention to bring the equipment to the site.

B. The Contractor shall furnish, operate, and maintain grading equipment as is necessary to produce uniform layers, sections, and smoothness of grade for compaction and drainage.

C. The Contractor shall furnish, operate, and maintain compaction equipment as is necessary to produce the required in-place soil density and moisture content. Low permeability soil liner material shall be placed in loose lifts that result in a compacted lift thickness of approximately 9 inches. Compaction shall be performed using a static padded-foot or sheepsfoot compactor having a minimum weight of 35,000 pounds (lbs). The “foot” of the compactor shall protrude a maximum of six inches and have an area of at least 9 square inches.

D. The Contractor shall furnish, operate, and maintain water tank trucks, pressure distributors, or other equipment designed to apply water uniformly and in controlled quantities to variable surface widths.

E. The Contractor shall furnish, operate, and maintain soil spreading equipment that travels on the material being spread without traveling on the surface of the underlying compacted soil surface layer.

F. The Contractor shall furnish, operate, and maintain miscellaneous equipment such as scarifiers, disks, spring tooth or spike tooth harrows, earth hauling equipment, and other equipment, as necessary for construction of the low permeability soil liner.

PART 3 EXECUTION

3.01 TEST FILL CONSTRUCTION

A. Purpose and Scope

1. The Test Fill is intended to establish the placement and compaction procedures to be used to construct the low permeability soil liner in conformance with these specifications. The test fill program will allow all parties (including the Owner, Contractor, and Engineer) to:

    a. familiarize themselves with the handling and compaction characteristics of the proposed soil materials;
    b. develop correlations between numbers of passes, soil moisture content, and soil dry density;
    c. develop correlations between moisture content and moisture conditioning requirements; and
    d. develop correlations between moisture content, dry density, and in-place hydraulic conductivity.

B. Foundation Preparation

1. The Test Fill shall be constructed in a part of the work area designated by the Owner.

2. If the Test Fill is not constructed in an area of the cell that has been prepared to receive low permeability soil liner, the area within the limits of the Test Fill shall be cleared and grubbed of all trees, debris, stumps, and any other vegetation. After clearing and grubbing, the area shall be stripped of topsoil and/or organic materials. The surface of the subgrade shall then be proof-rolled to identify soft zones, irregularities, and abrupt changes in grade. Areas found unsuitable by proof rolling shall be corrected as described in Section 31 23 00 – Excavation and Fill.

3. No standing water or excessive moisture shall be allowed to accumulate on the surface of the subgrade in the test fill area.

4. Construction of the Test Fill shall not commence until the foundation condition has been examined, documented and approved by the Engineer.

C. The Test Fill shall be constructed in a rectangular shape to a minimum plan area of 20-feet-wide by 60-feet-long, or larger if approved by the Owner. The Test Fill for the 24-inch-thick soil liner should consist of at least three lifts of soil. The first and second lifts shall be of uniform thickness with a maximum compacted thickness of 10 inches and an average compacted thickness of 9 inches, the last lift shall be of uniform thickness with a maximum compacted thickness of 7 inches and an average compacted thickness of 6 inches.

D. The Contractor shall define the target compaction criteria (i.e., range of acceptable moistures and densities) for each lift prior to the start of construction of each lift.

E. Fill Placement

1. The Test Fill shall be constructed in horizontal lifts in accordance with methods and procedures outlined below. The compaction parameters that will be evaluated during construction of the Test Fill include:
    a. type of compaction equipment;
    b. number of passes of the compaction equipment;
    c. soil moisture content;
    d. soil in-place dry density;
    e. hydraulic conductivity of soil; and
    f. quality control procedures.

2. First Lift
   a. The placement, compaction, and testing of the soils in the first lift of the Test Fill shall be in accordance with the following requirements:
      i. the Contractor shall, by trial and error, determine the loosely-placed soil thickness that will result in an average compacted lift thickness of 6 inches, and upon determining this, place the first lift of soil;
      ii. the soil moisture content shall be adjusted by the Contractor, as required, to meet the moisture content limitations established in Part 2.01 of this section;
      iii. the soil shall be compacted by applying two one-way passes using the same compaction equipment intended for the actual construction;
      iv. the Engineer will perform in-situ moisture content and dry density tests using ASTM D 3017 and ASTM D 2922;
      v. the lift shall be further compacted (second sequence) by applying two additional one-way passes with the same construction equipment as for the first two passes;
      vi. the testing, sampling, and repair procedures outlined in (iv) above shall be repeated at locations adjacent to the first set of tests;
      vii. the lift shall be further compacted (third sequence) by applying two additional one-way passes with the same construction equipment as for the previous passes;
      viii. the testing procedures outlined in (iv) above shall be repeated at locations adjacent to the first two sets of tests;
      ix. if needed, additional sequences of compaction, testing, sampling, and repair shall be carried out until the specified criteria for compaction are attained; at that point, a final set of two passes shall be carried out, followed by final testing; and
      xi. when the first lift is completed, the Engineer will collect undisturbed samples as described in Part 3.04(A)(4).

3. Subsequent Lifts
   a. The placement, compaction, and testing of the soils in the second and subsequent lifts of the Test Fill shall be performed in accordance with the following requirements:
      i. the Contractor shall place the second loose soil lift in a thickness which will result in a compacted lift thickness of 6 inches;
      ii. the Contractor shall place the final loose soil lift in a thickness which will result in a compacted lift thickness of 6 inches;
      iii. the Contractor shall ensure that a good bond exists between the two lifts, and the Engineer will verify that the two lifts are intermixed; and
      iv. sequences of compaction, testing, sampling, and repair shall be carried out in a manner identical to the first lift until the specified criteria for compaction are attained.
   b. When the test pad is completed, it shall be removed unless it is within the cell footprint and is approved by the Engineer for liner construction.

4. Additional Sampling and Laboratory Testing:
   a. The Engineer will obtain and test at least two undisturbed (Shelby tube) samples for hydraulic conductivity testing from each lift of the test fill. The Contractor shall assist the Engineer in obtaining the samples.
   b. The Contractor shall repair the holes in the test fill in accordance with the procedure outlined in Part 3.04(B).

5. The results of the tests performed on the test fill shall be used by the Contractor to propose a compaction procedure (i.e., equipment type and minimum number of passes) for the low permeability soil liner. The Contractor may also modify the target compaction criteria established in 2.01(C). The compaction procedure will be reviewed by the Engineer. At a minimum, five one-way passes of compaction equipment shall be required. Regardless of the approved compaction procedures, the final basis for acceptance of the low permeability soil liner shall be a maximum in-place hydraulic conductivity of 1×10^{-7} cm/sec, as measured in the laboratory for shelby tubes taken from the liner.

3.02 LOW PERMEABILITY SOIL LINER PLACEMENT

A. The low permeability soil liner shall be constructed to the grades, slopes, and elevations shown on the Drawings and as specified in this Section.

B. The low permeability soil liner shall be constructed on a subgrade surface that meets the requirements of specifications Section 31 23 00 – Excavation and Fill and Section 31 22 00 - Grading.

C. The Contractor shall mix the low permeability soil liner material prior to compaction by disc-harrowing or by an approved equivalent method to a homogenous consistency. Soil shall be mixed to reduce the size of any clods to a maximum of 2 inches, to moisture-condition soil (i.e., to mix water into the soil or to dry out soil) and to blend the soil to a homogenous consistency.

D. The Contractor shall use compaction equipment and construction methods based on the results of the Test Fill construction.

E. Low permeability soil liner material shall be compacted to the moisture and density target compaction criteria as determined by the laboratory and test fill programs, which should produce a material having a hydraulic conductivity no greater than 1×10^{-7} cm/sec. However, at least five passes of compaction equipment shall be applied to each lift and soil shall be compacted to at least 90 percent of the modified Proctor maximum dry density. Regardless of conformance of compacted material to the moisture and density compaction criteria determined from the laboratory and test fill programs, the Contractor is responsible for producing a soil liner that meets the maximum hydraulic conductivity requirement of 1×10^{-7} cm/sec in laboratory testing of undisturbed samples of compacted material performed by the Engineer.

F. At the beginning of each day's work, the Engineer will inspect the previously-placed low permeability soil liner. The Engineer may require recompaction and/or watering of the top surface of soil, as necessary, to provide a suitable surface for the next lift. This work shall be performed by the Contractor at no additional cost to the Owner.

G. The Engineer will perform testing on the material as described in the CQAP.

H. No low permeability soil liner material shall be placed on a lift which has not been tested and approved by the Engineer and CQA Surveyor except at Contractor's risk. Should the field tests indicate that the density or moisture content of any layer of low permeability soil liner, or portion thereof, are not within the required dry density or moisture content or does not meet the thickness and grading requirements shown on the Drawings and as specified in this Section, the particular layer, or portion thereof, shall be reworked by the Contractor at no extra cost to the Owner.

I. No frozen or thawing low permeability soil liner material shall be placed, spread, or compacted. No low permeability soil liner material shall be placed, spread, or compacted while the underlying soil is frozen or thawing, during unfavorable weather conditions, or during periods of heavy precipitation. Any compacted low permeability soil liner that is frozen or has been frozen and subsequently thawed shall be removed and replaced by the Contractor at no extra cost to the Owner.

J. The same material and compaction methods as outlined in this Section shall be used to replace unacceptable zones detected during execution of the work.

K. The low permeability soil liner surface shall be made smooth and free from ruts or indentations at the end of every working day when precipitation is forecast and/or at the completion of the compaction operations in that area. The Contractor shall compact the top surface of low permeability soil liner placed during the day with a smooth roller to create a smooth surface which will minimize moisture penetration and evaporation. The entire area shall be left in a manner to promote runoff at the end of each day.

3.03 PROTECTION OF WORK

A. The Contractor shall be responsible for protecting all completed work. At the beginning of each workday, the Engineer will evaluate the previous day's work. If problems are identified, such as ponded water or desiccation cracking, the Contractor shall correct the affected areas. Corrections may include, but are not limited to, regrading of layers, and removal, replacement, and recompaction of layers.

B. The Contractor shall minimize, to the maximum extent feasible, desiccation cracking of low permeability soil liner material. The low permeability soil liner shall be sprinkled with water at least twice daily and more frequently if cracking is observed or if directed by the Engineer. The Contractor may seal roll the surface of the clay to reduce evaporation. The Contractor may also protect exposed surfaces using light-colored or translucent membranes, such as visqueen, that will inhibit drying of the material. If significant cracking of the material occurs, in the sole opinion of the Engineer, the Contractor shall repair the affected area at no cost to the Owner.

C. The low permeability soil liner surface shall be seal-rolled and made smooth and free from ruts or indentations at the end of every working day when precipitation is forecasted and/or at the completion of the compaction operations in that area.

D. Low permeability soil liner material may be placed beginning at the top of the slope and working downward to a distance not less than 20 feet from the non-liner geotextile separator. All other sideslope low permeability soil liner placement shall be placed beginning at the bottom of the slope and working upward. All low permeability soil liner material shall be compacted by equipment traveling up and down the slope.

E. Completed sections of low permeability soil liner on the base of the landfill awaiting installation of the overlying geomembrane liner shall have a protective cover of either light-colored or translucent membrane, or loose, moist soil of 6-inch minimum thickness. The Contractor shall place geomembrane as soon as possible after the compaction of soil liner components has been completed.

F. The protective geomembrane or layer of soil at cell tie-in locations is to be removed prior to placement of any portion of geomembrane liner. The surface of the low permeability soil liner shall be trimmed (but shall still meet the minimum thickness requirements) and graded prior to installation of the geomembrane liner in accordance with the requirements and intent of the Contract Documents.

G. No synthetic sealants or other chemical treatments may be applied to the low permeability soil liner material.

H. Before secondary geomembrane liner installation (to be performed by others), the Contractor is responsible for protection of the low permeability soil liner until the material is accepted by the geomembrane installer for its work.

I. The low permeability soil liner shall be placed against temporary ends of previously placed similar material in a manner that provides no cracks or joints, in a manner approved by the Engineer.

3.04 FIELD QUALITY ASSURANCE

A. The Engineer will perform field quality assurance testing of all low permeability soil liner placement operations. The types and minimum frequencies of quality assurance testing for the low permeability soil liner are outlined below. The Contractor shall take the minimum testing frequencies into account in planning his construction schedule.

1. CQA During Test Fill Construction
   a. The Engineer will perform testing on the Test Fill as described in Section 3.02(E).
   b. The Shelby tubes will be sealed and shipped in accordance with ASTM D 4220 or other method approved by the Engineer to a geotechnical testing laboratory designated by the Owner.
   c. The Engineer will measure the moisture content and dry density within a 12-inch radius of each Shelby tube sample location.
   d. The independent geotechnical testing laboratory will perform the following tests on the Shelby tube samples:
      i. moisture content in accordance with ASTM D 2216;
      ii. dry density in accordance with ASTM D 2937; and
      iii. hydraulic conductivity in accordance with the method and effective confining pressure described in 2.01(C) of this Section.

2. The minimum testing frequencies for construction quality evaluation are presented in Table 02222-2, except that hydraulic conductivity tests will be performed on two samples per lift of test fill.

3. Sampling locations will be selected by the Engineer.

4. Undisturbed low permeability soil liner material samples for laboratory hydraulic conductivity testing will be taken by the Engineer with the assistance of the Contractor such that a Shelby sample tube is inserted vertically into the low permeability soil liner with a continuous smooth stroke from a hydraulic jack and using stationary construction equipment (such as a backhoe bucket or bulldozer blade) for reaction.

5. A special testing frequency will be used at the discretion of the Engineer when visual observations of construction performance indicate a potential problem. Additional testing for will be considered when:
   a. the rollers slip during rolling operation;
   b. the lift thickness is greater than specified;
   c. the low permeability soil liner material is at improper and/or variable moisture content;
   d. fewer than the specified number of roller passes are made;
   e. dirt-clogged rollers are used to compact the material;
   f. the rollers do not have optimum ballast; or
   g. the degree of compaction is doubtful.

6. During construction, the frequency of testing may also be increased by the Engineer in the following situations:
   a. adverse weather conditions;
   b. breakdown of equipment;
   c. at the start and finish of grading;
   d. if the material fails to meet specifications; or
   e. the work area is reduced.

B. Perforations

1. Perforations in the low permeability soil liner shall be filled by the Contractor. Perforations that must be filled include, but are not limited to:
   a. nuclear density test probe locations; and
   b. undisturbed sampling locations.

2. Perforations in the low permeability soil liner shall be backfilled with a soil-bentonite (powdered) mixture containing a minimum of 10 percent bentonite. The backfill shall be hand-tamped by the Contractor to the satisfaction of the Engineer.

C. Defective Areas

1. If a defective area is discovered in the low permeability soil liner, the Engineer will immediately determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the Engineer will determine the extent of the defective area by additional tests, observations, a review of records, or other means that the Engineer deems appropriate. If the defect is related to adverse site conditions, such as overly wet soils or surface desiccation, the Engineer will define the limits and nature of the defect.

2. After the extent and nature of a defect has been determined, the Contractor shall correct the deficiency to the satisfaction of the Engineer. The cost of corrective actions shall be borne by the Contractor.

3. Additional testing will be performed the Engineer to verify that the defect has been corrected. This additional testing will be performed before any additional work is allowed in the area of deficiency.

3.05 TOLERANCE

A. The minimum thickness of the low permeability soil liner shall be12 inches but may be greater than specified if approved by the Owner.

B. The minimum slopes shall be maintained within ± 5% of the slopes indicated on the Design Drawings (i.e., a 2-percent slope must be constructed to between 1.9 percent and 2.1 percent between any survey grid points).

TABLE 1

MINIMUM TESTING FREQUENCIES
FOR MATERIALS EVALUATION (CONFORMANCE) OF
LOW PERMEABILITY SOIL LINER MATERIAL(1)

TEST METHOD MINIMUM (SEE SECTION 01000-1.05)	FREQUENCY OF TESTING	
Natural Moisture Content	ASTM D 2216	1 per 1,000 yd^3 (minimum 1 per source)
Grain Size Analysis (Sieve and Hydrometer)	ASTM D 422	1 per 2,500 yd^3 (minimum 1 per source)
Atterberg Limits	ASTM D 4318	1 per 1,000 yd^3 (minimum 1 per source)
Modified Proctor	ASTM D 1557	1 per 5,000 yd^3 (minimum 1 test per material type and source)
Hydraulic Conductivity	ASTM D 5084	1 per 5,000 yd^3 (minimum 1 set of 3 tests per material type and source)

1 Tests to be performed by Engineer on samples of bulk soil collected from material placed in the cell, per the requirements of the CQAP. These tests will be performed in addition to the pre-qualification tests to be performed by the Owner's independent geotechnical testing laboratory.

TABLE 2

MINIMUM TESTING FREQUENCIES
LOW PERMEABILITY SOIL LINER[(1)]
(DURING CONSTRUCTION)

TEST METHOD MINIMUM (SEE SECTION 01000-1.05)	FREQUENCY OF TESTING	
Moisture Content (Nuclear Gauge)	ASTM D 3017	1 per 4,750 ft^2 minimum of six per lift
In-Place Dry Density[2] (Nuclear Gauge)	ASTM D 2922	1 per 4,750 ft^2 minimum of six per lift
Undisturbed Sampling	ASTM D 1587	minimum 1 per acre per lift
Hydraulic Conductivity	ASTM D 5084	minimum 1 per acre per lift

1 Tests are to be performed by the Engineer on in-place compacted material per the requirements of the CQAP.

2 Verify moisture and density readings from nuclear gauge testing by comparing gauge readings with moisture content and density data obtained from laboratory analysis of shelby tube samples.

END OF SECTION

SECTION 31 05 16 - AGGREGATES FOR EARTHWORK

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Providing all labor, materials, tools, equipment, and services as shown, specified, and required to furnish and install aggregate materials from on-site or off-site sources for the filling and backfilling, restoration of surfaces, and other purposes required by the Contract Documents.

2. Aggregate materials consist of:
   a. Cushion/Grading Layer Material
   b. Crushed Stone
   c. Dense Graded Aggregate
   d. Drainage Stone

B. Related sections

1. Section 31 05 13 – Soils for Earthwork
   Section 31 05 19.13 – Geotextiles for Earthwork
   Section 31 22 00 – Grading
   Section 32 91 19.13 – Topsoil Placement and Grading

1.02 REFERENCE STANDARDS

A. The following ASTM International (ASTM) and United States Environmental Protection Agency (USEPA) standards are referenced in this Section:

1. ASTM D- 1140, Standard Test Methods for Amount of Material in Soils Finer than No. 200 (75 µm) Sieve

2. ASTM D-1557, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort of 56,000 ft-lbf/ft3, also known as “Modified Proctor”

3. ASTM D-2216 Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures

4. ASTM D-4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

5. ASTM D-6913, Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

6. ASTM D-6938, Density of Soil and Soil-Aggregate in Place by Nuclear Method (Shallow Depth)

7. USEPA SW-846 Method 6010, Inductively Coupled Plasma-Atomic Emission Spectrometry

8. USEPA SW-846 Method 7471, Mercury in Solid or Semisolid Waste (Manual Cold Vapor Technique)

9. USEPA SW-846 Method 8081, Organochlorine Pesticides by Gas Chromatography

10. USEPA SW-846 Method 8082, Polychlorinated Biphenyls (PCBs) by Gas Chromatography
11. USEPA SW-846 Method 8151, Chlorinated Herbicides by GC Using Methylation or Pentafluorobenzylation Derivatization
12. USEPA SW-846 Method 8260, Volatile Organic Compounds by Gas Chromatography/ Mass Spectrometry (GC/MS)
13. USEPA SW-846 Method 8270, Semi-volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)
14. USEPA SW-846 Method 9012, Total and Amenable Cyanide (Automated Colorimetric, with Off-Line Distillation)

1.03 QUALITY ASSURANCE

A. Use materials, procedures, operations, and methods in strict conformance with the Contract Documents. Materials will be subjected to strict quality control monitoring as detailed herein. Conform the placed granular materials exactly to the Contract Documents, except as otherwise authorized in writing by the Construction Manager (CM).

B. Sampling of soil materials used for construction shall be conducted in accordance with the Field Sampling Plan/Quality Assurance Project Plan (FSP/QAPP [Arcadis2023[]).

1.04 SUBMITTALS

A. Submit background information for each proposed borrow pit to the CM for review as part of the borrow pit's initial screening for acceptance. At a minimum, background information shall include the following:

1. The location of each borrow pit including state, county, municipality, and address.
2. A description of the borrow pit including use history and quantity of material available from each pit.
3. A description of sampling methodology to be used to obtain geotechnical and analytical samples.
4. The results of geotechnical testing previously performed at each borrow pit and description of the geotechnical properties of the material and indication that the material meets the projects' geotechnical specifications.

B. Submit results of laboratory chemical analysis of each material type from each borrow pit at the frequencies specified in Section 2.02 of this specification.

C. Submit results of laboratory geotechnical testing of each material type from each borrow pit at the frequencies specified in Section 2.02 of this specification

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D. Submit laboratory compaction characteristic data (using Modified Proctor) for each borrow pit and for each material type having a minimum specified compaction objective. In the event of a change in the gradation of the material (as determined by the Contractor and/or the CM based on review of the particle-size analyses performed during production), additional laboratory compaction testing may be necessary to ensure applicable compaction criteria are being referenced for field compaction assessment.

E. Submit results of the particle-size analysis conducted in accordance with ASTM D-6913 and ASTM D-1140 for every 5,000 cubic yards of material brought to the site. Test results shall be submitted to the CM no less than one week prior to the anticipated placement of any granular materials.

F. Submit qualifications for the firm proposed for field nuclear density testing of fill materials.

1.05 DELIVERY

A. Notify the CM no less than one (1) week in advance of delivery of all granular materials.

PART 2 – PRODUCTS

2.01 GRANULAR MATERIALS

A. Granular materials shall meet the following gradation criteria unless otherwise approved by the Engineer.

B. Cushion/Grading Layer and Sand Bedding Material:

1. The cushion/grading layer material used for bedding below geosynthetics and sand bedding below pipes shall be a natural or artificially graded mixture of crushed stone, broken stone or natural or crushed sand complying with the gradation requirements below.

Sieve Sizes (Square Openings)	Percentage by Weight Passing Sieve
3/8-inch	100
No. 8	60-100

2. Material shall meet the requirements of Section M2.01.6 of the State of Massachusetts Department of Transportation Standard Specifications for Highways and Bridges, 2022.

C. Crushed Stone Material:

1. Materials used for the surface of the gravel cover system will consist of a natural or artificially graded mixture of crushed stone, broken stone or natural or crushed sand complying with the gradation requirements below.

Sieve Sizes (Square Openings)	Percentage by Weight Passing Sieve
1-inch	100
¾-inch	90-100
½-inch	20-55
3/8-inch	0-15
No. 4	0-5

2. Material shall meet the requirements of Section M2.01.4 of the State of Massachusetts Department of Transportation Standard Specifications for Highways and Bridges, 2022.

D. Dense Graded Aggregate

1. Material shall be naturally- or artificially graded mixture of natural or crushed gravel, crushed stone, or natural or crushed sand, complying with the gradation requirements below. Crushed slag is unacceptable.

Sieve Sizes (Square Openings)	Percentage by Weight Passing Sieve
2.5-inch	100
2-inch	95-100
¾-inch	50-75
¼-inch	25-45
No. 40	5-20
No. 100	2-12

2. Material shall meet the requirements for Dense Graded Crushed Stone for Sub-Base in Section M2.01.7-1 of the State of Massachusetts Department of Transportation Standard Specifications for Highways and Bridges, 2022.

E. Drainage Stone:

1. Material placed around collection piping shall be well-graded, clean, durable broken stone or screened gravel complying with the gradation requirements below.

Sieve Sizes (Square Openings)	Percentage by Weight Passing Sieve
1-inch	100
3/4-inch	90-100
1/2 -inch	20-55
3/8-inch	0-15
No. 4	0-5

2. Drainage stone shall be wrapped with non-woven geotextile as shown on the design drawings.

3. Material shall meet the requirements of Section M2.01.4 of the State of Massachusetts Department of Transportation Standard Specifications for Highways and Bridges, 2022.

2.02 SOURCE QUALITY CONTROL

A. Off-Site Materials: Contractor will coordinate, collect, and submit the sample, and pay for laboratory testing of each material to verify compliance with the Contract Documents.

1. Geotechnical Testing: Contractor will obtain representative samples of each material for the following:
   a. Gradation in accordance with ASTM D6913 and ASTM D1140
   b. Moisture/density relationship in accordance with ASTM D1557 (Dense graded aggregate only)
   c. Atterberg limits in accordance with ASTM D4318 (Dense graded aggregate only)
   d. Contractor shall collect samples for geotechnical analysis in accordance with relevant specifications in Article 2.02 of Section 31 05 13 – Soils for Earthwork.

e. Geotechnical testing shall be completed prior to shipment of fill. Fill material may not be accepted for import until results of chemical analysis are approved by the Construction Manager (CM).
f. Sampling and testing of each aggregate material from each borrow pit will be conducted as part of the off-site material source evaluation (to be completed in advance of construction earthwork activities with acceptable results identified no less than 15 days before material delivery to the Site). Sampled materials will be tested in accordance with Section 2.02 A.1. of this specification.
g. Contractor will collect at least two representative samples of each material type for testing.

2. Chemical Testing: Contractor will obtain representative samples of each material for chemical testing for fill material with greater than 10 percent by weight passing the No. 80 sieve as determined by gradation testing performed in accordance with Section 2.02.A.1 of this specification. Sampling will be performed as follows:
   a. Contractor shall collect samples for chemical analyses in accordance with relevant specifications in Article 2.02 of Section 31 05 13 – Soils for Earthwork.
   b. Chemical testing shall be completed prior to shipment of fill. Fill material may not be accepted for import until results of chemical analysis are approved by the Construction Manager (CM).

3. If testing results indicate that a borrow pit material does not comply with the Contract Documents, the Contractor shall identify and propose a new source for the specified material. Contractor shall provide the following:
   a. Submit required information for proposed borrow pit and Supplier in accordance with Section 1.04 of this specification.
   b. Contractor will collect samples and coordinate laboratory testing in accordance with this Section 2.02A of this specification.

4. Contractor shall be responsible for the cost of all testing.

B. Do not ship off-site fill materials to the Site until proposed materials, borrow pits, and Suppliers are accepted by Owner and CM.

PART 3 – EXECUTION

3.01 INSPECTION

A. Prior to placement of aggregate materials, verify that the geotextiles (if required), are free of tears, holes, wrinkles, and foreign objects, and are securely anchored.

B. Verify that subgrades, aggregate base grades, and final grades, slopes and elevations conform to specified requirements. Correct insufficient work at no additional cost to the Owner. Notify the CM immediately if a specified grade, slope, or elevation appears inconsistent with the others specified.

C. At the beginning of each day's Work, the CM will inspect the previously placed aggregate materials and the Contractor shall institute whatever corrective action, if any, that the CM deems appropriate, at no extra cost to the Owner, unless the action requested is clearly beyond the scope of the project Contract. This may include but is not limited to the removal and replacement of unsuitable aggregate materials.

3.02 PLACEMENT OF AGGREGATE MATERIAL

A. Do not allow heavy equipment to operate directly on exposed or thinly covered geotextile. Construct a platform of the aggregate material from which additional material can be spread.

B. Materials shall be placed, not dumped, to the limits and grades shown on Drawings.

C. Do not operate equipment in a manner that will cause equipment to dig into the geotextiles. If this occurs, even inadvertently, clear the area to demonstrate to the satisfaction of the CM that the geotextiles have not been damaged. Immediately repair any damage at the Contractor's expense.

D. Spread and grade aggregate material in single lifts to the final thickness and grades shown on the Drawings.

E. Place aggregate materials to the densities and lift thicknesses specified in Section 31 22 00 - Grading

F. Furnish and use equipment capable of adding measured amounts of water to the fill materials to bring fill materials to a condition within required moisture content range.

G. Furnish and use equipment capable of discing, aerating, and mixing the fill materials to ensure reasonable uniformity of moisture content throughout the fill materials, and to reduce moisture content of borrow materials by air drying, when necessary. When subgrade or lift of fill materials requires moisture-conditioning before compaction, fill material shall be sufficiently mixed or worked on the subgrade to ensure uniform moisture content throughout the lift of material to be compacted. Materials at moisture content in excess of specified limit shall be dried by aeration or stockpiled for drying.

H. Perform compaction with equipment suitable for the type of fill material being placed. Select and use equipment capable of achieving the minimum densities required in the Contract Documents.

I. Furnish and use equipment capable of compacting in restricted areas next to structures and around piping and Underground Facilities. Effectiveness of the equipment selected by Contractor shall be tested at start of compacted fill work by constructing a small section of fill within or adjacent to the area where fill will be placed. Record total number of coverages with selected compaction equipment and perform field moisture content and density tests to ensure that specified compaction of fill has been obtained. If test section results indicate that the required compaction has not been obtained, do one or more of the following:

   1. Increase the amount of coverages.
   2. Decrease the lift thicknesses.
   3. Use different compaction equipment.

J. Place fill materials in horizontal, loose lifts, not exceeding the specified lift thicknesses following compaction. Place fill in a manner ensuring uniform lift thickness after placing. Mechanically compact each lift, by not less than two complete coverages of the compactor. One coverage is defined as the conditions reached when all portions of the fill lift have been subjected to the direct contact of compactor’s compacting surface. Compaction of fill materials by inundation with water is unacceptable.

K. Do not place fill materials when standing water is present on the surface of the area where fill will be placed. Do not compact fill when standing water is present on the fill to be compacted.

L. Do not place or compact fill in a frozen condition or on top of frozen material.

M. Fill containing organic materials or other unacceptable materials previously described shall be removed and replaced prior to compaction.

N. If required densities are not obtained because of improper control of placement or compaction procedures, or because of inadequate or improperly functioning compaction equipment, the Contractor shall perform all work required to achieve the required densities. Such work shall include, at no additional cost to the Owner, complete removal of unacceptable fill areas and replacement and re-compaction until acceptable fill conditions are achieved.

O. Repair, at Contractor's expense, observed or measured settlement. Make repairs and replacements as required within five days after being so advised by CM.

3.03 FIELD QUALITY CONTROL

A. The CM will perform thickness measurements in the field to determine compliance with the Contract Documents.

B. Subcontract an independent third-party firm to test the in-place density and moisture of compacted lifts in accordance with specification Section 31 22 00 - Grading.

C. Record all test results and document their locations. The CM may require the Contractor to make additional tests or to re-test, at no additional cost to the Owner, a compacted material if the compaction procedures or the density of the material are in question.

3.04 CRITERIA AND TOLERANCES

A. Soil fill materials shall be constructed to the lines and grades shown on the contract drawings unless otherwise requested by the cm. Acceptance of final grades will be based on site observations by the cm and review of a final as-built survey information. Any settlements that occur prior to final acceptance of the work shall be restored to design and/or intended grades by the contractor at no additional cost to the owner.

END OF SECTION

SECTION 31 05 18.16 - GEOSYNTHETIC CLAY LINER

PART 1 GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary for the construction of the geosynthetic clay liner (GCL) portion of the primary and secondary soil liners as specified herein, as shown on the Drawings, and in accordance with the CQAP.

B. The Contractor shall be prepared to install the GCL in conjunction with the earthworks and the installation and construction of the other components of the liner system.

C. Notwithstanding the prequalification of any material sources for the GCL, the Contractor shall be entirely responsible for meeting the requirements of this Section.

1.02 RELATED SECTIONS

A. Section 31 05 13.10 – Low Permeability Soil Liner

B. Section 31 05 19.16 – High Density Polyethylene (HDPE) Geomembrane

1.03 QUALIFICATIONS

A. The Owner will contract a manufacturer to supply the GCL. The Manufacturer shall be responsible for the production and delivery of the GCL and shall be a well-established firm with more than two years experience in the manufacture of GCL. The Manufacturer shall submit a statement to the Engineer listing:
1. Certified minimum average roll property values of the proposed GCL and the tests used to determine those properties.
2. Production capacity, availability, and projected delivery dates for this project.

B. The Owner will directly contract a GCL installer.

1.04 SUBMITTALS

A. The Owner will obtain from the GCL Manufacturer and have available for the Contractor's or Installer's inspection, the following documentation on GCL production prior to the shipment of the GCL rolls.

1. Manufacturing quality control certificates for geotextiles, bentonite clay, and manufacturing process and each shift's production. The certificates shall identify the origin and the manufacturer of the bentonite. The certificates shall be signed by responsible parties employed by the manufacturer (such as the production manager).

2. The quality control certificate shall include:
   a. roll numbers and identification;
   b. sampling procedures; and
   c. results of quality control tests, including a description of the test methods used.

1.05 DELIVERY HANDLING AND STORAGE

A. Roll Identification

1. Provide GCL rolls wrapped in relatively impermeable and opaque protective covers and marked or tagged with following information.
   a. Manufacturer’s name.
   b. Product identification.
   c. Shipping lot.

2. Indicate special handling marked on GCL itself, e.g., “This Side Up.”

3. Conformance testing to indicate conformance with Specifications.

B. Handle GCL to protect from damage. GCL rolls shall be lifted by inserting a steel bar, capable of supporting the full weight of the roll, through the center core.

C. Store GCL in dry place under roof or other protective cover, protect from moisture by placing on skids, pallets, or dry ground.

D. Damaged GCL shall be removed and replaced at no cost to OWNER.

1.06 CONSTRUCTION QUALITY ASSURANCE

A. The installation of the GCL shall be monitored and tested by the Engineer as outlined in the project Construction Quality Assurance Plan (CQAP).

B. The Contractor shall be aware of the activities outlined in the CQAP and shall account for these CQA activities in the installation schedule.

C. The Engineer shall screen the surface of the GCL following deployment, with a metal detection device capable of detecting broken needles. In the event that broken needles are detected, the Geosynthetics Installer shall repair the GCL in accordance with Part 3.01 E of this section or replace the entire GCL panel (at the discretion of the Engineer) at no additional cost to the Owner.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Bentoliner; Solmax.

B. Or approved equal.

2.02 GENERAL

A. Except when specifically authorized, do not furnish special run or value-added products.

B. GCL characteristics

1. Flexible, layered liner consisting of continuous layer of sodium bentonite sandwiched between primary backing of woven polypropylene mat and cover of nonwoven polyester fabric.

2. GCL shall be of type to maintain integrity during installation, placement, and covering procedures.

3. The bentonite and geotextile composite shall be needlepunched to provide high shear resistance and durability.

2.03 GCL PROPERTIES

A. General Properties

1. Minimum Dimensions: 15 feet by 100 feet.

2. Thickness: 0.24 inches, minimum.

3. Bentonite Mass/Unit Area: 0.75 pounds/square foot (psf) minimum weight.

4. Permeability: 1 x 10^{-9} centimeters/second (cm/sec) or less at 1 foot head pressure of water.

5. Internal shear strength greater than that defined by φ' = 17 degrees and c' = 200 psf, over the normal stress range of 0-12,000 psf when inundated with water at the test confining pressure.

6. Grab Tensile: 95 lbs. minimum.

7. Puncture: 170 lbs. minimum.

8. Peel Strength: 5 lbs. minimum.

B. Primary Fabric Backing Material

1. Fabric woven polypropylene fabric, nontoxic, water soluble, nonbiodegradable on one side of bentonite core.

2. Fabric weight: 3.25 oz/sq yd, minimum.

3. Tensile Strength: 70 lbs/in., minimum.

4. Grab Strength: 70 lbs/in., minimum.

5. Mullen Burst Strength: 250 lbs/sq in., minimum.

6. Puncture Strength (5/16 mandril): 75 lbs minimum.

7. Filler Fabric: Nylon.

C. GCL Material

1. Sodium Bentonite.

2. Mineralogical Composition: 90% montmorillonite minimum by XRD method.

3. Bentonite graded for mat application.

D. Cover Fabric Material

1. Fabric: 100% nonwoven polyester with open weave to allow for bentonite expansion.

2. Fabric Weight: 7.25 oz sq yd, minimum.

3. Grab Strength: Warp 30 lbs, fill 13.6 lbs.

4. Burst Strength: 35 lbs/sq in.

PART 3 EXECUTION

3.01 INSTALLATION

A. Site Preparation

1. Grade and compact subgrade to provide smooth uniform surface. Do not place mat without the Installer's and Engineers subgrade approval.

2. Lay mat on prepared subgrade free of particles greater than 1 inch in diameter.

3. Provide grading to allow surface water to be directed away from installation area toward leachate collection sumps.

B. General

1. Place woven polypropylene side up.

2. Position GCL by pulling roll suspended by inserting heavy duty 3-inch diameter steel pipe with spreader bar (to prevent damage to mat edge) or suspended roll can be backed down slope and across excavation by supporting vehicle.

3. Lay GCL on side slopes perpendicular to base excavation.

4. Anchor GCL by sand bags or tires to prevent shifting of GCL. Do not temporarily anchor by wooden stakes.

5. Lay GCL on base so upstream mat overlaps downstream mat.

6. GCL overlap shall be free of dirt to provide seal.

7. Provide 6-inch minimum GCL overlap each side.

8. Do not install GCL in rain or standing water.

9. After installation, protect GCL from rain and moisture.

10. Do not deploy more GCL than can be covered at the end of the day.

11. Notify Engineer before placing any geomembrane cover over GCL. Do not cover until Engineer has approved of the installation and screening for broken needles has been completed.

C. Temporary Mat Cover:

1. In event of rain, immediately cover exposed mat with plastic sheeting or other methods.

D. Mat Cover

1. Place geomembrane over mat immediately after Engineer's approval to protect from precipitation.

2. Prevent seam damage or mat slippage during geomembrane placement.

3. Cover mat in forward direction working on previously placed geomembrane.

E. Repairs and Damaged Mat

1. Repair torn or damaged mat by covering 1 foot minimum overlap on sides.

2. Repair pieces shall be stapled, nailed or glued in position without damaging liner layers.

3. If tear exceeds 10% of width of roll on side slope, remove roll from slope and replace entire roll.

4. Replace damaged liner at no cost to OWNER.

3.02 COVER MATERIAL PLACEMENT

A. Place geomembrane in accordance with Section 31 05 19.16.

END OF SECTION

TABLE 1

BENTONITE MATTING TESTING

FACTORY QUALITY CONTROL (QC) CERTIFICATION AND
QUALITY ASSURANCE (QA) CONFORMANCE TESTING PROTOCOL

Factory QC and QA Conformance Testing Requirements Material - Bentonite Matting				
Specification Property	Specification Value	Test Method	MFR Frequency of Testing (QC)	Frequency of Testing (QA)
Bentonite Mass/Unit Area (lb/ft^2) (MARV)	0.75	ASTM D-5261	1/40,000 ft^2	1/100,000 ft^2
Swell Index (ml/2g) (min)	24	ASTM D 5890	1/40,000 ft^2	None required
Moisture Content (%) (Max)	12	ASTM D-4643-87	1/40,000 ft^2	1/100,000 ft^2
Hydraulic Conductivity (cm/sec) (Maximum)	1 x 10^{-9}	GRI GCL-2	1/100,000 ft^2	1/250,000 ft^2

(MARV) = Minimum average roll value.

SECTION 31 05 19.13 - GEOTEXTILES FOR EARTHWORK

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Providing all labor, materials, tools, equipment, and services as shown, specified, and required to furnish and install geotextiles.

B. Related Sections:

1. Section 31 05 13 – Soils for Earthwork
2. Section 31 23 00 – Excavation and Fill
3. Section 31 37 00 – Riprap

1.02 REFERENCE STANDARDS

A. The following Geosynthetics Research Institute (GRI) test methods are referenced in this Section:

1. GRI GT13 - Test Methods and Properties for Geotextiles Used as Separation Between Subgrade Soil and Aggregate.

B. The following American Association of State Highway and Transportation Officials (AASHTO) standards are referenced in this section.

1. AASHTO M 288 - Standard Specification for Geotextile Specification for Highway Applications.

C. Where reference is made to one of the above codes, standards, specifications, or publications, the revisions in effect at the time of bid shall apply.

1.03 QUALITY ASSURANCE

A. Geotextile manufacturer shall be a specialist in the manufacture of geotextile separation and stabilization fabrics and shall have produced and successfully installed a minimum of five million square feet of geotextile material.

1.04 SUBMITTALS

A. Prior to shipment of any geotextile materials, submit the following information on the geotextile product to the Engineer:

1. Lot and roll identification numbers for materials.
2. Quality control certificates that provide reference to the lot and roll identification numbers, sampling procedures, test methods and test results and other items such as:
   a. Name of Manufacturer
   b. Chemical Composition
   c. Product Identification
   d. Statement of Compliance

3. All certificates shall be signed by a representative of the manufacturer.
4. Geotextile quality assurance tests from the manufacturer including:

Test	Procedure
Unit Weight	ASTM D-5261
Flow Rate	ASTM D-4491
Permittivity	ASTM D-4491
Trapezoidal Tear Strength	ASTM D-4533
Grab Elongation	ASTM D-4632
Apparent Opening Size	ASTM D-4751
CBR Puncture	ASTM D-6241

5. Unless otherwise specified or approved by the Engineer, the quality assurance tests by the manufacturer shall be conducted at the frequency of one per lot or one per each 50,000 square feet. One lot is defined as a group of consecutively numbered rolls or panels from the same manufacturing line and using raw materials from the same resin batch.
6. The geotextile manufacturer shall replace any rolls that are rejected for non-compliance with these Specifications.
7. If a sample fails to meet the quality control requirements, the manufacturer shall test each roll manufactured from the same resin batch or at the same time as the failing roll.
8. Testing shall be at the manufacturer's expense and shall continue until a pattern of acceptable test results is established.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Each roll of geotextile delivered to the Site shall be labeled by the manufacturer identifying the manufacturer's name, product identification, lot number, roll number, and roll dimensions.

B. Inspect all rolls and packages upon delivery to the Site to confirm that the materials have not been damaged due to improper transportation, handling, or storage. If the protective wrapping is damaged, or if damage to the roll is suspected, separate the roll from the lot for more detailed inspection.

C. Notify Engineer if any loss or damage exists to geotextile. Replace loss and repair damage to new condition, in accordance with manufacturer's instructions.

D. Protect geotextile from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions. Ship and store geotextile rolls in relatively opaque and watertight wrappings.

E. Place geotextile only after the required submittals have been received and reviewed by the Engineer and the placement surface has been fully prepared and deemed acceptable for geotextile deployment.

PART 2– PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. GSE Environmental

B. TenCate Miarfi

C. Skaps Industries

D. Approved equal

2.02 MATERIALS

A. Non-Woven Geotextile:

1. Non-woven geotextile shall be of needle-punched construction and consist of long-chain polymeric fibers or filaments composed of polypropylene. The non-woven geotextile shall be chemically inert to naturally encountered chemicals, acids, and bases and resist biological degradation.

2. Non-woven geotextile shall be used as a separation layer between dissimilar material types as shown on the Drawings. The non-woven geotextile shall meet GRI GT13 specifications and have the following minimum average roll values (MARVs):

TABLE 1
REQUIREMENTS FOR NON-WOVEN GEOTEXTILE

Property	ASTM Test Method	Units	Value (MARV)*
Unit Weight	D5261	oz/yd^2	10
Grab Tensile Strength	D4632	lb	230
Grab Tensile Elongation	D4632	%	50
Trapezoidal Tear Strength	D4533	lb	95
Permittivity	D4491	sec^{-1}	1.3
CBR Puncture Strength	D6241	lb	700
UV Resistance (at 500 hours)	D7238	%strength retained	70

* Minimum Average Roll Value

B. Woven Geotextile:

1. Woven geotextile shall be composed of high-tenacity polypropylene yarns woven into a stable network such that the yarns retain their relative position. The woven geotextile shall be chemically inert to naturally encountered chemicals, acids, and bases and resist biological degradation.

2. Woven geotextile shall be used as a separation layer between the gravel surface layer and the general fill layer in the gravel cover system areas of the engineered cover.

3. The woven geotextile shall meet AASHTO M 288-05 requirements for a Class 2 separation geotextile, consist of 95% weight polyethylene or polyester, and have the following MARVs:

TABLE 2
REQUIREMENTS FOR WOVEN GEOTEXTILE

Property	ASTM Test Method	Units	Value (MARV, Except AOS)*
Grab Tensile Strength	D4632	lb	250
Grab Tensile Elongation	D4632	%	15
Trapezoidal Tear Strength	D4533	lb	90
CBR Puncture	D6241	lb	700
Permittivity	D4491	sec^{-1}	0.1
Flow Rate	D4491	$gal/min/ft^2$	4
AOS	D4751	mm	0.425
UV Resistance (at 500 hours)	D4355	% strength retained	70

* Minimum Average Roll Value

PART 3 – EXECUTION

3.01 INSPECTION

A. Examine the areas and conditions under which the Work will be performed and notify CM in writing of conditions detrimental to the proper and timely completion of the Work. Do not proceed with the Work until unsatisfactory conditions are corrected in a manner acceptable to CM.

3.02 PREPARATION

A. Excavate or fill subgrade, as required, to bring subgrade to elevations shown or indicated. Maintain all angles of repose. Confirm that subgrade is at proper elevations and that no further earthwork is required to bring the subgrade to proper elevations. Provide subgrade elevations that slope parallel to finished grade and, in the direction, shown on the Design Drawings.

B. Remove all stones greater than two inches in any dimension, construction debris, trash, rubble, and all other extraneous materials from the subgrade.

C. Notify CM that subgrade has been prepared and obtain CM's approval before installing geotextile.

3.03 INSTALLATION

A. Place (roll out) geotextiles in the direction of most frequent vehicular travel.

B. Overlap adjoining edges of geotextiles a minimum of 12 inches, unless otherwise specified or approved by the Engineer.

C. Weight geotextiles with sandbags or equivalent when required. Install sandbags (or equivalent) during placement and maintain until replaced with cover materials.

D. During placement of geotextiles, take care not to entrap excessive dust, mud, or moisture in the geotextile stone, that could damage or cause clogging of the geotextile, or hamper subsequent seaming.

E. Use proper tools to cut and size geotextiles; exercise care while cutting geotextiles.

F. Do not expose geotextiles to precipitation prior to being installed, and do not expose geotextiles to direct sunlight for more than 15 days.

3.04 GEOTEXTILE REPAIR

A. Any holes or tears in the fabric shall be repaired as follows:

1. On Slopes: Sew a fabric patch into place using a double sewn lock stitch (1/4 inch to 3/4 inch apart and no closer than one inch from any edge). Should any tear exceed 10 percent of the width of the roll, that roll shall be removed from the slope and replaced.

2. Non-Slopes: Spot-seam a fabric patch in place with a minimum of 18 inches of overlap in all directions.

3.05 PLACEMENT OF COVER MATERIALS

A. Place all granular materials located on top of the geotextile in such a manner as to ensure:

1. No damage of the geotextile or underlying layers;

2. Minimal slippage between the geotextile and the underlying layers; and,

3. No excess tensile stresses in the geotextile.

B. Do not drive equipment directly on the geotextile.

C. Utilize equipment exerting the lowest ground pressure practicable to place the granular materials to minimize the potential for damage to the geotextile. Under no circumstances shall the placement equipment exert more than 5 psi ground pressure.

END OF SECTION

SECTION 31 05 19.16 - GEOMEMBRANES FOR EARTHWORK

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Providing all labor, materials, tools, equipment, and services as shown, specified, and required to furnish and install 60 mil textured high-density polyethylene (HDPE) geomembrane liner as specified in this section and in accordance with the manufacturer's recommendations/specifications.

B. Related Sections:

1. Section 31 05 19.13 – Geotextiles for Earthwork

2. Section 31 05 19.26 – Geocomposite for Earthwork

3. Section 31 22 00 – Grading

1.02 REFERENCE STANDARDS

A. The following American Society of testing and materials (ASTM) International standards are referenced in this section:

1. D792 - Standard Test Methods for Density and Specific Gravity (Relative Gravity) of Plastics by Displacement

2. D1004 - Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting

3. D1505 - Standard Test Method for Density of Plastics by the Density-Gradient Technique

4. D1603 - Standard Test Method for Carbon Black Content in Olefin Plastics

5. D3895 - Standard Test Method for Oxidative Induction Time of Polyolefins by Differential Scanning Calorimetry

6. D4218 - Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique

7. D4437 - Standard Practice for Non-destructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes

8. D4833 - Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products

9. D5397 - Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test

10. D5596 - Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics

11. D5617 **-** Standard Test Method for Multi-Axial Tension Test for Geosynthetics

12. D5721 - Standard Practice for Air-Oven Aging of Polyolefin Geomembranes

13. D5885 - Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry

14. D5994 - Standard Test Method for Measuring Core Thickness of Textured Geomembrane

15. D6693 - Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes

16. D7466 - Standard Test Method for Measuring the Asperity Height of Textured Geomembrane

B. The following Geosynthetics Research Institute (GRI) test methods are referenced in this section:

1. GRI GM17 - Test Methods, Test Properties, and Testing Frequencies for Linear High-Density Polyethylene (HDPE) Smooth and Textured Geomembranes

C. Where reference is made to one of the above codes, standards, specifications, or publications, the revisions in effect at the time of bid shall apply.

1.03 QUALITY ASSURANCE

A. Geomembrane manufacturer shall be a specialist in the manufacture of geomembranes and shall have produced and successfully installed a minimum of five million square feet of geomembrane material.

B. Quality assurance/quality control (QA/QC) testing of HDPE geomembrane liner as specified in this section and in accordance with the manufacturer’s recommendations/specifications.

1.04 SUBMITTALS

A. The following items shall be submitted no later than 30 days prior to the start of geomembrane installation or 15 days prior proposed to delivery of the first geomembrane shipment, whichever is earliest.

1. The Geomembrane Manufacturer shall submit the following information in writing to the Owner and the Construction Manager (CM):
   a. Corporate background and information.
   b. Manufacturing Quality Control (MQC) Plan.
   c. Manufacturing capabilities, including:
      1) Information on plant size, equipment, personnel, number of shifts per day, and capacity per shift;
      2) Daily production quantity available for this Contract;
      3) Manufacturing quality control procedures; and

4) List of material properties, including certified test results, attached to which is a geomembrane sample.

d. A list of at least ten completed facilities for which the Geomembrane Manufacturer has manufactured a minimum of 10,000,000 square feet of polyethylene geomembrane. The following information shall be provided for each facility:
   1) Name, location, and purpose of facility, and date of installation;
   2) Names of Owner, Project Manager, Engineer, General Contractor, fabricator (if any), and installer.
e. Type, thickness, and quantity of geomembrane manufactured.
f. Copies of quality control certificates issued by the resin supplier.
g. Results of tests conducted by the Geomembrane Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project.
h. Certification that no reclaimed polymer is added to the resin during the manufacture of the geomembrane to be used for this project. The use of polymer recycled during the manufacturing process may be permitted if performed with appropriate cleanliness and if the recycled polymer does not exceed 10% by weight of the total polymer weight.
i. Manufacturing certificates for each shift's production of geomembrane, signed by responsible parties employed by the Geomembrane Manufacturer (such as the production manager), and notarized.
j. Quality control certificates providing the results of the quality control tests outlined in Section 2.03(A) of this Specification.
   1) The quality control certificates shall include:
      a) Roll numbers and identification;
      b) Sampling procedures; and
      c) Results of quality control tests, including descriptions of the test methods used.
k. Written certification that the minimum test values indicated in Section 2.02 of this specification are guaranteed by the manufacturer.
l. Manufacturer’s standard warranty for the geomembrane.
m. Material sample of the geomembrane.

2. The Geosynthetics Installer shall submit the following information in writing to the Owner and the Engineer:
   a. Corporate background and information.
   b. Copy of installer's letter of approval or license by the Geomembrane Manufacturer and/or fabricator.
   c. Construction Quality Control (CQC) Plan.
   d. Installation capabilities, including:
      1) Information on equipment and personnel;
      2) Average daily production anticipated for this project;
      3) Quality control procedures; and
      4) Samples of field seams, a certified list of minimum values for seam properties, and the test methods employed.
   e. A list of at least 10 completed facilities, for which the installer has installed a minimum of 5,000,000 square feet of polyethylene geomembrane. The following information shall be provided for each facility:
      1) The name and purpose of the facility, its location, and dates of installation;
      2) The names of the Owner, Project Manager, Engineer, General Contractor, Geomembrane Manufacturer, fabricator (if any), and the name of a contact at the facility who can discuss the project;
      3) Name and qualifications of the installer's supervisor(s);
      4) Thickness and surface area of installed geomembrane;
      5) Type of seaming and type of seaming apparatus used; and
      6) Duration of installation.

f. Resumes of all personnel who will perform seaming operations on this project, including dates and duration of employment.
g. Resume of the installation supervisor to be assigned to this project, including dates and duration of employment. The superintendent shall have supervised the installation of a minimum of 2,000,000 square feet of polyethylene geomembrane.
h. Proposed installation panel layout drawing showing the placement of geomembrane panels, seams and any variances or additional details which deviate from the Construction Drawings.
i. Installation schedule.
j. The name and qualifications of the proposed laboratory that will be responsible for laboratory testing of destructive seam samples.

3. The Contractor shall submit the following information in writing to the Owner and Engineer prior to installation of the geomembrane:
   a. Certification that the field-delivered geomembrane has not been damaged due to improper transportation, handling, or storage.
   b. Certification that the surface on which the geomembrane is to be installed is acceptable to both the Engineer and the Contractor. The certification is subject to the review and approval or rejection by the Owner.

B. During installation, the Geosynthetics Installer shall submit the following information to the Owner and the CM:

1. Certification that the surface on which the geomembrane is to be installed is acceptable to both the Engineer and the Contractor. The certification is subject to the review and approval or rejection by the Owner;

2. Daily field logs documenting the work being performed, personnel involved, general working conditions, and any problems encountered or anticipated on the project;

3. Field quality control documentation (i.e., trial seam tests, destructive tests, non-destructive tests, etc.); and

4. A Certificate of Calibration less than 12 months old for the field tensiometer referenced in Section 3.03(H)(2) of this Specification.

C. Geomembrane lot and roll number of field-delivered material.

D. Upon completion of the installation, the Geosynthetics Installer shall be responsible for the timely submission of the following:

1. Geomembrane installation certification;

2. As-built panel layout diagram; and

3. Warranty from Geomembrane Manufacturer/Installer as specified in Section 1.05 of this Specification.

1.05 WARRANTY

1. The geomembrane manufacturer and geosynthetics installer shall furnish a standard written warranty against defects in material and workmanship. warranty duration and conditions concerning limits of liability will be evaluated and must be acceptable to the owner.

PART 2– PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Solmax Geosynthetics.
B. AGRU America, Inc.
C. Poly-Flex, Inc.
D. Approved equal.

2.02 MATERIALS

A. Polyethylene Geomembrane Resin

1. The resin shall comply with the following HDPE specified properties:
   a. Specific Gravity: 0.97 g/ml, maximum (ASTM D792 Method B, or ASTM D1505)
   b. Melt Index: 1.0 g/10-minute, maximum (ASTM D1238 Condition E 190 ˚C, 2.16 kg)
2. Resin shall be virgin material with no more than 10% rework (by weight). Rework material shall be of the same formulation as parent material. No post-consumer resin shall be added to the formulation.

B. HDPE Geomembrane

1. HDPE Geomembrane material shall be HDPE geomembrane textured on both sides and meet the following minimum specification values listed in Table 1 below and as listed in GRI GM13.

TABLE 1
REQUIREMENTS FOR HDPE GEOMEMBRANE

Property	Test Method	Specification Limit 60 mil Textured
Density (min.)	ASTM D1505/D792	0.940 g/cc
Carbon Black Content	ASTM D1603 (3) /D4218	2.0 – 3.0%
Carbon Black Dispersion	ASTM D5596	9 of 10 views in category 1 or 2 1 of 10 views in category 3
Thickness (nominal) Thickness (min. avg.) lowest individual 8 of 10 values lowest individual of 10 values	ASTM D5994	60 mil 57 mil 54 mil 51 mil
Tensile Strength at Break (min.)	ASTM D6693 Type IV	126 lb/in
Elongation at Break (min.)		100%
Tear Resistance (min.)	ASTM D1004	42 lbs

Property	Test Method	Specification Limit
		60 mil Textured
Asperity Height	ASTM D7466	16 mil
Puncture Resistance (min.)	ASTM D4833	90 lbs

2. In addition to the property values listed in Table 1 of this specification, the geomembrane shall:
   a. Contain a maximum of 1% (by weight) of additives, fillers, or extenders (not including carbon black);
   b. Be free of striations, pinholes, or bubbles on the surface or in the interior;
   c. Be produced so as to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter; and
   d. Be manufactured in a single layer (thinner layers shall not be welded together to produce the final required thickness) and have a uniform textured appearance on both sides.

C. Welding Material

1. The resin used in the welding material shall be identical to the liner material.

2. All welding materials shall be of a type recommended and supplied by the Geomembrane Manufacturer and shall be delivered in the original sealed containers, each with an indelible label bearing the brand name, Geomembrane Manufacturer's mark number, and complete directions as to proper storage.

D. Fabrication

1. The geomembrane shall be delivered to the site in rolls or as factory panels. A factory panel is comprised of one or more rolls that have been seamed together in a factory.

2. Labels on each geomembrane roll shall identify the following information:
   a. Name of Geomembrane Manufacturer;
   b. Product identification;
   c. Roll number and dimensions;
   d. Batch number;
   e. Thickness of the material; and
   f. Directions to unroll the material.

2.03 GEOMEMBRANE TESTING REQUIREMENTS

A. Geomembrane Manufacturer’s Quality Control Testing

1. Polyethylene Geomembrane Resin
   a. The Geomembrane Manufacturer shall sample and test the resin to demonstrate that the resin complies with this Specification. The Geomembrane Manufacturer shall certify in writing that the resin meets this Specification and shall be held liable for any non-compliance.
   b. Geomembrane material manufactured from non-complying resin will be rejected. Replacement of any rejected geomembrane material will be at no cost to the Owner.

2. HDPE Geomembrane

   a. The Geomembrane Manufacturer shall continuously monitor the geomembrane during the manufacturing process for inclusions, bubbles, or other defects. No geomembrane that exhibits any defects will be accepted.
   b. The Geomembrane Manufacturer shall continuously monitor the geomembrane thickness during the manufacturing process. No geomembrane that fails to meet the specified minimum thickness will be accepted.
   c. The Geomembrane Manufacturer shall sample and test the geomembrane, in accordance with the MQC Plan to demonstrate that its properties conform to the values specified in Table 2 of this specification.
      1) Samples shall be taken across the entire width of the roll.
      2) At a minimum, the following manufacturing quality control tests shall be performed:

TABLE 2
MANUFACTURING QUALITY CONTROL TESTS

Test	Procedure
Thickness	ASTM D5994
Density	ASTM D1505/ ASTM D 792
Break Strength	ASTM D6693 Type IV
Break Elongation	ASTM D6693
Tear Resistance	ASTM D1004
Puncture Resistance	ASTM D4833
Carbon Black Content	ASTM D1603
Carbon Black Dispersion	ASTM D5596
Axi-Symmetric Break Resistance Strain	ASTM D5617
Asperity Height	ASTM D7466
Oxidative Induction Time (OIT)	ASTM D3895/ ASTM D5885
Oven Aging at 85°C	ASTM D5721/ ASTM D3895/ ASTM D5885
UV Resistance	ASTM D5885

   d. Any geomembrane sample that does not comply with this Specification will be rejected by the Owner.
   e. If a roll of geomembrane is rejected, the Geomembrane Manufacturer shall sample and test each roll manufactured in the same batch or at the same time as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established.
   f. The Contractor shall replace any rejected rolls at no additional cost to the Owner.
   g. Additional testing may be performed at the Geomembrane Manufacturer's discretion and expense, to identify the non-complying rolls more closely and/or to qualify individual rolls.

3. The Geomembrane Manufacturer’s test results shall be submitted by the Contractor to the Engineer for review, prior to shipping any rolls of geomembrane.

B. Conformance Testing

1. Prior to installation, samples of delivered geomembrane shall be taken and shipped to a third-party testing laboratory (i.e. the Owner's Conformance Testing Laboratory), for conformance testing independent of the manufacturer's testing. Unless otherwise specified, the samples shall be taken at a minimum frequency of one sample per 100,000 square feet with a minimum of one sample per lot of material delivered to the site (regardless of the dates of manufacturing or delivery dates). At least one sample shall also be obtained from geomembrane rolls representing each resin production batch.

2. Samples shall be at least 3 feet long by the roll width and shall not include the first 3 feet of any roll.

3. Conformance testing shall be the responsibility of the Owner.

4. The Contractor shall, at no additional cost to the Owner, provide whatever reasonable assistance the Engineer may require in obtaining the samples for conformance testing.

5. At a minimum, the following conformance tests shall be performed:

TABLE 3
CONFORMANCE TESTS

Test	Procedure
Thickness	ASTM D5994
Density	ASTM D1505/ ASTM D 792
Break Strength	ASTM D6693 Type IV
Break Elongation	ASTM D6693
Tear Resistance	ASTM D1004
Puncture Resistance	ASTM D4833
Carbon Black Content	ASTM D1603
Carbon Black Dispersion	ASTM D5596
Asperity Height	ASTM D7466

6. Prior to installation, the Engineer shall review the conformance test results against the material properties required by Table A of this specification. Non-conforming material will be rejected and bracketed from subsequent rolls from the same product batch.

7. If geomembrane material is rejected due to failing conformance test results, the Contractor shall be responsible for all costs associate with additional material testing and replacement of materials as necessary.

C. Interface Friction/Direct Shear Testing

1. Prior to installation, samples of delivered geomembrane shall be taken and shipped to the Owner's geosynthetics laboratory for interface friction/direct shear testing.

2. Samples shall be at least 3 feet long by the roll width and shall not include the first 3 feet of any roll.

3. Interface friction/direct shear testing shall be conducted on the following interfaces:
   a. 60 mil textured HDPE geomembrane versus cushion/grading layer material;
   b. 60 mil textured HDPE geomembrane versus non-woven geotextile; and
   c. 60 mil textured HDPE geomembrane versus geosynthetic drainage composite.

4. Soil samples of on-site materials shall be collected by the Engineer for interface friction/direct shear testing.

5. The minimum friction angle for each interface listed in Paragraph 3 above shall be 24.7 degrees for peak strength and 19.7 for residual strength.

6. Interface friction/direct shear testing shall be the responsibility of the Owner.

7. The Engineer shall review the results of the interface friction/direct shear test.
   a. If the Engineer determines that the proposed geomembrane will provide adequate slope stability, and the geomembrane rolls meet all other specifications, the geomembrane rolls shall be accepted.
   b. If the Engineer determines that the proposed geomembrane will not provide adequate slope stability, the geomembrane rolls shall not be accepted.
      1) The Contractor shall be responsible for removing all unacceptable geomembrane rolls from the site and replacing them with acceptable material.

D. Procedures for Determining Geomembrane Roll Test Failures

1. For test results reported in both machine and cross direction, results from each direction shall be compared to the acceptable specifications to determine acceptance.

2. For test methods requiring multiple samples, the criteria in Table 1 of this specification shall be met based on average results of multiple specimen tests.

3. The following procedures shall be used for interpreting results:
   a. If the test results meet the specification values provided in Table 1 of this specification, then the roll, batch and entire shipment, if applicable, shall be accepted provided the requirements of Section 2.03(A) of this specification are met; and
   b. If the test results do not meet the specification values provided in Table 1 of this specification, then the roll and batch shall be retested at the Contractor’s expense using specimens from the original roll sample or from another sample collected by the Engineer. For retesting, two additional tests shall be performed.
      1) If both retest values meet the specification values, then the roll and batch shall be accepted.
      2) If one additional test fails, then the roll and batch shall be rejected without further recourse.
         a) At the Contractor’s expense, the Engineer may obtain samples from other rolls within the batch. Based on the test results from these samples, the Engineer may choose to accept a portion of the batch while rejecting the remainder.
         b) If retesting does not result in passing test results as defined above, or if there is any other non-conformity with the material Specifications, then the geomembrane rolls shall be removed from the site. Once removed from the site, these same rolls shall not be resubmitted for use.
         c) The Contractor shall be responsible for removing all non-conforming geomembrane rolls from the site and replacing with acceptable material.

2.04 TRANSPORTATION

A. Transportation of the geomembrane shall be the responsibility of the Geomembrane Manufacturer. The Geomembrane Manufacturer shall be liable for all damages to the materials incurred prior to and during transportation to the site.

2.05 HANDLING AND STORAGE

A. Handling, storage, and care of the geomembrane prior to and following installation at the site, is the responsibility of the Contractor. The Contractor shall be liable for all damages to the materials incurred prior to final acceptance of the final cover system.

B. The Contractor shall be responsible for storage of the geomembrane at the site. During storage, the geomembrane shall be protected from excessive heat or cold, puncture, cutting, or other damaging or deleterious conditions. The geomembrane shall be stored in accordance with any additional requirements of the Geomembrane Manufacturer.

PART 3 - EXECUTION

3.01 EARTHWORK

A. Surface Preparation

1. The Geosynthetics Installer shall provide certification in writing that the surface on which the geomembrane will be installed is acceptable. The surface shall be free of stones, litter, organic matter, irregularities, protrusion, loose soil, and any abrupt changes in grade that could damage the geosynthetic. The certification of acceptance shall be given to the Engineer prior to commencement of geomembrane installation.

2. Special care shall be taken to maintain the prepared soil surface.

3. No geomembrane shall be placed onto an area which has been softened by precipitation or which has cracked due to desiccation. The soil surface shall be observed daily to evaluate the effects of desiccation cracking and/or softening on the integrity of the soil liner.

4. Any damage to the soil surface caused by installation activities shall be repaired at the Geosynthetics Installer's expense.

5. The Geosynthetics Installer shall be responsible for dewatering areas that have been accepted for geomembrane deployment, including anchor trenches.

B. Geosynthetics Anchor Trench

1. The anchor trench shall be excavated prior to geomembrane placement to the lines, grades, and configuration shown on the Construction Drawings.

2. No loose soil shall be allowed in the anchor trench beneath the geomembrane.

3. The anchor trench shall be backfilled and compacted after the geosynthetics have been installed in the trench. Care shall be taken when backfilling the trenches to prevent any damage to the geomembrane.

4. Corners where the geomembrane adjoins the trench shall be slightly rounded to avoid sharp bends in the geomembrane.

3.02 GEOMEMBRANE DEPLOYMENT

A. Layout Drawings: The Geosynthetics Installer shall produce layout drawings prior to geomembrane deployment. These drawings shall indicate the geomembrane configuration, dimensions, details, locations of seams, etc. Field seams shall be differentiated from factory seams (if any) on the drawings. Field seams shall be oriented up or down slope and not across slope. The layout drawings must be approved by the Engineer prior to the installation of any geomembrane. The layout drawings, as modified and/or approved by the Engineer shall become part of the Project Documents.

B. Field Panel Identification

1. A geomembrane field panel is defined as follows:
   a. If the geomembrane is not fabricated into factory panels, a field panel is a roll or a portion of roll cut in the field.
   b. If the geomembrane is fabricated into factory panels, a field panel is a factory panel or a portion of factory panel cut in the field.

2. Each field panel must be given an identification code (number or letter-number). This identification code shall be agreed upon by the Engineer and Geosynthetics Installer. The field panel identification code shall be related, through a table or chart, to the original resin, and the constituent rolls and factory panels.

C. Field Panel Placement

1. Field panels shall be installed as approved or modified at the location and positions indicated in the layout drawings.

2. Field panels shall be placed one at a time, and each field panel shall be seamed to adjacent panels the same day that it is placed.

3. Geomembranes shall not be placed when the ambient temperature is below 32˚F, unless otherwise authorized by the Engineer.

4. Geomembranes shall not be placed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of winds exceeding 20 miles per hour.

5. The Geosynthetics Installer shall employ placement methods consistent with the following:
   a. No vehicular traffic shall be allowed on the geomembrane.
   b. Equipment used shall not damage the geomembrane by handling, trafficking, leakage of hydrocarbons, or other means.
   c. Personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane.
   d. The method used to unroll the panels shall not scratch or crimp the geomembrane and shall not damage the supporting soil.
   e. The prepared surface underlying the geomembrane shall not be allowed to deteriorate after acceptance of the surface and shall remain acceptable up to the time of geomembrane placement.

f. The method used to place the panels shall minimize wrinkles (especially differential wrinkles between adjacent panels).

g. Temporary loads and/or anchors (e.g., sand bags, tires) not likely to damage the geomembrane may be placed on the geomembrane to prevent uplift by wind (in high winds, continuous loading is recommended along panel edges to minimize the risk of wind flow under the panels).

6. Any field panel or portion thereof that becomes seriously damaged (torn, twisted, or crimped) shall be replaced with new material at no cost to the Owner. Less serious damage may be repaired at the Engineer's sole discretion and at no cost to the Owner. Damaged panels or portions of damaged panels that have been rejected shall be removed from the work area.

3.03 FIELD SEAMING

A. Seam Layout: In general, seams shall be oriented parallel to the line of maximum slope, i.e., oriented down, not across, the slope. In corners and at odd-shaped geometric locations, the number of field seams shall be minimized. No horizontal seam shall be made within 5 feet of any toe of the slope, except where approved by the Engineer. No seams shall be located in an area of potential stress concentration, as defined by the Owner.

B. Personnel: All personnel performing seaming operations shall be qualified as indicated in Section 1.04(C)(3) of this specification. No seaming shall be performed unless a "master seamer" is present.

C. Weather Conditions for Seaming

1. Seaming shall not be attempted at ambient temperatures below 32˚F or above 104˚F or when wind velocity exceeds 20 miles per hour. At ambient temperatures between 32˚F and 50˚F, seaming shall be allowed if the geomembrane is preheated either by the sun or a hot air device, and if there is no excessive cooling from wind. At ambient temperatures above 50˚F, no preheating will be required. In all cases, the geomembrane shall be dry and protected from excessive wind.

2. If the Geosynthetics Installer wishes to use methods that may allow seaming at ambient temperatures below 32˚F or above 104˚F, he shall demonstrate that the seam so produced is equivalent to those produced under normally approved conditions, and that the overall quality of the geomembrane is not adversely affected. In addition, an addendum to the Contract between the Contractor and the Geosynthetics Installer shall be required. The addendum shall specifically state that the seaming procedure does not cause any physical or chemical modification to the geomembrane that will generate any short or long term damage to the geomembrane.

3. To minimize geomembrane contraction stresses, seaming should ideally be carried out in the morning and late evening when the geomembrane is relatively contracted and during the middle of the day if overcast conditions prevail. If the geomembrane must be seamed in the middle of a sunny day, the Geosynthetics Installer shall ensure that the panels to be seamed are at the same temperature and that there is sufficient slack in the geomembrane to prevent the generation of excessive stresses or trampolining when the geomembrane contracts as cooler temperatures prevail. The required amount of slack shall be determined by the Geosynthetics Installer, and it should not be so much so as to cause significant wrinkling of the geomembrane. If trampolining of the

geomembrane is observed, the Geosynthetics Installer will be required to make repairs so that the problem is eliminated.

4. Ambient temperatures shall be measured 6 inches above the geomembrane surface.

D. Overlapping and Temporary Bonding

1. Geomembrane panels shall be overlapped a minimum of 3 inches for extrusion welding and 5 inches for fusion welding, but in any event, sufficient overlap shall be provided to allow peel tests to be performed on the seam.

2. The procedure used to temporarily bond adjacent panels together shall not damage the geomembrane. The temperature of the air at the nozzle of spot welding apparatus shall be controlled such that the geomembrane is not damaged.

3. No solvent or adhesive shall be used unless the product has been approved in writing by the Owner. Samples of any proposed solvent or adhesive shall be submitted to the Engineer for testing and evaluation at the Geosynthetics Installer's expense.

E. Seam Preparation

1. Prior to seaming, the seam area shall be cleaned and made free of moisture, dust, dirt, debris of any kind, and foreign material.

2. If seam overlap grinding is required, the process shall be completed according to the Geomembrane Manufacturer's instructions within one hour of the seaming operation and in a manner that does not damage the geomembrane. The grind depth shall not exceed 10% of the geomembrane thickness. Grinding marks shall not appear beyond 0.25 inch of the extrudate after it is placed.

3. Seams shall be aligned with the fewest possible number of wrinkles and "fishmouths".

F. General Seaming Requirements

1. Seaming shall extend to the outside edge of panels to be placed in the anchor trench.

2. If required, a firm substrate shall be provided by using a flat board, a conveyor belt, or similar hard surface, directly under the seam overlap to achieve proper support.

3. If seaming operations are carried out at night, adequate illumination shall be provided by the Geosynthetics Installer for performing seaming activities.

4. Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed where possible; any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane that extends a minimum of 6 inches beyond the cut in all directions.

G. Seaming Process

1. Approved processes for field seaming are extrusion welding and fusion welding. Seaming equipment shall be operated in a manner that does not cause damage to the geomembrane. Only apparatus that the Engineer has specifically approved by make and model shall be used. Proposed alternate seaming processes shall be documented and submitted to the Engineer.

2. Extrusion Equipment and Procedures
   a. The Geosynthetics Installer shall maintain at least one spare operable extrusion seaming apparatus on-site at all times.
   b. Extrusion welding apparatus shall be equipped with gauges giving the temperature in the apparatus and at the nozzle.
   c. Prior to beginning a seam, the extruder shall be purged until all heat-degraded extrudate has been removed from the barrel. Whenever the extruder is stopped, the barrel shall be purged of all heat-degraded extrudate.
   d. The Geosynthetics Installer shall provide documentation regarding the extrudate to the Engineer and shall certify that the extrudate is compatible with the specifications and consists of the same resins as the geomembrane.
   e. The electric generator used for power supply to the welding machines shall be placed outside the area to be lined or mounted on soft tires such that no damage occurs to the geomembrane. The electric generator shall be equipped with a grounding rod that is driven into the ground outside the lined area. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

3. Fusion Equipment and Procedures
   a. The Geosynthetics Installer shall maintain at least one spare operable seaming apparatus on-site at all times.
   b. Fusion-welding apparatus shall be automated vehicular-mounted devices equipped with gauges that show the instantaneous temperatures and pressures of the machine.
   c. The edges of cross seams shall be abraded to a smooth incline (top and bottom) prior to welding.
   d. A movable protective layer may be used directly below each geomembrane overlap to be seamed to prevent the buildup of moisture between the sheets.
   e. The electric generator used for power supply to the welding machines shall be placed outside the area to be lined or mounted on soft tires such that no damage occurs to the geomembrane. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

H. Trial Seams

1. Trial seams shall be made prior to production seaming by all seamers and by all equipment to be used during production seaming. The trial seams shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period and at least once each five hours for each seaming apparatus used that day. Also, each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as actual seams. The trial seam sample shall be at least 5 feet long by 1-foot wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as specified in Section 3.03(D) of this Specification.

2. Two adjoining specimens, each 1-inch wide, shall be cut from the trial seam sample by the Geosynthetics Installer. The specimens shall be tested in shear and peel, respectively, using a field tensiometer, and the specimen shall fail by film tear bond rather than in the seam. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus or seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved.

3. The trial seams shall meet the required strength values shown in Table 2 of this specification.

I. Non-Destructive Seam Continuity Testing

1. The Geosynthetics Installer shall non-destructively test all field seams over their full length using a vacuum test, air pressure test (for double fusion seams only), or other approved method. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming. The installer shall complete any required repairs in accordance with Section 3.03(K) of this Specification. The following procedures shall apply to locations where seams cannot be non-destructively tested:
   a. If the seam is accessible to testing equipment prior to final installation, the seam shall be non-destructively tested prior to final installation.
   b. If the seam cannot be tested prior to final installation, the seaming operations must be observed in their entirety by the CM for uniformity and completeness.

2. Vacuum Testing
   a. The equipment shall comprise the following:
      1) A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge.
      2) A steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections.
      3) A rubber pressure/vacuum hose with fittings and connections.
      4) A bucket and applicator.
      5) A soapy solution.
   b. The following procedures shall be followed:
      1) Energize the vacuum pump and reduce the tank pressure to approximately 5 pounds per square inch (psi) gauge.
      2) Wet a strip of geomembrane seam having an area larger than the vacuum box assembly with the soapy solution.
      3) Place the box over the wetted area.
      4) Close the bleed valve and open the vacuum valve.
      5) Ensure that a leak tight seal is created.
      6) Examine the geomembrane through the viewing window for the presence of soap bubbles for not less than 10 seconds.
      7) If no bubbles appear after 10 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 inches overlap, and repeat the process.
      8) All areas where soap bubbles appear shall be marked with a marker that will not damage the geomembrane and repaired in accordance with Section 3.03(K) of this Specification.

3. Air Pressure Testing (For Double Fusion Seams Only)
    a. The following procedures are applicable to those processes which produce a double seam with an enclosed space.
    b. The equipment shall comprise the following:
        1) An air pump (manual or motor driven), equipped with a pressure gauge, capable of generating and sustaining a pressure between 25 and 30 psi, mounted on a cushion to protect the geomembrane.
        2) A rubber hose with fittings and connections.
        3) A sharp hollow needle or other, approved pressure feed device.
    c. The following procedures shall be followed:
        1) Seal both ends of the seam to be tested.
        2) Insert needle or other, approved pressure feed device, into the channel created by the fusion weld.
        3) Insert a protective cushion between the air pump and the geomembrane.
        4) Energize the air pump to a pressure between 25 and 30 psi, close valve, allow two minutes for pressure to stabilize, and sustain the pressure for not less than five minutes.
        5) If loss of pressure exceeds 4 psi, or if the pressure does not stabilize, locate faulty area and repair in accordance with Section 3.03(K) of this Specification.
        6) Cut opposite end to verify continuity of seam, remove needle, or other approved pressure feed device, and seal repair in accordance with Section 3.03(K) of this Specification.

J. Destructive Testing

1. Destructive seam tests shall be performed on samples collected from selected locations to evaluate seam strength and integrity. Destructive testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

2. The destructive seam tests shall meet the required strength values shown in Table 31 05 19.16 B below:

TABLE 4
HDPE TEXTURED GEOMEMBRANE SEAM TESTING

Item	Test Method	Frequency	Requirement
Shear Strength	ASTM D6392	1/500 feet (maximum)[1]	120 lb/in (minimum)
Peel Strength	ASTM D6392	1/500 feet (maximum)[1]	Fusion - 91 lb/in (minimum) Extrusion - 78 lb/in (minimum)

Notes:

1. For fusion welded seams, frequency is based on welding device footage; for extrusion welded seams, frequency is based on operator footage.

2. Minimum test values based on current manufacturers specifications and may change based on future manufacturers guaranteed minimum test values. List Locus of Break in laboratory test results.

3. Sampling
   a. Destructive test samples shall be collected at a minimum frequency of one test location per day per seaming crew or seaming machine at least every 500 feet of seam length (not including repairs). Test locations shall be determined during seaming, and may be prompted by suspicion of excess crystallinity, contamination, offset seams, or any other potential cause of imperfect seaming. The CM will be responsible for choosing the locations. The Geosynthetics Installer shall not be informed in advance of the locations where the seam samples will be taken. The Owner and/or Engineer reserve the right to increase the sampling frequency.
   b. Samples shall be cut by the Geosynthetics Installer at the locations designated by the Engineer as the seaming progresses in order to obtain laboratory test results before the geomembrane is covered by another material. All holes in the geomembrane resulting from the destructive seam sampling shall be immediately repaired in accordance with the repair procedures described in Section 3.03(K) of this Specification. The continuity of the new seams in the repaired areas shall be tested according to Section 3.03(I) of this Specification.
   c. Two strips, 1-inch wide and 12 inches long with the seam centered parallel to the width, shall be taken. The strips shall be spaced a clear distance of 42 inches apart. These samples shall be tested in the field in accordance with Section 3.03(J)(3) of this Specification. If these samples pass the field test, a laboratory sample shall be taken. The laboratory sample shall be at least 1-foot wide by 42 inches long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:
      1) One 1-foot-long portion to the Geosynthetics Installer for field testing.
      2) One 1.5-foot-long portion to the Engineer for laboratory testing.
      3) One 1-foot-long portion to the Engineer for archival storage.

4. Field Testing: The two 1-inch-wide strips shall be tested in the field using the field by tensiometer for peel and shear respectively. If any field test sample fails to pass, then the procedures outlined in Section 3.03(K) of this Specification shall be followed.

5. Laboratory Testing: Samples shall be tested in the laboratory in accordance with the methodology of ASTM D6392. Perform peel testing for dual hot wedge fusion welds on the inside and outside tracks.
   a. Each destructive seam sample shall be tested for the following:
      1) Shear strength, expressed in pounds per inch (ppi), when tested in general accordance with ASTM D6392.
      2) Peel strength, expressed in ppi, when tested in general accordance with ASTM D6392.
   b. The testing laboratory shall report the following values, along with the mean and standard deviations where appropriate, for each sample tested in shear:
      1) Maximum tension in pounds per square inch.
      2) Elongation at break (up to a tested maximum of 100%).
      3) The locus of failure.
   c. The testing laboratory shall report the following values, along with the mean and standard deviations where appropriate, for each sample tested in peel:
      1) Maximum tension in pounds per square inch.
      2) Seam separation (expressed as percent of original seam area).
      3) The locus of failure.
   d. Retesting of seams, because of failure to meet any or all of the specifications, may be performed at the sole discretion of the Engineer.

6. Destructive Test Failure

a. The following procedures shall apply whenever a sample fails a destructive test, whether the test is conducted by the Owner's laboratory, the Geosynthetics Installer's laboratory, or by a field tensiometer. The Geosynthetics Installer shall have two options, as described in b and c below.
b. The Geosynthetics Installer can reconstruct the seam (e.g., remove the old seam and re-seam) between any two passed test locations.
c. The Geosynthetics Installer can trace the welding path to an intermediate location, a minimum of 10 feet from the location of the failed test (in each direction) and take a small sample for an additional field test at each location. If these additional samples pass the tests, then full laboratory samples shall be taken. If these laboratory samples pass the tests, then the seam shall be reconstructed between these locations. If either sample fails, then the process shall be repeated to establish the zone in which the seam should be reconstructed. In any case, all acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. In cases where the length of reconstructed seam exceeds 150 feet, a destructive sample taken from within the reconstructed zone must pass destructive testing. Whenever a sample fails, the Engineer may require additional tests for seams that were formed by the same seamer and/or seaming apparatus or seamed during the same time shift.

K. Defects and Repairs

1. All seams and non-seam areas of the geomembrane will be examined by the Engineer for evidence of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be swept or washed by the Geosynthetics Installer if surface contamination inhibits examination. The Geosynthetics Installer shall ensure that this examination of the geomembrane precedes any seaming of that section.

2. Each suspect location, both in seam and non-seam areas, shall be non-destructively tested using the methods described Section 3.3(I) of this Specification, as appropriate. Each location which fails non-destructive testing shall be marked by the Engineer and repaired by the Geosynthetics Installer. Work shall not proceed with any materials which will cover repaired locations until laboratory test results with passing values are available.

3. When seaming of a geomembrane is completed (or when seaming of a large area of a geomembrane is completed) and prior to placing overlying materials, the Engineer shall identify all excessive geomembrane wrinkles. The Geosynthetics Installer shall cut and re-seam all wrinkles so identified. The seams thus produced shall be tested like any other seams.

4. Repair Procedures
   a. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or non-destructive test, shall be repaired by the Geosynthetics Installer. Several repair procedures are specified below. The final decision as to the appropriate repair procedure shall be agreed upon between the Engineer and the Geosynthetics Installer. The procedures available include:
      1) Patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter;
      2) Abrading and re-seaming, used to repair small sections of extruded seams;

3) Spot seaming, used to repair small tears, pinholes, or other minor, localized flaws;
4) Capping, used to repair long lengths of failed seams;
5) Removing bad seam and replacing with a strip of new material seamed into place (used with long lengths of fusion seams).

b. In addition, the following shall be satisfied:
1) Surfaces of the geomembrane to be repaired shall be abraded no more than one hour prior to the repair;
2) All surfaces must be clean and dry at the time of repair;
3) All seaming equipment used in repair procedures must be approved by the Engineer;
4) The repair procedures, materials, and techniques shall be approved in advance for the specific repair by the Engineer and Geosynthetics Installer;
5) Patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of patches shall be rounded with a radius of at least 3 inches; and
6) The geomembrane below large caps shall be appropriately cut to avoid water or gas collection between the two sheets.

5. Each repair shall be numbered and logged and shall be non-destructively tested using the methods described in Section 3.03(I) of this Specification, as appropriate. Repairs which pass the non-destructive test shall be taken as an indication of an adequate repair. Failed tests will require the repair to be redone and retested until a passing test result is achieved. At the discretion of the CM, destructive testing may be required on large caps.

3.04 MATERIALS IN CONTACT WITH THE LINER

A. The Geosynthetics Installer shall take all necessary precautions to ensure that the geomembrane is not damaged during its installation or during the installation of other components of the final cover system or by other construction activities. Installation on rough surfaces shall be performed carefully. If approved by the Engineer, additional loosely placed geotextile sections may be used by the Geosynthetics Installer to protect the geomembrane.

B. No granular materials shall be placed directly on the geomembrane at any time. A geotextile cushion shall be installed between aggregate and any geomembrane.

C. Equipment shall not be driven directly on the geomembrane. Unless otherwise specified by the Engineer, all equipment operating on materials overlying the geomembrane shall comply with the following:

Allowable Equipment Ground Pressure (psi)	**Thickness of Overlying Compacted Fill (ft)**
<5	1.0
<15	1.5
<20	2.0
>20	3.0

D. In heavily trafficked areas such as access ramps, and in areas trafficked by rubber tire vehicles, the thickness of overlying compacted fill shall be at least 3 feet.

E. Installation of the geomembrane in sump areas, and connection of the geomembrane to appurtenances shall be made according to these Specifications and as shown on the Construction Drawings. Extreme care shall be taken while seaming around sumps and appurtenances (where applicable), since neither non-destructive nor destructive testing may be feasible in these areas. The Geosynthetics Installer shall ensure that the geomembrane has not been visibly damaged while making connections to sumps and appurtenances. Because of the difficulty of vacuum testing seams in the sump area, fusion seams should be made at all possible locations in the sump.

3.05 GEOMEMBRANE ACCEPTANCE

A. The Geosynthetics Installer shall retain all ownership and responsibility for the geomembrane until accepted by the CM.

B. The geomembrane will not be accepted by the CM until all of the following conditions are met:

1. The installation is finished;
2. All documentation of installation is completed including the Engineer’s final report;
3. Verification of the adequacy of all field seams and repairs, including associated testing, is complete; and
4. Written certification documents shall be provided by the Geosynthetics Installer. Also, record drawings, certified by the Geosynthetics Installer and signed and sealed by a Professional Surveyor, shall be provided.

3.06 PRODUCT PROTECTION

A. The Contractor shall use all means necessary to protect all prior work and all materials and completed work of other Sections.

B. In the event of damage, the Contractor shall immediately make all repairs and replacements necessary to the approval of the CM and at no additional cost to the Owner.

END OF SECTION

SECTION 31 05 19.26 - GEOCOMPOSITE FOR EARTHWORK

PART 1 - GENERAL

1.01 DESCRIPTION

A. Scope:

1. Providing all labor, materials, tools, and equipment necessary to furnish and install geocomposite where specified in the Design Drawings.

B. Related Sections:

1. Section 31 05 13 – Soil for Earthwork
2. Section 31 05 19.13 – Geomembranes for Earthwork
3. Section 31 22 00 – Grading

1.02 REFERENCE STANDARDS

A. The following American Society of Testing and Materials (ASTM) International standards are referenced in this section:

1. D1238 - Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
2. D1505 - Standard Test Method for Density of Plastics by the Density-Gradient Technique
3. D1603 - Standard Test Method for Carbon Black Content in Olefin Plastics
4. D1777 - Standard Test Method for Thickness of Textile Materials
5. D3776 - Standard Test Methods for Mass per Unit Area (Weight) of Fabric
6. D4491 - Standard Test Methods for Water Permeability of Geotextiles by Permittivity
7. D4533 - Standard Test Method for Trapezoid Tearing Strength of Geotextiles
8. D4632 - Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
9. D4716 - Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
10. D4751 - Standard Test Method for Determining Apparent Opening Size of a Geotextile
11. D4833 - Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products
12. D5199 - Standard Test Method for Measuring Thickness of Geotextiles and Geomembranes
13. D5261 - Standard Test Method for Measuring Mass per Unit Area of Geotextiles
14. D7005 - Standard Test Method for Determining the Bond Strength (Ply Adhesion) of Geocomposites

15. F904 - Standard Test Method for Comparison of Bond Strength or Ply Adhesion of Similar Laminates Made from Flexible Materials

B. The following Geosynthetic Research Institute (GRI) test method is referenced in this section:

1. GRI GC7 - Determination of Adhesion and Bond Strength of Geocomposites

C. Where reference is made to one of the above codes, standards, specifications, or publications, the revisions in effect at the time of bid shall apply.

1.03 QUALITY ASSURANCE

A. Geocomposite manufacturer shall be a specialist in the manufacture of geocomposites and shall have produced and successfully installed a minimum of five million square feet of geocomposite material.

B. Quality Assurance/Quality Control (QA/QC) testing of geocomposite as specified in this section and in accordance with the manufacturer's recommendations/specifications.

1.04 SUBMITTALS

A. The following items shall be submitted no later than 30 days prior to the start of geocomposite installation or 15 days prior proposed to delivery of the first geocomposite shipment, whichever is earliest.

1. Manufacturer's data for the geocomposite including physical properties and roll size.
2. The origin (supplier's name and production plant) and identification (brand name and number) of the geotextile and geonet used to fabricate the geocomposite.
3. Material sample of geocomposite.
4. Manufacturer's installation procedures and specifications.
5. Manufacturer's Quality Assurance/Quality Control (QA/QC) program.
6. Written certification that the minimum test values provided under Part 2.02 of this section are guaranteed by the Manufacturer.
7. Contractor's proposed transportation, handling, and storage techniques for the geocomposite.
8. Shop drawings depicting installation details, a panel layout diagram, and a description of proposed installation techniques for the geocomposite.

B. During Installation, the Geosynthetics Installer shall submit the following information to the Owner and the CM:

1. Contractor's written certification (provided prior to the installation of the geocomposite) that the field-delivered geocomposite has not been damaged due to improper transportation, handling, or storage.

2. Contractor's written certification (provided prior to the installation of the geocomposite) that the surface on which the geocomposite is to be installed is acceptable to both the Owner and the Contractor. The certification is subject to the review and approval or rejection by the Owner/Engineer.

3. Daily field logs documenting the work being performed, personnel involved, general working conditions, and any problems encountered or anticipated on the project.

4. All personnel performing installation shall be qualified by previous experience.

C. Upon completion of the installation, the Geosynthetics Installer shall be responsible for the timely submission of the following:

1. Quality Control (QC) certificates (signed by a responsible party employed by the Manufacturer) for the geocomposite, which identify the sections of field-delivered material they represent. The QC certificates shall include lot and roll identification numbers, testing procedures, and results of QC tests. At a minimum, results shall be given in accordance with the Technical Drawings and Specifications for:

   i. Unit Weight of geotextile component (ASTM D5261)

   ii. Thickness of geonet component (ASTM D1777)

   iii. Geotextile-Geonet ply adhesion (ASTM D7005/F904/GRI GC7)

   iv. Transmissivity (ASTM D4716)

2. QC tests for the above-listed properties shall be performed in accordance with the Manufacturer's QA/QC program.

3. Contractor's written certification that the field-delivered material meets the Manufacturer's specifications. The Contractor shall also provide the lot and roll identification numbers for the field-delivered material.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. AGRU America, Inc.

B. TENAX

C. SKAPS Industries

D. Approved equal.

2.02 MATERIALS

A. The geocomposite shall be comprised of a high-density polyethylene (HDPE) drainage net composited with two, 8 oz/yd^2 non-woven geotextiles. The geotextiles shall be heat bonded to both sides of the drainage net.

1. The drainage net to be used in the composite shall be a profiled mesh made by extruding two sets of high-density strands together to form a diamond shaped, three-dimensional net to provide planar fluid flow. The drainage net shall be made of HDPE containing carbon black, antioxidants, and heat stabilizers that shall be manufactured from resin provided from one resin supplier.

2. The geotextile shall be a non-woven, needle punched polymeric material.

B. Geocomposite material may be acceptable for use provided the selected product meets the above-described requirements and the following minimum test values:

1. Drainage Net

Property	Test Method	Unit of Measure	Minimum Test Value
Specific Gravity	ASTM D1505	g/cm^3	0.94
Melt Flow Index	ASTM D1238 – Condition E	g/10 min.	0.3 maximum
Carbon Black Content	ASTM D1603	%	2.0 – 3.0

2. Geotextile

Property	Test Method	Unit of Measure	Minimum Test Value
Grab Tensile	ASTM D4632	lbs	158
Grab Elongation	ASTM D4632	%	50
Puncture	ASTM D4833	lbs	56
Trapezoidal Tear	ASTM D4533	lbs	56
Burst Strength	ASTM D3786	lbs	189
Permittivity	ASTM D4491	sec^{-1}	1.3
Apparent Opening Size	ASTM D4751	mm	< 0.25

3. Composited Materials for Baseliner System

Property	Test Method	Unit of Measure	Minimum Test Value
Transmissivity	ASTM D4716*	m^2/s	3.62×10^{-3} (0.10 gradient, minimal load condition) 1.29×10^{-3} (0.10 gradient, full-buildout condition) 6.1×10^{-4} (0.33 gradient)
Ply Adhesion	ASTM D7005/F904 GRI GC7	lb/in width	0.5

* Test method to be performed with the following modifications:

Substrate Material: 60-mil textured HDPE geomembrane on top of 6 inches of representative soil
Superstrate Material: 6 inches of representative soil
Applied Normal Compressive Load: 3,000 lbs/ft^2 (0.10 gradient, minimal load condition)
14,000 lbs/ft^2 (0.10 gradient, full-buildout condition)
1,500 lbs/ft^2 (0.33 gradient)

Seating Time: 100 hours (minimum)
Hydraulic Gradient: 0.1 or 0.33

Two tests to be performed on each material requiring testing. The first test shall be run in the machine direction (i.e., roll direction). The second test shall be run in transverse direction (i.e., perpendicular to roll length).

4. Composited Materials for Final Cover System

Property	Test Method	Unit of Measure	Minimum Test Value
Transmissivity	ASTM D4716*	m^2/s	3.87×10^{-3} (0.10 gradient), 3.10×10^{-4} (0.33 gradient)
Ply Adhesion	ASTM D7005/F904 GRI GC7	lb/in width	0.5

* Test method to be performed with the following modifications:

Substrate Material:	60-mil textured HDPE geomembrane on top of 6 inches of representative soil
Superstrate Material:	6 inches of representative soil
Applied Normal Compressive Load:	3,000 lbs/ft^2 (0.10 gradient) and 1,500 lbs/ft^2 (0.33 gradient)
Seating Time:	100 hours (minimum)
Hydraulic Gradient:	0.1 or 0.33

Two tests to be performed on each material requiring testing. The first test shall be run in the machine direction (i.e., roll direction). The second test shall be run in transverse direction (i.e., perpendicular to roll length).

C. Conformance testing of alternative materials shall be at the Contractor's expense.

D. Conformance test results will be reviewed by the Owner/Engineer. The material shall either be accepted or rejected by the Owner/Engineer based on the results of the conformance testing. Deployment of the geocomposite shall not commence until the Owner/Engineer has determined that the material is acceptable. If the Contractor has reason to believe that failing tests may be the result of the Construction Quality Assurance (CQA) Laboratory incorrectly conducting the tests, the Contractor may request that the sample in question be retested by the CQA Laboratory with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Contractor. Alternatively, the Contractor may have the sample retested at two different approved CQA Laboratories at the expense of the Contractor. If both laboratories produce passing results, the material may be accepted at the discretion of the Owner/Engineer. If both laboratories do not produce passing results, then the original CQA Laboratory's test results will be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Owner/Engineer.

E. If a test result is not in conformance with a required minimum test value, all material from the lot represented by the failing test shall be considered out of specification and rejected. Alternatively, at the option of the Owner/Engineer, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out-of-specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both of the additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) will be rejected. If one or both of the additional tests fail, then the entire lot will be rejected, or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot. The additional conformance test samples will be collected by the Owner/Engineer and submitted to the same CQA laboratory that was used for the original conformance testing. The costs associated with the additional conformance testing will be borne by the Contractor.

2.03 DELIVERY, STORAGE, AND HANDLING

A. The geocomposite shall be packaged and shipped by appropriate means so as to prevent damage. Geocomposite rolls will be wrapped in relatively opaque and watertight plastic to prevent damage during shipping and storage. Geocomposite rolls that have been delivered to the job site will be unloaded and stored in their original, unopened wrappers in a secure, dry area, and protected from weathering. Materials shall be delivered only after the required submittals have been received and approved by The Owner/Engineer.

B. The geocomposite shall be furnished in rolls marked or tagged with the following information:

1. Manufacturer's Name
2. Product Identification
3. Lot/Batch Number
4. Roll Number
5. Roll Dimensions

C. The geocomposite shall be stored in an area approved by the Owner/Engineer that prevents damage to the product or packaging.

D. The geocomposite shall be kept clean and free from dirt, dust, mud, and any other debris.

E. Any geocomposite found to be damaged shall be replaced with new material at the Contractor's expense.

2.04 QUALITY ASSURANCE

A. The field-delivered material shall meet the specification values according to the Manufacturer’s specification sheet and meet or exceed the requirements in this specification.

B. The Manufacturer shall have developed and shall adhere to its own QA program in the manufacture of the geocomposite.

PART 3 - EXECUTION

3.01 PREPARATION

A. The areas designated for placement of geocomposite shall be free from any deleterious material.

B. If the geocomposite is not clean before installation, it shall be washed by the Contractor until accepted by The Owner/Engineer.

C. Prior to installation of any geocomposite, the Owner/Engineer and the Contractor must both concur that the underlying geomembrane is acceptable. This will necessitate review of all QA/QC testing for the geomembrane by the Owner/Engineer and the Contractor. The Contractor shall submit written verification that both The Owner/Engineer and the Contractor agree that the underlying geomembrane is acceptable as specified in Section 1.04A.B.2. of this specification.

3.02 INSTALLATION

A. Geocomposite shall be installed at locations shown on the Design Drawings.

B. Adjacent rolls shall be installed so that the geonet component will have a minimum overlap of 4 inches.

C. The geonet shall be tied with plastic fasteners every 5 feet along the slope and every 6 inches on butt seams and in the anchor trenches.

D. The geotextiles shall be continuously sewn using a polymeric thread with chemical and ultraviolet resistance properties equal to or exceeding those of the geotextile.

E. The geocomposite shall be unrolled downslope, keeping the net in slight tension to minimize wrinkles and folds.

F. If a tri-planar material is used, it must be installed in the appropriate flow direction.

G. Adequate loading shall be placed to prevent uplift by wind.

H. Holes or tears in the geocomposite shall be repaired in accordance with the Manufacturer's recommendations.

I. Any portion of the geocomposite exhibiting a flaw shall be repaired. Prior to acceptance of the geocomposite, the Installer shall locate and repair all damaged areas as directed by Engineer.

END OF SECTION

SECTION 31 11 00 - CLEARING AND GRUBBING

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Providing all labor, materials, equipment, and incidentals required to perform clearing and grubbing as specified in the Contract Documents.
2. Removing and disposing trees, shrubs, brush, logs, vegetation, rubbish, and other objectionable material.
3. Paying all fees associated with transport and disposal of debris resulting from clearing and grubbing.
4. Clearing and grubbing, as necessary, to facilitate remedial activities at the site.

B. Related Sections:

1. Section 01 57 00, Temporary Controls
2. Section 31 25 00, Erosion and Sediment Controls

1.02 WARRANTY

A. The Contractor shall warrant that Work performed under this Section will not permanently damage trees, shrubs, turf, and plants designated to remain, or other adjacent work, facilities, or property. If damage resulting from the Contractor's operations becomes evident during the correction period, the Contractor shall replace damaged items and property at no additional cost to Owner.

PART 2 – PRODUCTS (NOT USED)

PART 3 – EXECUTION

3.01 PREPARATION

A. Protection:

1. Protect existing site improvements, including streets, drives, underground facilities to remain (if any), and adjacent property and structures throughout the Work. Repair damage caused by The Contractor to original condition or replace in kind, to satisfaction of Engineer, and at no additional cost to Owner.
2. Protect trees, shrubs, vegetation, and grassed areas to remain by providing temporary fencing, barricades, wrapping, or other methods shown, specified, or accepted by Engineer. Correct, at The Contractor's expense, damage caused by The Contractor outside the limits of clearing and grubbing Work.
3. Do not remove trees without the approval of Engineer, unless shown or indicated for removal on the Design Drawings.

4. Do not locate construction equipment, stored materials, or stockpiles within the drip line of trees and vegetation to remain following completed construction.

B. Site Preparation:

1. Delineation of Clearing and Grubbing Limits:
   a. Locate and clearly flag trees, vegetation, and other items to remain within the limits of clearing and grubbing.
   b. Provide flagging to delineate limits of areas to be cleared or grubbed. Review at Site with Engineer before initiating clearing and grubbing Work.
   c. Replace flagging that is lost, removed, or destroyed until clearing and grubbing Work is complete and Engineer allows removal of flagging.

2. Erosion and Sediment Controls:
   a. Install applicable erosion and sediment controls before initiating clearing and grubbing Work.
   b. Comply with erosion and sediment control requirements of Section 01 57 05 – Temporary Controls, and Section 31 25 00 - Erosion and Sediment Controls.
   c. Adjust, relocate, or install additional erosion and sediment controls as clearing and grubbing Work progresses to previously uncleared, ungrubbed areas of the Site.

3.02 CLEARING AND GRUBBING

A. Remove all trees, shrubs, brush, logs, vegetation, rubbish, and other objectionable material within the remedial limits and support areas (i.e., soil/sediment removal areas, staging areas, access roads, consolidation areas, and as indicated in the Contract Documents, unless otherwise shown or indicated. Blanket tree removal is prohibited. Where possible and if practicable, trees shall be cut flush with the ground and roots left in place. Stumps and roots shall be removed from within soil excavation areas and within areas designated for filling.

B. Trees and shrubs to remain that have been damaged or require trimming shall be treated and repaired under the direction of a qualified arborist, or other professional with qualifications acceptable to Engineer. Replace trees and shrubs that are damaged beyond repair or that are removed, but were intended to remain, at no additional cost to Owner.

3.03 DISPOSAL OF CLEARED AND GRUBBED MATERIALS

A. Properly manage, transport, and dispose of cleared and grubbed materials at appropriate, Owner-approved facilities in accordance with applicable Laws and Regulations. May include on site disposal of certain cleared and grubbed materials as approved by Owner.

1. Above-ground and below-ground vegetation that is cleared and grubbed to facilitate construction activities shall be managed as solid waste for off-site disposal in accordance with Section 01 73 30, Waste Management or managed on site as approved by Owner. Vegetation approved for on-site management by the Owner shall be ground and/or chipped to allow for reuse as erosion control materials. Designation of site areas for reuse of vegetation material shall be coordinated with the CM and Owner.

END OF SECTION

SECTION 31 22 00 - GRADING

PART 1 - GENERAL

1.01 DESCRIPTION

A. Scope:

1. Providing all labor, materials, services, and equipment necessary to complete the grading activities, including placing consolidation materials within the UDF as depicted on the Design Drawings and/or as directed by the Owner/Construction Manager (CM).

B. Related Sections

1. Section 31 05 13 – Soils for Earthwork
2. Section 31 11 00 – Clearing and Grubbing
3. Section 31 05 16 – Aggregates for Earthwork
4. Section 31 23 00 – Excavation and Fill

1.02 REFERENCE STANDARDS

A. The following American Society for Testing and Materials (ASTM) standards are referenced in this section:

1. C31 Standard Practice for Making and Curing Concrete Test Specimens in the Field
2. D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))
3. D1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 [2,700 kN-m/m^3])
4. D1633 Standard Test Methods for Compressive Strength of Molded Soil-Cement Cylinders
5. D6938 Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

1.03 QUALITY ASSURANCE

A. Use materials, procedures, operations, and methods in strict conformance with the Contract Documents. Materials will be subjected to strict quality control monitoring as detailed herein.

1.04 SUBMITTALS

A. Proposed equipment and compaction method(s) provided prior to earthwork activities.

B. Results of moisture/density tests performed on fill materials (determined by ASTM D1557).

C. Results of moisture/density tests performed on consolidation materials (determined by ASTM D698).

D. Results of strength testing performed on consolidation materials (determined by ASTM D1633).

E. Results of in-place density tests performed on fill and consolidation materials (determined by ASTM D6938).

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.01 BACKFILL MATERIALS

A. Backfill Material shall conform to that outlined in Section 31 23 00 – Excavation and Fill.

B. Consolidation materials for UDF operations phase.

1. Collect samples of consolidation material prior to placement of solidified materials at a frequency of one sample per 10,000 cubic yards and test the samples for moisture content (ASTM D2216) and Standard Proctor (ASTM D698). The CM may require additional samples be collected for testing due to variability in the solidified materials.

2. Verify that consolidation materials, when placed in the UDF cells have a minimum unconfined compressive strength (UCS) of 10 psi.

3. Consolidation material testing that does not meet the required strength criteria of 10 psi, may be moisture conditioned and/or mixed with other consolidation materials followed by compaction and testing until satisfactory results are achieved.

3.02 GENERAL BACKFILLING REQUIREMENTS

A. Backfill shall be started at the lowest section of the area to be backfilled.

B. Drainage of the areas being backfilled shall be maintained at all times.

C. Areas to be backfilled shall be inspected and approved by the Owner/CM prior to backfilling operations. All unsuitable materials and debris shall be removed.

D. Backfill material shall not be placed when moisture content is too high to allow proper compaction.

E. When material is too dry for adequate compaction, water shall be added to the extent necessary.

F. Backfill material shall not be placed on frozen ground nor shall the material itself be frozen or contain frozen soil fragments when placed.

G. No calcium chloride or other chemicals shall be added to prevent freezing.

H. Material incorporated in the backfilling operation that is not in satisfactory condition shall be subject to rejection and removal at the Contractor’s expense.

I. The maximum lift thickness is 12 inches (measured prior to compaction), unless otherwise noted in this Section or on the Design Drawings.

J. For backfill placed directly over geosynthetics (i.e., in areas where engineered barriers are installed), the minimum installed first lift thickness above the geosynthetics is 12 inches and shall be comprised of selected soils or sediments that are free of objects greater than three inches in any dimension, any sharp objects, or any other deleterious materials that could potentially damage geosynthetics within the underlying baseliner system. During placement of the initial lift, a spotter will be stationed on top of the baseliner system and to the side of the spreading equipment to observe the placement of the material. If objects are spotted that could possibly damage the baseliner system, the spotter will signal the equipment operator to stop operation to allow the objectionable material to be removed from the material being spread.

K. The Contractor shall use appropriately sized equipment and methods when placing and compacting backfill over engineered barriers so as not to damage underlying geosynthetic materials. Areas of the engineered barrier (i.e., geosynthetics) that may have been damaged during backfill installation as determined by the Contractor, Owner, or CM, shall be inspected, and repaired, if necessary, in accordance with the Technical Specifications at the Contractor's expense.

3.03 METHOD OF COMPACTION

A. General

1. The Contractor shall adopt compaction methods that produce the degree of compaction specified herein, prevent subsequent settlement, and provide adequate support.

2. Compaction methods used shall avoid disturbance to underlying fine-grained soils, subsurface utilities, and the geosynthetics used in the engineered barriers.

3. Hydraulic compaction by ponding or jetting shall not be permitted.

4. Backfill material shall not be left in an uncompacted state at the close of a day's construction.

5. Prior to terminating work, ridges of soil left on the final layer of compacted fill, by tractors, trucks, or other equipment used for compaction, shall be eliminated using low-pressure equipment. However, soil surfaces may be left in a "tracked" condition (i.e., with parallel indentations from the tracks of tracked equipment running horizontally along the slope) for purposes of erosion and sediment control.

6. As backfill progresses, the surface shall be graded such that no ponding of water shall occur on the surface of the fill.

B. Equipment

1. Unless otherwise specified, equipment for compaction shall be consistent with space limitations of the work areas and the need to protect adjacent facilities.

2. Compaction of fill material in confined areas shall be accomplished by means of a drum-type, power-driven, hand-guided vibratory compactor, or by hand-guided vibratory plate tampers.

3. If the proposed method does not produce the degree of compaction required, an alternate method shall be adopted until the required compaction is achieved.

4. The moisture content of backfill or fill material shall be adjusted, if necessary, to achieve the required degree of compaction.

C. Minimum Compaction Requirements

1. Unless otherwise specified on the Design Drawings, the degree of compaction specified for the various items listed below in Table 1 shall be the minimum allowable.

2. Unless the Contractor can successfully demonstrate that its methods will produce the required degree of compaction, materials to be compacted shall be placed in layers not exceeding the uncompacted thicknesses listed in Table 1.

3. Degree of compaction to be verified using in-place density tests (using ASTM D6938) and shall be performed by a certified geotechnical testing laboratory at the Contractor's expense.

4. The Owner/CM may order additional in-place density tests to ascertain conformance with the compaction requirements shown in Table 1.

5. The Contractor shall dig test holes at no additional cost to Owner when requested for the purpose of taking an in-place density test below the current fill level.
6. The Contractor shall provide free access to fill areas for the purpose of making such tests. Payment for all compaction tests shall be made by the Contractor.
7. The Contractor shall anticipate time needed due to testing procedures and shall not have claims for extra compensation occasioned by such time.

TABLE 1

Material	Maximum Uncompacted Lift Thickness (inches)	Minimum Compaction
Excavated Subgrade - Existing Undisturbed Soils (fill areas)	Not Applicable	Proof-rolling
Excavated Subgrade - Existing Undisturbed Soils (final grade for stormwater basins and SMAs)	Not Applicable	None (equipment tracking associated with excavation grading only)
General Fill – Non-Structural Fills	12	Compacted with tracked equipment or other appropriately sized equipment (minimum 3 passes)
General Fill - Structural Fills (berms, embankments, operations and staging areas)	6	90% (ASTM D1557) 1 test per lift per 5,000 square feet
Aggregate Fill – Subbase (paved roads, buildings, manholes)	6	95% (ASTM D1557) 1 test per lift per 1,000 square feet
Aggregate Fill – Subbase (storage tanks)	6	Per Tank Manufacturer Specifications
Aggregate Fill – Access Road, Operations and Staging Areas	12	Compact by appropriate-sized roller equipment (minimum three passes) and proof rolling
Sand – Pipe Bedding	6	90% (ASTM D1557) 1 test per 500 linear feet of trench
Topsoil	6	Compact by placing/tracking only
UDF Operations Phase Cell Consolidation Material	12	90% (ASTM D698) 1 test per lift per acre

8. When proof-rolling existing (or native) soils, the layer shall be acceptable when deformations caused by substantial earthwork equipment (e.g., roller, fully loaded dump truck) are no deeper than 1 inch. All soft or wet materials that continue to deform more than 1 inch shall be removed and replaced with suitable material and retested at the expense of the Contractor.

3.04 GRADING

A. UDF Construction Phase:

1. After the completion of all backfill operations, the Contractor shall grade the site to the lines, grades, and elevations shown on the Design Drawings, taking into account any subsequent site restoration requirements.

B. UDF Operations Phase:

1. Place consolidation materials in the limits of consolidation within UDF cells shown on the Design Drawings.
2. Take all necessary precautions to minimize disturbances of any completed consolidation fill areas when placing and compacting consolidation materials.
3. Place consolidation materials to the grades shown on the Design Drawings in a manner that promotes drainage and minimizes ponding surface water.
4. Perform compaction with equipment suitable for the type of material placed and capable of meeting the specified density.
5. Do not place consolidation materials when standing water is present on surface of the area where materials will be placed. Do not place or compact consolidation materials in a frozen condition or on top of frozen material.
6. If required strength or densities are not obtained because of improper control of placement or compaction procedures, or because of inadequate or improperly functioning compaction equipment, the Contractor will perform all work required to meet the required densities.

3.05 EXISTING FACILITIES

A. General

1. Existing subsurface facilities may be encountered during construction of the work or located in close proximity to the work.
2. These facilities may include, but are not necessarily limited to, sewers, drains, water mains, gas mains, electrical conduits, and their appurtenances. These facilities may or may not be shown on the Design Drawings. However, the sizes, locations, heights, and depths, if indicated, are only approximate and the Contractor shall conduct its operations with caution and satisfy itself as to the accuracy of the information given. The Contractor shall not claim, nor shall it be entitled to receive compensation for damages sustained by reason of the inaccuracy of the information given or by reason of its failure to properly maintain and support such structures.
3. There may be other subsurface facilities, the existence and/or location of which are not known, such as individual water and gas services, electrical conduits, sanitary and storm sewer drains, etc. The Contractor shall consult with the Owner/CM of such facilities and, if possible, shall determine, prior to construction, the location and depth of any such facilities that may exist in the area to be excavated.
4. If underground facilities are known to exist in an area but their location is uncertain, the Contractor shall exercise reasonable care in its excavation technique to avoid damage to them.
5. The Contractor shall notify Massachusetts Dig Safe at least 72 hours prior to any site work.

B. Notification and Protection Procedures

1. Except where superseded by state or local regulations, or in the absence of any applicable regulations, the Contractor shall, at a minimum, include the following procedures in its operations:
   a. Prior to Excavating:
      1) Determine correct field location of all nearby underground facilities or arrange for Representatives of the utilities to locate them.
      2) Notify owners of nearby underground facilities when excavation is to take place, allowing them reasonable time to institute precautionary procedures or preventive measures which they deem necessary for protection of their facilities.
      3) In cooperation with owners of nearby facilities, provide temporary support and protection of those underground facilities that may be especially vulnerable to damage by virtue of their physical condition or location, or those that could create hazardous conditions if damaged.
   b. Immediately notify any utility owner of any damage to its underground facilities resulting from the Contractor's operations and arrange for repairs to be made as soon as possible.
   c. In case of any emergency the Contractor shall follow the approved Contingency and Emergency Procedures Plan.

3.06 OTHER REQUIREMENTS

A. Unfinished Work

1. When, for any reason, the work is to be left unfinished, all trenches and excavations shall be filled, and all roadways and watercourses left unobstructed with their surfaces in a safe and satisfactory condition.

B. Hauling Material on Street

1. When hauling material over the streets or pavement, the Contractor shall provide suitably tight-sealing vehicles so as to prevent deposits on the streets or pavements. In all cases where any materials are dropped from the vehicles, the Contractor shall clean up the same as often as required to keep the crosswalks, streets, and pavements clean and free from dirt, mud, stone, and other hauled material.

C. Field Quality Control

1. Laboratory Strength Testing of Consolidation Materials:
   a. Collect confirmation samples of the consolidation materials placed in the UDF cells using an in-situ sampler and test the samples for compressive strength (ASTM D1633). Each set of samples shall consist of four (4) 3-inch by 6-inch sample specimens (cylinders) from a lift of consolidation materials in the UDF cells. Complete sampling and testing for the first two lifts of consolidation materials. Thereafter, collect samples at a frequency of one per acre per lift. Conduct UCS testing of the samples within 2 days of placement.
   b. Prepare and cure samples in accordance with ASTM C31. Send the core samples to a qualified QA/QC laboratory for testing at the Contractor's expense.
   c. Should strength testing indicate UCS below 10 psi, suspend placement of consolidation materials and modify consolidation materials and/or placement procedures. Results of additional testing that is necessary to further verify material placement, may be requested by the CM prior to resuming placement of consolidation materials in the UDF.

2. In-Place Density Testing of Fill Materials and Consolidation Materials:
   a. Perform field density tests in accordance with Section 3.03 C
   b. Submit test results, certified by testing laboratory, to CM within 24 hours after completion of test.

c. If testing laboratory reports or inspections indicate subgrade, bedding, or fill compaction below specified density, Contractor shall remove unacceptable materials as necessary and replace with specified materials, and provide additional compaction at Contractor's expense until subgrades, bedding, and fills are acceptable. Costs for retesting of subgrade, bedding, or fills that did not originally comply with specified density shall be paid by Contractor.

3.07 CRITERIA AND TOLERANCES

A. Fill materials shall be constructed to the lines and grades shown on the contract drawings unless otherwise requested by the Engineer. Acceptance of final grades will be based on site observations by the CM and review of a final as-built survey information by the Engineer. Any settlements that occur prior to final acceptance of the work shall be restored to design and/or intended grades by the contractor at no additional cost to the Owner.

END OF SECTION

CONSOLISECTION 31 23 00 - EXCAVATION AND FILL

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, equipment, and incidentals required to perform all excavating, filling, and grading, and disposing of earth materials as shown, specified, and required to complete the Work.
2. Design and provide temporary excavation support and protection systems in accordance with Laws and Regulations to prevent injury to persons and property, including surface structures and Underground Facilities, during excavation and fill Work.
3. Perform excavation and fill Work within the areas shown or indicated on the Design Drawings.
4. Preparation of subgrade for pavements and crushed stone surfacing is included under this Section.
5. No classification of excavated materials will be made. Excavation includes all materials regardless of type, character, composition, moisture, or condition thereof, except rock requiring drilling, blasting, or special equipment for removal.

B. Coordination:

1. Review procedures under this and other Sections and coordinate Work that must be performed with or before excavation and fill Work.

C. Related Sections:

1. Section 31 05 13 – Soils for Earthwork
2. Section 31 05 16 – Aggregates for Earthwork
3. Section 31 23 23 – Select Fill
4. Section 31 11 00 – Clearing and Grubbing

1.02 REFERENCE STANDARDS

A. Terminology:

1. The following words or terms are not defined but, when used in this Section, have the following meaning:
   a. "Debris" means man-placed buried or piled material including, but not limited to, brick, concrete, asphalt, metal, and wood.
   b. "Subgrade" means the uppermost surface of native soil material unmoved from the bottom of excavations.

B. The following standards are referenced in this Section:

1. ANSI/AISC 360, Specification for Structural Steel Buildings.

2. ASTM D6913, Standard Test Methods for Particle-Size Distribution (Gradation) of Soils using Sieve Analysis.

3. ASTM D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft3 [600 kN-m/m3]).

4. ASTM D1140, Standard Test Methods for Amount of Material in Soils Finer than No. 200 (75 µm) Sieve.

5. ASTM D4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

6. ASTM D6938, Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).

7. ASTM E329, Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection.

8. USEPA SW-846 Method 6010, Inductively Coupled Plasma-Atomic Emission Spectrometry.

9. USEPA SW-846 Method 7471, Mercury in Solid or Semisolid Waste (Manual Cold Vapor Technique).

10. USEPA SW-846 Method 8081, Organochlorine Pesticides by Gas Chromatography.

11. USEPA SW-846 Method 8082, Polychlorinated Biphenyls (PCBs) by Gas Chromatography.

12. USEPA SW-846 Method 8151, Chlorinated Herbicides by GC Using Methylation or Pentafluorobenzylation Derivatization.

13. USEPA SW-846 Method 8260, Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS).

14. USEPA SW-846 Method 8270, Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS).

15. USEPA SW-846 Method 9012, Total and Amenable Cyanide (Automated Colorimetric, with Off-Line Distillation).

1.03 QUALITY ASSURANCE

A. Qualifications:

1. Professional Engineer: Retain the services of a professional engineer licensed and registered in the State of Massachusetts and experienced in providing engineering services of the kind indicated. Responsibilities include, but are not necessarily limited to, the following:
   a. Reviewing temporary excavation support and protection system performance that may be required to perform the work indicated in the Contract Documents.
   b. Preparing or supervising the preparation of design calculations and related submittals verifying compliance of the temporary excavation support and protection system(s) with the requirements of the Contract Documents.
   c. Signing and sealing all calculations, drawings, and submittals prepared by professional engineer.

d. Certifying that:
   1) it has performed the design of the temporary excavation support and protection system(s) in accordance with the performance requirements stated in the Contract Documents; and
   2) said design conforms to Laws and Regulations, and to the prevailing standards of practice.

2. Testing Laboratory: Retain the services of an independent testing laboratory to perform field quality control testing required in this Section. Testing laboratory shall comply with ASTM E329 and shall be experienced in the types of testing required.

B. Regulatory Requirements:

1. Laws and Regulations applying to the Work under this Section include, but are not limited to, the following:
   a. 29 CFR 1910.120, Hazardous Waste Operations and Emergency Response.
   b. 29 CFR 1926.65, Hazardous Waste Operations and Emergency Response.
   c. 29 CFR 1926.650 through 29 CFR 1926.652, Subpart P – Excavations.

2. Comply with applicable provisions and recommendations of the following:
   a. Code of Massachusetts Regulations (CMR)
   b. MassDOT Standard Specifications and Standard Sheets.

3. Obtain required permits and approvals for excavation and fill Work, including work permits from right-of-way owners.

1.04 SUBMITTALS

A. Informational Submittals:

1. Excavation and Backfilling Plan: Submit acceptable plan for excavation, backfilling, and related Work not less than 21 days prior to starting excavation Work. Include the following:
   a. Name of Contractor's "competent person" in responsible charge of excavation and fill Work.
   b. Plan for coordinating shut-offs, locating, capping, abandoning, temporary services, and continuing utility services.
   c. Copies of "manufacturer's data" or other tabulated data if protective system(s) are designed on the basis of such data.
   d. Design drawings, design calculations, and assumptions for construction surcharges, including magnitude and location relative to excavations, prepared by Contractor's professional engineer. Engineer's review and acceptance of submittal does not imply approval by Engineer of the associated Work. Contractor shall be solely responsible for designing, installing, operating, and maintaining the system(s) required to satisfactorily perform all necessary shoring, bracing, and protection. This includes all excavation stabilization designs completed by the Contractor for excavation and backfilling work in the vicinity of the Eversource towers.
   e. Proposed excavation, dewatering, backfilling, and compaction procedures. Where different procedures or equipment will be used for different types of material or at different locations at the Site, indicate where each procedure and equipment item will be used. This includes procedures for excavation and backfilling work planned in the vicinity of the Eversource Power Line Towers.
   f. List of proposed equipment for excavation, dewatering, backfilling, and compaction Work.

g. Planned sequence of excavation and backfilling operations, including coordination with temporary pumping, selective demolition, and piping installation Work.
h. Detailed schedule of excavation and backfilling Work in accordance with the accepted Progress Schedule.

2. Qualifications Statements:
   a. Professional Engineer: Submit name, address of firm, and qualifications of professional engineer.
   b. Testing Laboratory: Submit name and qualifications of testing laboratory to be employed, and qualifications of testing laboratory's personnel that will perform field quality control testing required in this Section. If more than one laboratory will be employed, submit qualifications statement for each laboratory.

3. Source Quality Control Submittals: Submit Supplier name, source address, and proof of MassDOT approval, as required, for each proposed source of fill material.

4. Delivery Tickets: Submit copy of delivery ticket for each load of general fill material, subbase material, and pipe bedding material delivered to the Site. Each delivery ticket shall indicate Supplier name and source address, project name, contract number, date, material type, MassDOT item number when applicable, and quantity delivered.

5. Field Quality Control Submittals:
   a. Laboratory Test Reports: Submit in accordance with Paragraph 3.11.A of this Section.
   b. Daily Inspection Logs: Submit in accordance with Paragraph 3.11.B of this Section.

1.05 SITE CONDITIONS

A. Subsurface Information:

1. The Design Drawings indicate information available relative to subsurface conditions at the Site. Such information and data are not intended as a representation or warranty of continuity of conditions between soil borings or test pits, nor of groundwater levels at dates and times other than date and time when measured, nor that purpose of obtaining the information and data were appropriate for use by Contractor. Owner and Engineer will not be responsible for interpretations or conclusions drawn therefrom by Contractor.

2. Soil borings and other exploratory operations may be made by Contractor, at no additional cost to Owner. Coordinate Contractor-performed test borings and other exploratory operations with Owner, Village, and utility owners as appropriate. Perform such explorations without disrupting or otherwise adversely affecting operations of Owner, Village, or utility owners. Comply with Laws and Regulations relative to required notifications.

B. Existing Structures:

1. The Contract Documents show or indicate certain structures and Underground Facilities adjacent to or within the limits of the Work. Such information was obtained from existing records and is not guaranteed to be correct or complete. Contractor shall explore ahead of selective demolition, trenching, excavation, or other subsurface Work to determine the exact location of all existing structures and Underground Facilities. Existing structures and Underground Facilities shall be supported and protected from damage by Contractor. Immediately repair and restore existing structures and Underground Facilities damaged by Contractor without additional cost to Owner.

2. Movement or operation of construction equipment over Underground Facilities shall be at Contractor's sole risk and only after Contractor has prepared and submitted to Engineer and utility owners (as applicable), and received acceptance therefrom, a plan describing Contractor's analysis of the loads to be imparted and Contractor's proposed measures to protect structures and Underground Facilities during the Project.
3. Coordinate with utility owners for shut off of services in active piping and conduits, and for testing, shut off of services, and draining, purging, or de-energizing where specified or required of piping and conduits of unknown status. When required by utility owner, Owner will assist Contractor with utility owner notifications. Completely remove buried piping and conduits indicated for removal and not otherwise indicated as being abandoned or to remain in place.
4. In general, service lines and laterals to individual houses and businesses are not shown; however, Contractor shall assume that a service exists for each utility owner to each house, business, and property.
5. Do not interrupt existing utilities serving facilities occupied and used by Owner, City, or others, except when such interruption is indicated in the Contract Documents or when allowed in writing by Engineer after acceptable temporary utility services are provided by Contractor for the affected structure or property.

PART 2 – PRODUCTS

2.01 MATERIALS

A. None – See Sections 31 05 13 - Soils for Earthwork, 31 05 16 - Aggregates for Earthwork, and 31 23 23 - Select Fill for specifications related to fill materials.

PART 3 – EXECUTION

3.01 INSPECTION

A. Provide Engineer with sufficient notice and with means to examine areas and conditions under which excavating, filling, and grading Work will be performed. Engineer will advise Contractor in writing when Engineer is aware of conditions that may be detrimental to proper and timely completion of the Work. Do not proceed with the Work until unsatisfactory conditions are corrected.

3.02 PREPARATION

A. Erosion and Sediment Control: Provide temporary erosion and sediment controls in accordance with 31 25 00 – Erosion and Sediment Control.

B. Odor and Dust Control: Provide odor and dust controls in accordance with 1 57 00 – Temporary Controls.

C. Site Preparation:

1. Clearing and Grubbing: Comply with Section 31 11 00 – Clearing and Grubbing.

D. Temporary Barriers:

1. Provide temporary barrier surrounding excavations and excavation work areas to provide temporary protection to persons and property. Barrier shall have openings only at vehicular, equipment, and worker access points.

2. During non-working hours, completely enclose all sides of excavation with temporary barriers.

3. Minimum Material Requirements for Temporary Barriers:
   a. Temporary barrier shall be not less than snow fence-type fencing, four feet high.
   b. Fence shall be constructed of vertical hardwood slats measuring not less than 1.5 inches by 1/4 inch interwoven with strands of horizontal wire or shall be of equivalent plastic construction.
   c. Posts:
      1) Posts shall be steel, either "U"-, "Y"-, or "T"-shaped, or channel section.
      2) Posts shall have a nominal weight of not less than 1/3-pound per linear foot, exclusive of the anchor.
      3) Posts shall have tapered anchors weighing not less than 0.67 pound, each firmly attached by means of welding, riveting, or clamping.
      4) Posts shall have corrugations, knobs, notches, or studs placed and constructed to engage a substantial number of fence line wire in the proper position.
   d. Provide each post with sufficient quantity of galvanized wire fasteners or clamps, of not less than 0.120 inch in diameter, for attaching fence wire to post.

E. Maintenance and Protection of Traffic: Comply with 1 57 00 – Temporary Controls.

3.03 TEST PITS

A. General: In advance of the construction, excavate, make observations and measurements, and fill test pits to determine conditions or location of existing structures and Underground Facilities. Perform all Work required in connection with excavating, stockpiling, maintaining, sheeting, shoring, and filling test pits. Contractor shall be responsible for the definite location of each existing structure and Underground Facility involved within the areas of excavation for the Work. Exercise care during such location work to avoid damaging and disrupting the affected structure or Underground Facility. Contractor shall be responsible for repairing, at its expense, damage caused during the Work to existing structures or Underground Facilities to remain.

B. Payment for Test Pits: There shall be no separate payment for test pits.

3.04 DEWATERING

A. General:

1. Provide and maintain adequate drainage and dewatering equipment to remove and dispose of all surface water and groundwater entering excavation and fill areas, or other parts of the Work and work areas. To the extent practicable, keep each excavation and fill areas dry during excavation, subgrade preparation, and continually thereafter until backfilling operations are completed and acceptable to CM.

2. Keep all working areas at the Site free of surface water at all times. Provide temporary drainage ditches and temporary dikes and provide required temporary pumping and other work necessary for diverting or removing rainfall and all other accumulations of surface water from excavation and fill areas. Perform diversion and removal of surface water in a manner that prevents accumulation of water behind permanent or temporary structures and at any other locations in the work area where such accumulations may be detrimental.

3. Contractor shall be responsible for the condition of piping, conduits, and channels used for drainage, and such piping, conduits, and channels shall be clean and free of sediment. Piping, conduits, and channels used for drainage shall not be located in environmentally-sensitive areas such as wetlands.

B. Temporary Dewatering System:

1. Contractor shall design, provide, operate, and maintain dewatering system to include sufficient trenches, sumps, pumps, hose, piping, well points, and similar facilities, necessary to depress and maintain groundwater level two feet below the base of each excavation until backfilling operations are completed and acceptable to Engineer.

2. Design and operate dewatering system to avoid settlement and damage to existing structures and Underground Facilities, and to minimize the turbidity of the collected water.

3. To the extent practicable, groundwater table shall be lowered in advance of excavation for a sufficient period of time to allow dewatering of fine grain soils.

4. Operate dewatering system continuously during active excavation and backfilling Work. Provide standby pumping facilities and personnel to maintain the continued effectiveness of the system. Do not discontinue dewatering operations without first obtaining Engineer's acceptance for such discontinuation.

5. If, in Engineer's opinion, groundwater levels are not being lowered or maintained as required, provide additional or alternate temporary dewatering devices, as necessary, at no additional cost to Owner.

6. Locate elements of temporary dewatering system to allow continuous dewatering operation without interfering with the Work to the extent practicable. Location of temporary dewatering system shall not affect Village's operations, utility owners, adjacent wetlands, public access to streets and drives, or access to private property, unless approved by authorities having jurisdiction.

C. Disposal of Water Removed by Dewatering System:

1. Water resulting from excavation and fill area dewatering shall be discharged in a manner that does not cause excessive erosion or sedimentation and at an on-site location approved by the Owner and Engineer.

3.05 EXCAVATION

A. Perform all excavation required to complete the Work as shown, specified, and required in the Design Drawings. Excavation shall include removing and handling of earth, sand, clay, gravel, hardpan, soft, weathered, or decomposed rock, pavements, rubbish, debris, and other materials within the excavation limits.

B. Extent of open excavations shall be minimized to the greatest extent practical.

C. Excavation Protection: Provide excavation protection systems in accordance with Laws and Regulations to prevent injury to persons and property, including surface structures and Underground Facilities.

1. Excavation Less Than Five Feet Deep: Excavations in stable rock or in soil conditions where there is no potential for a cave-in may be made with vertical sides. Under all other conditions, excavations shall be sloped and benched, shielded, or shored and braced.

2. Excavations Greater Than Five Feet Deep: Excavations in stable rock may be made with vertical sides. Under all other conditions, excavations shall be sloped and benched, shielded, or shored and braced.

3. Provide and maintain excavation support and protection systems in accordance with submittal accepted by Engineer and required under Paragraph 1.04.A.1 of this Section.

D. Maintain excavations in dry condition in accordance with Article 3.04 of this Section.

E. Extend excavations sufficiently on each side of structures, footings, and similar construction to allow setting of forms, installation of shoring and bracing, and the safe sloping of banks, as necessary.

F. Subgrades:

1. General:
   a. Subgrades shall be firm and intact, dense, and thoroughly compacted and consolidated; shall be free of standing water and mud, muck, and other soft or unsuitable materials; and shall remain firm and intact under all construction operations. Subgrades that are otherwise solid but become soft or mucky on top due to construction operations shall be reinforced with general fill material. Finished elevation of stabilized subgrades shall not be above subgrade elevations shown or indicated.
   b. If, in Engineer's opinion, subgrade becomes softened or mucky because of construction delays, failure to dewater properly, or other cause within Contractor's control, the subgrade shall be excavated to firm material, trimmed, and backfilled with compacted general fill material at Contractor's expense.

G. Pipe Trench Preparation:

1. Not more than 150 feet of trench shall be opened in advance of installing pipe in trench.

2. Trench width shall be minimized to the greatest extent practical, and shall comply with the following:
   a. Trench width shall be sufficient to provide space for installing, jointing, and inspecting piping. Refer to the Drawings for trench requirements. In no case shall trench be wider at top of pipe than pipe barrel OD plus two feet, unless otherwise shown or indicated.
   b. Enlargement of trench width at pipe joints may be made when required and approved by Engineer.
   c. Trench width shall be sufficient for shoring and bracing or shielding and dewatering.
   d. Trench width shall be sufficient to allow thorough compaction of fill adjacent to bottom half of pipe.
   e. Do not use excavating equipment that requires the trench to be excavated to excessive width.
3. Depth of trench shall be as shown or indicated on the Drawings. If required and approved by Engineer in writing, depths may be revised.

4. Where bedrock or other unyielding material is encountered at the bottom of the trench, remove such material to a minimum depth of six inches below the bottom of the pipe and replace with pipe bedding material.

5. Where Engineer considers existing material beneath bedding material unsuitable, remove and replace such unsuitable material with pipe bedding material.

H. Unauthorized Excavation: All excavations outside the lines and grades shown or indicated and that are not approved by Engineer, together with removing and disposing of the excavated material and backfilling with suitable material, shall be at Contractor's expense. Fill unauthorized excavations with properly compacted general fill material at Contractor's expense.

3.06 TEMPORARY SHEETING, SHORING, AND BRACING

A. General:

1. If this method is used, design and provide temporary sheeting, shoring, bracing, and similar excavation supports as shown, specified, and required for the Work. Temporary excavation support and protection systems shall be capable of supporting excavation sidewalls and resisting soil and hydrostatic pressures and superimposed and construction loads.

2. Clearances and types of temporary sheeting, shoring, bracing, and similar excavation supports, insofar as they may affect the finished character of the Work, will be subject to Engineer's acceptance, but Contractor is responsible for adequacy of all sheeting, shoring, bracing, and similar excavation supports.

3. Materials:
   a. Previously-used materials shall be in good condition, and shall not be damaged or excessively pitted. New or used sheeting may be used for temporary sheeting, shoring, and bracing.
   b. All steel work for sheeting, shoring, bracing, and other excavation supports shall be in accordance with ANSI/AISC 360, except that field welding will be allowed.

4. Install sheeting, shoring, bracing, and similar excavation supports without damaging existing buildings, structures, Underground Facilities, and site improvements adjacent to excavation.

5. As excavation progresses, carry down shoring, bracing, and similar excavation supports to required elevation at bottom of excavation.

6. Comply with Laws and Regulations regarding sheeting, shoring, bracing, and similar excavation supports.

7. Maintain sheeting, shoring, bracing, and other excavation supports in excavations regardless of time period excavations will be open.

8. Unless otherwise shown, specified, or directed, remove materials used for temporary construction when the Work is completed. Perform such removal in manner not injurious to the structures and Underground Facility, their appearance, and adjacent construction.

B. Monitoring:

1. Monitor excavation support and protection systems and surrounding conditions daily during excavation progress and for as long as excavation remains open.

2. Immediately notify Engineer of any movement, cracking, or settlement of the ground surface surrounding the excavation, or of any visual damage to or movement of adjacent structures, utility poles, or other facilities.

3. Promptly correct bulges, breakage, leaks, or other evidence of movement to ensure that excavation support and protection systems remain stable.

C. Removal of Sheeting and Bracing:

1. Remove sheeting and bracing from excavations, unless otherwise directed by Engineer in writing, when construction has progressed sufficiently to support excavations and bear soil and hydrostatic pressures and superimposed and construction loads. Perform removal to avoid damaging the Work, adjacent construction, existing structures, and Underground Facilities to remain. Removal shall be equal on both sides of excavation to ensure no unequal loads on structures and Underground Facilities. Repair any damage at Contractor's expense.

2. Backfill voids resulting from the removal of sheeting and bracing with approved general fill material.

3. Clean sheeting and bracing of visible soil upon removal. If coal tar is observed on sheeting or bracing, wrap sheeting or bracing in minimum six-mil polyethylene sheeting and transport sheeting or bracing to a temporary containment area for further cleaning.

3.07 TRENCH SHIELDS

A. Excavation of earth material below bottom of trench shield shall not exceed the limits established in Laws and Regulations or manufacturer's specifications.

B. When using a shield for installing piping:

1. Portions of trench shield extending below the mid-diameter of an installed, rigid pipe, such as pre-stressed concrete pipe and other types of rigid pipe, shall be raised above the pipe's mid-diameter elevation prior to moving the shield along the trench for further construction.
2. Bottom of shield shall not at any time extend below mid-diameter of installed pipe that is flexible or has flexing capability, such as steel, ductile iron, PVC, CPVC, polyethylene, and other pipe that has flexing capability.

C. When using a shield for installing structures, bottom of the shield shall not extend below the top of the bedding for the structures.

D. When removing the shield or moving the shield ahead, exercise extreme care to prevent moving piping, structures, and other Underground Facilities, and to prevent disturbance of bedding material for piping, structures, and other Underground Facilities. When piping, structures, or Underground Facilities are disturbed, remove and reinstall the disturbed items in accordance with the Contract Documents.

3.08 FILL AND COMPACTION

A. Provide and compact all fill required for the finished grades as shown on the Design Drawings.

B. Construction fill material that includes organic materials or other unacceptable materials shall be removed and replaced with approved fill material in accordance with the Contract Documents.

C. Placement – General:

1. Place fill to the grades shown on the Design Drawings or indicated. Bring up evenly on all sides fill around structures and Underground Facilities.

2. Place fill materials to the density specified for each material type. Furnish and use equipment capable of adding measured amounts of water to the fill materials to bring fill materials to a condition within required moisture content range, if required. Furnish and use equipment capable of discing, aerating, and mixing the fill materials to ensure reasonable uniformity of moisture content throughout the fill materials, and to reduce moisture content of borrow materials by air drying, when necessary. When subgrade or lift of fill materials requires moisture-conditioning before compaction, fill material shall be sufficiently mixed or worked on the subgrade to ensure uniform moisture content throughout the lift of material to be compacted. Materials at moisture content in excess of specified limit shall be dried by aeration or stockpiled for drying.

3. Perform compaction with equipment suitable for the type of fill material placed. Select and use equipment capable of providing the minimum density required in the Contract Documents. Furnish and use equipment capable of compacting in restricted areas next to structures and around piping and Underground Facilities. Effectiveness of the equipment selected by Contractor shall be tested at start of compacted fill Work by constructing a small section of fill within or adjacent to the area where fill will be placed. Record total number of coverages with selected compaction equipment and perform field moisture content and density tests to ensure that specified compaction of fill has been obtained. If tests on the test section of fill indicate that required compaction has not obtained, do one or more of the following:
   a. Increase the amount of coverages.
   b. Decrease the lift thicknesses.
   c. Use different compaction equipment.

4. Place fill materials in horizontal, loose lifts, not exceeding specified uncompacted thickness. Place fill in a manner ensuring uniform lift thickness after placing. Mechanically compact each lift, by not less than three complete coverages of the compactor. One coverage is defined as the conditions reached when all portions of the fill lift have been subjected to the direct contact of compactor's compacting surface. Compaction of fill materials by inundation with water is unacceptable.

5. Do not place fill materials when standing water is present on surface of the area where fill will be placed unless otherwise approved by the Engineer. Do not compact fill when standing water is present on the fill to be compacted. Do not place or compact fill in a frozen condition or on top of frozen material. Fill containing organic materials or other unacceptable materials previously described shall be removed and replaced prior to compaction.

6. If required densities are not obtained because of improper control of placement or compaction procedures, or because of inadequate or improperly functioning compaction equipment, Contractor shall perform all work required to provide the required densities. Such work shall include, at no additional cost to Owner, complete removal of unacceptable fill areas and replacement and re-compaction until acceptable fill is provided.

7. Repair, at Contractor's expense, observed or measured settlement. Make repairs and replacements as required within five days after being so advised by CM.

D. Fill in Pipe Trenches:

1. Where shown or indicated, provide geotextile separation fabric between pipe embedment and native material in accordance with Section 31 05 19.13 – Geotextiles for Earthwork.

2. Place pipe bedding material in pipe trenches in horizontal layers, and thoroughly compact each layer before the next layer is placed.

3. Pipe trenches may be backfilled prior to testing of piping unless the nature of the test requires observation of piping during testing.

4. Pipe Bedding: Install piping on not less than four-inch layer of pipe bedding material. Pipe bedding material shall extend 12 inches above the top of the pipe.

5. Placing and Compacting Pipe Trench Fill: Unless otherwise shown, placement and compaction of pipe trench fill material shall comply with the following:
   a. Pipe bedding material shall be spread and the surface graded to provide a uniform and continuous support beneath piping at all points between bell holes or pipe joints. Slight disturbance of installed pipe bedding material surface during withdrawal of pipe slings or other lifting tackle is acceptable.
   b. After each pipe's bedding material has been graded, and the piping has been aligned, joined in accordance with the Contract Documents, and placed in final position on bedding material, provide and compact sufficient pipe trench fill material under and around each side of the pipe and back of the bell or end thereof to hold piping in proper position and maintain alignment during subsequent pipe jointing and embedment operations. Deposit and compact pipe trench fill material uniformly and simultaneously on each side of piping to prevent lateral displacement of piping. Place and compact pipe trench fill material to an elevation 12 inches above top of pipe, unless otherwise shown or specified.
   c. Each layer of pipe trench fill material shall be compacted by at least two complete coverages of all portions of surface of each lift using appropriate compaction equipment.
   d. Method of compaction and compaction equipment used shall be appropriate for material to be compacted and shall not transmit damaging shocks to the piping.

E. Subbase Placement:

1. Provide subbase material where indicated in the Contract Documents and to the limits required.

2. Place subbase material in compacted lifts not exceeding the specified thicknesses for each lift.

F. Compaction Density Requirements:

1. All soils and aggregates used for fill shall be compacted to the density specified for each material type.

2. Fill shall be wetted and thoroughly mixed to achieve optimum moisture content plus-or-minus three percent.

3. Replace natural, undisturbed soils or compacted soil subsequently disturbed or removed by construction operations with materials compacted as specified for their material type.

4. Field quality control testing for density, to verify that specified density was obtained, shall be performed in accordance with Paragraph 3.11.A of this Section.

5. When field quality control testing indicates unsatisfactory compaction, provide additional compaction necessary to obtain the specified compaction. Perform additional compaction Work at no additional cost to Owner until specified compaction is obtained. Such work includes complete removal of unacceptable (as determined by CM) fill areas and replacement and re-compaction until acceptable fill is provided in accordance with the Contract Documents.

G. Replacement of Unacceptable Excavated Materials: In cases where over-excavation to replace unacceptable soil materials is required, backfill the excavation to required subgrade with general fill material and thoroughly compact in accordance with Paragraph 3.08.G of this Section.

3.09 GRADING

A. General:

1. Uniformly grade areas within limits of grading under this Section, including adjacent transition areas.

2. Smooth subgrade surfaces within specified tolerances, compact with uniform levels or slopes between points where elevations are shown, or between such points and existing grades.

3. Blend grading over trench or excavation to elevations shown or indicated. Where elevations are not shown or indicated, blend finished grade with existing grade on each side of trench or excavation.

B. Grading Outside Building Lines: Grade areas adjacent to building lines to drain away from structures and to prevent ponding. Finish surfaces free of irregular surface changes, and comply with the following:

1. Grassed Areas or Areas Covered with Gravel, Stone, Wood Chips, or Other Special Cover: Finish areas to receive topsoil or special cover to within not more than one inch above or below the required subgrade elevations.

2. Pavements: Shape surface of areas under pavements to line, grade, and cross section, with finish surface not more than 1/2 inch above or below the required subgrade elevation.

C. Compaction: After grading, compact subgrade surfaces to achieve required subgrade elevations and percentage of maximum density for each material classification.

3.10 SUBBASE COURSE FOR PAVEMENT AND CRUSHED STONE SURFACING

A. General:

1. Place subbase material, in layers of specified thickness, over ground surface to support pavement base course or crushed stone surfacing.

2. After completing filling and grading, shape and compact subgrade to an even, firm foundation in accordance with this Section. Remove unsuitable subgrade materials, including soft materials, boulders, vegetation, and loose stones, and replace with compacted fill material as directed by Engineer.

B. Grade Control: During construction, maintain lines and grades including crown and cross-slope of subbase course.

C. Subbase Course Placement:

1. Place subbase course material on prepared subgrade in layers of uniform thickness, in accordance with indicated cross-section and thickness. Maintain optimum moisture content for compacting subbase material during placing operations.

2. Provide geotextile separation fabric over the prepared subgrade in accordance with Section 31 05 19.13.

3. Compaction and Grade Control: Comply with compaction requirements for excavation and fill in this Section, and the following requirements:
   a. Compaction with roller shall begin at the sides of the area to be paved or receive crushed stone surfacing and shall continue toward the center. Continue compaction until there is no movement of the course ahead of the roller.
   b. After rolling, check for grade with a line not less than 40 feet in length. Depressions over 1/2 inch deep shall be filled to satisfaction of CM.

4. After completing compaction, other than that necessary for bringing material for the next course, do not haul or drive over the compacted subbase.

5. Do not install subbase in excess of 500 feet in length without compacting to prevent softening of the subgrade.

6. If subgrade material becomes churned up into or mixed with the subbase material, remove the mixed material and replace with clean, compacted subbase material.

D. Shoulders:

1. Place shoulders along edges of subbase course to prevent lateral movement. Construct shoulders of acceptable soil materials, placed in such quantity to compact to thickness of each lift of subbase material.

2. Compact and roll not less than 12-inch width of shoulder simultaneously with compacting and rolling of each lift of subbase material.

3.11 FIELD QUALITY CONTROL

1. Perform field density tests in accordance with specification Section 31 22 00 – Grading.

2. Submit test results, certified by testing laboratory, to CM within 24 hours after completion of test.

3. If testing laboratory reports or inspections indicate subgrade, bedding, or fill compaction below specified density, Contractor shall remove unacceptable materials as necessary and replace with specified materials, and provide additional compaction at Contractor's expense until subgrades, bedding, and fills are acceptable. Costs for retesting of subgrade, bedding, or fills that did not originally comply with specified density shall be paid by Contractor.

A. Earthwork Inspections:

1. Perform daily or more frequent inspections of all excavations, adjacent areas, and protective systems as required by Laws and Regulations and this Section to ensure their continued effectiveness and integrity, and the safety of exposed employees.

2. Inspections shall be performed by Contractor's competent person, together with CM:
   a. Prior to the start of Work and as needed throughout the day.
   b. After every rainstorm or other hazard-increasing occurrence.

3. Where Contractor's competent person finds evidence of a situation that could result in a possible cave-in, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions, exposed employees shall be removed from the hazardous area until the necessary precautions or corrective actions have been taken to ensure their safety.

4. Document the date, time, and outcome of each inspection in a dedicated log. Submit copy of inspection log to CM with daily construction report.

END OF SECTION

SECTION 31 25 00 - EROSION AND SEDIMENT CONTROLS

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Providing and maintaining methods, equipment, materials, and temporary construction as required to control erosion and sediment transport at the Site and adjacent areas as specified in the project Stormwater Pollution Prevention Plan (SWPPP).
2. Maintain erosion and sediment controls until no longer required.

B. Related Sections:

1. Section 31 11 00 – Clearing and Grubbing
2. Section 31 23 00 – Excavation and Fill
3. Section 32 92 00 – Turfs and Grasses

1.02 REFERENCE STANDARDS

A. The following standards are referenced in this Section:

1. MassDEP Stormwater Handbook and Stormwater Standards

1.03 QUALITY ASSURANCE

A. Requirements:

1. Comply with applicable provisions and recommendations of the Project SWPPP.

1.04 SUBMITTALS

A. Action Submittals:

1. Product Data: Submit manufacturer's product data, specifications, and installation instructions for the following:
   a. Reinforced silt fencing.
   b. Straw wattles.
   c. Erosion control mats and associated anchoring materials.

PART 2– PRODUCTS

2.01 EROSION AND SEDIMENT CONTROLS

A. General:

1. Materials used for erosion and sediment controls shall be in accordance with the applicable regulatory requirements indicated in Article 1.03 of this Section, unless otherwise shown or indicated in the Contract Documents and or the SWPPP.

B. Reinforced Silt Fencing:

1. Filter Fabric:
   a. Material: Geotextile shall comply with MassDEP guidelines for Soil Erosion and Sediment Control standard and specifications for silt fence.
   b. Height: Three feet, minimum.

2. Fence Support Posts:
   a. Material: Hardwood or steel posts may be used.
      1) Hardwood posts shall be at least 1.25 inches by 1.25 inches in cross section.
      2) Steel posts shall be "T" or "U" shape in cross section with a minimum weight of 1.0 pound per linear foot.
   b. Length: Four feet, minimum.

3. Wire Reinforcing: Wire fencing shall be a minimum 14 gage with a maximum 6 in. mesh opening or as approved.

4. Fabric fasteners shall be heavy-duty staples, wire ties, or other fastener compatible with support post material.

C. Stabilized Construction Access:

1. Crushed stone shall be a clean, durable, matrix of sharp-angled fragments ranging in size from 1 to 3 inches.

2. Geotextile shall comply with MassDEP guidelines for Soil Erosion and Sediment Control standard and specifications for stabilized construction access use.

D. Temporary Erosion Control Blankets: Type 3.B, in accordance with FHWA FP-03, Section 713.17.

1. Product and Manufacturer: Provide one of the following:
   a. ECSC-2B, by East Coast Erosion Blankets, LLC.
   b. Curlex II FibreNet, by American Excelsior Company.
   c. Or equal.

2. Erosion control blankets shall be 100 percent natural and biodegradable and shall not incorporate plastic netting of any kind. Acceptable materials include jute, excelsior, straw or coconut fiber, and cotton.

3. Staples or anchoring stakes shall be 100 percent biodegradable.

E. Permanent Turf Reinforcement Mat (TRM): Type 5.A, in accordance with FHWA FP-03, Section 713.18.

1. Product and Manufacturer: Provide one of the following:
   a. C350 Turf Reinforcement Mat, by North American Green
   b. Or equal

2. Permanent TRM shall be non-degradable with sufficient thickness, strength, and void space for permanent erosion protection, per TRM manufacturers requirements.

3. Staples or anchoring stakes shall be per TRM manufacturers requirements and specifications.

F. Straw Wattles:

1. 12-inch diameter, bio-degradable straw wattle, 100% weed free
2. Up to 24-month life expectancy
3. 1/8-inch mesh opening
4. Minimum 180 psi strength per ASTM 5035

PART 3– EXECUTION

3.01 EROSION AND SEDIMENT CONTROL

A. Installation and Maintenance – General:

1. General:
   a. Provide erosion and sediment controls as shown and indicated on the Design Drawings and elsewhere in the Contract Documents, and as suggested in the Stormwater Prevention Control Plan. Provide erosion and sediment controls as the Work progresses into previously undisturbed areas.
   b. Install erosion and sediment controls shall be in accordance with the applicable regulatory requirements indicated in Article 1.03 of this Section, unless otherwise shown or indicated in the Contract Documents.
   c. Use necessary methods to successfully control erosion and sedimentation, including ecology-oriented construction practices, vegetative measures, and mechanical controls. Use best management practices in accordance with Laws and Regulations, and regulatory requirements indicated in Article 1.03 of this Section, to control erosion and sedimentation during the Project.
   d. Plan and execute construction, disturbances of soils and soil cover, and earthwork by methods to control surface drainage from cuts and fills, and from borrow and waste disposal areas, to prevent erosion and sedimentation. Provide temporary measures for controlling erosion and sedimentation, as indicated in the Contract Documents and as required for the Project.
   e. Regulate drainage and control erosion and sedimentation in areas that are cleared for storage of materials or equipment, or for temporary facilities.
   f. Provide erosion and sediment controls, including stabilization of soils, at the end of each work day.

2. Coordination:
   a. Coordinate erosion and sediment controls with this Section's requirements on water control.
   b. Coordinate temporary erosion and sediment controls with construction of permanent drainage facilities and other Work to the extent necessary for economical, effective, and continuous erosion and sediment control.

3. Provide all erosion and sediment control measures required by the Contract Documents for the areas where soil or soil cover will be disturbed before commencing activities that will disturb soil or soil cover at the Site.

4. Implement construction procedures associated with, or that may affect, erosion and sediment control to ensure minimum damage to the environment during construction.

5. Vegetation Removal:
   a. Remove only those shrubs, grasses, and other vegetation that must be removed for construction. Protect remaining vegetation.
      1) Grind removed stumps into mulch for use as temporary erosion control material of prepare stumps or unusable vegetation debris for off-site disposal as approved by the Owner/CM.

6. Access Roads and Parking Areas: When possible, access roads and temporary roads shall be located and constructed to avoid adverse effects on the environment. Provisions shall be made to regulate drainage, avoid erosion and sedimentation, and minimize damage to vegetation.

7. Earthwork and Temporary Controls:
   a. Perform excavation, fill, and related operations in accordance with Specification Section 31 23 00 – Excavation and Fill.
   b. Control erosion to minimize transport of silt from the Site into existing waterways and surface waters. Such measures shall include, but are not limited to, using berms, silt fencing, gravel or crushed stone, slope drains, and other methods. Apply such temporary measures to erodible materials exposed by activities associated with the remedial construction.
   c. Hold to a minimum the areas of bare soil exposed at one time.
   d. In performing earthwork, eliminate depressions that could serve as mosquito pools.
   e. Provide special care in areas with steep slopes. Minimize vegetation disturbance to maintain soil stability.

8. Inspection and Maintenance:
   a. Periodically inspect areas of earthwork and areas where soil or soil cover are disturbed to identify evidence of the start of erosion and sedimentation; apply corrective measures as required to control erosion and sedimentation. Continue inspections and corrective measures until soils are permanently stabilized and permanent vegetation has been established.
   b. Inspect erosion and sediment controls prior to conducting any intrusive activities. During Work, erosion and sediment controls shall be inspected at least once every seven days until restoration is complete.
   c. Repair or replace damaged erosion and sediment controls within one day of becoming aware of such damage.
   d. Periodically remove silt and sediment that has accumulated in or behind sediment and erosion controls. Properly dispose of silt and sediment.

9. Duration of Erosion and Sediment Controls:
   a. Maintain erosion and sediment controls in effective working condition until the associated drainage area has been permanently stabilized.
   b. Maintain erosion and sediment controls until the Site is restored and site improvements including landscaping, if any, are complete with underlying soils permanently stabilized.

10. Work Stoppage: Provide additional temporary controls necessary to prevent environmental damage to the Site and adjacent areas if the Work is temporarily stopped or suspended for any reason.

11. Failure to Provide Adequate Controls: In the event that Contractor repeatedly fails to satisfactorily control erosion and siltation, Owner reserves the right to employ outside assistance or to use Owner's own forces for erosion and sediment control. Cost of such work, plus engineering and inspection costs, will be deducted from monies due to Contractor.

B. Reinforced Silt Fencing:

1. Install and maintain silt fencing in a vertical plane, at the location(s) shown or indicated on the Design Drawings.

2. Locations of Reinforced Silt Fencing:
   a. Where possible, install silt fencing along contour lines so that each given run of fencing is at the same elevation.
   b. On slopes, install silt fencing at intervals that do not exceed the maximum lengths indicated in Table 1, unless otherwise approved by the Engineer.

TABLE 1
MAXIMUM LENGTH OF UPGRADIENT SLOPE BETWEEN RUNS

Slope	**Upgradient Slope Length (feet)**
< 2%	N/A
2 – 10%	250
10 – 20%	150
20 – 33%	80
33 – 50%	70
> 50%	30

   c. Provide silt fencing around the perimeter of each stockpile of topsoil, general fill material, and excavated material. Install silt fencing before expected precipitation and maintain until stockpile is removed.
   d. Do not install silt fencing at the following types of locations:
      1) Area of concentrated storm water flows such as ditches, swales, or channels.
      2) Where rock or rocky soils prevent full and uniform anchoring of silt fencing.
      3) Across upstream or discharge ends of storm water piping or culverts.

3. Installation:
   a. Securely fasten filter fabric to each support post in no less than four locations. Spacing between support posts shall not exceed 10 feet (center to center).
   b. When two sections of filter fabric abut each other, fold over edges and overlap by minimum of six inches and securely fasten to wire mesh.
   c. Embed posts in the ground to the depth necessary for proper controls, but not less than 16 inches below ground surface.
   d. Extend filter fabric a minimum of six inches below ground and a minimum of 16 inches above ground.
   e. Bury filter fabric at bottom of silt fence in a trench, in a “J” configuration, to a depth of six inches below grade.
   f. Remove sediment accumulated at silt fencing as required. Repair and reinstall silt fencing as required.

4. Maintenance:
   a. Conduct routine inspection at least once every seven days until final restoration.
   b. Remove accumulated sediment when depth reaches one-half the effective height of the sediment control.
   c. Repair and reinstall silt fencing as required.
   d. Do not allow formation of concentrated storm water flows on slopes above silt fencing unless so shown or indicated in the Contract Documents. If unauthorized concentrated storm water flows occur, stabilize the slope via earthmoving and other stabilization measures as required to prevent flow of concentrated storm water flows toward silt fencing.

C. Protection of Storm Water Drainage Inlets:

1. Protect each drainage inlets that has the potential to receive storm water run-off from exposed soils.
2. Install inlet filter bags inside of drainage inlet or catch basin in accordance with manufacturer's instructions. Secure inlet filter bag with the structure's grate or by other acceptable means.
3. Inlet filter bags shall not pose any obstruction above the elevation of the drainage inlet or catch basin grate requiring barricades or flashers.
4. When removing silt and sediment from inlet filter bag, do not dump filter bag's contents into the drainage inlet or catch basin.
5. Remove silt and sediment from inlet filter bag, or replace inlet filter bag, when inlet filter bag is not more than half full.

3.02 SURFACE WATER CONTROL

A. General:

1. Provide methods to control surface water to prevent damage to the Work, the Site, and adjoining properties.
2. Control fill, grading, and ditching to direct surface water away from disturbed areas, excavations, pits, tunnels, and other construction areas, and to direct drainage to proper run-off courses to prevent erosion, damage, or nuisance.

B. Equipment and Facilities for Surface Water Control:

1. Provide, operate, and maintain equipment and facilities of adequate size to control surface water.

C. Discharge:

1. Discharge surface water in a manner to prevent flooding, erosion, and other damage to any and all parts of the Site and adjoining areas, and that complies with Laws and Regulations.

3.03 REMOVAL OF EROSION AND SEDIMENT CONTROLS

A. Remove erosion and sediment controls only when directed by the Owner or Engineer.

END OF SECTION

SECTION 31 36 00 – WIRE MESH GABIONS AND GABION MATTRESSES

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, tools, equipment, and incidentals as shown, specified, and required to furnish and install gabions, gabion mattresses, and reno mattress.

2. Extent of gabions, gabion mattresses, and reno mattress are shown or indicated on the Design Drawings.

B. Coordination:

1. Review installation procedures under this and other Sections and coordinate the installation of items that must be installed with or before gabions.

C. Related Sections:

1. Section 31 05 19.13 – Geotextiles for Earthwork.

2. Section 31 11 00 – Clearing and Grubbing.

3. Section 31 23 00 – Excavation and Fill.

1.02 REFERENCE STANDARDS

A. The following standards are referenced in this Section:

1. ASTM C127, Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate.

2. A641 Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire.

3. A975 Standard Specification for Double-Twisted Hexagonal Mesh Gabions and Revet Mattresses (Metallic-Coated Steel Wire or Metallic-Coated Steel Wire with Polyvinyl Chloride (PVC) Coating).

4. A193 Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications.

1.03 QUALITY ASSURANCE

A. Regulatory Requirements:

1. Reference Specifications: Comply with applicable requirements of the MassDOT Standard Specifications.

1.04 SUBMITTALS

A. Informational Submittals:

1. Product Data: Manufacturer’s catalog cuts, specifications and installation instructions for wire mesh gabions.

2. Shop Drawings: Layout drawings showing the dimensions and elevations of the gabions and the locations they are to be installed, Drawings shall include details of basket connections, geogrid and geotextile placement.

3. Particle-size distribution of all proposed rock fill for gabions.

4. Proposed sources of rock fill for gabions.

5. Samples reports of type materials. Test reports shall include, but not be limited to, particle size distribution and soundness test.

PART 2 – PRODUCTS

2.01 MATERIALS

A. Gabions:

1. Material:
   a. Gabions and gabion mattresses shall be manufactured of double twisted wire mesh with a non-raveling mesh made by twisting continuous pairs of wires through three half turns to form a hexagonal-shaped opening. Wire mesh shall be zinc coated with the coating weight conforming to the requirements of ASTM A641, Class III soft temper coating.
   b. The minimum strength requirements of the mesh, selvedge wire to mesh connection, panel to panel connection, and punch test shall be as shown in Table 31 36 00 A.

Table 1

Property	Test Method	Gabions (lb/ft)
Mesh Tensile Strength (parallel to twist)	ASTM A975	3,500
Mesh Tensile Strength (perpendicular to twist)	ASTM A975	1,800
Connection to Selvedges	ASTM A975	1,400
Panel to Panel Strength	ASTM A975	1,400
Punch Test	ASTM A975	6,000

B. Gabion Mattress Fill:

1. Material:
   a. Rock used to fill gabions and stone cover fill shall be hard; durable; angular in shape; resistant to weathering and water action; free from overburden, spoil, shale, and organic material; and shall meet the gradation requirements for the type specified. Neither breadth nor thickness of a single stone should be less than one-third its length. Rounded stone or boulders shall be approved by the Engineer. Shale and stone with shale seams shall not be acceptable. Rock and stone shall meet the following requirements:
      1) Freeze-Thaw Test: A maximum of 10 percent loss, by weight, after 25 cycles of freezing and thawing.
      2) Magnesium Sulfate Soundness Test: A maximum 10% weight loss, by weight, after 10 cycles of the magnesium sulfate soundness test.

3) The size of rocks to fill gabions are to be within the 3 to 6 inches. The rock shall be large enough to prevent individual pieces from passing through the mesh openings. The rock shall have a minimum density of 155 pounds/cubic foot. The rock size limits may allow for a variation of 5% oversize rock or 5% undersize rock, or both.

b. Acceptance of rock gradation will be based on visual inspection and submittals accepted by Engineer.

2.02 SOURCE QUALITY CONTROL

A. Rock Source: Provide rock fill from a MassDOT-permitted mine, pit, or quarry. Source shall be approved by MassDOT for furnishing aggregates for MassDOT projects.

PART 3 – EXECUTION

3.01 INSPECTION

A. Examine the areas and conditions under which the Work will be performed and notify Engineer in writing of conditions detrimental to the proper and timely completion of the Work. Do not proceed with the Work until unsatisfactory conditions are corrected in a manner acceptable to Engineer.

3.02 PREPARATION

A. Clear ground surface of brush, trees, stumps, and other objectionable material, and dress to a smooth surface. Clearing and grubbing, where required, shall comply with Section 31 11 00.

B. Remove all soft or spongy material to depth shown or indicated on the Drawings or as directed by Engineer, and replace with acceptable material. Excavation, removal of unsuitable material if any, and backfilling shall comply with Section 31 23 00. Materials used for backfill of gabions and gabion mattresses shall comply with the requirements of Section 31 37 00 - Riprap. Placing of geosynthetics, where required, shall comply with Section 31 05 19.13 – Geotextile for Earthwork.

3.03 INSTALLATION

A. Gabion Mattress Placement:

1. Areas to be protected by gabions shall be properly prepared to be free of brush, topsoil, trees, stumps, and other objectionable material and shall be dressed to a smooth surface. All soft material under the gabions shall be removed and replaced with acceptable material and compacted.
2. Erect the sides, ends and diaphragms of each unit and ensure that all panels are in the correct position. Connect each gabion unit by binding all vertical edges with wire ties spaced 6 inches on center, or with a continuous piece of connecting wire stitched around the vertical edges with coils approximately every 4 inches.
3. Set gabions to line and grade in conformance with the indicated details.
4. Place gabions in tension prior to filling with stone to achieve alignment and compaction. Wire all adjacent courses together in the same manner as described for assembly.

5. Fill gabions by careful placement of stones along all visible faces to assure alignment and to minimize bulges and voids.
6. Close lid and secure with wire ties.

END OF SECTION

SECTION 31 37 00 - RIPRAP

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, tools, equipment, and incidentals as shown, specified, and required to furnish and install riprap.
2. Extent of riprap is shown or indicated on the Design Drawings.

B. Coordination:

1. Review installation procedures under this and other Sections and coordinate the installation of items that must be installed with or before riprap.

C. Related Sections:

1. Section 31 05 19.13 – Geotextiles for Earthwork.
2. Section 31 11 00 – Clearing and Grubbing.
3. Section 31 23 00 – Excavation and Fill.

1.02 REFERENCE STANDARDS

A. The following standards are referenced in this Section:

1. ASTM C127, Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate.

1.03 QUALITY ASSURANCE

A. Regulatory Requirements:

1. Reference Specifications: Comply with applicable requirements of the MassDOT Standard Specifications.

1.04 SUBMITTALS

A. Informational Submittals:

1. Source Quality Control Submittals: Submit Supplier name, source address, copy of current MassDOT mining permit, and proof of MassDOT approval for proposed source of riprap.
2. Delivery Tickets: Submit copy of delivery ticket for each load of riprap delivered to the Site. Each delivery ticket shall indicate Supplier name and source address, project name, contract number, date, material type, MassDOT item number when applicable, and quantity delivered.

PART 2 – PRODUCTS

2.01 MATERIALS

A. Riprap:

1. Material:
   a. Stone for riprap shall be hard, angular field or quarry stone that is sound, durable, free of shale seams and coatings, and of such characteristics that stone will not disintegrate when subjected to action of water.
   b. Stones shall have a minimum specific gravity of 2.5, as determined according to ASTM C127.
   c. Stones shall be free of dirt, debris, and deleterious material.

2. Size:
   a. Each load of riprap shall be well-graded, from smallest to largest size.
   b. Proportions: Width and thickness of each stone shall not be less than one-third the length of the stone.
   c. Gradation shall be as specified in the following Tables:

TABLE 1
GRADATION REQUIREMENTS FOR DRAINPIPE INLET/OUTLET

Size (inches)	Percentage Passing Through Square Openings
9	100
6	50
3	0-10

TABLE 2
GRADATION REQUIREMENTS FOR FOREBAY DRAINPIPE OUTLET

Size (inches)	Percentage Passing Through Square Openings
14	100
9	50
3	0-10

TABLE 3
GRADATION REQUIREMENTS FOR STORMWATER BASIN AND SMA

Size (inches)	Percentage Passing Through Square Openings
6	100
4	30-50
2	0-10

TABLE 4
GRADATION REQUIREMENTS GABION MATTRESS

Size (inches)	Percentage Passing Through Square Openings
6	100
3	0

TABLE 5
GRADATION REQUIREMENTS FOR CHECK DAM

Size (inches)	Percentage Passing Through Square Openings
6	100
4-6	30-50
2	0

B. Acceptance of gradation will be based on visual inspection and submittals accepted by the Engineer.

2.02 SOURCE QUALITY CONTROL

A. Riprap Source: Provide riprap from a MassDOT-permitted mine, pit, or quarry. Source shall be approved by MassDOT for furnishing aggregates for MassDOT projects.

PART 3 – EXECUTION

3.01 INSPECTION

A. Examine the areas and conditions under which the Work will be performed and notify the Engineer in writing of conditions detrimental to the proper and timely completion of the Work. Do not proceed with the Work until unsatisfactory conditions are corrected in a manner acceptable to the Engineer.

3.02 PREPARATION

A. Clear ground surface of brush, trees, stumps, and other objectionable material, and dress to a smooth surface. Clearing and grubbing, where required, shall comply with Section 31 11 00 - Clearing and Grubbing.

B. Remove all soft or spongy material to depth shown or indicated on the Design Drawings or as directed by the Engineer and replace with acceptable material. Excavation, removal of unsuitable material if any, and backfilling shall comply with Section 31 23 00 - Excavation and Fill.

3.03 INSTALLATION

A. Riprap Placing:

1. Minimum total thickness of riprap shall be as shown on the Drawings.
2. Place riprap stones so that weight of stone is carried by underlying material and not by adjacent stones. Carefully place the stones on geosynthetics, where required, to produce an even distribution of pieces, with minimum of voids and without damaging the geosynthetic. Place the full-course thickness in one operation while preventing segregation and avoiding displacing of underlying material. Do not place stones in layers, by dumping into chutes, or by other methods that cause segregation or damage to geosynthetic, if any. When necessary, rearrange individual stones for uniform distribution.

3. Riprap may be placed using equipment, and placing shall produce an installation of firm and solid riprap. Level the top surface of riprap to required alignment and slope by hand-placing stones to fill large voids and to make surface even.
4. On slopes, place the largest stones at the bottom. Riprap shall be properly sized to form compact, solid blanket to protect the slope or channel, as applicable. On slopes steeper than one foot vertical to 1.5 feet horizontal, do not use rounded boulders or cobbles without grouting stones in place.
5. When existing riprap is in proximity to riprap provided under this Section, place riprap to conform as closely as practicable in size and character to existing riprap.

END OF SECTION

SECTION 31 91 19.13 - TOPSOIL PLACEMENT AND GRADING

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, tools, equipment, and incidentals as shown, specified, and required to furnish and grade topsoil as shown or indicated on the Design Drawings.

B. Coordination:

1. Review installation procedures under this and other Sections and coordinate the installation of other items that must be completed with or before topsoil placement, grading, and vegetating.

C. Related Sections:

1. Section 31 11 00, Clearing and Grubbing
2. Section 32 92 00, Turfs and Grasses
3. Section 31 23 00, Excavation and Fill

1.02 REFERENCES

A. Terminology:

1. The following words or terms are not defined but, when used in this Section, have the following meaning:
   a. “Finished grade” describes the finished surface elevation of topsoil.
   b. “Subgrade” describes the surface or elevation of subsoil remaining after completing excavation, or the top surface of a fill or backfill, before placing topsoil.

B. Reference Standards:

1. The following standards are referenced in this Section:
   a. Association of Official Analytic Chemists (AOAC), Official Methods of Analysis of AOAC International.
   b. ASTM D422, Standard Test Method for Particle-Size Analysis of Soils.
   c. ASTM D5268, Standard Specification for Topsoil Used for Landscaping Purposes.

1.03 QUALITY ASSURANCE

A. Topsoil shall be installed in the locations and thicknesses specified in the Design Drawings.

PART 2– PRODUCTS

2.01 MATERIALS

A. Topsoil:

1. Material shall be fertile, friable, natural-loam surface soil, capable of sustaining vigorous plant growth; free of any admixture of subsoil, clods of hard earth, plants or roots, sticks, stones larger than one inch in diameter, pests and pest larvae, or other extraneous material harmful to plant growth, in compliance with ASTM D5268.

2. Gradation shall be as specified in Table 1.

TABLE 1
GRADATION REQUIREMENTS FOR TOPSOIL

U.S. Sieve Size	Percentage by Weight Passing Sieve
1-inch	100
No. 10	90-100
No. 200	35-70

3. Clay content of material passing the No. 200 sieve shall not exceed 20 percent.

4. Material shall have a pH range of 5.0 to 7.0.

5. Organic content of material passing the No. 10 sieve shall be not less than five percent, and shall not exceed 20 percent.

6. Material shall be free of foreign chemical contaminants and shall comply with the soil cleanup objectives for residential use.

2.02 SOURCE QUALITY CONTROL

A. Topsoil Source: Provide imported topsoil from a permitted mine, pit, or quarry, or a commercial processing facility specializing in the manufacture of topsoil.

B. Contractor shall collect samples for geotechnical (gradation only) and chemical analyses in accordance with relevant specifications in Article 2.02 of Section 31 05 13 – Soils for Earthwork.

C. Do not ship topsoil to the Site until proposed material, source, and Supplier are accepted by Engineer.

PART 3 – EXECUTION

3.01 INSPECTION

A. Examine the areas and conditions under which placement and grading will be performed and notify CM in writing of conditions detrimental to the proper and timely completion of the Work. Do not proceed with the Work until unsatisfactory conditions are corrected in a manner acceptable to CM.

3.02 PREPARATION

A. Provide erosion control measures to prevent erosion or displacement of soils and discharge of soil-bearing water runoff or airborne dust to adjacent properties and walkways.

B. Excavate or fill subgrade, as required, to bring subgrade to elevations shown or indicated. Maintain all angles of repose. Confirm that subgrade is at proper elevations and that no further earthwork is required to bring the subgrade to proper elevations. Provide subgrade elevations that slope parallel to finished grade and in the direction shown on the Drawings.

C. Remove all construction debris, trash, rubble, and other extraneous materials from subgrade. In the event that fuels, oils, concrete washout, or other material harmful to plant growth or germination have been spilled into the subgrade, excavate the subgrade sufficiently to remove all such harmful materials and fill with approved fill, compacted to the required subgrade compaction level.

D. Notify CM that subgrade has been prepared and obtain CM’s approval before spreading topsoil.

3.03 FINE GRADING

A. Do not attempt to spread excessively wet, muddy, or frozen topsoil. Do not spread topsoil more than five days before seeding.

B. Spread topsoil to a depth of six inches but not less than required to meet finished grades after light rolling and natural settlement.

1. Spread approximately one-half the thickness of required topsoil depth. After spreading topsoil, rototill, disk, or harrow topsoil and subgrade to bring top two inches of subgrade upward into topsoil layer, so that there is a transitional layer between topsoil and subgrade.
2. Spread remainder of topsoil to required finished grades.
3. Compact each lift sufficiently to reduce settling, but not enough to prevent the movement of water and feeder roots through topsoil.
4. Phase the placement of the final lift so that wheeled vehicles do not have to travel over areas where final lifts have already been placed.
5. Spread and compact to a smooth, uniform surface plane, to within plus-or-minus 1/2 inch of finished elevations. Roll and rake and remove all ridges, and fill depressions, as required. Remove all stones larger than one inch in any dimension, and all sticks, roots, trash, and other extraneous materials.

C. Moisten prepared areas before seeding. Water thoroughly and allow surface moisture to dry before seeding. Do not create a muddy topsoil condition.

D. Restore topsoil to specified condition if eroded or otherwise disturbed after fine grading and before seeding.

3.04 CLEANING AND PROTECTION

A. Promptly remove soil and debris, created by topsoil placement, from paved areas. Clean wheels of vehicles before leaving Site to avoid tracking soil onto roads, walks, or other paved areas.

END OF SECTION

SECTION 32 12 00 - FLEXIBLE PAVING

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. The Contractor shall provide all labor, materials, equipment, and incidentals as shown, specified, and required to furnish and install flexible, hot-mix, hot-laid, asphalt concrete pavement.

2. The Work includes:
   a. Preparation such as saw-cutting, milling where required, cleaning, and other preparation for installing flexible pavements;
   b. Providing asphalt concrete paving materials;
   c. Providing tack coat material;
   d. Providing pavement markings, if required; and
   e. Providing quality controls and testing.

B. Coordination:
1. Review installation procedures under this and other Sections and coordinate.

C. Related Sections:

1. Section 31 05 13 – Soils for Earthwork

2. Section 31 05 16 – Aggregates for Earthwork

3 .Section 31 23 05 – Excavation and Fill

1.02 REFERENCES

A. Standards referenced in this Section are:

1. Massachusetts Department of Transportation (MassDOT):
   a. Standard Specifications for Highways and Bridges, 2022.

2. American Society for Testing and Materials, (ASTM):
   a. D2950 - Standard Test Method for Density of Bituminous Concrete in Place by Nuclear Methods.

1.03 QUALITY ASSURANCE

A. Qualifications:

1. Asphalt Concrete Production Facility:
   a. Production facility for asphalt concrete, tack coat materials, and other bitumastic materials shall be certified by the Massachusetts Department of Transportation for furnishing such materials for highways.

2. Contractor's Testing Laboratory:
   a. Retain the services of independent testing laboratory to perform testing and determine compliance with the Contract Documents of the materials provided under this Section.
   b. Do not employ the same laboratory hired by Owner for field quality control testing under the "Field Quality Control" Article of this Section.

c. Testing laboratory shall be experienced in the types of testing required.
d. Selection of testing laboratory is subject to Engineer's and Owner's acceptance.

B. Regulatory Requirements:

1. Reference Specifications and Details:
   a. Comply with applicable requirements of Massachusetts Department of Transportation Standard Specifications for Highways and Bridges, 2022.

1.04 SUBMITTALS

A. Action Submittals: Submit the following.

1. Shop Drawings:
   a. Submit the proposed asphalt concrete mix design for each asphalt concrete material, and other bituminous materials, required under this Section, providing complete data on materials, including location in the Work, source, material content and percentages, temperatures, and all other pertinent data. Indicate proportion of bituminous material from reclaimed asphalt pavement.
   b. Proposed gradation for each aggregate to be used in flexible paving. Submit gradation test results for the same material furnished on a previous project. Indicate the proportion of reclaimed asphalt pavement.

2. Product Data:
   a. Manufacturer's complete product data on all pavement marking materials proposed for use, including product literature, specifications, and recommended application techniques and other installation data.

B. Informational Submittals: Submit the following:

1. Quality Assurance Test Data Submittals and Source Quality Control Submittals:
   a. Submit for quality assurance tests and source quality control tests required.

2. Delivery Tickets:
   a. Submit copy of delivery ticket for each load of asphalt concrete, tack coat materials, and other materials obtained from asphalt concrete production facility, signed by Contractor.

3. Field Quality Control Submittals:
   a. Submit results of required field quality control testing.

1.05 SITE CONDITIONS

A. Weather Limitations:

1. Temperature:
   a. For surface course paving or other pavement courses in lifts less than two inches thick, temperature of surface on which pavement is to be placed shall be 50 degrees F or greater.

2. Prohibitions:
   a. Do not place flexible paving materials when weather is foggy or during precipitation.
   b. Do not place flexible paving materials when the base on which the material will be placed contains moisture in excess of optimum.
   c. Place flexible paving materials only when Construction Manager (CM) concurs that weather conditions are suitable.

PART 2 - PRODUCTS

2.01 SYSTEM PERFORMANCE

A. System Description:

1. Provide subbase course of the thickness shown or indicated, in accordance with Section 31 23 00 - Excavation and Fill.

2. Flexible Pavement Courses:
   a. Provide the flexible pavement courses indicated below.
      1) Binder Course: 4 inches compacted thickness; and
      2) Surface Course (Wearing Course or Top Course): 2 inches compacted thickness.

2.02 ASPHALT CONCRETE MIXES

A. Asphalt Concrete Mixtures: Provide the following materials designed and manufactured in accordance with reference specifications indicated in Article 1.3 of this Section.

1. Binder Course: HMA S0.375 superpave mix complying with Section M3.01.1 of State of Massachusetts Department of Transportation Standard Specifications for Highways and Bridges, 2022.

2. Surface Course (Wearing Course, Top Course): HMA S0.375 superpave mix complying with Section M3.06.1 of State of Massachusetts Department of Transportation Standard Specifications for Highways and Bridges, 2022.

2.03 BITUMINOUS MATERIALS

A. Bituminous Materials for Asphalt Concrete:

1. Bituminous materials for asphalt concrete shall comply with the reference specifications indicated in Article 1.3 of this Section, for the asphalt concrete mixes specified.

B. Tack Coat:

1. Tack coat shall be emulsified asphalt.

2. Provide tack coat complying with ASTM D977, Type RS-1 or RSH-1.

2.04 AGGREGATES IN FLEXIBLE PAVEMENTS

A. Aggregates for Asphalt Concrete – General:

1. Aggregate materials used in flexible pavement shall be in accordance with the reference specifications indicated in Article 1.3 of this Section, for the asphalt concrete mix designs indicated.

B. Reclaimed Asphalt Pavement (RAP):

1. Processed material obtained by milling or full depth removal of existing asphalt concrete pavement may be used as aggregate in asphalt concrete base course and binder course.

2. Maximum proportion of RAP in the asphalt concrete provided shall comply with requirements of the reference specifications indicated in Article 1.3 of this Section.

PART 3 - EXECUTION

3.01 INSPECTION

A. Examine the subbase and base on which flexible paving will be installed. Notify CM in writing of conditions detrimental to the proper and timely completion of the Work. Do not proceed with the Work until unsatisfactory conditions are corrected.

B. Do not place materials on subgrades, or subbase that is muddy or has water thereon.

3.02 PREPARATION

A. Preparation: Before starting installation of flexible paving, perform the following:

1 Grade Control: Establish and maintain throughout flexible paving installation the required lines and grades, including crown and cross-slope for each asphalt concrete course during construction operations.

2. Prepare subgrade and provide subbase for flexible pavement in accordance with Section 31 23 00 - Excavation and Fill. Before installing flexible pavement, obtain CM's concurrence that subgrade and subbase are suitable for installing flexible pavement.

3. Provide appropriate maintenance and protection of traffic measures during placement of pavement.

4. Provide tack coat as indicated in Article 3.03 of this Section.

3.03 INSTALLATION OF FLEXIBLE PAVING

A. General:

1. Provide final pavement surfaces of uniform texture, at required grades and cross-sections.

2. Construct roadways to the lines, grades, and typical sections shown or indicated.

B. Installation of Asphalt Concrete:

1. Asphalt concrete mixture shall be transported to the site of paving and placed as soon as possible after mixing.

2. Placement of each asphalt concrete course shall be completed over the full width of the section under construction during each day's paving operations.

3. Spread and finish asphalt concrete courses by means of self-propelled mechanical spreading and finishing equipment. Compacted thickness of layers placed shall not exceed 150 percent of specified thickness unless approved in writing by the CM.

4. Compaction:
   a. Rollers:
      1) Use sufficient rolling equipment to satisfactorily compact and finish the quantity of asphalt concrete placed. There shall be not less than two rollers on the Project at all times. When acceptable to CM, one of the rollers may be a pneumatic-tire roller.
      2) During rolling operations, roller speed shall not exceed three miles per hour. When sufficient number of rollers is not available, reduce the quantity of asphalt concrete placed to accommodate the available rollers' speed.

3) Required rollers shall be at the Site, in acceptable operating condition, prior to placing of asphalt concrete.
4) Use of vibratory rollers in lieu of steel-wheeled rollers is acceptable, however when thickness of asphalt concrete is one-inch or less, rolling shall be in the static mode.

b. Rolling of initially placed asphalt concrete material, or breakdown rolling, shall begin as soon as the asphalt concrete mixture will bear the roller without undue displacement.
c. Rolling shall be longitudinal, overlapping on successive trips by not less than one-half roller rear wheel width, and not more than three-quarters of roller rear wheel width. Alternate trips of the roller shall be of slightly different lengths.
d. At all times, roller motion shall be slow enough to avoid displacing the asphalt concrete.
e. Operate rollers continuously from breakdown of laid asphalt concrete through finish rolling.
f. Perform finish rolling using a steel-wheeled roller or a vibratory steel-wheel roller operating in the static mode.
g. Perform rolling with consecutive passes to achieve even and smooth finish without roller marks.
h. At each location not accessible to roller, thoroughly compact asphalt concrete with tampers and finish, where necessary, with a hot smoothing iron to provide uniform, smooth layer over the entire area so compacted.

5. Each compacted asphalt concrete course shall be within plus or minus 1/4-inch of the indicated thickness.

D. Construction Joints:

1. Construction joints shall be made in such a manner as to ensure a neat junction, thorough compaction, and bond throughout.

2. Provide a transverse joint extending over the full width of the strip being laid and at right angles to its centerline at end of each workday and at other times when the placement of hot-mix asphalt concrete will be suspended for a period of time that will allow asphalt concrete mixture to chill.

3. Thoroughly compact by rolling the forward end of a freshly laid strip of asphalt concrete before the asphalt concrete mixture becomes chilled. When the Work is resumed, the end shall be cut vertically for the full depth of the layer.

E. Joining of Pavements:

1. When pavement is to join existing or previously laid pavement, the existing or previously laid pavement shall be neatly and carefully edged to allow for overlapping and feathering of the subsequent course of asphalt concrete material.

2. Where new pavement is to meet existing pavement, the existing pavement shall be sawcut and notched.

3. Where new pavement will meet existing asphalt pavement, remove existing pavement 12 inches onto undisturbed existing pavement course at edges where new pavement will meet existing pavement.

4. Tack Coat:
    a. Provide tack coat material at the following locations:
        1) At edges where new pavement will connect to existing or previously installed pavement.
        2) On surface of existing or previously installed pavement course over which new pavement will be installed, prior to placement of the subsequent pavement course. Tack coat may be deleted when a succeeding layer of asphalt pavement is being applied over a freshly placed asphalt pavement course that has been subjected to very little or no traffic, with approval of CM.
        3) Where new pavement will abut curbing, concrete gutters, drainage structures and frames, manhole cover frames, valve boxes, and similar items.
    b. Tack Coat Installation: Install tack coat immediately prior to installing pavement. Place pavement while tack coat is wet. Apply tack coat in accordance with reference specification indicated in Article 1.3 of this Section.

F. Curing:

1. Do not allow traffic onto pavement until directed by CM. Traffic will not be allowed on new asphalt concrete pavement until surface temperature is less than 140 degrees F.

G. Defective Pavement Work:

1. When directed by CM, remove, and replace defective flexible paving Work. Cut out such areas of defective pavement and fill with fresh asphalt concrete materials, compacted to required density.

3.04 FIELD QUALITY CONTROL

A. Asphalt Concrete Mix Temperature: Measure temperature at time of placement, record, and submit to CM.

B. Surface Smoothness:

1. Test finished surface of each flexible paving course for smoothness, using a ten-foot straightedge applied parallel to and at right angles to centerline of paved areas.

2. Check surfaced areas at intervals as directed by CM.

3. Surfaces will be acceptable relative to smoothness when measurements are equal to or less than the following:
    a) Binder Course: 3/8-inch vertical in ten feet horizontal;
    b) Surface Course (Wearing Course): 1/4-inch vertical in ten feet horizontal; and
    c) Surfaces will be acceptable when variance is equal to or less than 1/4-inch from the template.

4. The surface of asphalt curbing shall be tested with a ten-foot straightedge, and any variation from a true line exceeding 1/4 inch shall be satisfactorily corrected.

5. Elevation: Finished surface of pavement shall be within plus or minus 1/2-inch of elevations shown or indicated.

C. Density:

1. Test Method: ASTM D2950 nuclear method; test one sample every 1,000 square yards of pavement. Test for each asphalt concrete course installed.

2. In addition, compare density of in-place flexible paving materials against laboratory specimen or certificates on same asphalt pavement mixture, using nuclear density device.

3. Criteria for Acceptance: Density of in-place asphalt pavement material shall be not less than 90 percent of the recorded laboratory specimen or certificate density. Density shall be not greater than 98 percent.

3.05 ADJUSTING

A. Pavement Adjustment:

1. Repair or replace in manner acceptable to CM areas of pavement that are observed to pond or collect water.

3.06 CLEANING

A. Cleaning: After completing the paving operations, clean surfaces of excess or spilled bituminous materials, excess asphalt concrete, and foreign matter.

3.07 PROTECTION

A. Protect finished pavement until pavement has become properly hardened and cool.

B. Cover openings of drainage structures, manholes, valve boxes, and similar items in the paved area until permanent coverings are provided.

END OF SECTION

SECTION 32 92 00 - TURF AND GRASSES

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, tools, equipment, and incidentals as shown, specified, and required to furnish and install lawns.

2. Extent of lawns is shown or indicated on the Design Drawings.

3. Types of products required under this Section include the following:
   a. Grass seed mixture.
   b. Fertilizers.
   c. Mulches.
   d. Erosion-control blankets.

B. Related Sections:

1. Section 31 25 00 – Erosion and Sediment Controls

C. Coordination:

1. Review installation procedures under this and other Sections and coordinate the installation of items that must be installed with or before lawns.

1.02 REFERENCES

A. Terminology:

1. The following words or terms are not defined but, when used in this Section, have the following meaning:
   a. "Finished grade" describes the finished surface elevation of topsoil.
   b. "Percent pure live seed", or "percent PLS", is the percent (%) purity multiplied by percent (%) germination divided by 100 and shall be calculated for all seed lots using each seed lot's own unique purity and germination test results. A PLS pound is the bulk weight of seed required to equal one pound of 100 percent pure, germinated seed.
   c. "Subgrade" describes the surface or elevation of subsoil remaining after completing excavation, or the top surface of a fill or backfill, before placing topsoil.

1.03 QUALITY ASSURANCE

A. Qualifications:

1. Installer:
   a. Engage a single landscape installer skilled, trained, and with successful and documented experience in the planting of lawns and in the installation of the types of materials required (i.e., native seed mixes), and who agrees to employ only tradesmen with specific skill and successful experience in the type of Work required.
   b. When requested by the Engineer, submit record of experience documenting not less than three successful, completed projects. For each project, submit the following information:
      1) Project name.

2) Location of project.
3) Names and telephone numbers of owner, architects, or engineers responsible for the project.
4) Approximate area of lawns installed.
5) Approximate contract price of lawns installed.

c. Installer’s Site Supervisor: Require installer to maintain an experienced full-time landscape supervisor on-site during the time of preparation for, and planting of, lawns. Supervisor shall have achieved landscape or horticultural certification acceptable to governing authorities having jurisdiction at the Site.

d. Ratio of laborers to certified landscape supervisors shall not exceed twelve to one. Certified landscape supervisor shall be on-site throughout the day-to-day performance of the Work of this Section.

E. Application of herbicides, chemicals, and insecticides shall be done by personnel licensed to perform such applications by governing authorities having jurisdiction at the Site and in accordance with each manufacturer’s instructions provided on each product label.

1.04 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Submit planting schedule showing scheduled start and finish dates for lawn Work in each area of the Site.

2. Product Data:
   a. Submit composition and analysis of commercial starter fertilizer and all purchase receipts showing the total quantity actually purchased for the Project.
   b. Submit proportions of each component contained in hydroseed mixture. Identify number of pounds of each component required for each 100 gallons of water. Include the number of square feet of seed mixture that can be installed with each full tank of hydroseed mixture.
   c. Submit percent PLS for each type of seed and each seed lot. Include bulk weight of seed required to equal one pound of 100 percent pure, germinated seed.

B. Informational Submittals:

1. Qualifications Statements:
   a. Installer: Submit name and address of landscape installer. When requested by the Engineer, submit qualifications and record of experience.
   b. Landscape Supervisor: When requested by the Engineer, submit name and qualifications of installer’s landscape supervisor, including copy of valid certifications applicable to the Project.

2. Certificates:
   a. For each seed mixture, submit seed Supplier’s certification stating the botanical and common name, and percentage by weight of each species and variety, and percentage of purity, germination, and weed seed. Include the year of production and date of packaging. Certify that seed has been stored in compliance with all recommendations of the seed Supplier.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Delivery:

1. Do not deliver fertilizer, or grass seed until Site conditions are ready for installation.
2. Deliver packaged materials in containers showing weight, analysis, and name of manufacturer. Protect materials from deterioration during delivery.
3. Deliver seed in undamaged, original containers, sealed by the Supplier and indicating compliance with the required seed mixture.
4. Inspect materials upon arrival at the Site. Immediately and permanently remove unacceptable materials from Site.

B. Storage:

1. Store and cover materials to prevent deterioration. Remove packaged materials that become wet or show deterioration or water marks from the Site.
2. Seed that becomes wet, moldy, or damaged during the time of storage on-site, or that has been damaged during transit, is not acceptable.

1.06 SITE CONDITIONS

A. Environmental Requirements:

1. Proceed with and complete lawn planting as rapidly as portions of the Site become available, working within the seasonal limitations for each type of lawn planting required.
2. Proceed with planting only when current and forecasted weather conditions are favorable to successful planting and establishment of lawns.
   a. Do not spread seed when wind velocity exceeds five miles per hour.
   b. Do not plant when drought, excessive moisture, or other unsatisfactory conditions prevail.

B. Scheduling:

1. Plant during one of the following periods:
   a. Spring Planting: March 15 to June 1.
   b. Fall Planting: September 1 to October 30.
2. Do not begin lawn planting until water, acceptable for use and adequate in supply, is available on-Site and can be successfully transported to the areas of Work. Coordinate provision of adequate and acceptable water supply with Progress Schedule.

PART 2 – PRODUCTS

2.01 MATERIALS

A. Grass Seed:

1. Grass Seed Mixture: Provide fresh, clean, new crop seed complying with the tolerance for purity and germination established by AOSA. Provide seed of the grass species, proportions, and minimum percentages of purity and germination, and maximum percentage of weed seed, specified.

2. New England Erosion Control/Restoration Mixture for Dry Sites: Seed with New England Wetland Plants Inc. (www.newp.com) New England Erosion Control/Restoration Mixture for Dry Sites at a rate of 1lb/1250sq. ft. or approved equivalent mixture. Apply seed mix by hydro-seeding, mechanical spreader, or on smaller sites it may be spread by hand. Lightly rake or roll to ensure proper soil-seed contact. Preparation of a clean weed free seed bed is necessary for optimal results.
    a. Seed species are as follows: Creeping Red Fescue, (Festuca rubra), Canada Wild Rye, (Elymus canadensis), Annual Ryegrass, (Lolium multiflorum), Perennial Ryegrass, (Lolium perenne), Little Bluestem, (Schizachyrium scoparium), Indian Grass, (Sorghastrum nutans), Switch Grass, (Panicum virgatum).
    b. Seed in the Spring or Late summer for optimal results. If seeding during the late Spring or Mid-Summer, light mulching of weed-free straw may be used to conserve moisture.
    c. If conditions encountered are drier than usual, watering will be required per manufacturer's specifications or recommendations.
    d. Fertilization is not required unless the soils are particularly infertile.

B. Fertilizer: Commercial-grade, complete starter fertilizer of neutral character, consisting of fast- and slow-release nitrogen, 50 percent derived from natural organic sources of urea formaldehyde, phosphorous, and potassium.

C. Mulches:

1. Straw Mulch: Provide clean, dry, and seed-free salt hay or threshed straw of wheat, rye, oats, or barley.

2. Fiber Mulch: Biodegradable, dyed-wood, cellulose-fiber mulch; non-toxic; free of plant-growth or germination inhibitors; with maximum moisture content of 15 percent and pH range of 4.5 to 6.5.

3. Non-Asphaltic Tackifier: Colloidal tackifier recommended by fiber mulch manufacturer for slurry application; non-toxic and free of plant-growth or germination inhibitors.

4. Asphalt Emulsion: ASTM D977, Grade SS-1; non-toxic and free of plant-growth or germination inhibitors.

D. Water: Clean, acceptable for lawn application, and containing no material harmful to plant growth and establishment.

2.02 SOURCE QUALITY CONTROL

A. Analysis and Standards: Package all products with manufacturer's certified analysis performed in accordance with methods established by AOAC, wherever applicable, or as specified.

B. Seed that has been stored at temperatures, or under conditions not recommended by the seed Supplier, or has become wet, moldy, or otherwise damaged, shall not be acceptable. The PLS for each seed lot shall be 75 percent, minimum.

C. Certify that all seed has been stored under conditions recommended by the seed Supplier and has not been subjected to conditions damaging to PLS percentages.

D. Seed may be mixed by an approved method on-site or at the seed Supplier's facilities. If the seed is mixed on-site, each variety shall be delivered in the original containers and shall bear the Supplier's certified analysis. Where seed is mixed by the seed Supplier, provide the Engineer with the seed Supplier's certified statement as to the composition of the mixture.

PART 3– EXECUTION

3.01 INSPECTION

A. Examine the areas and conditions under which lawn Work will be performed and notify the Engineer in writing of conditions detrimental to the proper and timely completion of the Work. Do not proceed with the Work until unsatisfactory conditions are corrected in a manner acceptable to the Engineer.

3.02 PREPARATION

A. Protect structures, utilities, sidewalks, pavements, and other facilities, and trees, shrubs, and other plants from damage caused by planting operations. Protect adjacent and adjoining areas from hydroseeding overspray.

B. Provide erosion control measures to prevent erosion or displacement of soils and discharge of soil-bearing water runoff or airborne dust to adjacent properties and walkways.

C. Excavate or fill subgrade, as required, to bring subgrade to elevations shown or indicated. Maintain all angles of repose. Confirm that subgrade is at proper elevations and that no further earthwork is required to bring the subgrade to proper elevations. Provide subgrade elevations that slope parallel to finished grade and in the direction shown on the Drawings.

D. Remove all construction debris, trash, rubble, and other extraneous materials from subgrade. In the event that fuels, oils, concrete washout, or other material harmful to plant growth or germination have been spilled into the subgrade, excavate the subgrade sufficiently to remove all such harmful materials and fill with approved fill, compacted to the required subgrade compaction level.

3.03 CONVENTIONAL SEEDING

A. Maintain grade stakes until removal is approved by the Engineer.

B. Rake or harrow all seedbeds immediately prior to seeding to produce a rough, grooved surface, no deeper than one inch. Seed only when seedbed is in a friable condition and not muddy or hard.

C. Sow seed using a spreader or seeding machine.

D. Distribute seed evenly over entire area by sowing equal quantity in two directions at right angles to each other.

E. Sow grass seed mixture at a rate of not less than 30 pounds per acre.

F. Rake the seed lightly into the uppermost 1/8 inch of topsoil and roll in two directions with a light lawn roller. Take care during raking that seed is not raked from one spot to another.

G. Protect seeded areas against erosion by spreading straw mulch after completion of seeding operations.

1. Spread straw mulch at an approximate rate of two tons per acre to form a continuous loose blanket not less than 1.5 inches deep.

2. Anchor mulch by spraying with asphalt emulsion at a rate of 10 to 13 gallons per 1,000 square feet.

3. Spread mulch with equipment that will blow or eject, by means of a constant air stream, controlled quantities of the mulch and asphalt in a uniform pattern over the specified area. If the mulch is excessively cut or broken, take measures to reduce the cutting or breakage. Introduce the asphalt into the air stream by means of a spray arranged so that it will partially coat the mulch with a spotty asphalt tack prior to the depositing of the mulch covering. Rate of application shall be not less than 75 gallons per ton of mulch.

H. Mulch shall be used as erosion control on all slopes less than 1:3 (V:H). Where slopes meet or exceed 1:3 (V:H), erosion control blankets shall be installed to protect seeded areas, unless otherwise approved by the Engineer. Erosion control blankets shall be installed in accordance with manufacturer's specifications and as follows:

1. Cover entire area to be stabilized with erosion control blankets.

2. Provide anchoring trenches at the top and bottom of slopes to receive erosion control blankets. Bury at least the top and bottom ends of erosion control blanket, four inches or more wide, at top and bottom of slope. Tamp trench full of soil. Four inches from trench, secure erosion control blanket with appropriate stakes or staples spaced at intervals of 10 inches, or as recommended by the manufacturer.

3. Overlap adjacent strips of erosion control blanket by not less than four inches.

I. Using a uniform fine spray, thoroughly and evenly water seeded areas. Provide adequate water to moisten seedbed to a depth of two inches.

J. Maintain all seedbeds in a uniformly moist condition, conducive to seed germination and plant establishment, as specified.

K. Reseed areas that remain without mulch for longer than three days.

L. Take precautions to prevent damage or staining of construction or other plantings adjacent to mulched areas. Immediately clean damaged or stained areas.

M. Prevent foot or vehicular traffic, or the movement of equipment, over the mulched areas. Reseed areas damaged as a result of such activity.

3.04 HYDROSEEDING

A. Mix specified seed, fertilizer, and fiber mulch in water, using equipment specifically designed for hydroseed application. Continue mixing until uniformly blended into homogeneous slurry suitable for hydraulic application.

B. Mix slurry with asphalt-emulsion tackifier.

C. Apply slurry uniformly to all areas to be seeded in a two-step process.

1. Apply first slurry application at a minimum rate of 500 pounds per acre dry weight, but not less than the rate required to obtain specified seed sowing rate so that the seed comes into direct contact with topsoil.

2. Apply slurry cover coat of fiber mulch at a rate of 1,000 pounds per acre.

D. Where slopes exceed 1:6 (V:H), provide erosion control blankets to protect hydroseeded areas. Unless otherwise approved by the Engineer. Install in accordance with manufacturer's specifications and as follows:

1. Cover entire area to be stabilized with erosion control blankets.

2. Provide anchoring trenches at the top and bottom of slopes to receive erosion control blankets. Bury at least the top and bottom ends of erosion control blanket, four inches or more wide, at top and bottom of slope. Tamp trench full of soil. Four inches from trench, secure erosion control blanket with appropriate stakes or staples spaced at intervals of 10 inches, or as recommended by the manufacturer.

3. Overlap adjacent strips of erosion control blanket by not less than four inches.

3.05 RECONDITIONING EXISTING LAWNS

A. Recondition existing lawns damaged by Contractor’s operations, including areas used for the storage of materials and equipment and areas damaged by the movement of vehicles. Recondition existing lawns where minor regrading is required.

B. Provide fertilizer, seed, and mulch as required to recondition existing lawns. Provide new topsoil as required to fill low spots and meet final or existing grades, as specified.

C. Till stripped, bare, and compacted areas thoroughly to a depth of 12 inches.

D. Remove diseased or unsatisfactory lawns; do not bury into soil. Remove topsoil containing extraneous materials resulting from Contractor’s operations, including oil drippings, stone, gravel, and other construction materials.

E. In areas approved by the Engineer, where substantial lawns remain (but are thin), mow, dethatch, core aerate, and rake. Fill low spots, remove humps, cultivate soil, fertilize, and seed. Apply mulch, if required, to maintain moist condition.

F. Water newly planted areas and keep moist until new lawns are established, as specified.

3.06 ACCEPTANCE CRITERIA FOR RESTORATION AREAS WITH NATIVE SEED MIXES

A. Lawn Work will be considered acceptable when a healthy, uniform, close stand of grass has been established, free of weeds and surface irregularities, with coverage exceeding 80 percent over any 10 square feet and bare spots not exceeding five inches by five inches.

3.07 CLEANING AND PROTECTION

A. Promptly remove soil and debris, created by lawn Work, from paved areas. Clean wheels of vehicles before leaving Site to avoid tracking soil onto roads, walks, or other paved areas.

B. Take all precautions to ensure that hydroseed slurry is only placed on the areas designated. Completely clean any overspray, on areas not designated to receive slurry.

C. Erect barricades and warning signs as required to protect newly planted areas from traffic. Maintain barricades until specified acceptance criteria is achieved.

3.08 MAINTENANCE

A. Maintain lawns until specified acceptance criteria is achieved.

1. Maintain lawns by watering, fertilizing, weeding, mowing, trimming, replanting, and other operations. Roll, regrade, and replant bare or eroded areas and re-mulch to produce a uniformly smooth lawn.

2. In areas where mulch has been disturbed by wind or maintenance, add new mulch. Anchor as required to prevent displacement.

3. Watering: Provide and maintain temporary piping, hoses, and lawn watering equipment to convey water from sources. Keep newly germinated plants uniformly moist to a depth of four inches, applied at a minimum rate of one inch per week or greater as required to maintain minimum moisture depth specified.
   a. Schedule watering to prevent wilting, puddling, erosion, and displacement of seed or mulch. Lay out temporary watering system to avoid walking over muddy or newly planted areas.
   b. After grasses show mature blades, watering shall be performed to provide moisture to a depth of six inches and shall not be performed again until top one inch of loam has dried.

4. After seed has passed its expected germination period, reseed all areas and parts of areas that fail to show a uniform stand of grass. Reseed repeatedly until all areas are covered with grass.

END OF SECTION

SECTION 33 05 05 - BURIED WATER PIPE

PART 1 - GENERAL

1.1 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, equipment, and incidentals as shown, specified, and required to install and test all buried piping, fittings, and specials associated with fire hydrant waterline piping. The Work includes the following:
   a. All types and sizes of buried piping, except where buried piping installations are specified under other Sections.
   b. Unless otherwise shown or specified, this Section includes all buried piping Work required, beginning at the outside face of structures or structure foundations, including piping beneath structures, and extending away from structures.
   c. Work on or affecting existing buried piping.
   d. Installation of all jointing and gasket materials, specials, flexible couplings, mechanical couplings, harnessed and flanged adapters, sleeves, tie rods, cathodic protection, and other Work required for a complete, buried piping installation.
   e. Supports, restraints, and thrust blocks.
   g. Field quality control, including testing.
   h. Cleaning and disinfecting.
   i. Incorporation of valves, meters, and special items shown or specified into piping systems in accordance with the Contract Documents and as required.

B. Coordination:

1. Review installation procedures under this and other Sections and coordinate installation of items to be installed with or before buried piping Work.

C. Related Sections:

1. Section 40 05 53 – Hydrants
2. Section 03 00 05 - Concrete
3. Section 31 23 00 – Excavation and Fill

1.2 REFERENCES

A. Standards referenced in this Section are:

1. American Society for Non-Destructive Testing (ASNT), ASNT-TC-1A, Recommended Practice, Personnel Qualification, and Certification in Non-destructive Testing.
2. ASTM B32, Specification for Solder Metal.
3. ASTM D2321, Practice for Underground Installation of Thermoplastic Pipe for Sewers and other Gravity-Flow Applications.
4 ASTM D2774, Practice for Underground Installation of Thermoplastic Pressure Piping.
5. ASTM D4174, Practice for Cleaning, Flushing and Purification of Petroleum Fluid Hydraulic Systems.

6. ASTM F1417, Test Method for Installation Acceptance of Plastic Gravity Sewer Lines using Low-Pressure Air.

7. ASTM F2164, Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressure.

8. ANSI/AWWA C105, Polyethylene Encasement for Ductile-Iron Pipe Systems.

9. ANSI/AWWA C111, Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.

10. ANSI/AWWA C206, Field Welding of Steel Water Pipe.

11. ANSI/AWWA C600, Installation of Ductile-Iron Water Mains and Their Appurtenances.

12. ANSI/AWWA C605, Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe and Fittings for Water.

13. ANSI/AWWA C606, Grooved and Shouldered Joints.

14. ANSI/AWWA C651, Disinfecting Water Mains.

15. AWWA M23, PVC Pipe - Design and Installation.

16. AWWA M41, Ductile-Iron Pipe and Fittings.

17. AWWA M55, PE Pipe - Design and Installation.

18. ASCE 37, Design and Construction of Sanitary and Storm Sewers.

19. Chlorine Institute, Inc., Piping Systems for Dry Chlorine, Pamphlet No. 6.

20. NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.

1.3 QUALITY ASSURANCE

A. Regulatory Requirements:

1. Comply with requirements and recommendations of authorities having jurisdiction over the Work, including.
    a. Town of Lee, Massachusetts
    b. Berkshire County

2. Obtain required permits for Work in roads, rights-of-way, and other areas of the Work.

1.4 SUBMITTALS

A. Action Submittals: Submit the following:

1. Shop Drawings:
    a. Laying schedules for concrete pipe and piping with restrained joints.
    b. Details of piping, specials, joints, harnessing and thrust blocks, and connections to piping, structures, equipment, and appurtenances.

2. Product Data:
    a. Manufacturer’s literature and specifications, as applicable, for products specified in this Section.

3. Testing Procedures:
    a. Submit proposed testing procedures, methods, apparatus, and sequencing. Obtain the Engineer’s approval prior to commencing testing.

B. Informational Submittals: Submit the following:

1. Certificates:
   a. Certificate signed by manufacturer of each product certifying that product conforms to applicable referenced standards.

2. Field Quality Control Submittals:
   a. Results of each specified field quality control test.

C. Closeout Submittals: Submit the following:

1. Record Documentation:
   a. Maintain accurate and up-to-date record documents showing modifications made in the field, in accordance with approved submittals, and other Contract modifications relative to buried piping Work. Submittal shall show actual location of all piping Work and appurtenances at same scale as the Drawings.
   b. Show piping with elevations referenced to Project datum and dimensions from permanent structures. For each horizontal bend in piping, include dimensions to at least three permanent structures, when possible. For straight runs of piping provide offset dimensions as required to document piping location.
   c. Include profile drawings with buried piping record documents when the Contract Documents include piping profile drawings.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Delivery:

1. Deliver materials to the Site to ensure uninterrupted progress of the Work.

2. Upon delivery inspect pipe and appurtenances for cracking, gouging, chipping, denting, and other damage and immediately remove from Site and replace with acceptable material.

B. Storage:

1. Store materials to allow convenient access for inspection and identification. Store material off ground using pallets, platforms, or other supports. Protect packaged materials from corrosion and deterioration.

2. Pipe and fittings other than PVC and CPVC may be stored outdoors without cover. Cover PVC and CPVC pipe and fittings stored outdoors.

C. Handling:

1. Handle pipe, fittings, specials, and accessories carefully in accordance with pipe manufacturer's recommendations. Do not drop or roll material off trucks. Do not drop, roll or skid piping.

2. Avoid unnecessary handling of pipe.

3. Keep pipe interiors free from dirt and foreign matter.

4. Protect interior linings and exterior coatings of pipe and fittings from damage. Replace pipe and fittings with damaged lining regardless of cause of damage.

PART 2 - PRODUCTS

2.1 MATERIALS

A. General:

1. Pipe Markings:
   a. Manufacturer shall cast or paint on each length of pipe and each fitting pipe material, diameter, and pressure or thickness class.

2.2 BURIED PIPING IDENTIFICATION

A. Polyethylene Underground Warning Tape for Metallic Pipelines:

1. Tracer tape shall be of inert, acid- and alkali-resistant, polyethylene, four mils thick, six inches wide, suitable for direct burial. Tape shall be capable of stretching to twice its original length.

2. Message shall read, “CAUTION [insert customized name of pipe service, i.e., “POTABLE WATER”, “SANITARY SEWER”, “CHLORINE GAS”, “PIPE BURIED BELOW” [or other service as appropriate, as indicated in the Buried Pipe Schedule at the end of this Section], with bold letters approximately two inches high. Messages shall be printed at maximum intervals of two feet.

3. Manufacturer: Provide products of one of the following:
   a. Brady Corporation
   b. Seton Identification Products
   c. Marking Services, Inc.
   d. Or equal.

B. Detectable Underground Warning Tape for Non-Metallic Pipelines:

1. Tape shall be of inert, acid- and alkali-resistant, polyethylene, five mils thick, six inches wide, with aluminum backing, and have 15,000 psi tensile strength and 80 percent elongation capability. Tape shall be suitable for direct burial.

2. Message shall read, “CAUTION [insert customized name of pipe service, i.e., “POTABLE WATER”, “SANITARY SEWER”, “CHLORINE GAS” “PIPE BURIED BELOW”, or other appropriate service, with bold letters approximately two inches high. Messages shall be printed at maximum intervals of two feet.

3. Manufacturer: Provide products of one of the following:
   a. Brady Corporation
   b. Seton Identification Products
   c. Marking Services, Inc.
   d. Or equal.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Install piping as shown, specified, and as recommended by pipe and fittings manufacturer.

2. In event of conflict between manufacturer’s recommendations and the Contract Documents, request interpretation from the Engineer before proceeding.

3. The Engineer will observe excavations and bedding prior to laying pipe by Contractor. Notify the Engineer in advance of excavating, bedding, pipe laying, and backfilling operations.

4. Minimum cover over buried piping shall be 4 feet, unless otherwise shown or approved by the Engineer.

5. Earthwork is specified in Section 31 22 00 - Grading.

6. Excavation more than that required or shown, and that is not authorized by the Engineer shall be filled at Contractor's expense with granular material furnished, placed, and compacted in accordance with Section 31 22 00 - Grading.

7. Comply with NFPA 24 for "Outside Protection", where applicable to water piping systems used for fire protection.

B. Separation of Sewers and Potable Water Piping:

1. Horizontal Separation:
   a. Where possible, existing, and proposed potable water mains and service lines, and sanitary, combined, and storm sewers shall be separated horizontally by clear distance of at least ten feet.
   b. If local conditions preclude the specified clear horizontal separation, installation will be allowed if potable water main is in separate trench or on undistributed earth shelf on one side of sewer and with bottom of potable water main at least 18 inches above top of sewer.
   c. Exception:
      1) Where it is not possible to provide minimum horizontal separation described above, construct potable water main of cement-lined ductile iron pipe with restrained push-on joint or restrained mechanical joint pipe complying with public water supply design standards of authority having jurisdiction. Hydrostatically test water main and sewer as specified in this Section prior to backfilling. Hydrostatic test pressure at crossing shall be at least 150 psi.

2. Vertical Separation:
   a. Provide minimum vertical distance of 18 inches between outside of potable water main and outside of sewer when sewer crosses over potable water main.
   b. Center a section of potable water main pipe at least 17.5 feet long over sewer so that sewer joints are equidistant from potable water main joints.
   c. Provide adequate structural support where potable water main crosses under sewer. At minimum, provide compacted select backfill for ten feet on each side of crossing.
   d. Exceptions:
      1) Where it is not possible to provide minimum vertical separation described above, construct potable water main of cement-lined ductile iron pipe with restrained push-on joint or restrained mechanical joint pipe. Hydrostatically test water main and sewer as specified in this Section, prior to backfilling. Hydrostatic test pressure at crossing shall be at least 150 psi.
      2) Encase either potable water main or sewer in watertight carrier pipe extending ten feet on each side of crossing, measured perpendicular to potable water main.

C. Plugs:

1. Temporarily plug installed pipe at end of each day of work or other interruption of pipe installation to prevent entry of animals, liquids, and persons into pipe, and entrance or insertion of deleterious materials into pipe.

2. Install standard plugs in bells at dead ends, tees, and crosses. Cap spigot and plain ends.

3. Fully secure and block plugs, caps, and bulkheads installed for testing to withstand specified test pressure.

4. Where plugging is required for phasing of the Work or subsequent connection of piping, install watertight, permanent type plugs, caps, or bulkhead acceptable to the Engineer.

D. Bedding Pipe: Bed pipe as specified and in accordance with details on the Drawings.

1. Trench excavation and backfill, and bedding materials shall conform to Section 31 05 16 – Aggregates for Earthwork, as applicable.

2. Where the Engineer deems existing bedding material unsuitable, remove and replace existing bedding with approved granular material furnished, placed, and compacted in accordance with Section 31 22 00 - Grading. Payment for additional excavation and providing granular material will be made under the unit price payment items in the Contract.

3. Where pipe is installed in rock excavation, provide minimum of three inches of granular bedding material underneath pipe smaller than four-inch nominal diameter, and minimum of six inches of granular bedding material underneath pipes four-inch nominal diameter and larger.

4. Excavate trenches below bottom of pipe by amount shown and indicated in the Contract Documents. Remove loose and unsuitable material from bottom of trench.

5. Carefully and thoroughly compact pipe bedding with handheld pneumatic compactors.

6. Do not lay pipe until the Engineer approves bedding condition.

7. Do not bring pipe into position until preceding length of pipe has been bedded and secured in its final position.

E. Laying Pipe:

1. Conform to manufacturer's instructions and requirements of standards and manuals listed below, as applicable:
   a. Ductile Iron Pipe: ANSI/AWWA C600, ANSI/AWWA C105, AWWA M41.
   b. Steel Pipe: ANSI/AWWA C206, AWWA M11.
   c. Thermoplastic Pipe: ASTM D2321, ASTM D2774, ANSI/AWWA C605, AWWA M23, AWWA M45, AWWA, M55.

2. Install pipe accurately to line and grade shown and indicated in the Contract Documents, unless otherwise approved by the Engineer. Remove and reinstall pipes that are not installed correctly.

3. Slope piping uniformly between elevations shown.

4. Keep groundwater level in trench at least 24 inches below bottom of pipe before laying pipe. Do not lay pipe in water. Maintain dry trench conditions until jointing and backfilling are complete. Keep clean and protect interiors of pipe, fittings, valves, and appurtenances.

5. Start laying pipe at lowest point and proceed towards higher elevations, unless otherwise approved by the Engineer.

6. Place bell and spigot-type pipe so that bells face the direction of laying, unless otherwise approved by the Engineer.

7. Excavate around joints in bedding and lay pipe so that pipe barrel bears uniformly on trench bottom.

8. Deflections at joints shall not exceed 75 percent of amount allowed by pipe manufacturer, unless otherwise approved by the Engineer.

9. For PVC and CPVC piping with solvent welded joints, 2.5-inch diameter and smaller, and copper tubing, snake piping in trench to compensate for thermal expansion and contraction.

10. Carefully examine pipe, fittings, valves, and specials for cracks, damage, and other defects while suspended above trench before installation. Immediately remove defective materials from the Site and replace with acceptable products.

11. Inspect interior of all pipe, fittings, valves, and specials and completely remove all dirt, gravel, sand, debris, and other foreign material from pipe interior and joint recesses before pipe and appurtenances are moved into excavation. Bell and spigot-type mating surfaces shall be thoroughly wire brushed, and wiped clean and dry immediately before pipe is laid.

12. Field cut pipe, where required, with machine specially designed for cutting the type of pipe being installed. Make cuts carefully, without damage to pipe, coating or lining, and with smooth end at right angles to axis of pipe. Cut ends on push-on joint type pipe shall be tapered and sharp edges filed off smooth. Do not flame-cut pipe.

13. Do not place blocking under pipe, unless specifically approved by the Engineer for special conditions.

14. Touch up protective coatings in manner satisfactory to the Engineer prior to backfilling.

15. Notify the Engineer in advance of backfilling operations.

16. On steep slopes, take measures acceptable to the Engineer to prevent movement of pipe during installation.

17. Thrust Restraint: Where required, provide thrust restraint conforming to Article 3.3 of this Section and as shown in the Contract Documents.

18. Exercise care to avoid flotation when installing pipe in cast-in-place concrete, and in locations with high groundwater.

F. Jointing Pipe:

1. Ductile Iron Mechanical Joint Pipe:
   a. Immediately before making joint, wipe clean the socket, plain end, and adjacent areas. Taper cut ends and file off sharp edges to provide smooth surface.
   b. Lubricate plain ends and gasket with soapy water or manufacturer’s recommended pipe lubricant, in accordance with ANSI/AWWA C111, just prior to slipping gasket onto plain end of the joint assembly.
   c. Place gland on plain end with lip extension toward the plain end, followed by gasket with narrow edge of gasket toward plain end.
   d. Insert plain end of pipe into socket and press gasket firmly and evenly into gasket recess. Keep joint straight during assembly.
   e. Push gland toward socket and center gland around pipe with gland lip against gasket.
   f. Insert bolts and hand-tighten nuts.
   g. If deflection is required, make deflection after joint assembly and prior to tightening bolts. Alternately tighten bolts approximately 180 degrees apart to seat gasket evenly. Bolt torque shall be as follows:

Pipe Diameter (inches)	**Bolt Diameter (inches)**	**Range of Torque (ft-lbs)**
3	5/8	45 to 60
4 to 24	3/4	75 to 90
30 to 36	1	100 to 120
42 to 48	1.25	120 to 150

h. Bolts and nuts, except those of stainless steel, shall be coated with two coats, minimum dry film thickness of eight mils each, of high build solids epoxy or bituminous coating manufactured by Tnemec, or equal.
i. Restrained mechanical joints shall be as required for Ductile Iron Process Pipe.

2. Ductile Iron Push-On Joint Pipe:
   a. Prior to assembling joints, thoroughly clean with wire brush the last eight inches of exterior surface of spigot and interior surface of bell, except where joints are lined or coated with a protective lining or coating.
   b. Wipe clean rubber gaskets and flex gaskets until resilient. Conform to manufacturer's instructions for procedures to ensure gasket resiliency when assembling joints in cold weather.
   c. Insert gasket into joint recess and smooth out entire circumference of gasket to remove bulges and to prevent interference with proper entry of spigot of entering pipe.
   d. Immediately prior to joint assembly, apply thin film of pipe manufacturer's recommended lubricant to surface of gasket that will come in contact with entering spigot end of pipe, or apply a thin film of lubricant to outside of spigot of entering pipe.
   e. For assembly, center spigot in pipe bell and push pipe forward until spigot just makes contact with rubber gasket. After gasket is compressed and before pipe is pushed or pulled in the rest of the way, carefully check gasket for proper position around the full circumference of joint. Final assembly shall be made by forcing spigot end of entering pipe past gasket until spigot makes contact with base of the bell. When more than a reasonable amount of force is required to assemble the joint, remove spigot end of pipe to verify proper positioning of gasket. Do not use gaskets that have been scored or otherwise damaged.
   f. Maintain an adequate supply of gaskets and joint lubricant at the Site when pipe jointing operations are in progress.

3. Ductile Iron Proprietary Joints:
   a. Install pipe that utilizes proprietary joints for restraint specified in accordance with manufacturer's instructions.

4. Ductile Iron Flanged Joints:
   a. Assemble flanged joints using ring-type gaskets, thickness as recommended by pipe manufacturer but not less than 1/8-inch thick, for raised face flanges. Use full face gaskets for flat face flanges, unless otherwise approved by the Engineer or recommended by pipe manufacturer. Gaskets shall be suitable for service intended in accordance with manufacturer's ratings and instructions. Gaskets shall be properly centered.
   b. Bolts shall be tightened as recommended by the manufacturer in sequence that ensures equal distribution of bolt loads.
   c. Length of bolts shall be uniform. Bolts shall not project beyond the nut more than 1/4-inch when fully tightened. Bolts shall not fall short of the nut when fully taken up. Ends of bolts shall be machine cut and neatly rounded. Do not use washers.
   d. Prior to assembly, lubricate bolt threads and gasket faces.
   e. After assembly, coat all bolts and nuts, except those of stainless steel, with two coats, minimum dry film thickness of eight mils each, of high-build epoxy or bituminous coating manufactured by Tnemec, or equal.

5. Steel Pipe Joints:
   a. Joints in steel pipe shall be bell and spigot when so specified for steel water pipe in accordance with AWWA C200, or butt welded or lap welded joints, except that mechanical couplings~~,~~ or flanged connections shall be provided at connections to valves, meters, and similar equipment. .

b. Welding shall conform to ANSI/AWWA C206. When butt-welding or lap welding joints, weld pipe 36-inch diameter and larger both inside and outside of pipe.
c. Field welded lap joints shall have fillet welds both inside and outside. Outside weld may be seal weld.
d. After welding, coat the joint and surrounding damaged or uncoated area with same coating and thickness as shop-applied coating.
e. Where flanged connections or couplings are provided, flanges, couplings, bolts, and nuts, except when stainless steel, shall be coated with two coats, minimum dry film thickness of eight-mils each, of high-build epoxy or bituminous coating manufactured by Tnemec, or equal.
f. Welds shall be free from embedded scale and slag and shall have tensile strength across weld not less than thinnest of connected sections.
g. Welds shall be watertight.
h. Provide cathodic protection at steel pipe joints as specified in this Section.

6. Mechanical Coupling Joints:
   a. Mechanical couplings include: sleeve-type flexible couplings, split flexible couplings, ANSI/AWWA C606 grooved or shouldered end couplings, plasticized PVC couplings, and other mechanical couplings.
   b. Prior to installing and assembling mechanical couplings, thoroughly clean joint ends with wire brush to remove foreign matter.
   c. For mechanical couplings that incorporate gaskets, after cleaning apply lubricant to rubber gasket or inside of coupling housing and to joint ends. After lubrication, install gasket around joint end of previously installed piece and mate joint end of subsequent piece to installed piece. Position gasket and place coupling housing around gasket and over grooved or shouldered joint ends. Insert bolts and install nuts tightly by hand. Tighten bolts uniformly to produce an equal pressure on all parts of housing. When housing clamps meet metal to metal, joint is complete and further tightening is not required.
   d. For plasticized PVC couplings, loosen the stainless steel clamping bands and remove clamps from coupling. Slide coupling over plain ends of pipes to be joined without using lubricants. Place clamps over each end of coupling at grooved section and tighten with torque wrench to torque recommended by manufacturer.

7. HDPE Pipe Joints:
   a. Bell and Spigot Joints:
      1) Remove all burrs and provide reference mark at correct distance from pipe end. Place mark such that no more than 1/2-inch of machined spigot surface will be visible outside of bell after pipe has been joined.
      2) Clean spigot end and bell thoroughly with soap and water before positioning gasket.
      3) Lubricate spigot groove with manufacturer’s recommended lubricant. Thoroughly clean gasket and place in spigot groove starting at bottom, ensuring that gasket fins face backwards toward pipe.
      4) Thoroughly lubricate gasket with pipe manufacturer’s recommended lubricant and equalize stretch in gasket by running screwdriver under gasket around its entire circumference three times. Reposition gasket in groove after stretching.
      5) Thoroughly clean and lubricate receiving bell. Align pipe as straight as possible and insert spigot end of pipe carefully into bell until reference mark on spigot is flush with bell.
      6) If mechanical means are used to insert spigot end, protect with wood the end of pipe being pushed, to ensure even distribution of pressure.
   b. Butt Fusion Welded Joints:
      1) Install joints in accordance with manufacturer’s instructions using hydraulic butt fusion machine or manual machine equipped with torque wrench. Equipment shall

be able to achieve and maintain heating tool temperature range of 400 to 450 degrees F and an interface pressure of 60 to 90 psi.

2) Clean interior and exterior of pipe and fitting ends with clean, dry, lint-free cloth.
3) Align ends to be joined in the fusion machine without forcing ends into alignment. Adjust alignment as necessary and tighten clamps to prevent slippage.
4) Place facing tool between ends to be joined and face them to provide clean, smooth, parallel mating surface. If stops are present, face ends down to the stops. Remove all shavings after facing without touching ends.
5) Re-check alignment of ends and check for slippage against fusion pressure. There shall be no detectable gaps between ends. Align outside diameters.
6) Heating tool shall maintain pipe manufacture's recommended temperature range. Place the tool between ends to be joined. Move ends against heating tool to achieve full contact. Hold ends against heating tool without force until the following melt bead size is formed:

Pipe Diameter (inches)	**Required Melt Bead Size (inches)**
2 to 4	1/8 to 3/16
4 to 12	3/16 to 1/4
12 to 24	1/4 to 7/16
24 to 54	7/16 to 9/16

7) Upon forming proper melt bead size, quickly separate ends and remove heating tool. Quickly inspect melted ends and bring ends together applying joining force recommended by manufacturer, using 60 to 90 psi interfacial pressure to form double bead rolled over surface of pipe on both ends.
8) Hold joining force against ends until joint is cool to the touch. Cooling period shall be 30 to 90 seconds per inch of pipe diameter. Heavier wall thicknesses may require longer cooling times as recommended by pipe manufacturer.
9) Upon completing joint, inspect to verify double bead has been formed on both sides, uniformly rounded and consistent in size all around joint. Remove faulty joints and re-joint.

G. Backfilling:

1. Conform to applicable requirements of Section 31 22 00 - Grading.
2. Place backfill as Work progresses. Backfill by hand and use power tampers until pipe is covered by at least one foot of backfill.

H. Connections to Valves and Hydrants:

1. Install valves and hydrants as shown and indicated in the Contract Documents.
2. Conform to applicable requirements of Section 40 05 53 - Hydrants.
3. Provide suitable adapters when valves or hydrants and piping have different joint types.
4. Provide thrust restraint at all hydrants and at valves located at pipeline terminations.

I. Transitions from One Type of Pipe to Another:

1. Provide necessary adapters, specials, and connection pieces required when connecting different types and sizes of pipe or connecting pipe made by different manufacturers.

J. Closures:

1. Provide closure pieces shown or required to complete the Work.

3.2 TRACER TAPE INSTALLATION

A. Polyethylene Underground Warning Tape for Metallic Pipelines:

1. Provide polyethylene tracer tape for buried metallic piping, which includes pipe that is steel, ductile iron, cast iron, concrete, copper, and corrugated metal.

2. Provide tracer tape 12 to 18 inches below finished grade, above and parallel to buried pipe.

3. For pipelines buried eight feet or greater below finished grade, provide second line of magnetic tracer tape 2.5 feet above crown of buried pipe, aligned along pipe centerline.

4. Tape shall be spread flat with message side up before backfilling.

B. Detectable Underground Warning Tape for Non-Metallic Pipelines:

1. Provide polyethylene tracer tape with aluminum backing for buried, non-metallic piping, which includes pipe that is PVC, CPVC, polyethylene, HDPE, FRP, ABS, and vitrified clay.

2. Provide magnetic tracer tape 12 to 18 inches below finished grade, above and parallel to buried pipe.

3. For pipelines buried eight feet or greater below finished grade, provide second line of magnetic tracer tape 2.5 feet above crown of buried pipe, aligned along the pipe centerline.

4. Tape shall be spread flat with message side up before backfilling.

3.3 THRUST RESTRAINT

A. Provide thrust restraint on pressure piping systems where shown or indicated in the Contract Documents.

B. Thrust restraint may be accomplished by using restrained pipe joints, concrete thrust blocks, or harnessing buried pipe. Thrust restraints shall be designed for axial thrust exerted by test pressure specified in the Buried Piping Schedule at the end of this Section.

C. Place concrete thrust blocks against undisturbed soil. Where undisturbed soil does not exist, or for projects where the Site consists of backfill material, thrust restraint shall be provided by restrained pipe joints.

D. Restrained Pipe Joints:

1. Pipe joints shall be restrained by means suitable for the type of pipe being installed.
   a. Ductile Iron, Push-on Joints and Mechanical Joints: Restrain with proprietary restrained joint system as required for Ductile Iron Process Pipe; lugs and tie rods; or other joint restraint systems approved by the Engineer.
   b. Thermoplastic and HDPE Joints: Where bell and spigot-type or other non-restrained joints are utilized, provide tie rods across joint or other suitable joint restraint system, subject to the approval of the Engineer.

E. Concrete Thrust Blocks:

1. Provide concrete thrust blocks on pressure piping at changes in alignment of 15 degrees or more, at tees, plugs and caps, and where shown or indicated in the Contract Documents. Construct thrust blocks of Class B concrete, conforming to 03 11 00, Concrete Forming.

2. Install thrust blocks against undisturbed soil. Place concrete so that pipe and fitting joints are accessible for repair.

3. Concrete thrust block size shall be as shown on the Design Drawings or as approved by the Engineer.

3.4 WORK AFFECTING EXISTING PIPING

A. Location of Existing Underground Facilities:

1. Locations of existing Underground Facilities shown on the Design Drawings should be considered approximate.

2. Determine the true location of existing Underground Facilities to which connections are to be made, crossed, and that could be disturbed, and determine location of Underground Facilities that could be disturbed during excavation and backfilling operations, or that may be affected by the Work.

B. Taking Existing Pipelines and Underground Facilities Out of Service:

1. Notify the Engineer in writing prior to taking pipeline or Underground Facilities out of service. Shutdown notification shall be provided in advance of the shutdown.

C. Work on Existing Pipelines or Underground Facilities:

1. Cut or tap piping or Underground Facilities as shown or required with machines specifically designed for cutting or tapping pipelines or Underground Facilities, as applicable.
   a. For tapping the Town of Scriba water main, engage a qualified Contractor with 5-years or more of successful large-pipe tapping experience.

2. Install temporary plugs to prevent entry of mud, dirt, water, and debris into pipe.

3. Provide necessary adapters, sleeves, fittings, pipe, and appurtenances required to complete the Work.

3.5 FIELD QUALITY CONTROL

A. General:

1. Test all piping, except as exempted in the Buried Piping Schedule in this Section.

2. When authorities having jurisdiction are to witness tests, notify the Engineer and authorities having jurisdiction in writing at least 48 hours in advance of testing.

3. Conduct all tests in presence of the Engineer.

4. Remove or protect pipeline-mounted devices that could be damaged by testing.

5. Provide all apparatus and services required for testing, including:
   a. Test pumps, compressors, hoses, calibrated gages, meters, test containers, valves, fittings, and temporary pumping systems required to maintain the Owner’s operations.
   b. Temporary bulkheads, bracing, blocking, and thrust restraints.

6. Provide air if an air test is required, power if pumping is required, and gases if gases are required.

7. Unless otherwise specified, the Owner will provide fluid required for hydrostatic testing. The Contractor shall provide means to convey fluid for hydrostatic testing into piping being tested. The Contractor shall provide fluid for other types of testing required.

8. Repair observed leaks and repair pipe that fails to meet acceptance criteria. Retest after repair.

9. Unless otherwise specified, testing shall include existing piping systems that connect with new piping system. Test existing pipe to nearest valve. Piping not installed by the Contractor and that fails the test shall be repaired upon authorization of the Owner. Unless otherwise included in the Work, repair of existing piping or Underground Facilities will be paid as extra Work.

B. Test Schedule:

1. Refer to the Buried Piping Schedule in this Section for type of test required and required test pressure.

2. Unless otherwise specified, required test pressures are at lowest elevation of pipeline segment being tested.

3. For piping not listed in Buried Piping Schedule in this Section:
   a. Hydrostatically test pipe that will convey liquid at a pressure greater than five psig. Provide process air pipe test for pipe that will convey air or gas under pressure or vacuum, except chlorine gas, which requires separate test.
   b. Use exfiltration testing, low-pressure air testing, or vacuum testing for other piping.
   c. Disinfect for bacteriological testing piping that conveys potable water.

4. Test Pressure:
   a. Use test pressures listed in Buried Piping Schedule in this Section.
   b. If test pressure is not listed in Buried Piping Schedule, or if test is required for piping not listed in the Buried Piping Schedule, test pressure will be determined by the Engineer based on maximum anticipated sustained operating pressure and methods described in applicable ANSI/AWWA manual or standard that applies to the piping system.

C. Hydrostatic Testing:

1. Preparation for Testing:
   a. For thermoplastic pipe and fiberglass pipe, follow procedures described in Section 7 of ANSI/AWWA Standard C605.
   b. For HDPE pipe, follow procedures described in ASTM F2164. Test duration, including time to pressurize, time for initial expansion, time at test pressure, and time to depressurize, shall not exceed eight hours. If re-testing of a test section or pipeline is required, at least eight hours shall elapse between tests.
   c. For steel pipe, follow procedures described in ANSI/AWWA Manual M11. Wetting period is not required for pipe that is not cement-lined.
   d. For other piping follow procedures described in ANSI/AWWA Manual M9, except that minimum wetting period required immediately prior to testing for asbestos cement pipe shall be 24 hours rather than the 48 hours prescribed for concrete pipe. Wetting period is not required for pipe that is not cement mortar-lined.
   e. Prior to testing, ensure that adequate thrust protection is in place and joints are properly installed.

2. Test Procedure:
   a. Fill pipeline slowly to minimize air entrapment and surge pressures. Fill rate shall not exceed one foot of pipe length per second in pipe being tested.
   b. Expel air from pipe as required. Obtain approval of the Engineer prior to tapping pipe for expelling air.
   c. Examine exposed joints and valves and make repairs to eliminate visible leakage.
   d. After specified wetting period, add fluid as required to pressurize line to required test pressure. Maintain test pressure for a stabilization period of ten minutes before beginning test.
   e. HDPE Pipe: After filling pipeline, gradually pressurize pipe to test pressure and maintain required test pressure for three hours for pipe to expand. During expansion, add fluid to maintain required test pressure. Begin timed test period after expansion period and other requirements are met.
   f. Timed test period shall not begin until after pipe has been filled, exposed to required wetting period, air has been expelled, and pressure stabilized.
   g. Timed Test Period: After stabilization period, maintain test pressure for at least two hours. During timed testing period, add fluid as required to maintain pressure within five psig of required test pressure. For HDPE pipe, after three-hour expansion phase, reduce test pressure by ten psig and do not add liquid. Test pressure shall then remain steady for one hour, indicating no leakage.
   h. Pump from test container to maintain test pressure. Measure volume of fluid pumped from test container and record on test report. Record pressure at test pump at 15-minute intervals for duration of test.

3. Allowable Leakage Rates: Leakage is defined as the quantity of fluid supplied to pipe segment being tested to maintain pressure within five psi of test pressure during timed test period. Allowable leakage rates for piping are:
   a. No Leakage: Pipe with flanged, welded, fused, threaded, soldered, or brazed joints.
   b. Rates based on formula or table in ANSI/AWWA Manual M41:
      1) Metal and fiberglass pipe joined with rubber gaskets as sealing members, including the following joint types:
         a) Bell and spigot and push-on joints.
         b) Mechanical joints.
         c) Bolted sleeve type couplings.
         d) Grooved and shouldered couplings.
   c. Rates based on make-up allowance in ANSI/AWWA Manual M9:
      1) Prestressed concrete cylinder pipe and other types of concrete pipe joined with O-ring rubber gasket sealing members.
   d. Rates based on formula or table in ANSI/AWWA C605:
      1) Plastic pipe joined with O-ring gasket sealing members.
   e. Rates based on formula or table in ANSI/AWWA C603:
      1) Asbestos-cement pipe.

I. Examination of Welds:

1. Personnel performing examination of welds shall be qualified to at least Level II in accordance with ASNT SNT-TC-1A.

2. Conform to ASME Boiler and Pressure Vessel Code Section V and applicable articles for examination of welds.

3. Visually examine all welds, Category D Fluid Service, in conformance with ASME B31.3.

4. Examine at least ten percent of welds using liquid penetrant examination.

5. If defect is detected, all welds shall be examined by liquid penetrant examination.

6. At conclusion of liquid penetrant examination, remove penetrant test materials by flushing, washing, or wiping clean with applicable solvents.

J. Bacteriological Testing:

1. Bacteriological testing for potable water lines, finished water lines, and other piping in accordance with the Buried Piping Schedule, is specified in Article 3.6 of this Section.

3.6 CLEANING AND DISINFECTION

A. Cleaning, General: Clean pipe systems as follows:

1. Thoroughly clean all piping, including flushing with water, dry air, or inert gas as required, in manner approved by the Engineer, prior to placing in service. Flush chlorine solution and sodium hypochlorite piping with water.

2. Piping 24-inch diameter and larger shall be inspected from inside and debris, dirt and foreign matter removed.

3. For piping that requires disinfection and has not been kept clean during storage or installation, swab each section individually before installation with five percent sodium hypochlorite solution.

B. Disinfection:

1. Disinfect all potable and finished water piping.

2. Suggested procedure for accomplishing complete and satisfactory disinfection is specified below. Other procedures may be considered for acceptance by the Engineer.
   a. Prior to disinfection, clean piping as specified and flush thoroughly.
   b. Conform to procedures described in ANSI/AWWA C651. Use continuous feed method of disinfecting unless alternative method is acceptable to the Engineer.

3. Water for initial flushing, testing, and disinfection will be furnished by the Owner. The Contractor shall provide all temporary piping, hose, valves, appurtenances, and services required. Cost of water required for disinfection will be paid by the Contractor to the Owner at water utility's standard rates.

4. Chlorine shall be provided by the Contractor.

5. Bacteriologic tests will be performed by the Owner. Certified test laboratory report will be provided to the Contractor, if requested.

6. Chlorine concentration in water entering the piping shall be between 50 and 100 ppm, such that minimum residual concentration of 25 mg/L remains after 24-hour retention period. Disinfect piping and all related components. Repeat as necessary to provide complete disinfection.

7. After required retention period, flush chlorinated water to closed drain line, unless otherwise acceptable to the Engineer. Properly dispose of chlorinated water in accordance with Laws and Regulations. Do not discharge chlorinated water to storm sewers, ditches, or overland.

END OF SECTION

SECTION 33 05 05

CORREGATED HDPE PIPE

PART 1 - GENERAL

1.1 DESCRIPTION

A. Scope:

1. CONTRACTOR shall provide all labor, materials, equipment, and incidentals as shown, specified, and required to install all buried piping and culverts.

B. Coordination:

1. Review installation procedures under this and other Sections and coordinate installation of items to be installed with or before buried piping Work.

C. Related Sections:

1. Section 31 23 05 – Excavation and Fill

1.2 REFERENCES

A. Standards referenced in this Section are:

1. ASTM F2306 – Standard Specification for 12” to 60” Annular Corrugated Profile Wall Polyethylene (PE) Pipe and Fittings for Gravity-Flow Storm Sewer and Subsurface Drainage Applications.

2. ASTM F2648 – Standard Specification for 2” to 60” Annular Corrugated Profile Wall Polyethylene (PE) Pipe and Fittings for Land Drainage Applications.

3. ASTM D2321- Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and other Gravity-Flow Applications.

4. ASTM D3212 - Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals.

5. ASTM F477 - Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe.

6. ASTM F2487 - Standard Practice for Infiltration and Exfiltration Acceptance Testing of Installed Corrugated High-Density Polyethylene and Polypropylene Pipelines.

7. ASTM F1417 – Standard Test Method for Installation Acceptance of Plastic Gravity Sewer Lines Using Low-Pressure Air.

8. ASTM F3058- Standard Practice for Preliminary Field Testing of Thermoplastic Pipe Joints for Gravity Flow (Non-Pressure) Sewer Lines.

9. AASHTO M252 – Standard Specification for Corrugated Polyethylene Drainage Pipe.

1.3 SUBMITTALS

A. Action Submittals: Submit the following:

1. Shop Drawings:
   a. Full details of piping, joints, and connections to piping, equipment, and appurtenances.
2. Product Data:
   a. Manufacturer's literature and specifications, as applicable, for products specified in this Section.

B. Informational Submittals: Submit the following:

1. Certificates:
   a. Certificate signed by manufacturer of each product certifying that product conforms to applicable referenced standards.

C. Closeout Submittals: Submit the following:

1. Record Documentation:
   a. Maintain accurate and up-to-date record documents showing modifications made in the field, in accordance with approved submittals, and other Contract modifications relative to buried piping Work. Submittal shall show actual location of all piping Work and appurtenances at same scale as the Drawings.
   b. Show piping with elevations referenced to Project datum and dimensions from permanent structures. For each horizontal bend in piping, include dimensions to at least three permanent structures, when possible. For straight runs of piping provide offset dimensions as required to document piping location.
   c. Include profile drawings with buried piping record documents when the Contract Documents include piping profile drawings.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Delivery:

1. Deliver materials to the Site to ensure uninterrupted progress of the Work.

2. Upon delivery inspect pipe and appurtenances for cracking, gouging, chipping, denting, and other damage and immediately remove from Site and replace with acceptable material.

B. Storage:

1. Store materials to allow convenient access for inspection and identification. Store material off ground using pallets, platforms, or other supports. Protect packaged materials from corrosion and deterioration.

2. The inside of pipes shall be kept free of dirt and debris. Store pipe in a manner that provides protection from construction activities.

3. Limit stacking to a height that will not cause excessive deformation of the bottom layers of pipes under anticipated temperature conditions.

4. Cover stockpiled pipe to protect from ultraviolet degradation.

C. Handling:

1. Handle pipe and accessories carefully in accordance with pipe manufacturer's recommendations. Do not drop or roll material off trucks. Do not drop, roll or skid piping.
2. Avoid unnecessary handling of pipe.
3. Keep pipe interiors free from dirt and foreign matter.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Piping materials are specified in the Buried Piping Schedule at end of this Section.

B. General:

1. Pipe Markings:
   a. Manufacturer shall cast or paint on each length of pipe and each fitting pipe material, diameter, and pressure or thickness class.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Install piping as shown, specified, and as recommended by pipe and fittings manufacturer.
2. In event of conflict between manufacturer's recommendations and the Contract Documents, request interpretation from ENGINEER before proceeding.
3. ENGINEER will observe excavations and bedding prior to laying pipe by CONTRACTOR. Notify ENGINEER in advance of excavating, bedding, pipe laying, and backfilling operations.
4. Earthwork is specified in Section 31 23 00 – Excavation and Fill.

B. Bedding Pipe: Bed pipe as specified and in accordance with details on the Construction Drawings.

1. Trench excavation and backfill and bedding materials shall conform to Section 31 23 00 – Excavation and Fill as applicable.
2. Where ENGINEER deems existing bedding material unsuitable, remove and replace existing bedding with approved granular material furnished, placed, and compacted in accordance with Section 31 23 00 – Excavation and Fill
3. Excavate trenches below bottom of pipe by amount shown and indicated in the Contract Documents. Remove loose and unsuitable material from bottom of trench.
4. Carefully and thoroughly compact pipe bedding with vibratory plate tampers.
5. Do not lay pipe until ENGINEER approves bedding condition.
6. Do not bring pipe into position until preceding length of pipe has been bedded and secured in its final position.

C. Laying Pipe:

1. Install pipe accurately to line and grade shown and indicated in the Contract Documents, unless otherwise approved by ENGINEER. Remove and reinstall pipes that are not installed correctly.

2. Slope piping uniformly between elevations shown.

3. Start laying pipe at lowest point and proceed towards higher elevations, unless otherwise approved by ENGINEER.

4. Carefully examine pipe and fittings for cracks, damage, and other defects while suspended above trench before installation. Immediately remove defective materials from the Site and replace with acceptable products.

5. Notify ENGINEER in advance of backfilling operations.

D. Jointing Pipe:

1. HDPE Pipe Joints:
   a. Bell and Spigot Joints (Double-Wall Corrugated HDPE Pipe):
      1) Remove all burrs and provide reference mark at correct distance from pipe end. Place mark such that no more than 1/2-inch of machined spigot surface will be visible outside of bell after pipe has been joined.
      2) Clean spigot end and bell thoroughly with soap and water before positioning gasket.
      3) Lubricate spigot groove with manufacturer’s recommended lubricant. Thoroughly clean gasket and place in spigot groove starting at bottom, ensuring that gasket fins face backwards toward pipe.
      4) Thoroughly lubricate gasket with pipe manufacturer’s recommended lubricant and equalize stretch in gasket by running screwdriver under gasket around its entire circumference three times. Reposition gasket in groove after stretching.
      5) Thoroughly clean and lubricate receiving bell. Align pipe as straight as possible and insert spigot end of pipe carefully into bell until reference mark on spigot is flush with bell.
      6) If mechanical means are used to insert spigot end, protect with wood the end of pipe being pushed, to ensure even distribution of pressure.

   b. Plain-Ended Pipe Joints (Single-Wall Corrugated HDPE Pipe):
      1) Joints for 3- to 24- inch shall be made with split couplings.
      2) Standard connection shall meet the soil-tightness requirements of AASHTO M252 or M294.
   c. For all pipe joints on non-perforated pipes, use Mar Mac Polyseal pipe wrap-couplers or equivalent joint securing system.

E. Backfilling:

1. Conform to applicable requirements of Section 31 23 00 – Excavation and Fill.

2. Place backfill as Work progresses.

3. Carefully slice backfill by hand under pipe haunches.

3.5 FIELD QUALITY CONTROL

A. General:

1. Test all piping, except as exempted in the Buried Piping Schedule in this Section.

2. Conduct all tests in presence of ENGINEER.

3. Remove or protect pipeline-mounted devices that could be damaged by testing.

4. Provide all apparatus and services required for testing, including:

5. Repair observed leaks and repair pipe that fails to meet acceptance criteria. Retest after repair.

B. Test Schedule:

1. Refer to the Buried Piping Schedule in this Section for type of test required and required test pressure.

2. Unless otherwise specified, required test pressures are at lowest elevation of pipeline segment being tested.

3. For piping not listed in Buried Piping Schedule in this Section:
   a. Hydrostatically test pipe that will convey liquid at a pressure greater than 5 psig.
   b. Use exfiltration testing, low-pressure air testing, or vacuum testing for other piping.

4. Test Pressure:
   a. Use test pressures listed in Buried Piping Schedule in this Section.
   b. If test pressure is not listed in Buried Piping Schedule, or if test is required for piping not listed in the Buried Piping Schedule, test pressure will be based on maximum anticipated sustained operating pressure and methods described in applicable ANSI/AWWA manual or standard that applies to the piping system.

C. Low-Pressure Air Testing:

1. Test for leakage using low pressure air per ASTM F1417.

2. Pipeline leakage testing shall be performed following installation of entire run of each pipe. More frequent testing may be performed at the discretion of the CONTRACTOR.

3. When leakage exceeds the maximum amount specified for the pipe diameter and tested length of pipeline, satisfactory correction, as approved by the ENGINEER, shall be made and the testing shall be repeated until passing results are achieved.

3.6 SCHEDULES

A. Schedules listed below, following the “End of Section” designation, are part of this Specification section.

1. Table 1 - Buried Piping Schedule, of this Section.

END OF SECTION

TABLE 1 - BURIED PIPING SCHEDULE

Service	Diameter (inch)	Material	Pressure Class/ Thickness	Test
Stormwater Culvert	Varies (12 inch, 24-inch)	HDPE	Double-Wall Corrugated Exterior, Smooth Interior and Single-Wall Corrugated Exterior-Interior	NR
Final Cover Drainage Layer Collection Pipe	6-inch	HDPE	Perforated Single-Wall Corrugated and Non-Perforated Single-Wall Corrugated	NR

The following abbreviations are used in the Buried Piping Schedule.

A. Material Abbreviations

Material	Abbrev.
High Density Polyethylene	HDPE

B. Test Abbreviations

Test	Abbrev	Test	Abbrev.
Hydrostatic Test (test pressure in psig)	HYD ( )	No Test Required	NR

SECTION 33 05 33 - HIGH DENSITY POLYETHYLENE PIPE AND FITTINGS

PART 1 - GENERAL

1.01 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, equipment and incidentals as shown, specified and required to furnish and install all high density polyethylene (HDPE) pipe, fittings, and appurtenances as specified herein, and as shown on the Design Drawings
2. Pipe in this section is designated for use with installation of the leachate collection and conveyance system piping.
3. Contractor shall be prepared to install HDPE pipe and fittings in conjunction with the earthwork and other components of the liner and leachate collection and conveyance systems.
4. The work shall include procurement, installation, connection, and testing of all piping, fittings, and appurtenances.

1.02 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. ASTM D638 - Standard Test Method for Tensile Properties of Plastics.
2. ASTM D790 - Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
3. ASTM D1238 - Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer.
4. ASTM D1248 - Standard Specification for Polyethylene Plastics Extrusion Materials for Wires and Cables.
5. ASTM D1505 or ASTM D792 - Standard Test Method for Density of Plastics by the Density-Gradient Technique.
6. ASTM D1693 - Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics.
7. ASTM D2122 - Standard Method of Determining Dimensions of Thermoplastic Pipe and Fittings.
8. ASTM D2412 - Standard Test Method for Determining External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.
9. ASTM D2837 - Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products.
10. ASTM D3350 - Standard Specification for Polyethylene Plastic Pipe and Fittings Materials.

11. ASTM D3261 - Standard Specification for Butt Heat Fusion of Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing.

12. ASTM F714 - Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.

1.03 SUBMITTALS

A. Include results of Manufacturer's tests with shipment of materials, with 2 additional copies of such test results furnished to the Owner. Cost for additional required testing not performed by the Manufacturer shall be borne by the Contractor.

B. If Manufacturer's test data inadequate or unavailable, the Owner reserves right to require cores drilled for compressive strength tests. Costs of these tests shall be borne by the Contractor.

C. Submit manufacturing data listing stock density, melt flow, flexural modulus, tensile strength, and coloration.

D. Submit in accordance with Section 01340.

1.03. QUALITY ASSURANCE

A. Source Quality Control:

1. Conduct tests by the Owner approved testing agency to determine the following:
   a. Pipe dimensions:
      1) Average outside diameter.
      2) Average inside diameter.
      3) Minimum and average wall thickness.
   b. Pipe flattening:
      1) Deflect pipe to 40% deflection.
      2) Remove load and examine specimen for evaluation of splitting, cracking, or breaking.

2. Test reports shall show results of tests and conformance to ASTM requirements.

3. The Engineer must confirm that all manufacturer's piping certifications have provided testing to confirm that the required design parameters are met.

4. The Engineer will randomly verify the pipe characteristics by measurement of the piping wall thickness and perforation hole diameter and spacing.

PART 2 - PRODUCTS

2.01 PHYSICAL PROPERTIES OF PIPE COMPOUND

A. Density: ASTM D1505 or ASTM D792, not less than 0.941 to 0.955 gm/cu cm.

B. Melt Flow: ASTM D1238, Condition E, not greater than 0.4 gms/10 min.

C. Flexural Modules: ASTM D790, 110,000 to less than 160,000 psi.

D. Tensile Strength at Yield: ASTM D638, 3,000 to less than 3,500 psi.

E. Environmental Stress Crack Resistance (ESCR): ASTM D1693 - Condition C, shall be in excess of 1,000 hrs (5,000 hrs) with zero failures.

F. Hydrostatic Design Basis: ASTM D2837, 1,600 psi at 23^0C.

2.02 PIPE

A. Manufacturers:
   1. Chevron Phillips Chemical, Performance Pipe.
   2. Or equal.

B. High performance, high molecular weight, high density polyethylene pipe.

C. ASTM D1248 (Type III, Class C, Category 5, P34).

D. ASTM D3350, minimum cell classification value PE 345464C.

E. Marking: Intervals of 5 ft. or less.

   1. Manufacturer's name or trademark.

   2. Nominal pipe size.

   3. HDPE cell classification, ASTM D3350.

   4. Legend: 1000 Industrial pipe SDR (number).

   5. ASTM D1248.

   6. Extrusion date, period of manufacture or lot number.

F. Dimensions:

HDPE PIPE DIMENSIONS (inches) for SDR 7.3
(Cell Leachate Collection, Sump, and Side Riser Pipes)

Nominal Size	Nominal OD	Approx. ID	Minimum Wall	Nominal Weight lbs/ft
2-in.	2.375	1.686	0.325	0.92
3-in.	3.500	2.485	0.479	1.99
4-in.	4.500	3.194	0.616	3.29
6-in.	6.625	4.700	0.908	7.12
8-in.	8.625	6.119	1.182	12.07

Nominal Size	Nominal OD	Approx. ID	Minimum Wall	Nominal Weight lbs/ft
10-in.	10.750	7.627	1.473	18.75
12-in.	12.750	9.046	1.747	26.38
24-in.	24.000	17.029	3.288	93.48

HDPE PIPE DIMENSIONS (inches) for SDR 26
(Leachate Conveyance pipes)

Nominal Size	Nominal OD	Approx. ID	Minimum Wall	Nominal Weight lbs/ft
2-in.	2.375	---	---	---
3-in.	3.500	---	---	---
4-in.	4.500	4.133	0.173	1.03
6-in.	6.625	6.085	0.255	2.23
8-in.	8.625	7.921	0.332	3.80
10-in.	10.750	9.873	0.413	5.88
12-in.	12.750	11.710	0.490	8.27
24-in.	24.000	22.043	0.923	29.30
26-in.	26.000	23.880	1.000	34.39
28-in.	28.000	25.717	1.077	39.88
30-in.	30.000	27.554	1.154	45.78
32-in.	32.000	29.391	1.231	52.09
34-in.	34.000	31.228	1.308	58.81

2.03 FITTINGS

A. Molded from polyethylene compound having cell classification equal to or exceeding compound used in pipe to ensure compatibility of polyethylene resins.

B. Be or same manufacture as pipe being provided.

C. Flange Joints:
   1. 150-lb stainless steel manufacturer-installed backup flanges as recommended by manufacturer.
   2. Stainless steel bolts.
   3. Flanges and bolt patterns as specified by manufacturer.
   4. Surface weld joints to seal edges.
   5. Seal riser joints within 80 mil HDPE boot welded and clamped to riser.
   6. Stainless steel boot clamps.

D. Markings:
   1. Manufacturer’s name of trademark.
   2. Nominal size.

3. Material designation “HDPE”.

4. ASTM D1248.

2.04 LINER PENETRATION BOOTS

A. Minimum in accordance with dimensions indicated on Drawings.

B. Construction from 80 mil HDPE flexible membrane, with manufacturer’s recommendations. Clamp each boot to riser with stainless steel boot clamps, which will remain in-place after boot is welded to riser. Exposed edges of boot shall be filet welded to prevent moisture from penetrating between HDPE surfaces.

2.05 HIGH DENSITY POLYETHYLENE (HDPE) FLATSTOCK

A. Manufacturers:

1. Chevron Phillips Chemical.

2. Or equal.

B. High performance, high molecular weight, sheet stock.

C. Provide sizes and thickness indicated on the Drawings.

D. Conform to resin quality of pipe stock and liner stock.

E. Round cut edges to minimize potential for liner damage during installation.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Trench, backfill, and compact in accordance with the Design Drawings and specifications.

B. Welded Joints:

1. Weld in accordance with manufacturer’s recommendation for butt fusion methods.

2. Butt fusion equipment used in joining procedures shall be capable of meeting conditions recommended by pipe manufacturer, including, but not limited to, temperature requirements, alignment, and fusion pressures.

3. Extrusion welding may be allowed as a secondary method for joining containment piping where butt fusion welding is not practical, but only where approved by the Engineer and the Owner in writing.

C. Mechanical Jointing:

1. Use on riser pipe sections.
2. Butt fuse fabricated flange adapters to pipe.
3. Connect slip-on stainless steel backup flanges with stainless steel bolts.
4. Weld HDPE adapters to provide watertight fit. Fit mechanical jointing on risers with protective HDPE boots clamped and bolted to riser.
5. Clamp boot to riser with boot clamps to remain in-place after boot is welded to riser.
6. Filet weld exposed edges of boot to prevent moisture from penetrating between HDPE surfaces.

3.02 FIELD QUALITY CONTROL

A. Pipe may be rejected for failure to conform to specifications or the following:

1. Fractures or cracks passing through pipe wall, except single crack not exceeding 2 in. in length at either end of pipe which could be cut off and discarded. Pipes within one shipment will be rejected if defects exist in more than 5% of shipment of delivery.
2. Cracks sufficient to impair strength, durability or serviceability of pipe.
3. Defects indicating improper proportioning, mixing, and molding.
4. Damaged ends, where such damage prevents making satisfactory joint.

B. Acceptance of fittings, stubs or other specially fabricated pipe sections shall be based on visual inspection at job site and documentation they conform to these Specifications.

C. The leachate collection pipes along the centerline of the primary and secondary leachate collection systems shall be placed directly on the geocomposite drainage layer. There shall be no requirement for tolerance regarding achievement of design grade and shimming is not required.

3.03 PRESSURE TESTING

A. Test in accordance with ASTM F2164.

B. Pressure testing is not required for the perforated leachate collection pipe and solid leachate side riser pipe extending from cell sumps to cell vaults.

END OF SECTION

SECTION 33 41 01 – FINAL COVER DRAINAGE PIPING

PART 1 – GENERAL

1.1 DESCRIPTION

A. Scope

1. Install high density polyethylene (HDPE) drainage pipe to the alignments and grades as indicated on the Design Drawings or as specified by the Engineer for the final cover drainage layer system.

B. Related Sections

1. Section 31 05 16 – Aggregates for Earthwork
2. Section 31 23 00 – Excavation and Fill

1.2 REFERENCE STANDARDS

A. The following reference standards are applicable to this specification:

1. ASTM D2321 - Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.
2. ASTM D3212 - Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals.
3. ASTM D3350 - Standard Specification for Polyethylene Plastic Pipe and Fittings Materials.
4. ASTM F477 - Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe.
5. ASTM F714 - Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.
6. ASTM F2487 - Standard Practice for Infiltration and Exfiltration Acceptance Testing of Installed Corrugated High Density Polyethylene and Polypropylene Pipelines.
7. ASTM F2648 - Standard Specification for 2 to 60 inch [50 to 1500 mm] Annular Corrugated Profile Wall Polyethylene (PE) Pipe and Fittings for Land Drainage Applications

1.3 SUBMITTALS

A. Detailed, dimensioned drawings and schedules conforming to the requirements of these Specifications a minimum two (2) weeks prior to the anticipated start of installation. Do not fabricate, ship, or commence pipe installation prior to Engineer's approval.

B. Maintain an accurate record of the location of the piping with reference to project baselines, grades, and elevations. Indicate all changes made in the piping installation relative to the layout and materials shown on the Design Drawings and submit to the Engineer for approval before proceeding with changes.

C. Piping specifications, shop drawings, dimensions, joint details, perforation patterns, design and installation details, and descriptive literature of pipe materials and accessories.

D. Verify to the Engineer that the specified bedding material and requirements are acceptable to the HDPE Pipe Manufacturer or submit alternative installation recommendations.

E. The HDPE Pipe Manufacturer shall submit the following information in writing:

1. Handling, storage, and installation guidelines.
2. Certification of compliance with these Specifications for all materials delivered to the site.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Storage

1. Inspect materials delivered to the site for damage.
2. Unload and store materials with a minimum of handling. Store materials in a clean, level area and do not store materials directly on the ground. The inside of pipes shall be kept free of dirt and debris. Store pipe in a manner that provides protection from construction activities.
3. Limit stacking to a height that will not cause excessive deformation of the bottom layers of pipes under anticipated temperature conditions. Where necessary, due to ground conditions, store the pipe on wooden sleepers, spaced suitably and of such width as not to allow deformation of the pipe at the point of contact with the sleeper or between supports.

B. Handling

1. Handle materials in such a manner as to ensure placement in sound, undamaged condition.
2. Handle pipe in accordance with the Pipe Manufacturer’s recommendations.

1.5 WARRANTY

A. The Pipe Manufacturer and Contractor shall furnish a standard written warranty against defects in materials and workmanship in accordance with ASTM D3350 and ASTM F714. Warranty conditions concerning limits of liability will be evaluated and shall be acceptable to the Owner.

PART 2 – PRODUCTS

2.1 HDPE MATERIAL PROPERTIES

A. Material for pipe productions shall be an engineered compound on virgin and recycled high density polyethylene conforming with the minimum requirements of cell classification 424420C (ECR Test Condition B) for 4- through 10-inch diameter pipe, as defined and described in the latest version of ASTM D3350, with the exception that carbon black content shall not exceed 4%.

B. HDPE pipe shall be ADS N-12 pipe (per ASTM F2648) or approved equivalent.

2.2 HDPE DRAINAGE COLLECTION PIPE

A. HDPE drainage pipes shall be perforated smooth-bore corrugated HDPE pipe and comply with the requirements of ASTM F2648.

B. Pipe joints shall be soil tight.

C. Pipe sizes shall match those indicated on the Design Drawings.

2.3 HDPE DRAINAGE OUTLET PIPE

A. HDPE outlet pipes shall be solid wall smooth and corrugated interior HDPE pipe and comply with the requirements of ASTM F2648.

B. Pipe joints shall be watertight and meet the requirements of ASTM D3212.

C. Pipe sizes and types shall match those indicated on the Design Drawings.

2.4 PIPE FITTINGS AND JOINTS

A. All pipe fittings and joints shall be installed in accordance with pipe manufacturer's recommendations.

B. Pipe fittings shall conform to ASTM F2648.

C. Pipe shall be joined using a bell and spigot joint meeting ASTM F2648.

D. Gaskets, where applicable, shall meet the requirements of ASTM F477 and be installed in accordance with the Pipe Manufacturer's recommendations. Gaskets shall be covered with a removable, protective wrap to ensure the gasket is free from debris.

2.5 PIPE BEDDING

A. Bedding material shall meet the requirements of Section 31 05 16 – Aggregates for Earthwork and be installed in accordance with Section 31 23 00 – Excavation and Fill and the Design Drawings.

PART 3– EXECUTION

3.1 INSPECTION

A. Inspect pipe and appurtenances before installation to verify quality and condition of material.

3.2 PREPARATION

A. Remove dirt and foreign material, inside and outside, from pipe before installation.

3.3 PIPE BEDDING AND BACKFILLING

A. Install pipe bedding and backfill trenches in accordance with the Design Drawings and Section 31 23 00 – Excavation and Fill.

3.4 HANDLING AND INSTALLATION

A. Installation and handling of HDPE pipe shall be performed in accordance with ASTM D2321 and the Pipe Manufacturer's guidelines.

B. Exercise care when transporting, handling, and placing HDPE pipe, such that the pipe will not be cut, kinked, twisted, or otherwise damaged.

C. Prior to installation carefully examine all HDPE pipe for damage. Remove from the site and replace defective materials, as determined by the Engineer, immediately at no cost to the Owner.

D. Make HDPE pipe field-cuts, where required, with a machine specifically designed for cutting pipe. Make cuts carefully, without damage to pipe, so as to leave a smooth end at right angles to the axis of pipe. Smooth and deburr cut pipe ends.

E. Do not lay any HDPE pipe until the CM has approved the bedding conditions.

F. The maximum allowable depth of cuts, gouges, or scratches on the exterior surface of the solid wall HDPE outlet pipe or fittings is 10 percent of the wall thickness. The interior of the pipe and fittings shall be free of cuts, gouges, and scratches. Sections of pipe with excessive cuts, gouges, or scratches, as determined by the Engineer, shall be removed and the ends of the pipe rejoined at no cost to the Owner.

G. Blocking under piping shall not be permitted.

H. Whenever pipe installation activities are not actively in progress, protect open ends of pipe that have been placed within the trench from clogging by sediment.

I. Survey the installed location and elevation of all new piping for inclusion in the "As-Built" drawings.

END OF SECTION

SECTION 33 49 00 - PRECAST STRUCTURES

PART 1 – GENERAL

1.01 DESCRIPTION

A. Scope:

1. Contractor shall provide all labor, materials, equipment, and incidentals as shown, specified, and required to furnish, install, and test precast concrete storm drainage structures.

B. Coordination:

1. Review installation procedures under this and other Sections and coordinate the installation of items that must be installed with or before manholes.

C. Related Sections:

1. Section 31 23 00 – Excavation and Fill.

1.02 REFERENCE STANDARDS

A. The following standards are referenced in this Section:

1. ANSI A14.3, American National Standard for Ladders, Fixed, Safety Requirements.
2. ASTM A48/A48M, Standard Specification for Gray Iron Castings.
3. ASTM C32, Standard Specification for Sewer and Manhole Brick (Made from Clay or Shale).
4. ASTM C144, Standard Specification for Aggregate for Masonry Mortar.
5. ASTM C150/C150M, Standard Specification for Portland Cement.
6. ASTM C207, Standard Specification for Hydrated Lime for Masonry Purposes.
7. ASTM C443, Standard Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets.
8. ASTM C478, Standard Specification for Precast Reinforced Concrete Manhole Sections.
9. ASTM C923, Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes, and Laterals.
10. ASTM C1107/C1107M, Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink).

1.03 QUALITY ASSURANCE

A. Regulatory Requirements:

1. Laws and Regulations applying to the Work under this Section include, but are not limited to, the following:
   a. 29 CFR 1910, Occupational Safety and Health Standards.
2. Comply with requirements and recommendations of authorities having jurisdiction over the Work.
3. Obtain required permits for Work in roads, rights-of-way, and other areas of the Work.

1.04 SUBMITTALS

A. Action Submittals:

1. Shop Drawings: Submit drawings showing design and construction details for the following:
   a. Precast concrete structures, including details of joints between the bases and riser sections and stubs or openings for connections.
   b. Access entry steps.
   c. Cast iron frames and covers.
2. Product Data: Submit manufacturer's data and specifications for the following:
   a. Resilient pipe connectors and corrugated pipe adapter.
   b. Cast iron frames and covers.

B. Closeout Submittals:

1. Record Documentation:
   a. Maintain accurate and up-to-date record documents showing modifications made in the field, in accordance with approved submittals, and other Contract modifications relative to Work. Submittal shall show actual location of all completed Work and appurtenances at same scale as the Drawings.
   b. Show structure(s) with rim and invert elevations referenced to Project datum.

PART 2– PRODUCTS

2.01 PRECAST CONCRETE

A. Except where otherwise specified, precast structure components shall consist of reinforced concrete pipe sections especially designed for structure construction and manufactured in accordance with ASTM C478, except as modified herein.

B. Precast, reinforced concrete structure bases, riser sections, flat slab tops, and other components shall be manufactured by wet cast methods only, using forms that will provide smooth surfaces free from irregularities, honeycombing, or other imperfections.

C. Joints between structure components shall be bell-and-spigot-type, employing a single, continuous rubber O-ring gasket complying with ASTM C443. The circumferential and longitudinal steel reinforcement shall extend into the bell and spigot ends of the joint without breaking the continuity of the steel.

D. All precast structure components shall be of approved design and of sufficient strength to withstand the loads imposed upon them. They shall be designed for a minimum earth cover loading of 130 pounds per cubic foot, AASHTO H-20 wheel loadings, and an allowance of 30 percent in roadways and 15 percent in rights-of-way for impact. Precast structure bases shall have two cages of reinforcing steel in their walls, each of the area equal to that required in the riser sections. Wall thickness shall be not less than five inches. Concrete flat slab tops shall be not less than six inches thick.

E. Lifting holes, if used in structure components, shall be tapered, and no more than two holes shall be cast in each section. Tapered, solid rubber plugs shall be furnished to seal the lifting holes. Lifting holes shall be made to be sealed by plugs driven from the outside face of the section only.

F. The point of intersection of the sewer pipe centerlines shall be marked with a 1/4-inch diameter steel pin firmly enclosed in the floor of each structure base and protruding approximately one inch above the finished floor of the base.

G. Mark date of manufacture and name or trademark of manufacturer on inside of barrel.

H. The barrel of the structure shall be constructed of various lengths of riser pipe manufactured in increments of one foot to provide the correct height with the fewest joints. Openings in the barrel of the structures for sewer or drop connections will not be permitted closer than one foot from the nearest joint. Special structure base or riser sections shall be furnished as necessary to meet this requirement.

I. Pipe openings shall be precast, or machine cored. Provide resilient pipe connector and corrugated pipe adapter complying with ASTM C923 for each opening. Connectors shall be flexible and watertight.

J. A precast flat slab top shall be provided at the top of the structure barrel to receive the cast iron frame and cover.

K. Structure steps shall conform to the requirements of 29 CFR 1910.27 and ANSI A14.3. Vertical separation of steps shall be uniform at maximum of 12 inches on centers. Steps shall project evenly from structure walls.

2.02 FRAMES AND COVERS

A. Cast iron 24-inch diameter frames and covers shall be provided for the “closed” manhole cover types and cast iron 30-inch square frames and grates shall be provided for the “open” manhole cover types identified in the Design Drawings. Frames and covers shall be designed for AASHTO H20 wheel loadings.

1. Castings: ASTM A48/A48M, Class No. 30B. Provide castings of uniform quality, free from pouring faults, sponginess, cracks, blowholes, and other defects in positions affecting their strength.

2. Identification: The words “STORM SEWER” shall be cast integrally in center of cover in raised letters.

3. Manufacturers: Provide products of one of the following:
    a. East Jordan Iron Works, Inc.
    b. Neenah Foundry Company.
    c. Or equal.

2.03 RELATED MATERIALS

A. Aggregate Bedding Material for Structures: Pipe bedding material in accordance with Section 31 23 00 – Excavation and Fill,, unless otherwise shown or indicated.

B. Non-Shrink Grout: ASTM C1107/C1107M.

1. Pre-packaged, non-metallic, cementitious grout requiring only the addition of water at the Site.

2. Minimum Compressive Strength at 28 Days: 7,000 psi.

3. Product and Manufacturer: Provide one of the following:
    a. NS Grout by Euclid Chemical Company.
    b. Set Grout by Master Builders, Inc.
    c. NBEC Grout by Five Star Products, Inc.
    d. Or equal.

C. Grade Rings: ASTM C478.

D. Brick: ASTM C32, Grade MS.

E. Mortar: Mortar shall be composed of Portland cement, hydrated lime, and sand, in which the volume of sand shall not exceed three times the sum of the volumes of cement and lime.

1. Portland Cement: ASTM C150/C150M, Type II.
2. Hydrated Lime: ASTM C207, Type S.
3. Sand: ASTM C144, except that 100 percent of the sand shall pass the No. 8 sieve.

PART 3 – EXECUTION

3.01 INSPECTION

A. Verify Site conditions, including locations, invert elevations, materials, and dimensions of existing piping to which connections are to be made, before ordering precast structures.

B. Examine the areas and conditions under which the Work will be performed and notify Engineer in writing of conditions detrimental to the proper and timely completion of the Work. Do not proceed with the Work until unsatisfactory conditions are corrected in a manner acceptable to CM.

3.02 INSTALLATION

A. Precast Structure Bases:

1. Install precast bases on not less than 12-inch layer of aggregate bedding material placed and compacted in accordance with Section 31 23 00. Precast bases shall be set at the proper grade and carefully leveled and aligned.

B. Precast Structure Sections:

1. Install sections, joints, and gaskets in accordance with manufacturer's recommendations.
2. Set sections vertical with steps and sections in true alignment. All joints shall be sealed inside and out with non-shrink grout and troweled smooth to the contour of the wall surface. Raised or rough joint finishes will not be accepted.
3. Lifting holes shall be sealed tight with a solid rubber plug driven into the hole from the outside of the barrel and the remaining void filled with 1:2 cement-sand mortar.

C. Structure Channels:

1. All invert channels through structures shall be constructed of Class "A" concrete in accordance with Section 03 00 05.
   a. Accurately shape invert to a semi-circular bottom conforming to inside of connecting pipes, and steel-trowel finish to a smooth, dense surface.
   b. Make changes in size and grade gradually.
   c. Make changes in direction of entering sewer and branches to a true curve of as large a radius as structure size will permit.
   d. Benches shall be built up to the heights shown or as directed by Engineer and shall be given a uniform float finish. Care shall be taken to slope all benches for proper drainage to the invert channel.

D. Grade Rings:

1. Grade rings or brick stacks shall be used for all precast structures and structures, where required. Stacks or grade rings shall be a maximum of 12 inches in height, constructed on the flat slab or conical top on which the structure frame and cover shall be placed. The height of the brick stack or grade rings shall be such as required to bring the structure frame to the proper grade.

2. Each grade ring or brick course shall be laid in a full bed of mortar and shall be thoroughly bonded.

3. Brick shall be satisfactorily wet when being laid and each brick shall be laid in mortar so as to form full bed, end, and side joints in one operation. The joints shall not be wider than 3/8 inch, except when the bricks are laid radially, in which case the narrowest part of the joint shall not exceed 1/4 inch. Masonry work shall be kept moist for a period of three days after completion, and precautions shall be taken to prevent freezing during cold weather.

4. The outside of brick stacks and grade rings shall be neatly plastered with 1/2 inch of cement mortar as the Work progresses.

3.03 GRADING AT STRUCTURES

A. All structures and structures in unpaved areas shall be built, as shown or directed by Engineer, to an elevation higher than the original ground. The ground surface shall be graded to drain away from the structure. Fill shall be placed around structures to the level of the upper rim of the structure frame, and the surface evenly sloped and graded to the existing surrounding ground, unless otherwise shown or directed by Engineer. The slope shall be covered with a minimum of four inches of topsoil, seeded, and maintained until a satisfactory growth of grass is obtained.

B. Structures in paved areas shall be constructed to meet the final surface grade. In paved areas, all structures shall be 1/2 inch below final wearing surfaces. Structures shall not project above finished roadway pavements to prevent damage from snowplows.

C. Contractor shall be solely responsible for the proper height of all structures and structures necessary to reach the final grade at all locations. Contractor is cautioned that Engineer's review of Shop Drawings for structure components will be general in nature and Contractor shall provide an adequate supply of random length precast structure riser sections to adjust any structure to meet field conditions for final grading.

END OF SECTION

SECTION 35 20 23 – VEGETATION REMOVAL AND SUBAQUEOUS BACKFILL

PART 1 – GENERAL

1.01 DESCRIPTION

A. Work Specified

1. Provide all supervision, labor, materials, tools, equipment, accessories, and appurtenances necessary to perform vegetation removal, backfill, and related Work.

2. Vegetation removal and subaqueous backfill is planned for the gravel pond (the Pond) located adjacent to the western boundary of the Site. Earthwork within the Pond will include the removal of vegetation within the pond and in the areas surrounding the pond where filling is specified and subsequent placement of fill materials to reach finished grade elevations as specified in the Design Drawings.

B. Related Specifications

1. Section 01 57 05 – Temporary Controls

2. Section 02 21 00 – Surveys

3. Section 31 11 00 – Clearing and Grubbing

1.02 REFERENCES

A. Not Used

1.03 QUALITY ASSURANCE

A. Applicable Codes, Standard, and Specifications:

1. Laws and Regulations applying to the Work under this Section include, but are not limited to, the following:
   a. 29 CFR 1910, Occupational Safety and Health Standards.
   b. 29 CFR 1926, Safety and Health Regulations for Construction.
   c. 49 CFR 171.8, Transportation, Definitions and Abbreviations.

2. Comply with applicable provisions and recommendations of the following:

3. Recommendations of the National Institute of Occupational Safety and Health (NIOSH).

4. Obtain required permits and approvals for excavation and fill Work, including work permits from right-of-way owners.

5. Comply with requirements of authorities having jurisdiction.

6. Whenever there is a conflict or overlap of the above reference, the most stringent provision shall be applicable.

1.04 SUBMITTALS (NOT USED)

PART 2– PRODUCTS

2.01 MATERIALS

A. Backfill

1. Reuse of site soils obtained from on-site excavations shall be used for Pond filling. Coarse, self-compacting, granular materials shall be used for initial placement in the Pond (i.e., to approximately one-foot above pond-water elevation at time of construction). Selection of on-site soils for Pond filling to be determined in coordination with the Engineer.

PART 3 – EXECUTION

3.01 VEGETATION REMOVAL

A. No vegetation removal activities may be initiated without the approval of the Construction Manager (CM) and the Owner.

B. Prior to the start of vegetation removal, the Contractor must install and operate a temporary hydraulic bypass/pump to remove water to the maximum extent practicable in order to complete the specified Work. Water removed from Pond by temporary bypass/pump to be discharged to adjacent gravel pond.

C. Prior to the start of backfill within the Pond, complete removal of vegetation and any debris along the shorelines and within the Pond as necessary to complete the Work.

D. Cleared vegetation and debris shall be managed in accordance with specification Section 31 11 00 – Clearing and Grubbing.

3.02 BACKFILLING

A. Backfill shall not be placed until all removal activities have been completed. The Pond backfill area shall be reviewed and approved by the CM/Engineer prior to placement of backfill materials.

B. The Pond areas shall be backfilled as follows:

1. The initial backfill placement shall be comprised of coarse, self-compacting material to approximately one-foot above the water surface elevation at the time of construction.
2. The completed initial backfill placement surface shall be dynamically compacted to ensure adequate placement densities have been achieved. The Contractor shall propose the type of dynamic compaction to be employed which will be reviewed by the Engineer prior to use.
3. Backfill materials shall be placed and compacted to the grades shown on the Design Drawings and as specified in the Contract Documents.

C. Survey control shall be maintained throughout backfill placement activities and be utilized to confirm the horizontal and vertical extents of placement have been achieved in accordance with Section 02 21 00 – Surveys.

END OF SECTION

SECTION 40 05 53 - HYDRANTS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Scope:
   1. Contractor shall provide all labor, materials, equipment, and incidentals as shown, specified, and required to furnish and install process valves, four-inch diameter and larger, and appurtenances, complete and operational.

B. Coordination:
   1. Review installation procedures under this and other Sections and coordinate installation of items that must be installed with or before process valves Work.

C. Related Sections:
   1. Section 33 05 05, Buried Piping Installation.

1.2 REFERENCES

A. Standards referenced in this Section are listed below:

   1. American Bearing Manufacturers Association (ABMA).
   2. ANSI B16.1, Cast-Iron Pipe Flanges and Flanged Fittings.
   3. ANSI B16.34, Valves-Flanged, Threaded and Welding end. (ASME B16.34).
   4. ANSI/NSF 61 Drinking Water Components – Health Effects.
   5. API STD 594, Check Valves, Flanged Lug, Wafer and Butt-Welding.
   6. API STD 598, Valve Inspection and Testing.
   7. ASTM A126, Specification for Gray Iron Castings for Valves, Flanges and Pipe Fittings.
   8. ASTM A536, Specification for Ductile Iron Castings.
   9. ASTM B62, Specification for Composition Bronze or Ounce Metal Castings.
   10. AWWA C500, Metal-Seated Gate Valves for Water Supply Service.
   11. AWWA C502, Dry-Barrel Fire Hydrants.
   12. AWWA C509, Resilient-Seated Gate Valves for Water Supply Service.
   13. AWWA C550, Protective Interior Coatings for Valves and Hydrants.
   14. FS TT-C-494, Coating Compound, Bituminous, Solvent Type, Acid-Resistant.

1.3 QUALITY ASSURANCE

A. Manufacturer's Qualifications:
   1. Manufacturer shall have minimum of five years of experience producing substantially similar materials and equipment to that required and be able to provide evidence of at least five installations in satisfactory operation for at least five years.

B. Component Supply and Compatibility:

1. Obtain each type of equipment and appurtenances included in this Section, regardless of the component manufacturer, from a single manufacturer of the type of process valve. For each type of valve, do not furnish valves of more than one manufacturer.

2. Supplier of each type of equipment specified shall review and approve or prepare all Shop Drawings and other submittals for all components associated with the type of process valve Supplier is furnishing.

3. Components shall be suitable for use in the specified service conditions. Components shall be integrated into the overall assembly by the process valve manufacturer.

1.4 SUBMITTALS

A. Action Submittals: Submit the following:

1. Shop Drawings:
   a. Installation drawings showing orientation of valve in both plan and elevation view. Drawings shall clearly identify valve and its appurtenances, including controls, actuators, valve stems, and other components. Show dimensions of valves and appurtenances in relation to piping and structural and architectural components, where applicable.

2. Product Data:
   a. Product data sheets.
   b. Complete catalog information, including dimensions, weight, specifications, and identification of materials of construction of all parts.
   c. Corrosion resistance information to confirm suitability of valve materials for the application. Furnish information on chemical resistance of elastomers from elastomer manufacturer.
   d. Cv values and hydraulic headloss curves.

3. Testing Plans:
   a. Submit plan for shop testing of each valve for which shop testing is specified, including testing plan's and test facility's limitations proposed.

B. Informational Submittals: Submit the following:

1. Certificates:
   a. Certificates of compliance with referenced standards, where applicable, including those of AWWA, NSF, and others required by Engineer.

2. Manufacturer Instructions:
   a. Submit manufacturer's instructions for handling, storing, and installing valves and appurtenances. Provide templates and setting drawings for valves and appurtenances that require anchor bolts or similar anchorages.

3. Source Quality Control Submittals:
   a. Submit copies of shop test results and inspection data, certified by manufacturer.

4. Field Quality Control Submittals:
   a. Submit results of field tests required.

5. Supplier’s Reports:
    a. When requested by Engineer, submit written report of results of each visit to Site by Supplier’s serviceman, including purpose and time of visit, tasks performed, and results obtained.

6. Qualifications Statements:
    a. When requested by Engineer, submit manufacturer’s qualifications demonstrating compliance with the Specifications, including list of existing installations with contact names and telephone number(s) for each.

C. Closeout Submittals: Submit the following:

1. Operations and Maintenance Data:
    a. Furnish operation and maintenance manuals.
    b. Furnish in operations and maintenance manuals complete nameplate data for each valve and electric actuator.

D. Maintenance Material Submittals: Submit the following:

1. Spare Parts, Extra Stock Materials, and Tools:
    a. Spare Parts and Extra Stock Materials: Furnish as specified for each valve type.
    b. Tools: Furnish two sets of special tools (excluding metric tools, if applicable) for each size and type of valve furnished.

1.5 DELIVERY, STORAGE AND HANDLING

A. Packing, Shipping, Handling, and Unloading:

1. Deliver materials and equipment to Site to ensure uninterrupted progress of the Work. Deliver anchorage products that are to be embedded in concrete in ample time to prevent delaying the Work.

2. Inspect boxes, crates, and packages upon delivery to Site and notify Engineer in writing of loss or damage to materials and equipment. Promptly remedy loss and damage to new condition in accordance with manufacturer’s instructions.

3. Conform to Section 01 65 00, Product Delivery Requirements.

B. Storage and Protection:

1. Keep products off ground using pallets, platforms, or other supports. Store equipment in covered storage and prevent condensation and damage by extreme temperatures. Store in accordance with manufacturer's recommendations. Protect steel, packaged materials, and electronics from corrosion and deterioration.

2. Conform to Section 01 66 00, Product Storage and Handling Requirements.

PART 2 - PRODUCTS

2.1 GENERAL

A. Valves, General:

1. Provide each valve with manufacturer's name and rated pressure cast in raised letters on valve body.

2. Provide valves with brass or Type 316 stainless steel nameplate attached with Type 316 stainless steel screws. Nameplates shall have engraved letters displaying the following minimum information:
   a. Valve size.
   b. Pressure and temperature ratings.
   c. Application (other than water and wastewater).
   d. Date of manufacture.
   e. Manufacturer's name.

3. Provide valves to turn clockwise to close, unless otherwise specified.

4. Provide valves with permanent markings for direction to open.

5. Manually operated valves, with or without extension stems, shall require not more than 40-pound pull on manual operator to open or close valve against specified criteria. Gear actuator and valve components shall be able to withstand minimum pull of 200 pounds on manual operator and input torque of 300-foot pounds to actuator nut. Manual operators include handwheel, chainwheel, crank, lever, and T-handle wrench.

B. Valve Materials:

1. Valve materials shall be suitable for the associated valve's service or application, as shown.

2. Protect wetted parts from galvanic corrosion caused by contact of different metals.

3. Wetted components and wetted surfaces of valves used with potable water or water that will be treated to become potable shall conform to ANSI/NSF 61.

4. Clean and descale fabricated stainless-steel items in accordance with ASTM A380 and the following:
   a. Passivate all stainless steel welded fabricated items after manufacture by immersing in pickling solution of six percent nitric acid and three percent hydrofluoric acid. Temperature and detention time shall be sufficient for removing oxidation and ferrous contamination without etching surface. Perform complete neutralizing operation by immersing in trisodium phosphate rinse followed by clean water wash.
   b. Scrub welds with same pickling solution or pickling paste and clean with stainless steel wire brushes or by grinding with non-metallic abrasive tools to remove weld discoloration, and then neutralize and wash clean.

2.3 RESILIENT-SEATED GATE VALVES

A. Manufacturers: Provide products of one of the following:

1. M&H Valve Company

2. US Pipe and Foundry.

3. Or equal.

B. General:

1. Provide valves conforming to AWWA C509 and as specified in this Section.
2. Sizes: Four-inch through 12-inch diameter, 16-inch and 20-inch diameter.
3. Type:
   a. Provide non-rising stem (NRS) valves for buried service.
   b. For interior and exposed service, provide outside screw and yoke (OS&Y) rising-stem valves, unless otherwise specified.
   c. Provide position indicators for NRS valves used in exposed service.
4. Minimum Rated Working Pressure:
   a. Valves 12-inch Diameter and Smaller: 200 psig.
   b. Valves 16-inch and 20-inch Diameter: 150 psig.
5. Maximum Fluid Temperature: 150 degrees F.
6. Provide valves with fully encapsulated resilient wedges, unless otherwise specified.

C. Materials of Construction: Shall conform to AWWA C509 and shall be as follows:

1. Valve Body, Bonnet, and Stuffing Box: Cast-iron.
2. Wedge: Cast-iron, symmetrically and fully encapsulated with molded rubber having minimum 1/8-inch thickness.
3. Stem: Manganese bronze.
4. Rubber Items: Buna-N or other synthetic rubber suitable for the application.
5. Internal and external bolting and other hardware including pins, set screws, plug, studs, bolts, nuts, and washers shall be Type 316 stainless steel.

D. Interior Coating:

1. Valves shall be coated inside. Steel, cast-iron, and ductile iron surfaces, except machined surfaces, shall be epoxy coated in accordance with AWWA C550.

E. Testing:

1. Test valves in valve manufacturer’s shop in accordance with AWWA C509.

F. Gear Actuators for Manually Operated Valves:

1. Provide valves with gear actuators conforming to AWWA C500.
2. Size gear actuators for the following maximum differential pressures:

2.20 FIRE HYDRANTS

A. Products and Manufacturers: Provide one of the following:

1. Mueller, Model: Super Centurion.
2. Kennedy, Model: Guardian K81D.
3. Or equal.

B. General:

1. Provide fire hydrants conforming to AWWA C502, Underwriters' Laboratories-listed and Factory Mutual approved, and as specified herein.

2. Rated Working Pressure: 175 psig, minimum.

3. Rated Hydrostatic Test Pressure: 400 psig, minimum.

4. Length of Bury: as shown on the Design Drawings.

C. Construction:

1. Type: Three-way fire hydrants with two hose nozzles and one pumper nozzle.

2. Nozzles:
   a. Provide one 4.5-inch diameter pumper nozzle and two 2.5-inch diameter hose nozzles with NFPA threads.
   b. Nozzles shall be O-ring sealed, threaded, and retained with stainless steel locks. Nozzles shall be field replaceable.
3. Main Valve and Drainage Assembly:
   a. Opening: 5.25-inch diameter.
   b. Main valve shall be compression type provided with upper and lower metal plates and lower valve plate nut.
   c. Barrel drainage shall be through dual drain valves. Opening and closing of main valve shall cause force-flush of dual drain ports.
   d. Main valve seat ring shall be easily replaceable from above-ground.
4. Provide an oil filled reservoir for lubrication of stem threads and bearing surfaces. Oil shall be U.S. Food and Drug Administration approved and ANSI/NSF 61-listed, and shall flow freely in temperature range of -60 to 158 degrees F.
5. Provide traffic flange in barrel and safety coupling in stem.
6. Inlet Connection: Six-inch diameter mechanical joint, restrained.

D. Materials of Construction: Materials of construction shall conform to the requirements of AWWA C502 and shall be as follows:

1. Upper and Lower Barrels, Shoe, and Bonnet: Cast-iron.

2. Stem and Accessories:
   a. Upper and Lower Stems: Steel.
   b. Operating Nut: Bronze.
   c. Safety Coupling: Stainless steel.

3. Nozzles:
   a. Pumper and Hose Nozzles: Bronze.
   b. Nozzle Caps: Cast-iron.
   c. Cap Chains: Steel.

4. Main Valve Assembly:
   a. Main Valve: Rubber.
   b. Upper Valve Plate: Bronze.
   c. Lower Valve Plate and Nut: Cast-iron.

5. Drain Valves:
   a. Drain Ring Housing: Cast-iron.
   b. Drain Ring: Bronze.

6. O-ring Gaskets: Rubber.

7. External Assembly Bolts: Steel.

8. Internal Pins and Other Hardware: Stainless steel, ASTM A276.

E. Testing:

1. Test each fire hydrant in manufacturer’s shop in conformance with AWWA C502.

F. Interior Coating:

1. Hydrants shall be coated on the interior. Steel, cast-iron, and ductile iron surfaces, except machined surfaces, shall be epoxy coated in accordance with AWWA C550.

G. Exterior Painting:

1. Below- and above-ground painting shall be as specified under Article 2.27 of this Section and Article 2.28 of this Section.

2.24 APPURTENANCES FOR BURIED METALLIC VALVES

A. Wrench Nuts:

1. Provide wrench nuts on buried valves of nominal two-inch size, in accordance with AWWA C500.

2. Arrow indicating direction of opening the valve shall be cast on the nut along with the word “OPEN”.

3. Material: Ductile iron or cast-iron.

4. Secure nut to stem by mechanical means.

B. Extension Stems for Non-Rising Stem Gate Valves and Quarter-turn Buried Valves:

1. Provide extension stems to bring operating nut to six inches below valve box cover.

2. Materials of Stems and Stem Couplings: Type 316 stainless steel.

3. Maximum Slenderness Ratio (L/R): 100

4. Provide top nut and bottom coupling of ductile iron or cast-iron with pins and set screws of Type 316 stainless steel.

C. Valve Boxes:

1. Valve boxes shall be as indicated and as required.

2. Type: Heavy-duty, suitable for highway loading, two-piece telescopic, and adjustable. Lower section shall enclose valve operating nut and stuffing box and rest on valve bonnet.

3. Material: Cast-iron or ductile iron.

4. Coating: Two coats of asphalt varnish conforming to FS TT-C-494.

5. Marking: As required for service.

2.26 TOOLS, LUBRICANTS, AND SPARE PARTS

A. Provide the following T-handle operating wrenches for buried valves:

1. Length of T-Handle Operating Wrench: Provide 2-foot minimum height above finish grade.

2. Quantity: 1.

B. Lubricants: For valves, actuators, and appurtenances requiring lubricants, provide suitable lubricants for initial operation and for first year of use following Substantial Completion. Lubricants for equipment associated with conveying potable water or water that will be treated to become potable shall be food-grade and ANSI/NSF 61-listed.

C. Tools, spare parts, and maintenance materials shall conform with Section 01 78 43, Spare Parts and Extra Materials.

2.27 PAINTING OF EXPOSED VALVES, HYDRANTS, AND APPURTENANCES

A. Exterior steel, cast-iron, and ductile iron surfaces, except machined surfaces of exposed valves and appurtenances, shall be finish painted in manufacturer's shop. Surface preparation, priming, finish painting, and field touch-up painting shall conform to Section 09 91 00, Painting.

2.28 PAINTING OF BURIED VALVES

A. Exterior steel, cast-iron, and ductile iron surfaces, except machined or bearing surfaces of buried valves, shall be painted in valve manufacturer's shop with two coats of asphalt varnish conforming to FS TT-C 494.

PART 3 - EXECUTION

3.1 INSPECTION

A. Examine conditions under which materials and equipment are to be installed and notify Engineer in writing of conditions detrimental to proper and timely completion of the Work. Do not proceed with the Work until unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. General:

1. Install valves and appurtenances in accordance with:
   a. Supplier's instructions and the Contract Documents.
   b. Requirements of applicable AWWA standards.
   c. Applicable requirements of Section 33 05 05, Buried Piping Installation.

2. Install valves plumb and level. Install all valves to be free from distortion and strain caused by misaligned piping, equipment, and other causes.

3. Position swing check valves and butterfly valves so that, when valve is fully open, valve disc does not conflict with piping system elements upstream and downstream of valve.

B. Exposed Valves:

1. Provide supports for large or heavy valves and appurtenances as shown or required to prevent strain on adjoining piping.

2. Operators:
   a. Install valves so that operating handwheels or levers can be conveniently turned from operating floor without interfering with access to other valves, piping, structure, and equipment, and as approved by Engineer.
   b. Avoid placing operators at angles to floors or walls.
   c. Orient chain operators out of way of walking areas.
   d. Install valves so that indicator arrows are visible from floor level.
   e. For motor-operated valves located lower than five feet above operating floor, orient motor actuator to allow convenient access to pushbuttons and handwheel.

3. Floor Stands and Stems:
   a. Install floor stands as shown and as recommended by manufacturer.
   b. Provide lateral restraints for extension bonnets and extension stems as shown and as recommended by manufacturer.
   c. Provide sleeves where operating stems pass through floor. Extend sleeves two inches above floor.

C. Buried Valves:
1. Install valve boxes plumb and centered, with soil carefully tamped to a lateral distance of four feet on all sides of box, or to undisturbed trench face if less than four feet.
2. Provide flexible coupling next to each buried valve.

3.3 FIELD QUALITY CONTROL

A. Field Tests:

1. Adjust all parts and components as required to provide correct operation of valves.

2. Conduct functional field test on each valve in presence of Engineer to demonstrate that each valve operates correctly.

3. Verify satisfactory operation and controls of motor operated valves.

4. Demonstrate satisfactory opening and closing of valves at specified criteria requiring not more than 40 pounds effort on manual actuators.

5. Test ten percent of valves of each type by applying 200 pounds effort on manual operators. There shall be no damage to gear actuator or valve.

END OF SECTION

Appendix D

Geotechnical Calculations

ARCADIS

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.: 30197838**

Calc No.: **D-1** **Subject:** **Leachate Collection Layer Design**

Prepared By: **Maeve Tucker** **Date:** **February 13, 2024**

Reviewed By: **Mandy Giampaolo** **Date:** **February 13, 2024**

Objective

Evaluate the global slope stability of the proposed Upland Disposal Facility (UDF) at five cross section locations (Sections A, B, C, D, and E) as shown in Attachment A. The objectives of the slope stability evaluations summarized herein include:

- Confirm stability meets design criteria under a static load case for temporary conditions related to excavation and consolidated material grading.
- Confirm stability meets design criteria under both static and seismic load cases for final buildout of UDF.

References

1. Arcadis. 2024. UDF Final Design Plan. GE-Pittsfield/Housatonic River Site. February.
2. Holtz and Kovacs. *An Introduction to Geotechnical Engineering,* Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1981.
3. Joseph E. Bowles. *Foundation Analysis and Design, 4th Edition*, McGraw-Hill, Inc., 1988.
4. Arcadis. 2024. Stability Evaluation of Final Buildout – Veneer Stability. Upland Disposal Facility Area. GE-Pittsfield/Housatonic River Site, Lee, Massachusetts. February.
5. SLOPE/W® 2021.3 Version 11.2.2.23310 by GeoStudio for slope stability using Spencer's Method.
6. US Geological Survey (USGS) Earthquake Hazards Program - Unified Hazard Tool.

Attachments

A. Upland Disposal Facility Configuration with Test Boring and Cross-Section Locations

B. Soil Analysis

C. Global Stability – Slope/W Output

Assumptions

1. Critical Stability Sections: The proposed final grading for the UDF is shown on Drawing 8 (Reference 1, Appendix A). The proposed excavation subgrades, perimeter berm limits and existing ground surface is also shown on Drawings 1 through 7 of Appendix A of Reference 1. Based on review of soil conditions and proposed grades, five section locations are determined to be critical to the evaluation. Though final grading is fairly consistent across the proposed grading design, multiple sections were

analyzed due to the variation in soils across the site. The locations of the sections are included in Attachment A and are summarized below:

a. Section A: This section is representative of the proposed grading and subsurface conditions in the southern portion of the proposed UDF. This section also cuts through a low-lying area of the site and includes the tallest perimeter berm in this area of the UDF.

b. Section B: This section is located through the longest slope on the western side of the proposed grading design and is representative of the deepest excavation to baseliner subgrade.

c. Section C: This section is representative of the shortest slope length for the proposed UDF. It is also located on the western side of the proposed grading design where the perimeter berm is of minimal height.

d. Section D: This section is located through the northwestern end of the proposed grading design. It was selected to evaluate the subsurface conditions in this area and the proposed filling of the existing Gravel Pit Pond.

e. Section E: This section is through a typical slope on the northeastern end of the proposed grading design, is representative of slope conditions with no perimeter berm, and deepest excavation to baseliner subgrade.

2. Stratigraphy: A total of 22 borings were completed to evaluate the stratigraphy and soil conditions across the Site. In general, the stratigraphy consists of alternating layers of silty sands and mixed deposits overlying bedrock. The stratigraphy used in the stability analyses was developed from 19 of these explorations, as listed in Table 1 for each section evaluated.

Table 1 – Boring Summary

Section	Boring Designations
Section A	MW-2022-9, B-2022-6, B-2022-7, MW-2022-6, PZ-2022-7, B-2022-1
Section B	PZ-2022-5, B-2022-1, MW-2022-8, B-2022-6, B-2022-5, MW-2022-5
Section C	MW-2022-8, B-2022-5, B-2022-3, B-2022-2, MW-2022-4
Section D	B-2022-2, PZ-2022-2, B-2022-3, MW-2022-3, PZ-2022-1
Section E	B-2022-2, PZ-2022-2, PZ-2022-3, MW-2022-1

3. Design Soil Parameters: Material parameters for the stability analyses were developed from a review of the subsurface investigations, results of laboratory testing of selected samples, published correlations and engineering judgement. The soil analysis completed to support the development of design parameters for existing site soils is included in Attachment B. These parameters are summarized in Table 2 below. Table 2 also includes the parameters developed for the UDF materials and the basis for their selection.

Table 2 – Material Parameters

Soil Layer	Unit Weight (pcf)	Internal Friction Angle (deg)	Cohesion (psf)
Consolidated Material (1)	110	30	25
Upper Fine Sands and Silts	115	30	0
Upper Mixed Deposits	120	34	0
Lower Fine Silts and Sands	120	32	0
Lower Mixed Deposits	130	36	0
General Fill (2)	110	30	0
Aggregate Fill (3)	130	34	0
UDF Cap Soils (4)	110	32	0
Base Liner System (5)	57.6	24	0

Notes:

1. Parameters for the Consolidated Material assumed that the dredged sediment from the Housatonic River is generally granular, typically a silty sand based on review of available sediment data collected by others from in-river samples. Soil parameters developed for this material assumed placement methods would yield a granular soil having a medium-dense consistency.
2. Excavated on-site soils are proposed for re-use as General Fill. Parameters for the General Fill were developed for silty sand soils assuming industry standard placement methods to a medium- dense consistency.
3. Aggregate Fill is proposed for backfilling the Gravel Pit Pond to subgrade level. It is assumed that the aggregate fill is an angular self-compacting material, equivalent to a No. 2 stone gradation. For conservatism, a loose consistency has been assumed for developing the aggregate density and strength parameters.
4. Parameters for the UDF Cap Soils were developed for granular soils assuming industry standard placement methods to a medium-dense consistency.
5. The UDF design includes a baseliner system beneath the Consolidated Materials, extending across the floor of the UDF and along the interior side slopes of the perimeter berm/excavation, consisting of a combination of geomembrane and clay liners. The baseliner system will consist of two composite liners – an upper (primary) liner and a lower (secondary) liner. For the purposes of this stability analysis, the base liner materials are modeled as two systems with an interface angle of 24 degrees, which is slightly less than the minimum required interface angle under peak conditions for the system. (**Reference 4**)

4. Groundwater Level: A piezometric surface is included in the stability analyses for the UDF based on groundwater elevations encountered during boring investigations and from review of monitoring well data. For Section D, the piezometric surface through the Gravel Pit Pond is estimated and considers the post-construction grades in the pond area (i.e., filling of pond during construction of the UDF).

5. A horizontal seismic coefficient of 0.084g was used to evaluate the stability of the UDF under pseudo-static conditions. The coefficient was based on the site location entered into the USGS Unified Hazard Tool (Reference 6).

6. Both circular and block searches were used in the stability analyses. Sliding block searches are

conducted to evaluate the stability at the geotextile interface in the base liner system.

7. Surcharge: A surcharge of 250 psf over a minimum 50-foot length is assumed and based on temporary equipment loads during construction. This surcharge was included in static cases only for both temporary and final buildout conditions.

8. Factors of Safety: Global stability is analyzed for each critical section to determine adequate factor of safety (FOS) values under the various soil conditions. Minimum acceptable FOS values are as follows:

    a. Static FOS – 1.5.

    b. Seismic FOS – 1.0.

    c. Temporary FOS – 1.3.

Calculations

Global stability analyses for each critical section is completed using the SLOPE/W® computer program by Geo-Slope International, Ltd. (Reference 5). The analyses are performed using the Spencer method, which satisfies both moment and force equilibrium. Circular searches with forced exit and entry locations are performed to evaluate failure surfaces for the critical cross sections. The limits of the exit/entry locations are varied to estimate the critical failure surface and corresponding minimum FOS. Sliding block analysis are also performed to evaluate stability along the interface of the baseliner system for each critical section.

Detailed output from the stability analyses, including figures showing the critical failure surface, are provided in Attachment C. Findings are further discussed below.

<u>Temporary Slope Evaluations:</u>

Using the design criteria listed in the assumptions section, two scenarios for each critical section are evaluated for the following temporary conditions: 1.) excavation grading and 2.) consolidated material side slope. Exit/entry locations were positioned to evaluate the global stability of these temporary slopes under static conditions with a construction surcharge. Results of these evaluations are summarized in Table 3 below.

Table 3 – Factors of Safety – Temporary Slope Evaluations

Section	FOS Criteria	FOS Excavation Grading	FOS Consolidated Material Side Slope
Section A	1.30	1.74	1.35
Section B	1.30	1.79	1.79
Section C	1.30	1.74	1.80
Section D	1.30	1.77	2.07
Section E	1.30	3.01	2.11

Final UDF Buildout Evaluations:

Stability evaluations for the final UDF buildout are completed using circular specified searches that extend through the Consolidated Material and baseliner systems. Sliding block searches are also completed to evaluate the FOS sliding at geotextile interfaces in the base liner system.

The results of the circular specified searches are presented in Table 4 below for both static and pseudo-static load cases.

Table 4 – Factors of Safety – Final UDF Buildout – Circular Surfaces

Section	Static			Pseudo-Static		
	FOS Criteria	FOS Perimeter Berm	FOS Global	FOS Criteria	FOS Perimeter Berm	FOS Global
Section A	1.50	1.77	2.10	1.0	1.37	1.60
Section B	1.50	1.74	2.08	1.0	1.37	1.58
Section C	1.50	2.37	2.10	1.0	2.90	1.60
Section D	1.50	2.01	2.26	1.0	1.52	1.68
Section E	1.50	NA	2.41	1.0	NA	1.77

Note:
NA – Not Applicable

For the sliding block analyses, the critical failure surface was assumed to occur along the weakest interface in the base liner system. For the purposes of these global stability evaluations, the baseliner system was modeled in two layers and the lower, secondary liner, was assumed to an impenetrable material.

The results of the block specified searches are presented in Table 5 below for both static and pseudo-static load cases. As shown in Table 5, block searches for each section were completed to evaluate failure surfaces along the bottom of the UDF and for surfaces along the side slopes of the liner system.

Table 5 – Factors of Safety – Final UDF Buildout – Sliding Block Surfaces

Section	Bottom Baseliner				Side Slope Baseliner			
	Static		Pseudo-Static		Static		Pseudo-Static	
	FOS Criteria	FOS	FOS Criteria	FOS	FOS Criteria	FOS	FOS Criteria	FOS
Section A	1.50	5.60	1.0	3.66	1.50	3.59	1.0	2.62
Section B	1.50	4.36	1.0	3.20	1.50	2.49	1.0	1.91
Section C	1.50	4.23	1.0	3.09	1.50	2.40	1.0	1.84
Section D	1.50	3.89	1.0	2.84	1.50	2.56	1.0	1.95
Section E	1.50	3.36	1.0	2.48	1.50	2.57	1.0	1.88

Summary

The slope stability evaluations provided herein indicates that acceptable factors of safety (i.e., greater than 1.50 for static and 1.0 for seismic) can be achieved for the proposed UDF final buildout geometry given in Reference 1.   Acceptable factors of safety are also achieved for the temporary conditions (i.e., greater than 1.30 for static) considered for the excavation stages of construction and post Consolidated Material placement in the UDF.

The acceptable global stability results also provides guidance for placement of Consolidated Materials in the UDF. The parameters assumed for the Consolidated Materials in this stability evaluation should be considered when developing specification requirements and methods for placement of the Consolidated Materials.

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.: 30197838**

Calc No.: **D-2** **Subject:** **Settlement Analyses**

Prepared By: **Liz Pittman** **Date:** **February 26, 2024**

Reviewed By: **Mandy Giampaolo** **Date:** **February 26, 2024**

Objective

Estimate the elastic settlement from construction of the Upland Disposal Facility (UDF). Using a 3D generalized stratigraphy model of the complete site (Reference 1) to evaluate the following:

- Change in grade/settlement between pre- and post-construction elevation of the floor of the UDF.
- Change in grade/settlement of the consolidated material from installation of the final cover system.

References

1. Arcadis. 2024. UDF Final Design Plan. GE-Pittsfield/Housatonic River Site. February.
2. Settle3, 2023 Build 5.022 by RocScience.

Attachments

A. Soil Analysis

B. Settle3 Model

C. Settlement Cross-Sections

Assumptions

1. Limits of excavation and UDF construction were imported into Settle3 based on design drawings available at the time of the analysis. The proposed final grading for the UDF is shown on Drawing 8 (Reference 1, Appendix A). The proposed excavation subgrades, perimeter berm limits and existing ground surface is also shown on Drawings 1 through 7 of Appendix A of Reference 1.

2. Stratigraphy: A total of 22 borings were completed to evaluate the stratigraphy and soil conditions across the Site. In general, the stratigraphy consists of alternating layers of silty sands and mixed deposits overlying bedrock. The stratigraphy used in the settlement analyses was developed from the borings.

3. Design Soil Parameters: Material parameters for the settlement analyses were developed from a review of the subsurface investigations, results of laboratory testing of selected samples, published correlations and engineering judgement. The soil analysis completed to support the development of

design parameters for existing site soils is included in Attachment A. These parameters are summarized in Table 1 below. Table 1 also includes the parameters developed for the UDF materials and the basis for their selection.

Table 1 – Material Parameters

Soil Parameter	Fine Sands and Silts		Mixed Deposits		Consolidated Material[1]	
	Upper Layer	Lower Layer	Upper Layer	Lower Layer	Upper Layer	Lower Layer
Total Unit Weight, γ_T (pcf)	115	120	120	130	110	110
Modulus of Elasticity, Es (ksf)	200	300	800	1,200	250	400

ksf = kips per square foot
pcf = pounds per cubic foot

Notes:
1. Parameters for the Consolidated Material assumed that the dredged sediment from the Housatonic River is generally granular, typically a silty sand based on review of available sediment data collected by others from in-river samples. Soil parameters developed for this material assumed placement methods would yield a granular soil having a medium-dense consistency, with higher stiffness parameters assumed at depth. Based on previous project experience a unit weight of 110 pcf was chosen for this material.

5. Areas of former borrow pits within the footprint were assigned the lower stratigraphy, higher modulus values from review of conditions observed from borings in these low-lying areas. Former borrow pit areas can be seen in the figure below.

Figure 1: Former Borrow Areas

Calculations

Immediate settlement was calculated using RocScience Settle 3 program. Settle3 is a 3-dimensional program for the analysis of vertical settlement and consolidation under surface loads. However, displacements (settlement) and pore pressures are computed in one-dimension, assuming only vertical displacements can occur. An analysis for the subgrade floor and an analysis for the final cover system were completed as described below.

Subgrade Floor:

The settlement of the subgrade floor was modelled in 2 stages, existing conditions and final buildout grades. The existing grade was brought into Settle3 using a nonhorizontal surface on a 60 ft by 60 ft grid across the subgrade floor. The loads were then brought in as polygonal loads and the change in pressure applied from existing grade to final grade was calculated around the outside perimeter of the final cover area as well as the final cover plateau perimeter at the top of the disposal area. They were split into two loads to apply to the model, the outside perimeter, and the inside perimeter load. The inside perimeter load was calculated by finding the total load at the point and subtracting the load already applied by the outer perimeter, therefore a double load was not applied within the final cover plateau footprint.

A field grid of 600 evaluation points was utilized in the evaluation. Evaluation points were approximately 42 ft apart in spacing over the footprint of the evaluation. Output from Settle3 is included below as Figure 2 and in Attachment B. The figure below represents the immediate settlement contours for the final stage of construction. A maximum settlement of approximately 1.22 ft is estimated for the southwest corner of the floor.

A comparison of the design grade versus the design grade post-settlement was performed to confirm that the slopes within the subgrade were acceptable. Cross sections representing critical areas of the floor were developed to confirm acceptable grades post-final buildout and are included in Attachment C.

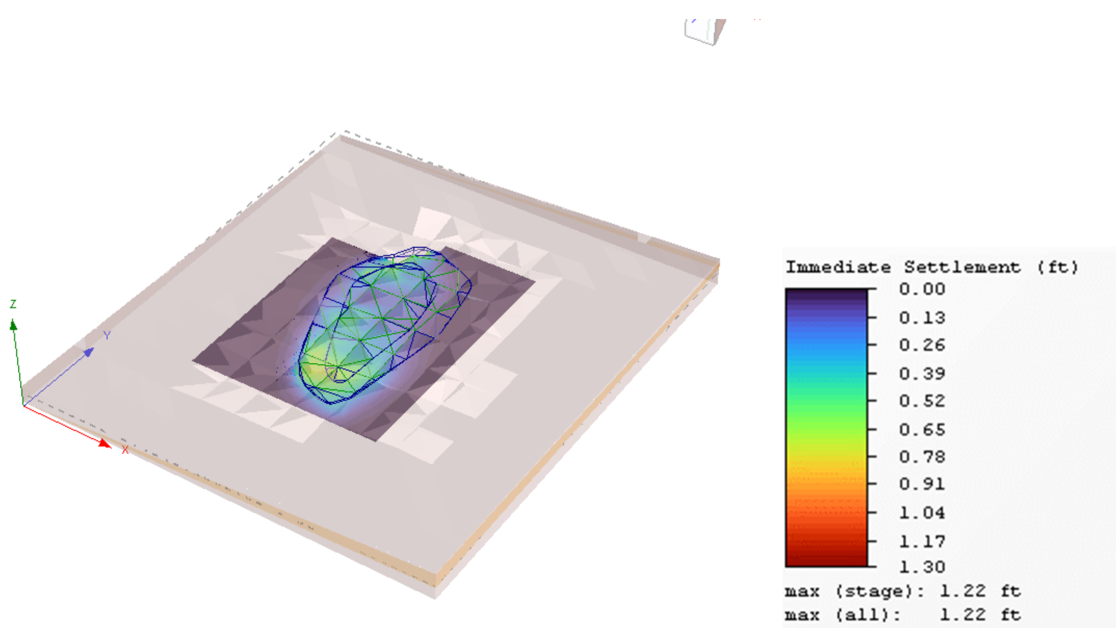


Figure 2: Subgrade Settlement Contours

As shown in the figures above and cross-sections in Attachment C, the maximum estimated floor settlements occurs in the southwest and northwest corners of the floor and gradually decreases across the subgrade.

Consolidated Material:

The consolidated material was evaluated for settlement after placement of the final cover system. The final cap (cover system) construction will consist of 1.5 ft of general soil fill and 0.5 ft of seeded topsoil, as shown in Figure 3 below:

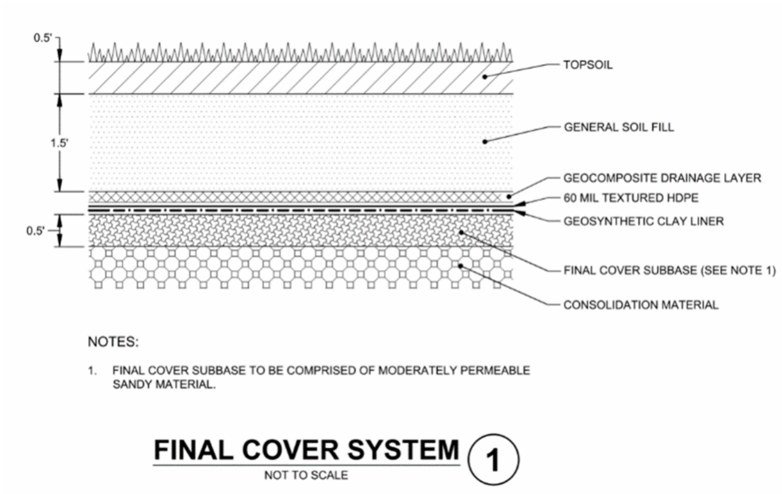


Figure 3: Final Cover System

The cap was modelled using two fill loads to represent each layer. A unit weight of 115 pcf was selected for the topsoil and a unit weight of 120 pcf was selected for the general fill material. Each layer was modelled in the software as a load and applied across the footprint of the final cover system.

A nonhorizontal query was performed over the footprint of the consolidation material and resulted in a maximum estimated settlement of 0.0037 ft (approximately 0.04 in). The greatest settlement occurs in the center of the final cover where the height of the placed consolidated material is the greatest. A graphical representation of the settlement estimated by Settle3 is shown below in Figure 4 and in Attachment B:

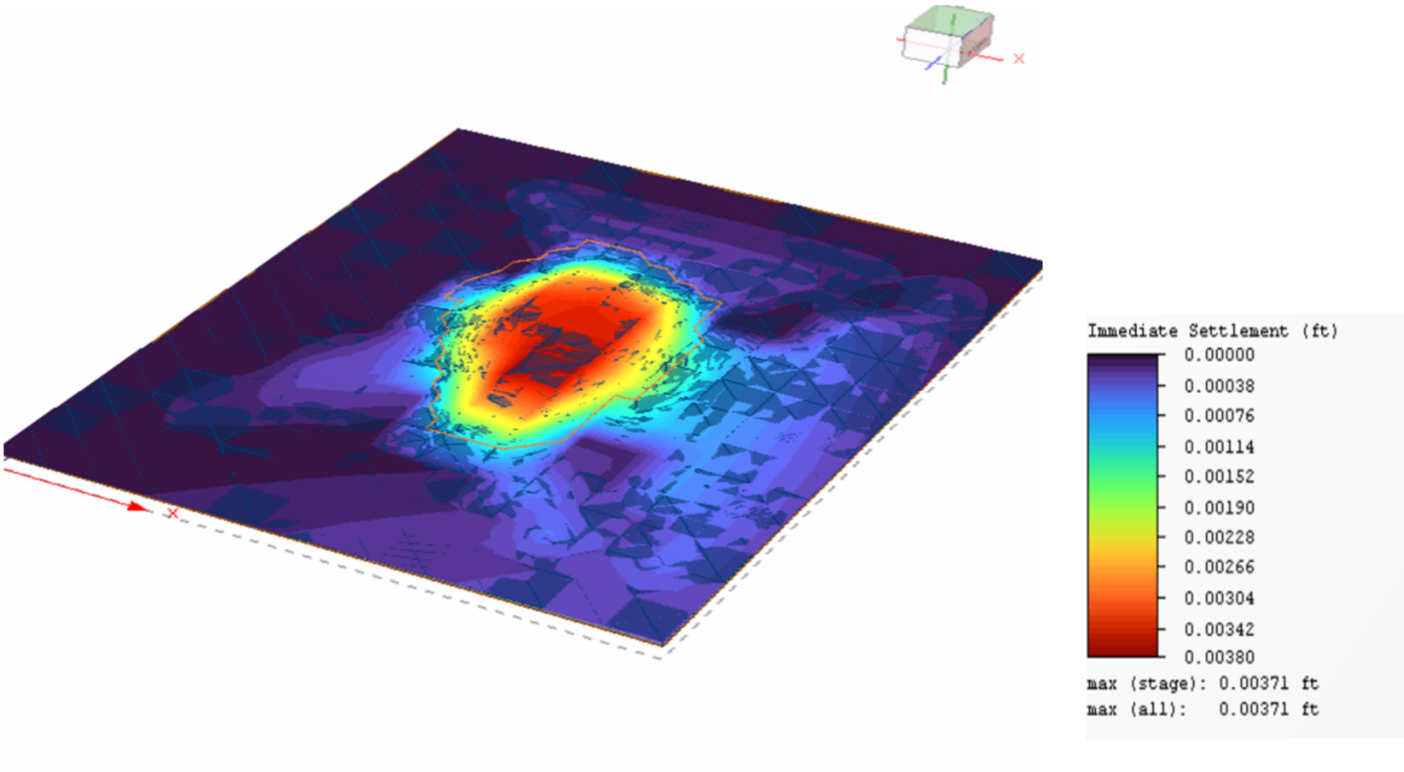


Figure 4: Consolidated Material Settlement

Cross sections showing estimated settlement of the cover system are included in Attachment C.

Conclusions

Settlement of the subgrade floor post-UDF construction is estimated to typically range from approximately 0.10 to 0.70 ft, with a maximum estimated settlement of 1.2 ft. The Settle3 evaluations showed that settlement would be greatest in the deeper areas of the UDF cells, which could result in the post-settlement baseliner floor grades becoming steeper (not flatter). As such, the baseliner floor subgrade is designed at 2% to conform with 310 CMR 19.110 but could potentially increase in areas to around 3.5% following consolidation. Assessment of the baseliner geomembrane performance in response to the estimated floor settlement was also conducted. That assessment showed that geomembrane strain resilience (tensile properties) for a 60-mil HDPE geomembrane will be sufficient to maintain barrier integrity after settlement.

For the settlement of the consolidated material, the loading from final cover system shows insignificant settlement across the footprint of the cover system. Evaluation of the estimated settlement conditions (i.e., the depths and locations within the UDF cells) and the design grading for the final cover system shows that the minimum 5% grade provided for the final cover is sufficient to maintain proper drainage of surface runoff and infiltration water collected in the final cover drainage layer post-settlement.

Attachment A

Soil Analysis

Attachment 2 – Soil Analysis for Design Parameters
General Electric Company
Upland Disposal Facility, Final Design Plan
GE-Pittsfield/Housatonic River Site

General

Soil parameters used in the evaluations of the proposed Upland Disposal Facility (UDF) were developed from the geotechnical data collected during the Pre-Design Investigation program and from the geologic units and soil properties described in the Revised Final Pre-Design Investigation Data Summary Report for Upland Disposal Facility Area, dated January 2024. The general stratigraphy consists of unconsolidated, glacial outwash deposits overlying marble bedrock. The unconsolidated deposits consist predominantly of fine-grained silts, sands, and gravels. These deposits vary laterally across the UDF area, and with depth, in terms of density, stratification, and heterogeneity.

From review of the boring logs and results of the laboratory testing, the glacial outwash deposits for design purposes are categorized into two main soil units: a fine sand and silt unit and a mixed sand, gravel, and silt unit. While these soil units are present at each boring location, the depths and thicknesses for each unit vary among boring locations.

The selection of design soil parameters is generally based on laboratory and field data in conjunction with the use of engineering judgment. For estimating drained strength parameters (internal friction angle) and unit weights, correlations with corrected SPT blow counts were used for the granular soil layers for the UDF area. Guidance on selection of shear strength properties is provided in various references as cited in Table 1 (USACE1995, Terzaghi et al. 1996, Bowles). Similar comparisons were completed for estimating the stiffness parameters of the soils and are based on review of various references as cited in Table 2.

The selected design soil parameters are as follows:

Soil Parameter	Fine Sands and Silts		Mixed Deposits	
	Upper Layer	Lower Layer	Upper Layer	Lower Layer
Total Unit Weight, γ_T (pcf)	115	120	120	130
Angle of Internal Friction, ϕ' (degrees)	30	32	34	36
Modulus of Elasticity, Es (ksf)	200	300	800	1,200

Notes:
ksf = kips per square foot
pcf = pounds per cubic foot

Basis for Design Soil Parameter Selection

Fine Sand and Silt Unit

Soils representative of the fine sand and silt unit generally consist of alternating layers of light brown silty sand and sandy silt. This unit of the glacial outwash is generally comprised of finer-grained soils with most of the gradation between silt and fine sand. Soil samples were typically described as light brown silty fine sand to sandy silt. Stringers of coarse sand and gravel were observed and are discontinuous across the unit. Results of laboratory testing classified soils in this unit typically as SM or ML having non-plastic fines as determined through Atterburg limit testing. Plots of corrected N-values with depth are included as Figures 1, 2 and 3.

From review of these figures and from visual observations of the split-spoon samples, this unit was divided into an upper and lower layer with the upper layer typically characterized as having lower N-values than samples collected from this same unit but at depths greater than 50 ft bgs. Further description of these layers follows along with basis for soil parameter selection.

- Upper Layer: Corrected blow counts for the upper layer of the fine sand and silt unit range from a low of 1 blow per foot (bpf) to greater than 50 bpf, as shown on Figures 1 and 2. The average corrected N-value for this layer is 24 bpf and for design purposes, a design N-value of 15 bpf is selected and is representative of the 25^{th} percentile of the N-value data for conservatism. Observations of the split-spoon samples indicate that the consistency of this unit is generally medium dense.

  Design values for unit weight and internal friction angle considered the fine-grained nature of this layer with added conservatism in the selected values. For the modulus of elasticity design value, several N-value based methods and references for typical values were reviewed as shown in Table 2. The selected value represents the lower end of the range of modulus of elasticity values for conservatism and is based on engineering judgement.

- Lower Layer: Corrected blow counts for the lower layer of the fine sand and silt unit range from a low of 6 bpf to greater than 50 bpf, as shown on Figures 1 and 3. The average corrected N-value for this layer is 32 bpf and for design purposes, a design N-value of 24 bpf is selected and is representative of the 25^{th} percentile of the N-value data for conservatism. Observations of the split-spoon samples indicate that the consistency of this unit is generally medium dense to dense.

  Design values for unit weight and internal friction angle considered the fine-grained nature of this layer with added conservatism in the selected values. For the modulus of elasticity design value, several N-value based methods and references for typical values were reviewed as shown in Table 2. The selected value represents the lower end of the range of modulus of elasticity values for conservatism and is based on engineering judgement.

Mixed Deposits

The soil unit of mixed sand, gravel, and silt is typically coarser than the fine sand and silt unit. It is composed of heterogeneous silty fine to coarse sand and fine to medium gravel. Layers of gravel and cobble-sized materials were noted in the boring logs and were generally found to be rock fragments in the split-spoon samples. Recorded N values and visual observations of the split-spoon samples indicate the consistency of the mixed sand, gravels, and silt is generally loose to dense. N-values greater than 50 were recorded where fractured rock was noted in the sample and at the bedrock interface. Results of laboratory testing classified soils in this unit typically as SM or GP-GM having non-plastic fines as determined through Atterburg limit testing. Plots of corrected N-values with depth are included as Figures 4, 5 and 6.

From review of these figures and from visual observations of the split-spoon samples, this unit was divided into an upper and lower layer with the upper layer typically characterized as having lower N-values than samples collected from this same unit but at depths greater than 50 ft bgs. Further description of these layers follows along with basis for soil parameter selection.

- Upper Layer: Corrected blow counts for the upper layer of the mixed deposits unit range from a low of 2 blows per foot (bpf) to greater than 50 bpf, as shown on Figures 4 and 5. The average corrected N-value for this layer is 24 bpf and for design purposes, a design N-value of 15 bpf is selected and is representative of the 25th percentile of the N-value data for conservatism. Observations of the split-spoon samples indicate that the consistency of this unit is generally medium dense.

  Design values for unit weight and internal friction angle considered the coarse-grained nature of this layer with added conservatism in the selected values due to this unit's variability in coarseness. For the modulus of elasticity design value, several N-value based methods and typical values were reviewed as shown in Table 2. The selected value represents the lower end of the range of modulus of elasticity values for conservatism and is based on engineering judgement.

- Lower Layer: Corrected blow counts for the lower layer of the fine sand and silt unit range from a low of 6 bpf to greater than 50 bpf, as shown on Figures 4 and 6. The average corrected N-value for this layer is 32 bpf and for design purposes, a design N-value of 24 bpf is selected and is representative of the 25th percentile of the N-value data for conservatism. Observations of the split-spoon samples indicate that the consistency of this unit is generally medium dense to dense.

  Design values for unit weight and internal friction angle considered the coarse-grained nature of this layer with added conservatism considered in the selected values. For the modulus of elasticity design value, several N-value based methods and typical values were reviewed as shown in Table 2. The selected value represents the lower end of the range of modulus of elasticity values for conservatism and is based on engineering judgement.

Attachments:

Table 1 - Design Soil Parameter Evaluation - Unit Weight and Strength
Table 2 - Design Soil Parameter Evaluation - Stiffness Parameters

Figure 1 – N-value vs Depth – Fine Sands and Silts
Figure 2 – N-value vs Depth – Upper Layer of Fine Sands and Silts Unit
Figure 3 – N-value vs Depth – Lower Layer of Fine Sands and Silts Unit
Figure 4 – N-value vs Depth – Mixed Deposits
Figure 5 – N-value vs Depth – Upper Layer of Mixed Deposits Unit
Figure 6 – N-value vs Depth – Lower Layer of Mixed Deposits Unit

Table 1 - Design Soil Parameter Evaluation - Unit Weight and Strength
Upland Disposal Facility Area
GE-Pittsfield/Housatonic River Site

Unit	Layer	Applicable Depth *(ft bgs)*	Design N-value ($N1_{60}$) *(bpf)*	General Soil Layer Description	Total Unit Weight by Reference			Internal Friction Angle by Reference			Selected Design Values	
					USACE [1] *(pcf)*	Bowles [2] *(pcf)*	Caltrans [3] *(pcf)*	USACE [1] *(deg)*	Bowles [2] *(deg)*	Caltrans [3] *(deg)*	Unit Weight *(pcf)*	Internal Friction *(deg)*
Fine Sand and Silt												
	Upper	0 to 50	15	Silty Fine Sand to Sandy Silt	115	120	115	31	30	31	115	30
	Lower	> 50	24		120	120	120	33	32	33	120	32
Mixed Deposits												
	Upper	0 to 50	15	Silty Sand and Gravel	115	120	125	32	34	33	120	34
	Lower	> 50	28		130	130	128	36	36	37	130	36

References:

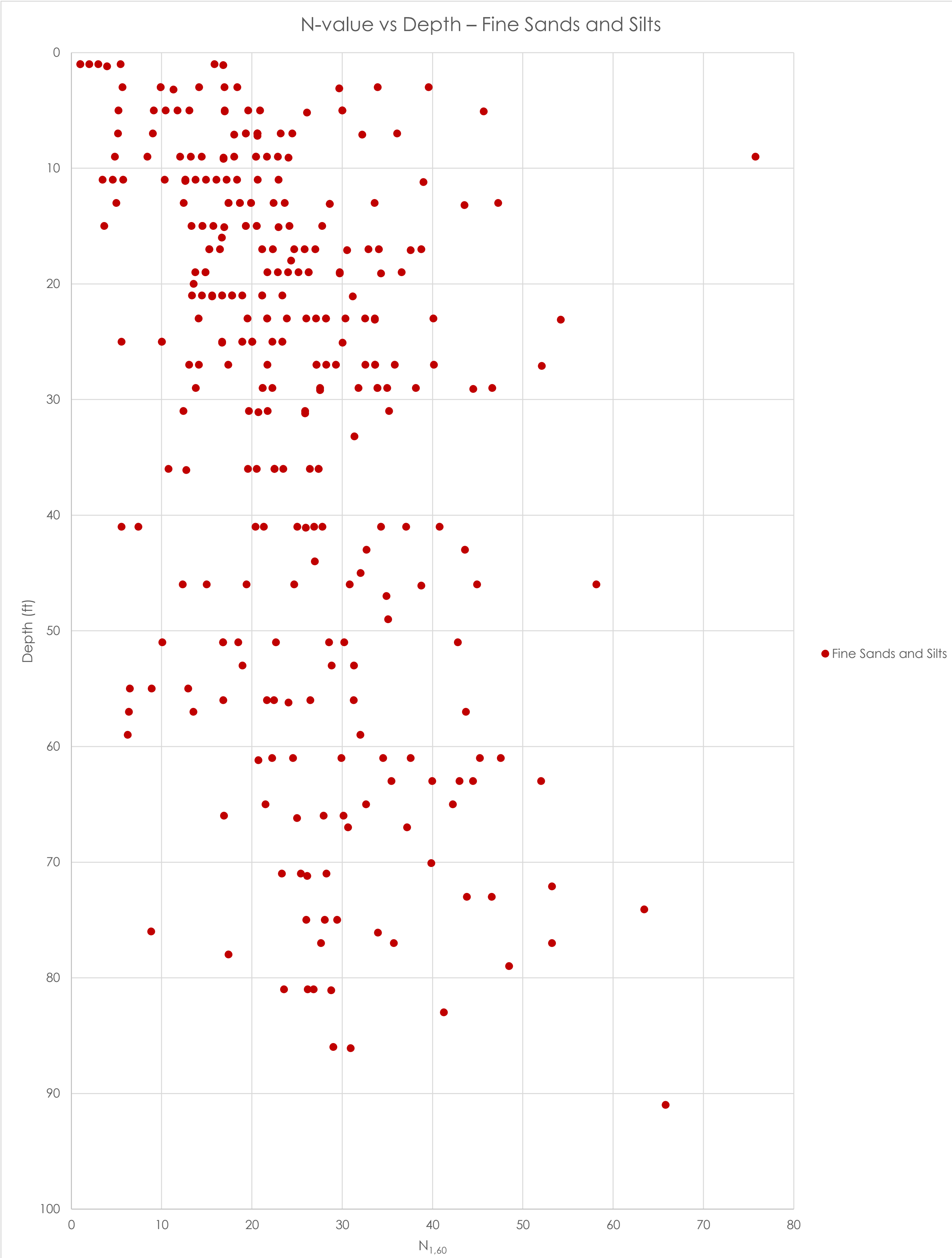
(1) USACE EM1110-2-2504
(2) Bowles, Jospeh E., Foundation Analysis and Design, 4th Edition.
(3) Caltrans Geotechnical Manual, 2021

Table 2 - Design Soil Parameter Evaluation - Stiffness Parameters
Upland Disposal Facility Area
GE-Pittsfield/Housatonic River Site

Unit	Layer	Applicable Depth	Design N-value ($N1_{60}$)	General Soil Layer Description	Estimated Modulus of Elasticity (Es) by Reference					Selected Design Values	
					FHWA [1]	FHWA [2]	Bowles [3]	Bowles [4]	Das [5]	Average Es	Selected Es
		(ft bgs)	*(bpf)*		*(ksf)*	*(ksf)*	*(ksf)*	*(ksf)*	*(ksf)*	*(ksf)*	*(ksf)*
Fine Sand and Silt											
	Upper	0 to 50	15	Silty Fine Sand to Sandy Silt	219	251	250	132	288	228	200
	Lower	> 50	24		351	418	400	188	360	343	300
Mixed Deposits											
	Upper	0 to 50	15	Silty Sand and Gravel	376	1045	1000	526	1440	877	800
	Lower	> 50	28		702	1671	1500	852	1728	1291	1200

References:

(1) FHWA-IF-02-034, Table 29.
(2) FHWA-IF-02-034, Table 28.
(3) Table 2-7 of Bowles, Jospeh E., Foundation Analysis and Design, 4th Edition.
(4) Table 5-5 of Bowles, Joseph E., Foundation Anaysis and Design, 4th Edition.
(5) Table 3.9 of Das, Braja M. Principles of Foundation Engineering, 3rd Edition.



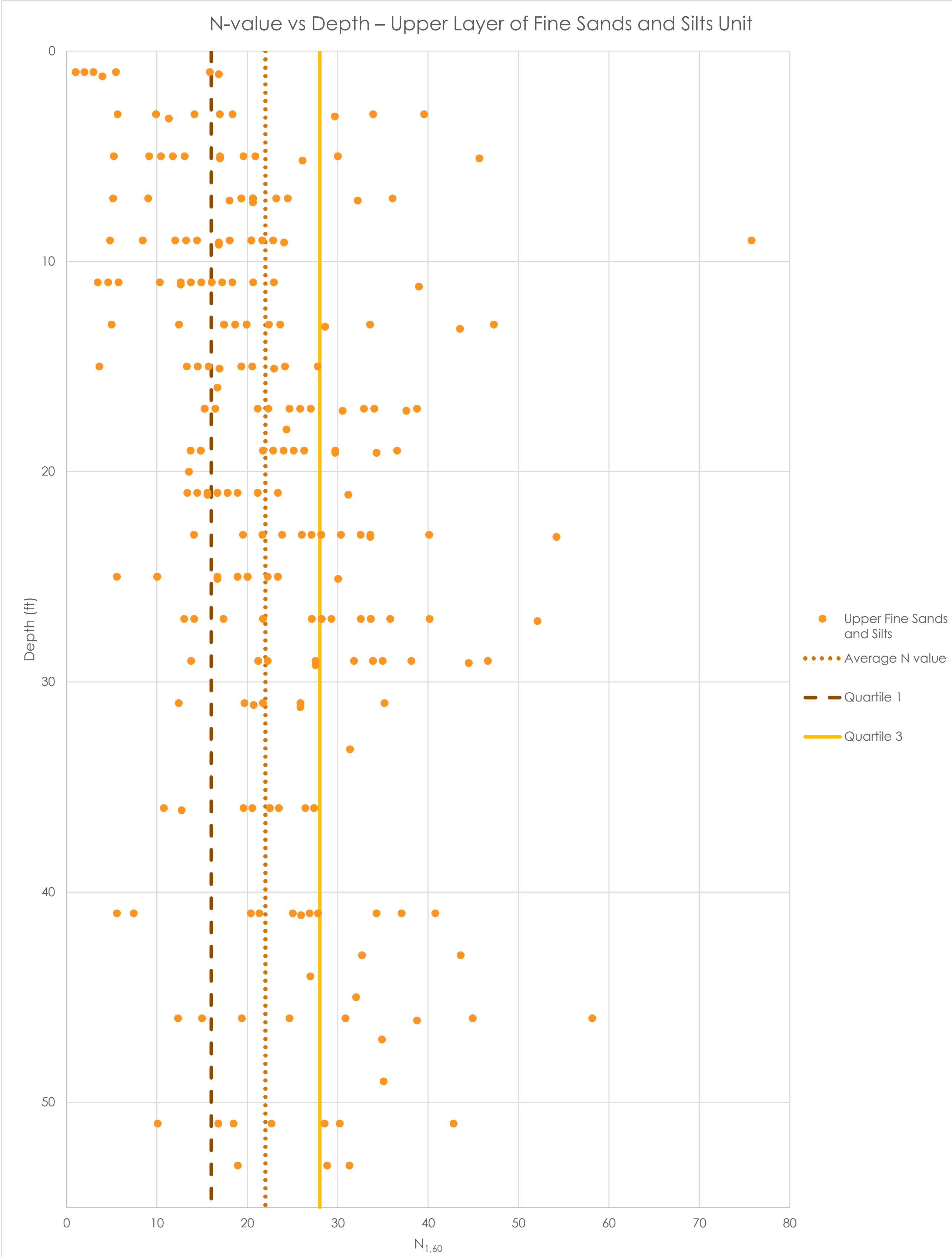
NOTES:
1. $N_{1,60}$ = CORRECTED SPT BLOW COUNT.
2. SPT = STANDARD PENETRATION TEST
3. TEST DATA COLLECTED BY ARCADIS IN 2022.
4. N VALUES GREATER THAN 80 WERE NOT USED IN DATA ANALYSIS

GE-PITTSFIELD/HOUSATONIC RIVER SITE
LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

N-VALUE VS DEPTH – FINE SANDS AND SILTS

ARCADIS

FIGURE
1



NOTES:
1. $N_{1,60}$ = CORRECTED SPT BLOW COUNT.
2. SPT = STANDARD PENETRATION TEST
3. TEST DATA COLLECTED BY ARCADIS IN 2022.
4. N VALUES GREATER THAN 80 WERE NOT USED IN DATA ANALYSIS
5. QUARTILE 1: 25% OF DATA HAS AN N VALUE LESS THAN 16
6. QUARTILE 3: 25% OF DATA HAS AN N VALUE GREATER THAN 28

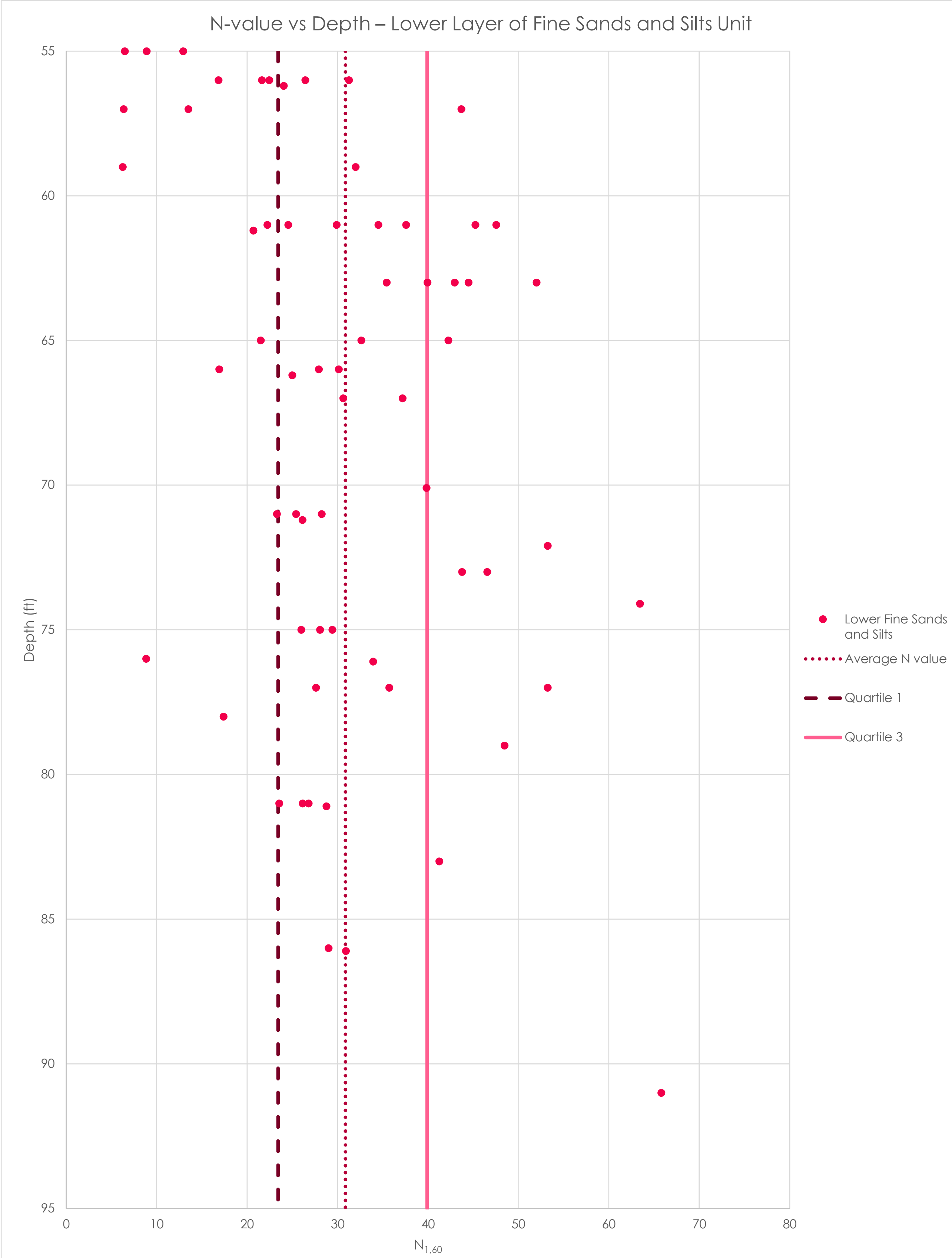
GE-PITTSFIELD/HOUSATONIC RIVER SITE
LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

N-VALUE VS DEPTH – UPPER LAYER OF FINE SANDS AND SILTS UNIT

ARCADIS

FIGURE
2

ms_SPT chart figures.xlsx_Fig 2_2/14/2024



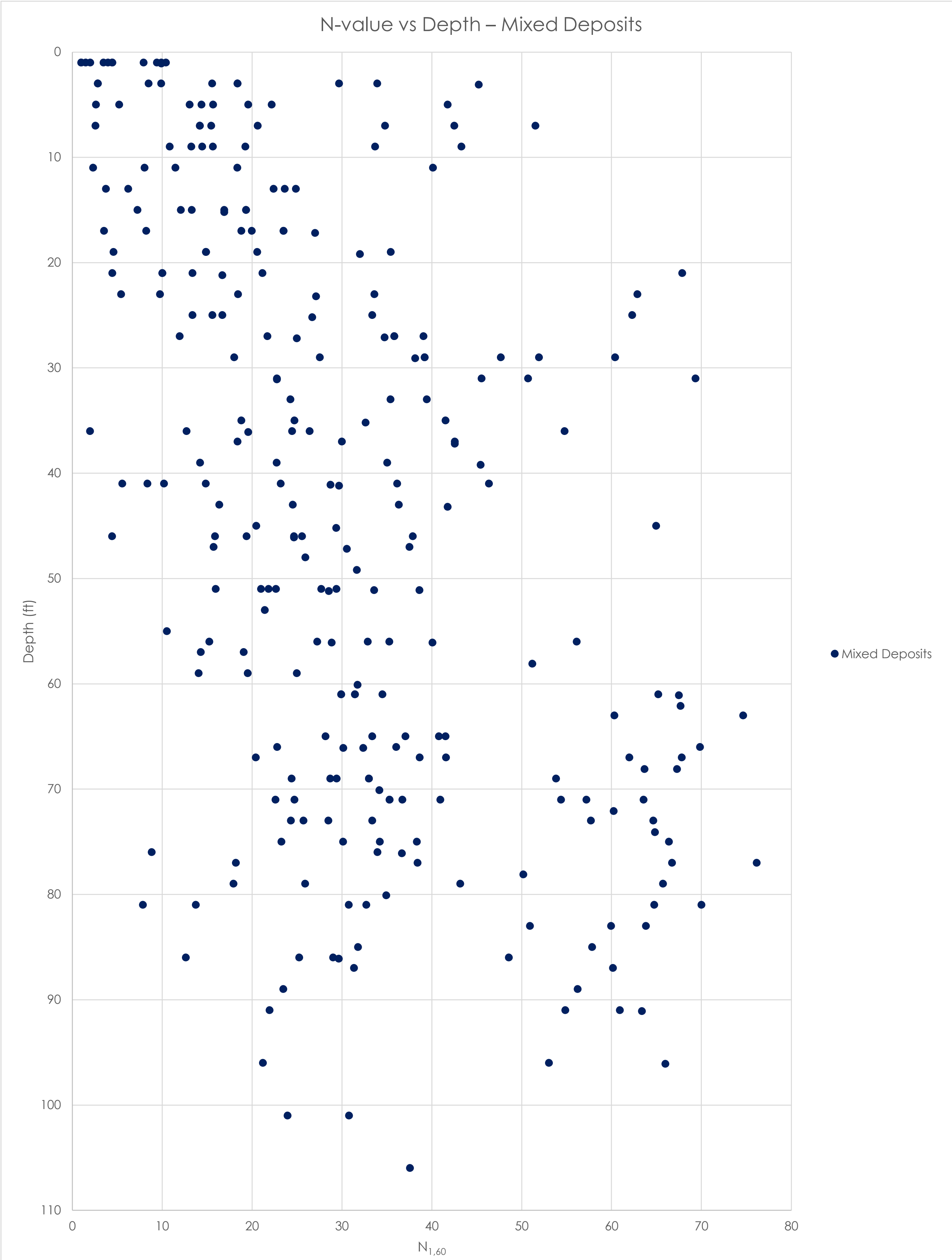
NOTES:
1. $N_{1,60}$ = CORRECTED SPT BLOW COUNT.
2. SPT = STANDARD PENETRATION TEST
3. TEST DATA COLLECTED BY ARCADIS IN 2022.
4. N VALUES GREATER THAN 80 WERE NOT USED IN DATA ANALYSIS
5. QUARTILE 1: 25% OF DATA HAS AN N VALUE LESS THAN 23
6. QUARTILE 3: 25% OF DATA HAS AN N VALUE GREATER THAN 40

GE-PITTSFIELD/HOUSATONIC RIVER SITE
LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

N-VALUE VS DEPTH – LOWER LAYER OF FINE SANDS AND SILTS UNIT

ARCADIS

FIGURE
3



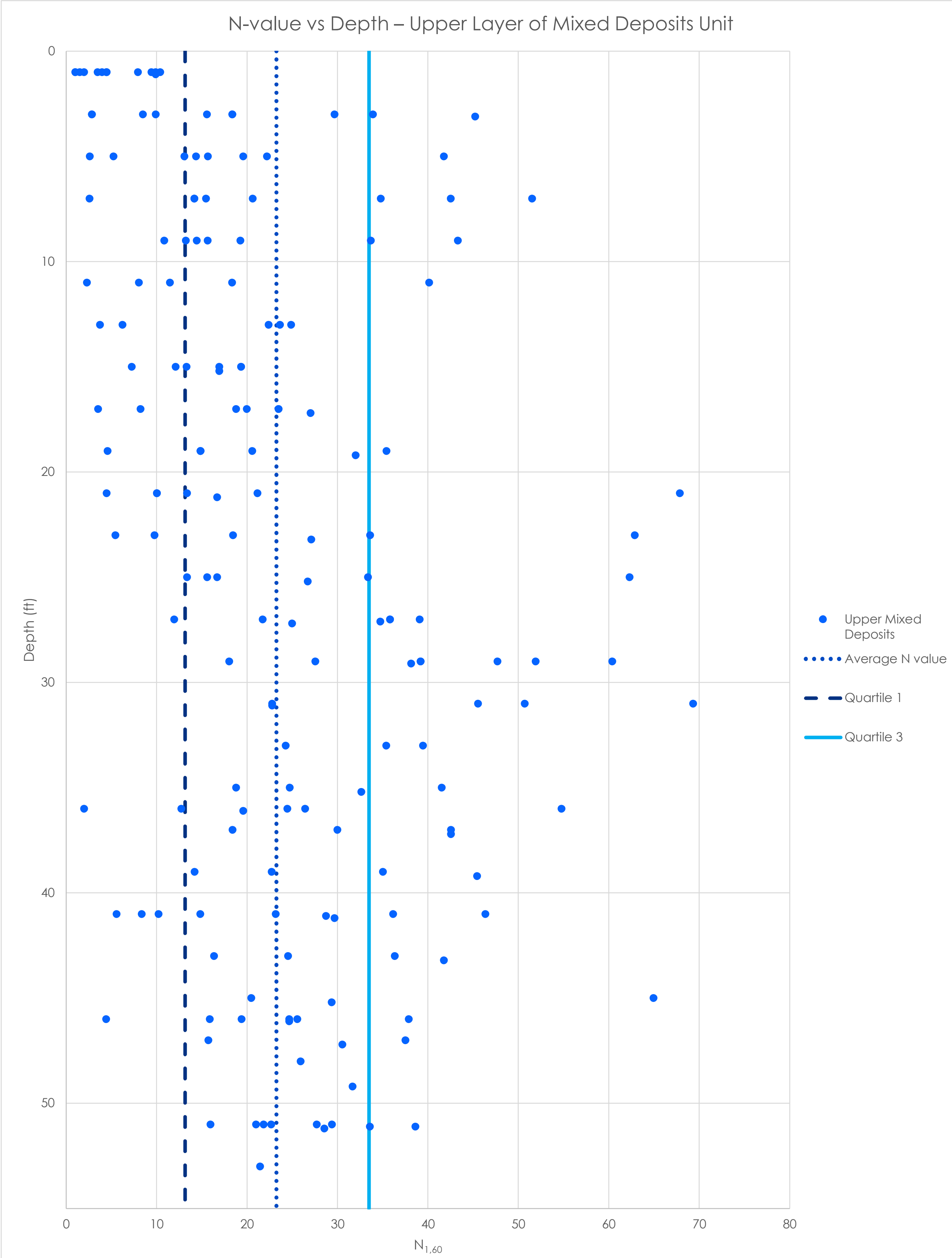
NOTES:
1. $N_{1,60}$ = CORRECTED SPT BLOW COUNT.
2. SPT = STANDARD PENETRATION TEST
3. TEST DATA COLLECTED BY ARCADIS IN 2022.
4. N VALUES GREATER THAN 80 WERE NOT USED IN DATA ANALYSIS

GE-PITTSFIELD/HOUSATONIC RIVER SITE
LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

N-VALUE VS DEPTH – MIXED DEPOSITS

ARCADIS

FIGURE
4



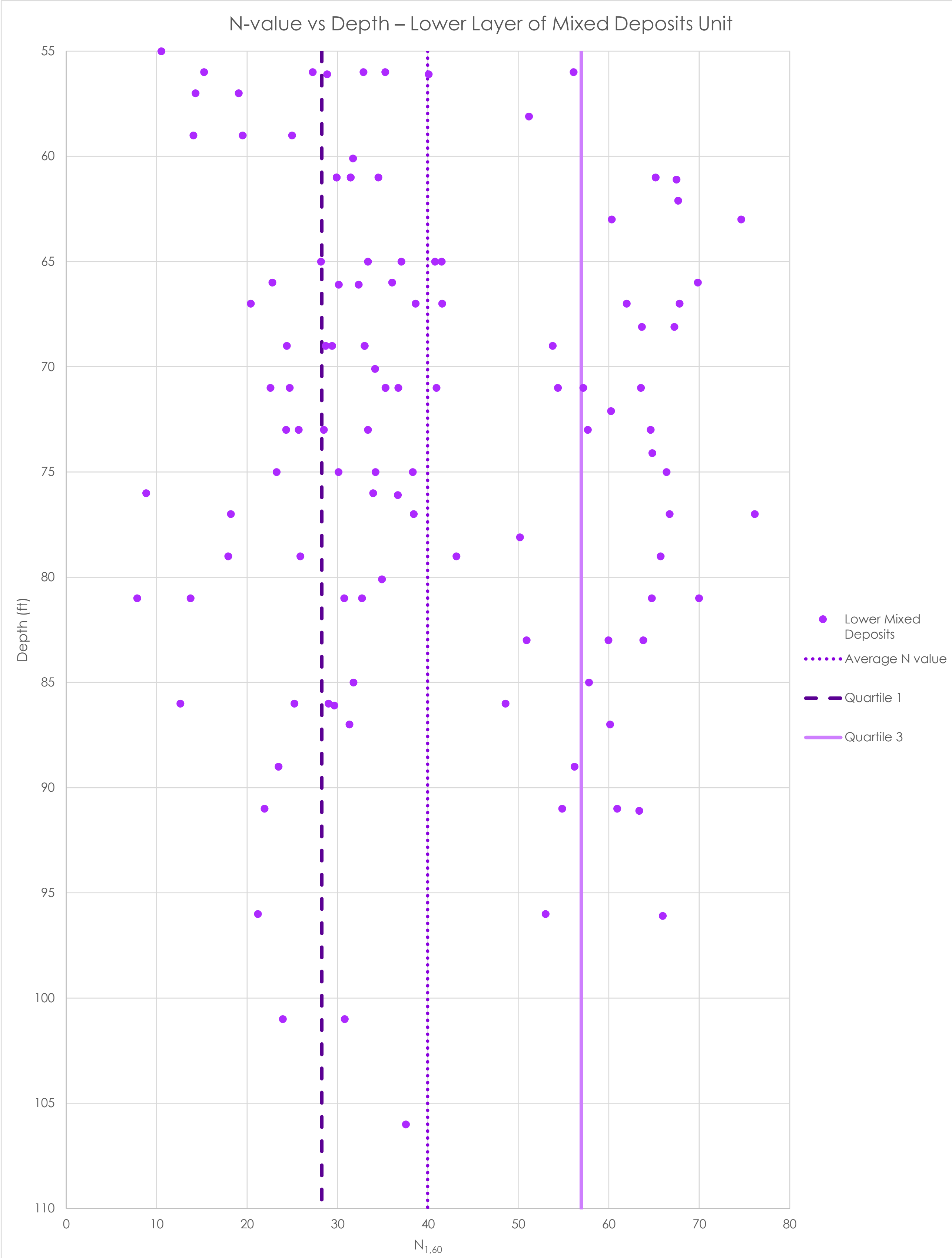
NOTES:
1. $N_{1,60}$ = CORRECTED SPT BLOW COUNT.
2. SPT = STANDARD PENETRATION TEST
3. TEST DATA COLLECTED BY ARCADIS IN 2022.
4. N VALUES GREATER THAN 80 WERE NOT USED IN DATA ANALYSIS
5. QUARTILE 1: 25% OF DATA HAS AN N VALUE LESS THAN 13
6. QUARTILE 3: 25% OF DATA HAS AN N VALUE GREATER THAN 33

GE-PITTSFIELD/HOUSATONIC RIVER SITE
LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

N-VALUE VS DEPTH – UPPER LAYER OF MIXED DEPOSITS UNIT

ARCADIS

FIGURE
5



NOTES:
1. $N_{1,60}$ = CORRECTED SPT BLOW COUNT.
2. SPT = STANDARD PENETRATION TEST
3. TEST DATA COLLECTED BY ARCADIS IN 2022.
4. N VALUES GREATER THAN 80 WERE NOT USED IN DATA ANALYSIS
5. QUARTILE 1: 25% OF DATA HAS AN N VALUE LESS THAN 28
6. QUARTILE 3: 25% OF DATA HAS AN N VALUE GREATER THAN 57

GE-PITTSFIELD/HOUSATONIC RIVER SITE
LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

N-VALUE VS DEPTH – LOWER LAYER OF MIXED DEPOSITS UNIT

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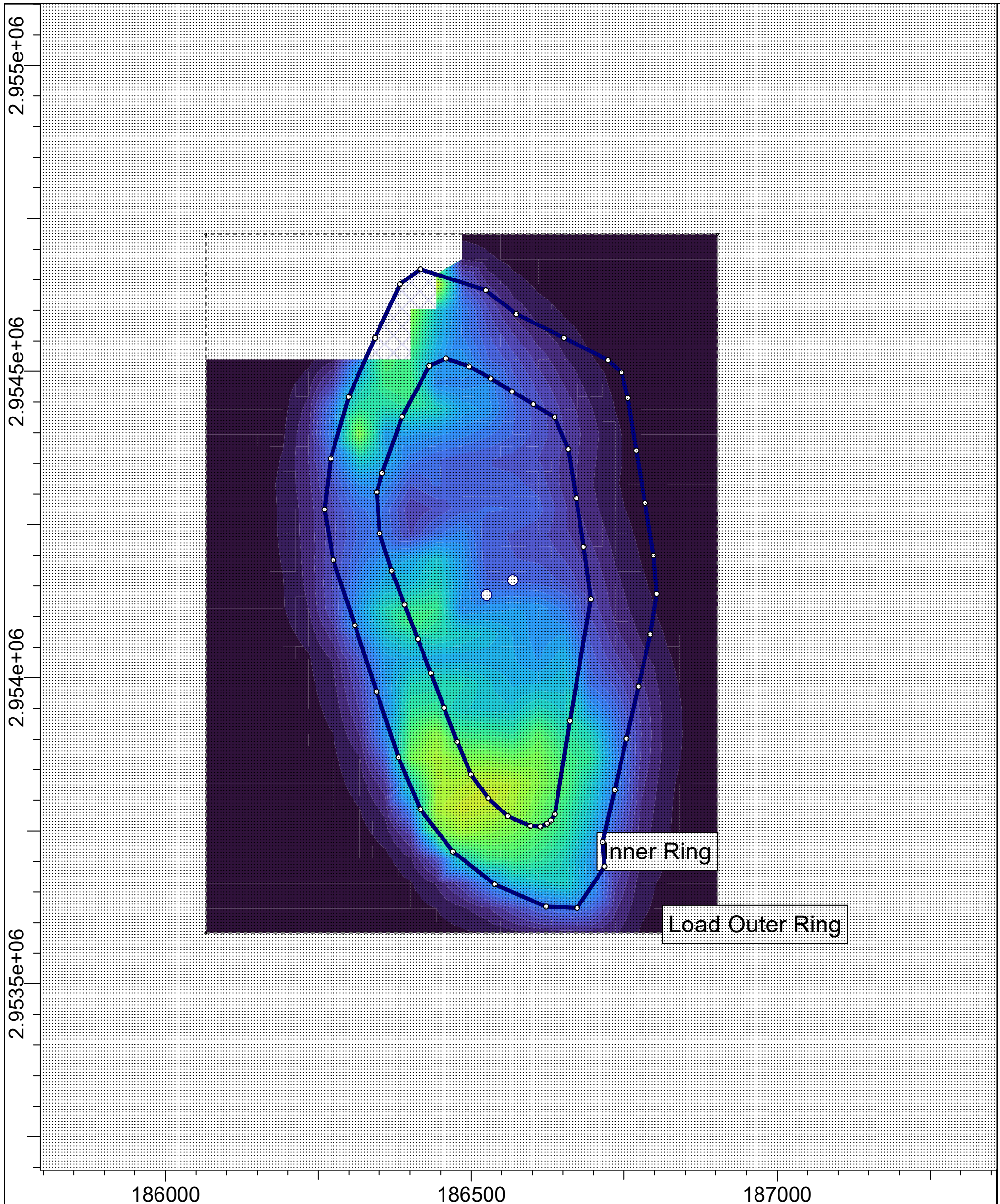
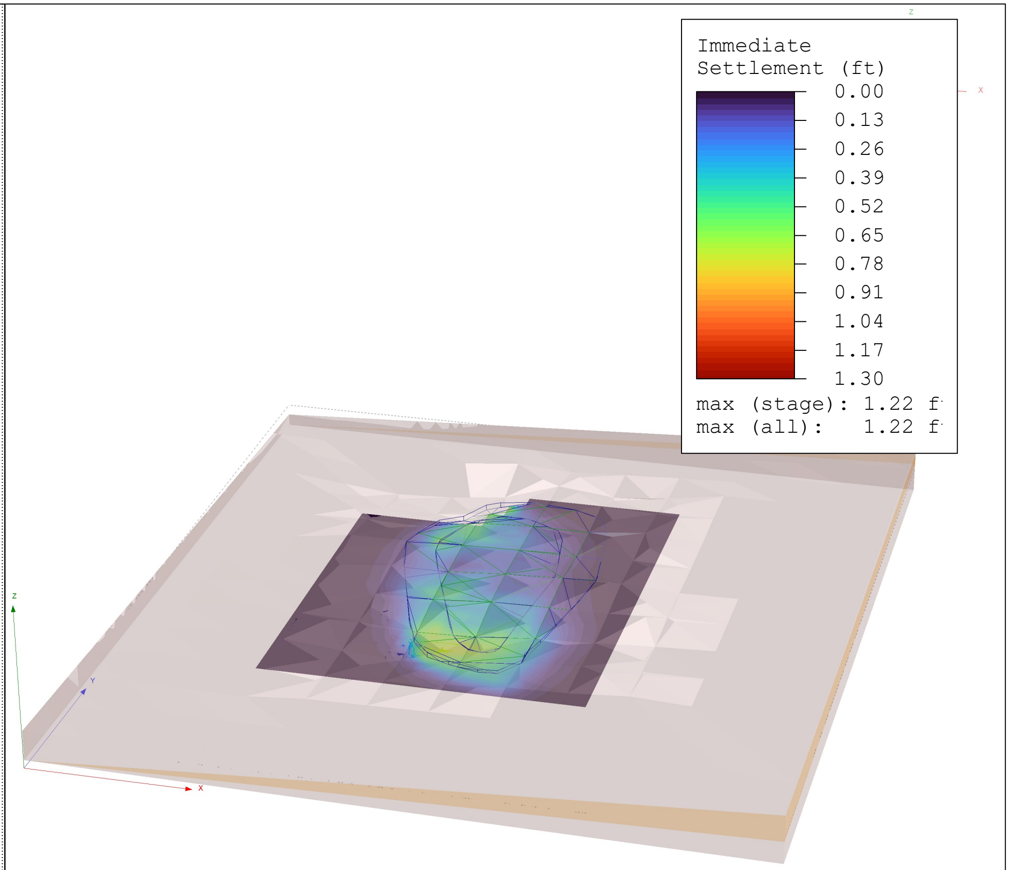
FIGURE
6

Attachment B

Settle3 Model

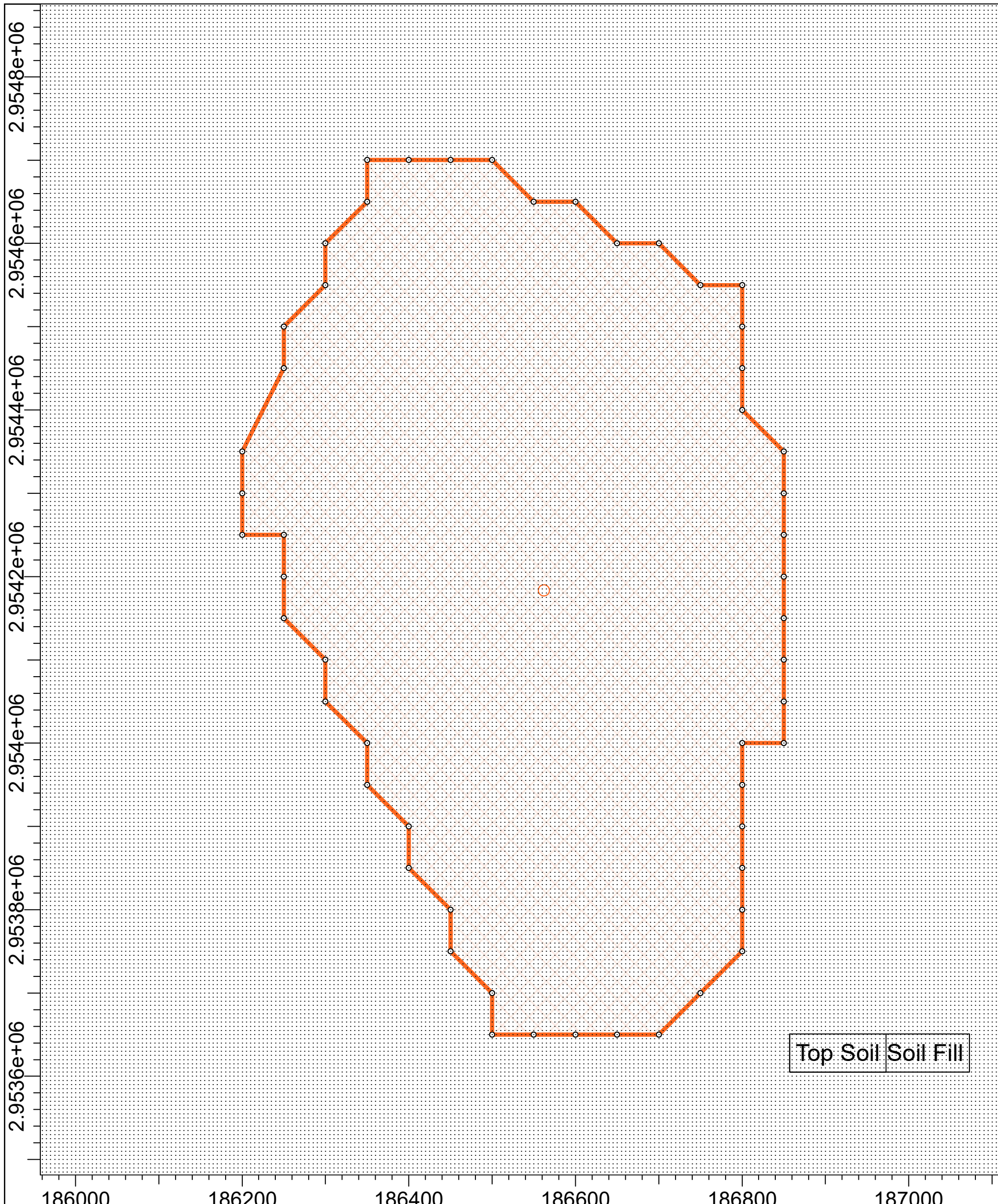


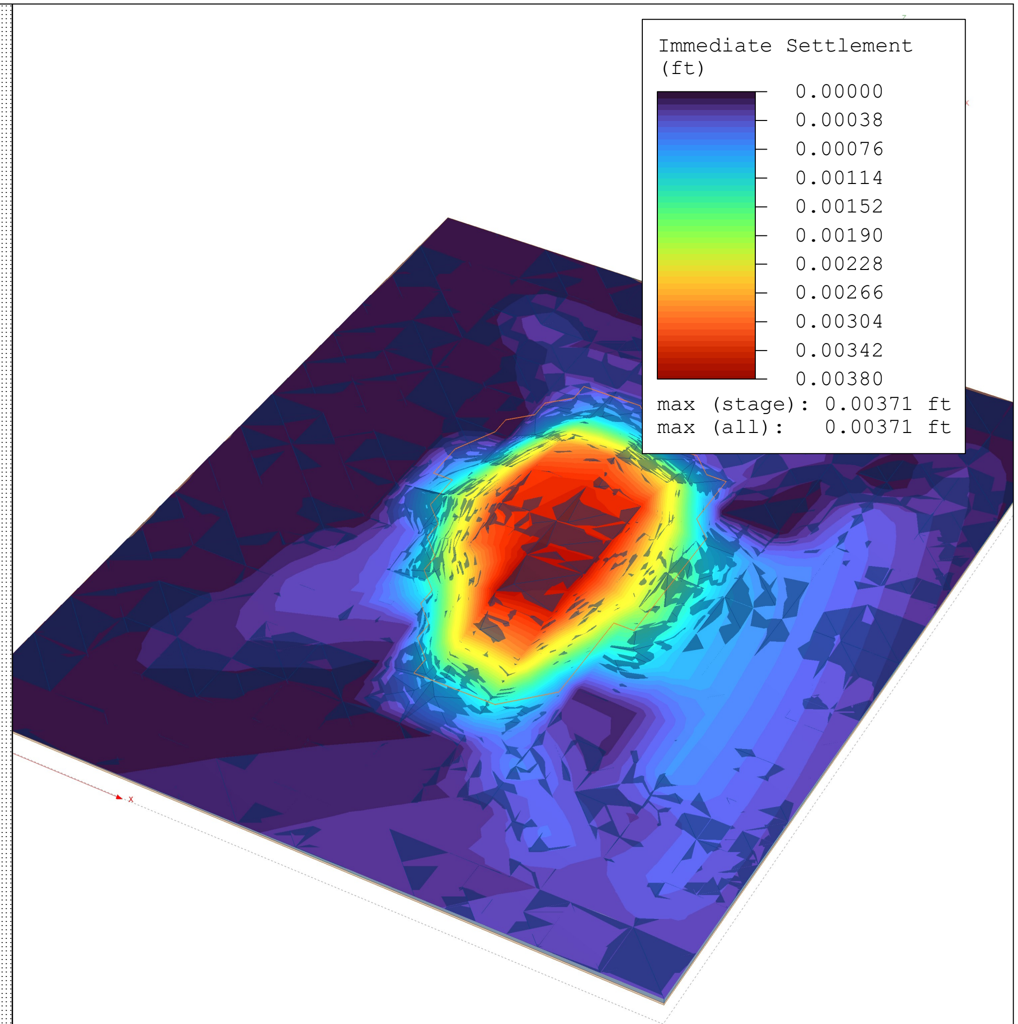


rocscience

SETTLE3 5.022

Project	GE UDF Lee
Analysis Description	Subgrade Settlement
Drawn By	L. Pittman
Company	Arcadis
Date	4/27/2023, 2:15:17 PM
File Name	GE UDF SubGrade Settlement_DRAFT FINAL_V4.s3z





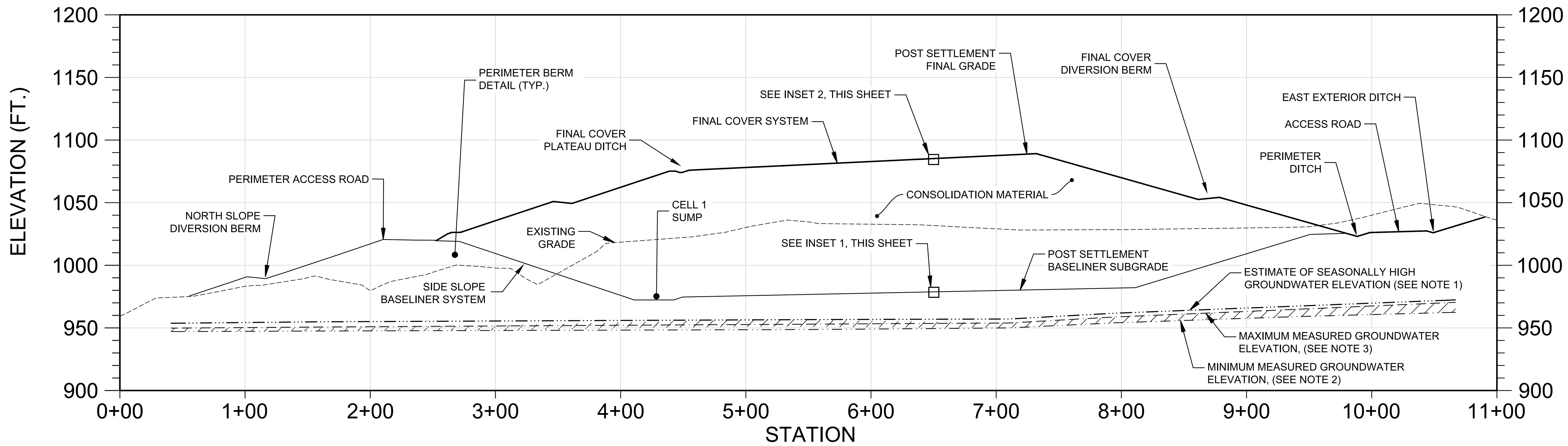
rocscience

SETTLE3 5.022

Project	GE UDF Lee		
Analysis Description	Consolidation Material Settlement		
Drawn By	L. Pittman	*Company*	Arcadis
Date	2/14/2024, 8:35:37 AM	*File Name*	Conolidation Material Settlement GE UDF.s3z

Attachment C

Settlement Cross-Sections



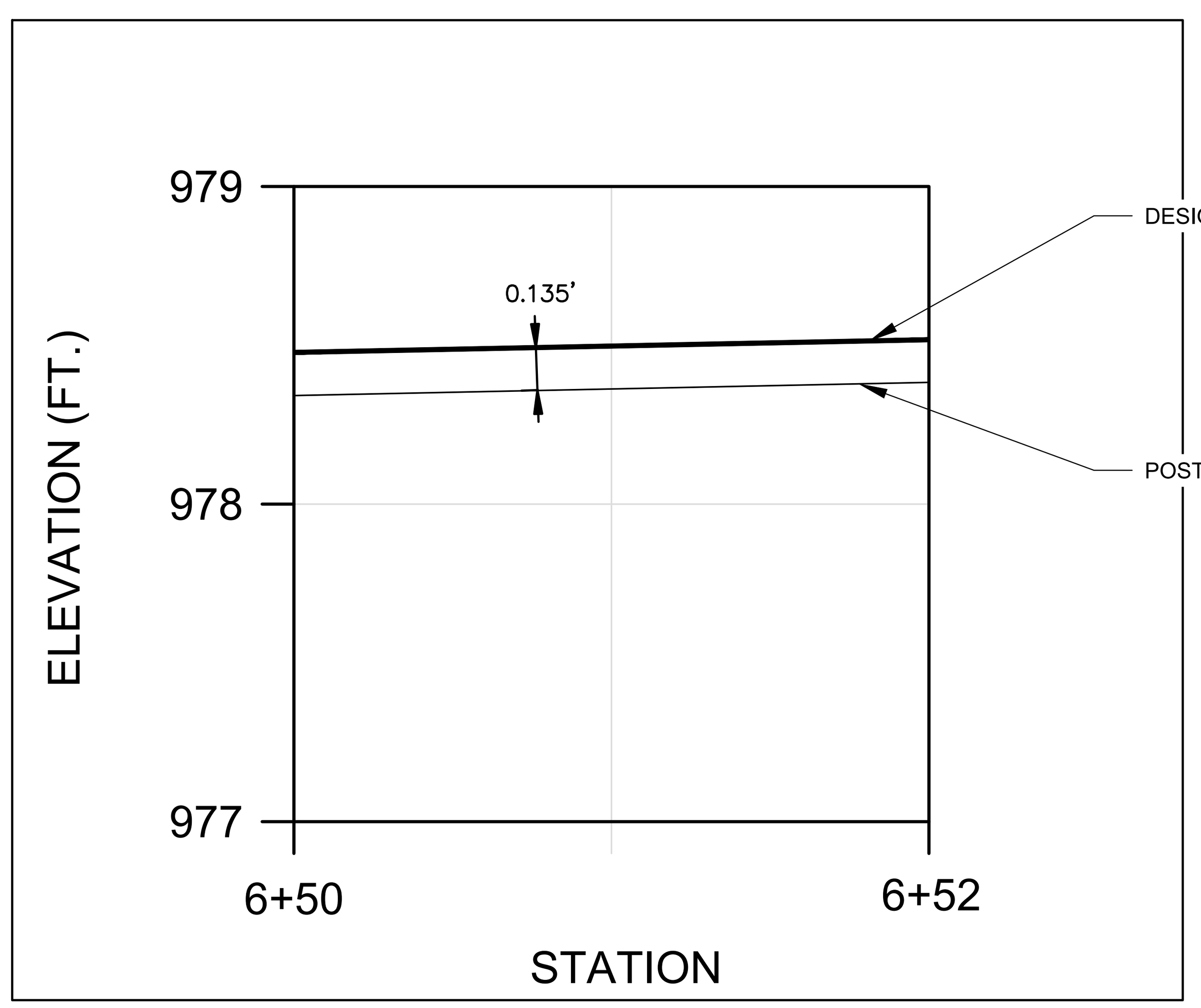
SITE SETTLEMENT CROSS SECTION (D')

SCALE: 1" = 60'
(NO VERTICAL EXAGGERATION)

0 60' 120'
GRAPHIC SCALE

NOTES:

1. THE ESTIMATE OF SEASONALLY HIGH GROUNDWATER ELEVATION SHOWN IS BASED ON THE METHODOLOGY AND RESULTING CALCULATIONS DESCRIBED IN SECTION 3.6.2 OF THE FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024).
2. MINIMUM MEASURED GROUNDWATER ELEVATION IS BASED ON TRANSDUCER AND MANUAL GROUNDWATER ELEVATION GAUGING CONDUCTED FROM JUNE 2022 THROUGH JUNE 2023 AS DESCRIBED IN SECTION 3.6.1 OF THE FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024). THE ELEVATIONS SHOWN REPRESENT THE LOWEST RECORDED GROUNDWATER ELEVATIONS FOR THE TRANSDUCER GAUGING PERIOD.
3. MAXIMUM MEASURED GROUNDWATER ELEVATION IS BASED ON TRANSDUCER GROUNDWATER ELEVATION GAUGING CONDUCTED FROM JUNE 2022 THROUGH JUNE 2023 AS DESCRIBED IN SECTION 3.6.1 OF THE FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024). THE ELEVATIONS SHOWN REPRESENT THE HIGHEST RECORDED GROUNDWATER ELEVATIONS FOR THE TRANSDUCER GAUGING PERIOD.
4. SECTION II.B.5.A OF THE REVISED PERMIT SETS FORTH THE PERFORMANCE STANDARDS FOR THE UDF THAT REQUIRES THE BASELINER BE A MINIMUM OF 15 FEET ABOVE A CONSERVATIVE ESTIMATE OF THE SEASONALLY HIGH GROUNDWATER ELEVATION. THE SEASONALLY HIGH GROUNDWATER ELEVATION SHOWN ON THIS DRAWING AND USED FOR DESIGN OF THE UDF IS BASED ON THE FRIMPTER METHOD WHICH PROVIDES A CONSERVATIVE ESTIMATE OF THE GROUNDWATER ELEVATIONS USING SITE-SPECIFIC GROUNDWATER ELEVATION DATA COLLECTED IN THE LOCATION OF THE UDF THAT IS MODIFIED (PROJECTED) TO ACCOUNT FOR HISTORICAL GROUNDWATER LEVEL FLUCTUATIONS AT SIMILARLY SITED OFF-SITE, LONG-TERM MONITORING WELLS IN MASSACHUSETTS.



SETTLEMENT OF SUBGRADE (1)

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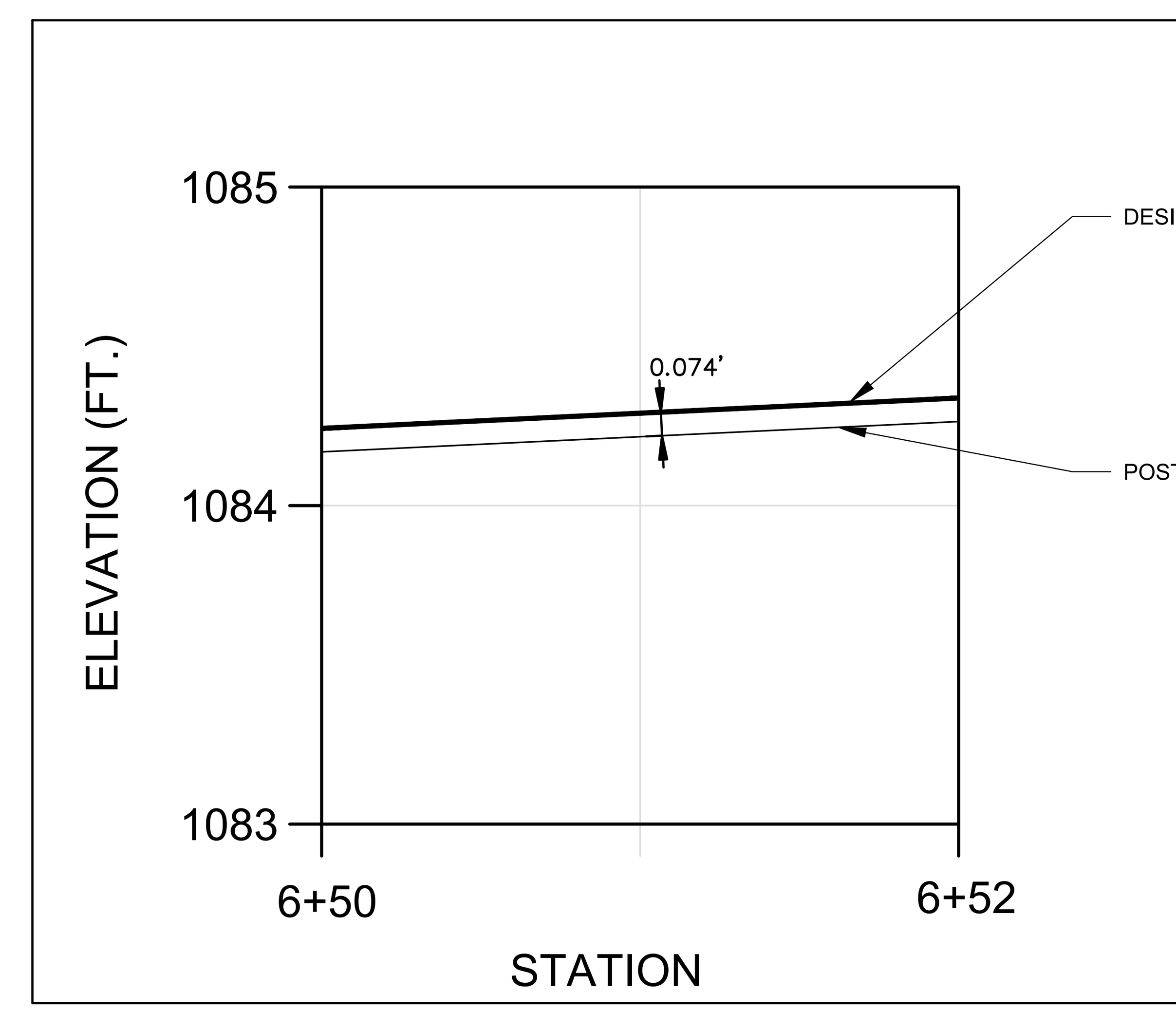
SCALE: 1"=0.5'



SETTLEMENT OF FINAL GRADE (2)

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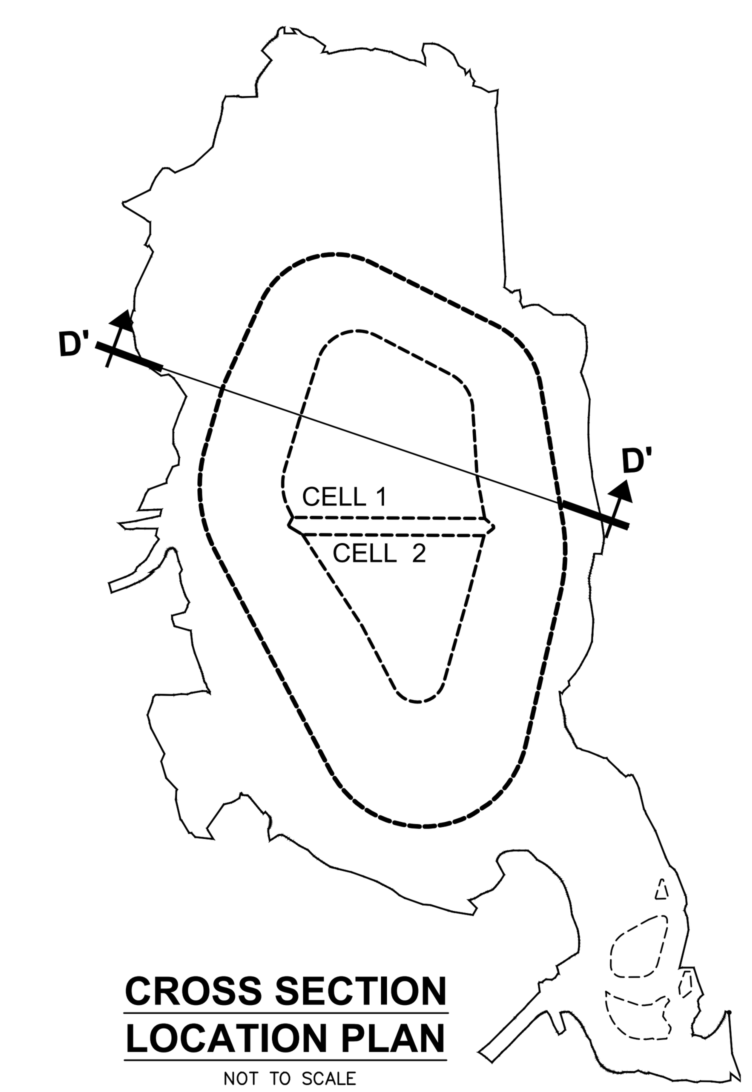
SCALE: 1"=0.5'



CROSS SECTION LOCATION PLAN

NOT TO SCALE

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PLOTSTYLETABLE: ---- PLOTTED: 2/26/2024 3:57 PM BY: SARTORI, KATHERINE
XREFS: X-INT DRAFT-UDF-BDR-C-LD IMAGES: Arcadis Logo BW.PNG

SCALE(S) AS INDICATED

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

THIS DRAWING IS THE PROPERTY OF THE ARCADIS ENTITY IDENTIFIED IN THE TITLE BLOCK AND MAY NOT BE REUSED OR ALTERED IN WHOLE OR IN PART WITHOUT THE EXPRESS WRITTEN PERMISSION OF SAME.

Professional Engineer's Name: MARK O. GRAVELDING
Professional Engineer's No.: 42983

State	Date Signed	Project Mgr.
MA		DK
Designed by	**Drawn by**	**Checked by**
BMS	KLS	PHB

INTERNAL
DRAFT

ARCADIS
ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

SITE SETTLEMENT CROSS SECTION

ARCADIS Project No. 30158182.3
Date FEBRUARY 2024
ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.: 30197838**

Calc No.: **D-3** **Subject:** **Liquefaction Susceptibility Analysis**

Prepared By: **Daniel Bonner, PE** **Date:** **February 2024**

Reviewed By: **Mandy Giampaolo, PE** **Date:** **February 2024**

Objective

Evaluate the liquefaction potential of soils at the proposed Upland Disposal Facility (UDF). The evaluation considered soils at 6 locations where soil borings had been advanced.

References

1. A. ASCE. (2016). Minimum Design Loads for Buildings and Other Structures - ASCE 7-16.

2. U.S. Geological Society. (2023, December). Unified Hazard Tool. Retrieved from https://earthquake.usgs.gov/hazards/interactive/

3. Youd, T. I. (2001). Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEERINSF.

Attachments:

1. Liquefaction Susceptibility Calculations

Assumptions

1. Liquefaction Susceptibility Calculations

2. Soil Geotechnical Properties: Site lithology, soil properties, and SPT blow counts were taken from the Pre-Design Investigation Summary Report for Upland Disposal Area.

3. Groundwater Depth: Depths to groundwater were evaluated at locations where borings had been installed including MW-2022-9, B-2022-3, B-2022-5, B-2022-6, B-2022-7, and PZ-2022-2. To account for potential fluctuations in depth to groundwater, it has been assumed that the groundwater elevations could be up to ten feet higher than observed in each boring.

Calculations

The liquefaction potential analysis followed the simplified method described in the "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 CNEERINSF". (Youd, T.I. (2001)).

Based on the available soil data provided, the site was assigned a Site Class D designation following the procedures in ASCE 7-2016. (ASCE, 2016)

Seismic parameters to establish the Maximum Considered Earthquake (MCE) were obtained using the U.S. Geological Survey's (USGS) Unified Hazard Tool. (U.S. Geological Society, 2023) and using a 2,475 year return period (2% recurrence in 50 years).

Evaluations of liquefaction susceptibility were performed at each of the six boring locations described in item 2 above.

Summary

Based on the evaluation, it was determined that none of soils examined are expected to liquify during the MCE.

Attachment 1

Liquefaction Susceptibility Calculations

Client:	GE UDF
Prepared by:	D. Bonner
Checked by:	M. Giampaolo
Subject:	Liquefaction Analysis using "Simplified Procedure" (Youd et al. 2001)
Boring	**MW-2022-9**

			Elevation (NAVD88)
depth to water table =	32	ft	956
Assumed water table fluctuation =	10	ft	
Assumed depth to water table for check =	22	ft	966
unit weight of water =	62.4	pcf	
ground surface elevation =	988	ft	

Seismic Setting

Site Class (ASCE 7-16): D (Stiff Soil)

Maximum Considered Earthquake (MCE)

earthquake magnitude$_{MCE}$ = 4.90

a_{max} = 0.134 g

MSF_{Idriss} = 2.97

Sample ID	Material Type	Depth (ft)	Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)	u (psf)	σ'_{v0} (psf)	Fines Content (%)	$(N_1)_{60}$	α	β	$(N_1)_{60CS}$	$CRR_{7.5}$	r_d	CSR_{MCE}	K_α	*f*	K_σ	FS_{MCE}	Remarks
S-14	Upper Fine Sands and Silts	25	963	115	2945	187	2758	19.8	6	4	1	10	0.1135	0.9418	0.0874	1	0.7	0.9236	2.00	Not Expected To Liquify
S-17	Upper Mixed Deposits	34	954	120	4010	749	3261	16.1	38	3	1	43	4.0000	0.8974	0.0959	1	0.7	0.8783	2.00	Not Susceptible To Liquefaction
S-18	Upper Mixed Deposits	36	952	120	4250	874	3376	27.5	42	5	1	52	4.0000	0.8835	0.0967	1	0.7	0.8692	2.00	Not Susceptible To Liquefaction
S-21	Upper Mixed Deposits	42	946	120	4970	1248	3722	11.8	26	1	1	28	0.3797	0.8328	0.0967	1	0.7	0.8442	2.00	Not Expected To Liquify
S-23	Upper Mixed Deposits	45	943	120	5330	1435	3895	13.4	20	2	1	23	0.2538	0.8036	0.0956	1	0.7	0.8327	2.00	Not Expected To Liquify

Lithology to 50 Feet	Depth (ft)	Layer Bottom Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)
Upper Mixed Deposits	3	985	120	360
Upper Fine Sands and Silts	11	977	115	1280
Upper Mixed Deposits	22	966	120	2600
Upper Fine Sands and Silts	28	960	115	3290
Upper Mixed Deposits	48	940	120	5690

(N1)60 Values taken from N-Value vs Depth Date - MT 08.17.23

Sample locations taken from Table 3B - Summary of Geotech Lab Results.xlsx

Footnotes:

[1] Assessment of liquefaction susceptibility is discussed in the main text of the Liquefaction Assessment Report.

Symbols:

a_{max} = peak horizontal acceleration at the ground surface

MSF = magnitude scaling factor

N_m = measured standard penetration resistance

σ_{v0} = total overburden stress

σ'_{v0} = effective overburden stress

C_N = factor to normalize N_m to a common reference effective overburden stress

C_E = correction for hammer energy ratio (ER)

C_B = correction factor for borehole diameter

C_R = correction factor for rod length

C_S = correction for samplers with or without liners

$(N_1)_{60}$ = standard penetration test (SPT) blow count normalized to an overburden stress of approximately 100 kPa and a hammer energy ratio or hammer efficiency of 60%

$(N_1)_{60CS}$ = equivalent clean sand $(N_1)_{60}$ value

CSR = cyclic stress ratio

CRR = cyclic resistance ratio

r_d = stress reduction coefficient (spreadsheet uses average value)

K_σ = correction factor for confining stress

f = exponent for calculation of K_σ

K_α = correction factor for sloping ground

FS = factor of safety against liquefaction

Client: GE UDF
Prepared by: D. Bonner
Checked by: M. Giampaolo
Subject: Liquefaction Analysis using "Simplified Procedure" (Youd et al. 2001)
Boring **B-2022-6**

			Elevation (NAVD88)
depth to water table =	24	ft	976
Assumed water table fluctuation =	10	ft	990
Assumed depth to water table for check =	14	ft	986
unit weight of water =	62.4	pcf	
ground surface elevation =	1000	ft	

Seismic Setting

Site Class (ASCE 7-16): D (Stiff Soil)

Maximum Considered Earthquake (MCE)

earthquake magnitude$_{MCE}$ = 4.90

a_{max} = 0.134 g

MSF_{Idriss} = 2.97

Sample ID	Material Type	Depth (ft)	Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)	u (psf)	σ'_{v0} (psf)	Fines Content (%)	$(N_1)_{60}$	α	β	$(N_1)_{60CS}$	$CRR_{7.5}$	r_d	CSR_{MCE}	K_α	*f*	K_σ	FS_{MCE}	Remarks
S-11	Upper Fine Sands and Silts	21	979	115	2415	437	1978	49.8	23	5	1	36	4.0000	0.9542	0.1013	1	0.7	1.0000	2.00	Not Susceptible To Liquefaction
S-16	Upper Fine Sands and Silts	31	969	115	3565	1061	2504	12.6	23	2	1	26	0.3033	0.9153	0.1133	1	0.7	0.9507	2.00	Not Expected To Liquify
S-17/18	Upper Fine Sands and Silts	35	965	115	4025	1310	2715	8.7	19	0	1	20	0.2126	0.8906	0.1148	1	0.7	0.9280	2.00	Not Expected To Liquify
S-23	Upper Mixed Deposits	45	955	120	5200	1934	3266	12.2	65	2	1	69	4.0000	0.8036	0.1113	1	0.7	0.8779	2.00	Not Susceptible To Liquefaction
S-25	Upper Mixed Deposits	51	949	120	5920	2309	3611	13.8	28	2	1	31	4.0000	0.7426	0.1058	1	0.7	0.8518	2.00	Not Susceptible To Liquefaction
S-28	Lower Mixed Deposits	65	935	130	7650	3182	4468	24.3	42	4	1	51	4.0000	0.6221	0.0926	1	0.7	0.7992	2.00	Not Susceptible To Liquefaction

Lithology to 50 Feet	Depth (ft)	Layer Bottom Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)
Upper Fine Sands and Silts	40	960	115	4600
Upper Mixed Deposits	60	940	120	7000
Lower Mixed Deposits	70	930	130	8300
Lower Mixed Deposits	80	920	130	9600
Lower Mixed Deposits	100	900	130	12200

(N1)60 Values taken from N-Value vs Depth Date - MT 08.17.23

Sample locations taken from Table 3B - Summary of Geotech Lab Results.xlsx

Footnotes:

[1] Assessment of liquefaction susceptibility is discussed in the main text of the Liquefaction Assessment Report.

Symbols:

a_{max} = peak horizontal acceleration at the ground surface
MSF = magnitude scaling factor
N_m = measured standard penetration resistance
σ_{v0} = total overburden stress
σ'_{v0} = effective overburden stress
C_N = factor to normalize N_m to a common reference effective overburden stress
C_E = correction for hammer energy ratio (ER)
C_B = correction factor for borehole diameter
C_R = correction factor for rod length
C_S = correction for samplers with or without liners

$(N_1)_{60}$ = standard penetration test (SPT) blow count normalized to an overburden stress of approximately 100 kPa and a hammer energy ratio or hammer efficiency of 60%
$(N_1)_{60CS}$ = equivalent clean sand $(N_1)_{60}$ value
CSR = cyclic stress ratio
CRR = cyclic resistance ratio
r_d = stress reduction coefficient (spreadsheet uses average value)
K_σ = correction factor for confining stress
f = exponent for calculation of K_σ
K_α = correction factor for sloping ground
FS = factor of safety against liquefaction

Client: GE UDF
Prepared by: D. Bonner
Checked by: M. Giampaolo
Subject: Liquefaction Analysis using "Simplified Procedure" (Youd et al. 2001)
Boring **B-2022-7**

			Elevation (NAVD88)
depth to water table =	50	ft	955
Assumed water table fluctuation =	10	ft	995
Assumed depth to water table for check =	40	ft	965
unit weight of water =	62.4	pcf	
ground surface elevation =	1005	ft	

Seismic Setting
Site Class (ASCE 7-16): D (Stiff Soil)

Maximum Considered Earthquake (MCE)
earthquake magnitude$_{MCE}$ = 4.90
a_{max} = 0.134 g

MSF_{Idriss} = 2.9723369

Sample ID	Material Type	Depth (ft)	Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)	u (psf)	σ'_{v0} (psf)	Fines Content (%)	$(N_1)_{60}$	α	β	$(N_1)_{60CS}$	$CRR_{7.5}$	r_d	CSR_{MCE}	K_α	*f*	K_σ	FS_{MCE}	Remarks
S-26	Upper Mixed Deposits	50.8	954.2	120	5951	674	5277	28.4	29	5	1	38	4.0000	0.7446	0.0730	1	0.7	0.7602	2.00	Not Susceptible To Liquefaction
S-28	Upper Mixed Deposits	60.8	944.2	120	7151	1298	5853	13.9	21	2	1	24	0.2743	0.6528	0.0693	1	0.7	0.7370	2.00	Not Expected To Liquify

Lithology to 50 Feet	Depth (ft)	Layer Bottom Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)
Upper Fine Sands and Silts	29	976	115	3335
Upper Mixed Deposits	72	933	120	8495
Lower Mixed Deposits	75	930	130	8885
Lower Mixed Deposits	85	920	130	10185
Lower Mixed Deposits	105	900	130	12785

(N1)60 Values taken from N-Value vs Depth Date - MT 08.17.23
Sample locations taken from Table 3B - Summary of Geotech Lab Results.xlsx

Footnotes:
[1] Assessment of liquefaction susceptibility is discussed in the main text of the Liquefaction Assessment Report.

Symbols:
a_{max} = peak horizontal acceleration at the ground surface
MSF = magnitude scaling factor
N_m = measured standard penetration resistance
σ_{v0} = total overburden stress
σ'_{v0} = effective overburden stress
C_N = factor to normalize N_m to a common reference effective overburden stress
C_E = correction for hammer energy ratio (ER)
C_B = correction factor for borehole diameter
C_R = correction factor for rod length
C_S = correction for samplers with or without liners
$(N_1)_{60}$ = standard penetration test (SPT) blow count normalized to an overburden stress of approximately 100 kPa and a hammer energy ratio or hammer efficiency of 60%
$(N_1)_{60CS}$ = equivalent clean sand $(N_1)_{60}$ value
CSR = cyclic stress ratio
CRR = cyclic resistance ratio
r_d = stress reduction coefficient (spreadsheet uses average value)
K_σ = correction factor for confining stress
f = exponent for calculation of K_σ
K_α = correction factor for sloping ground
FS = factor of safety against liquefaction

Client: GE UDF
Prepared by: D. Bonner
Checked by: M. Giampaolo
Subject: Liquefaction Analysis using "Simplified Procedure" (Youd et al. 2001)
Boring **B-2022-5**

			Elevation (NAVD88)
depth to water table =	65	ft	957
Assumed water table fluctuation =	10	ft	1012
Assumed depth to water table for check =	55	ft	967
unit weight of water =	62.4	pcf	
ground surface elevation =	1022	ft	

Seismic Setting

Site Class (ASCE 7-16): D (Stiff Soil)

Maximum Considered Earthquake (MCE)

earthquake magnitude$_{MCE}$ = 4.90

a_{max} = 0.134 g

MSF_{Idriss} = 2.9723369

Sample ID	Material Type	Depth (ft)	Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)	u (psf)	σ'_{v0} (psf)	Fines Content (%)	$(N_1)_{60}$	α	β	$(N_1)_{60CS}$	$CRR_{7.5}$	r_d	CSR_{MCE}	K_α	*f*	K_σ	FS_{MCE}	Remarks
S-26	Lower Mixed Deposits	65.9	956.1	130	7907	680	7227	77.5	32	6	2	59	4.0000	0.6162	0.0586	1	0.7	0.6918	2.00	Not Susceptible To Liquefaction
S-28/29	Lower Fine Sands and Silts	70.9	951.1	120	8538	992	7546	53.6	53	5	1	79	4.0000	0.5871	0.0578	1	0.7	0.6829	2.00	Not Susceptible To Liquefaction
S32	Lower Fine Sands and Silts	80.9	941.1	120	9738	1616	8122	61.1	29	6	1	48	4.0000	0.5451	0.0568	1	0.7	0.6680	2.00	Not Susceptible To Liquefaction

Lithology to 50 Feet		Depth (ft)	Layer Bottom Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)
	Upper Fine Sands and Silts	22	1000	115	2530
	Upper Mixed Deposits	55	967	120	6490
	Lower Mixed Deposits	69	953	130	8310
	Lower Fine Sands and Silts	102	920	120	12270
	Lower Mixed Deposits	122	900	130	14870

(N1)60 Values taken from N-Value vs Depth Date - MT 08.17.23

Sample locations taken from Table 3B - Summary of Geotech Lab Results.xlsx

Footnotes:

[1] Assessment of liquefaction susceptibility is discussed in the main text of the Liquefaction Assessment Report.

Symbols:

a_{max} = peak horizontal acceleration at the ground surface
MSF = magnitude scaling factor
N_m = measured standard penetration resistance
σ_{v0} = total overburden stress
σ'_{v0} = effective overburden stress
C_N = factor to normalize N_m to a common reference effective overburden stress
C_E = correction for hammer energy ratio (ER)
C_B = correction factor for borehole diameter
C_R = correction factor for rod length
C_S = correction for samplers with or without liners

$(N_1)_{60}$ = standard penetration test (SPT) blow count normalized to an overburden stress of approximately 100 kPa and a hammer energy ratio or hammer efficiency of 60%
$(N_1)_{60CS}$ = equivalent clean sand $(N_1)_{60}$ value
CSR = cyclic stress ratio
CRR = cyclic resistance ratio
r_d = stress reduction coefficient (spreadsheet uses average value)
K_σ = correction factor for confining stress
f = exponent for calculation of K_σ
K_α = correction factor for sloping ground
FS = factor of safety against liquefaction

Client: GE UDF
Prepared by: D. Bonner
Checked by: M. Giampaolo
Subject: Liquefaction Analysis using "Simplified Procedure" (Youd et al. 2001)
Boring **B-2022-3**

			Elevation (NAVD88)
depth to water table =	55	ft	951
Assumed water table fluctuation =	10	ft	
Assumed depth to water table for check =	45	ft	961
unit weight of water =	62.4	pcf	
ground surface elevation =	1006	ft	

Seismic Setting

Site Class (ASCE 7-16): D (Stiff Soil)

Maximum Considered Earthquake (MCE)

earthquake magnitude$_{MCE}$ = 4.90

a_{max} = 0.134 g

MSF_{Idriss} = 2.9723369

Sample ID	Material Type	Depth (ft)	Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)	u (psf)	σ'_{v0} (psf)	Fines Content (%)	$(N_1)_{60}$	α	β	$(N_1)_{60CS}$	$CRR_{7.5}$	r_d	CSR_{MCE}	K_α	*f*	K_σ	FS_{MCE}	Remarks
S-21	Upper Fine Sands and Silts	46.6	959.4	115	5784	100	5684	95.2	35	6	2	73	4.0000	0.7875	0.0697	1	0.7	0.7435	2.00	Not Susceptible To Liquefaction
S-22	Upper Mixed Deposits	48.6	957.4	120	6027	225	5802	92.1	35	6	2	71	4.0000	0.7670	0.0693	1	0.7	0.7389	2.00	Not Susceptible To Liquefaction
S-26	Upper Mixed Deposits	56.6	949.4	120	6987	724	6263	76.5	6	6	2	16	0.1660	0.6885	0.0668	1	0.7	0.7221	2.00	Not Expected To Liquify
S-27	Upper Mixed Deposits	58.6	947.4	120	7227	849	6378	14.6	20	2	1	23	0.2617	0.6709	0.0661	1	0.7	0.7182	2.00	Not Expected To Liquify
S-30	Upper Mixed Deposits	70.6	935.4	120	8667	1597	7070	14.4	57	2	1	62	4.0000	0.5887	0.0627	1	0.7	0.6964	2.00	Not Susceptible To Liquefaction

Lithology to 50 Feet	Depth (ft)	Layer Bottom Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)
Upper Mixed Deposits	5	1001	120	600
Upper Fine Sands and Silts	10	996	115	1175
Lower Fine Sands and Silts	24	982	120	2855
Lower Mixed Deposits	46	960	130	5715
Lower Fine Sands and Silts	86	920	120	10515

(N1)60 Values taken from N-Value vs Depth Date - MT 08.17.23

Sample locations taken from Table 3B - Summary of Geotech Lab Results.xlsx

Footnotes:

[1] Assessment of liquefaction susceptibility is discussed in the main text of the Liquefaction Assessment Report.

Symbols:

a_{max} = peak horizontal acceleration at the ground surface
MSF = magnitude scaling factor
N_m = measured standard penetration resistance
σ_{v0} = total overburden stress
σ'_{v0} = effective overburden stress
C_N = factor to normalize N_m to a common reference effective overburden stress
C_E = correction for hammer energy ratio (ER)
C_B = correction factor for borehole diameter
C_R = correction factor for rod length
C_S = correction for samplers with or without liners

$(N_1)_{60}$ = standard penetration test (SPT) blow count normalized to an overburden stress of approximately 100 kPa and a hammer energy ratio or hammer efficiency of 60%
$(N_1)_{60CS}$ = equivalent clean sand $(N_1)_{60}$ value
CSR = cyclic stress ratio
CRR = cyclic resistance ratio
r_d = stress reduction coefficient (spreadsheet uses average value)
K_σ = correction factor for confining stress
f = exponent for calculation of K_σ
K_α = correction factor for sloping ground
FS = factor of safety against liquefaction

Client: GE UDF
Prepared by: D. Bonner
Checked by: M. Giampaolo
Subject: Liquefaction Analysis using "Simplified Procedure" (Youd et al. 2001)
Boring **PZ-2022-2**

			Elevation (NAVD88)	
depth to water table =	55	ft	951	
Assumed water table fluctuation =	10	ft		
Assumed depth to water table for check =	45	ft	961	
unit weight of water =	62.4	pcf		
ground surface elevation =	1006	ft		

Seismic Setting

Site Class (ASCE 7-16): D (Stiff Soil)

Maximum Considered Earthquake (MCE)

earthquake magnitude$_{MCE}$ = 4.90

a_{max} = 0.134 g

MSF_{Idriss} = 2.9723369

Sample ID	Material Type	Depth (ft)	Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)	u (psf)	σ'_{v0} (psf)	Fines Content (%)	$(N_1)_{60}$	α	β	$(N_1)_{60CS}$	$CRR_{7.5}$	r_d	CSR_{MCE}	K_α	*f*	K_σ	FS_{MCE}	Remarks
S-21	Upper Fine Sands and Silts	46.6	959.4	115	5784	100	5684	95.2	35	6	2	73	4.0000	0.7875	0.0697	1	0.7	0.7435	2.00	Not Susceptible To Liquefaction
S-22	Upper Mixed Deposits	48.6	957.4	120	6027	225	5802	92.1	35	6	2	71	4.0000	0.7670	0.0693	1	0.7	0.7389	2.00	Not Susceptible To Liquefaction
S-26	Upper Mixed Deposits	56.6	949.4	120	6987	724	6263	76.5	6	6	2	16	0.1660	0.6885	0.0668	1	0.7	0.7221	2.00	Not Expected To Liquify
S-27	Upper Mixed Deposits	58.6	947.4	120	7227	849	6378	14.6	20	2	1	23	0.2617	0.6709	0.0661	1	0.7	0.7182	2.00	Not Expected To Liquify
S-30	Upper Mixed Deposits	70.6	935.4	120	8667	1597	7070	14.4	57	2	1	62	4.0000	0.5887	0.0627	1	0.7	0.6964	2.00	Not Susceptible To Liquefaction

Lithology to 50 Feet	Depth (ft)	Layer Bottom Elev. (ft)	Unit Weight (pcf)	σ_{v0} (psf)
Upper Mixed Deposits	5	1001	120	600
Upper Fine Sands and Silts	10	996	115	1175
Lower Fine Sands and Silts	24	982	120	2855
Lower Mixed Deposits	46	960	130	5715
Lower Fine Sands and Silts	86	920	120	10515

(N1)60 Values taken from N-Value vs Depth Date - MT 08.17.23

Sample locations taken from Table 3B - Summary of Geotech Lab Results.xlsx

Footnotes:

[1] Assessment of liquefaction susceptibility is discussed in the main text of the Liquefaction Assessment Report.

Symbols:

a_{max} = peak horizontal acceleration at the ground surface
MSF = magnitude scaling factor
N_m = measured standard penetration resistance
σ_{v0} = total overburden stress
σ'_{v0} = effective overburden stress
C_N = factor to normalize N_m to a common reference effective overburden stress
C_E = correction for hammer energy ratio (ER)
C_B = correction factor for borehole diameter
C_R = correction factor for rod length
C_S = correction for samplers with or without liners

$(N_1)_{60}$ = standard penetration test (SPT) blow count normalized to an overburden stress of approximately 100 kPa and a hammer energy ratio or hammer efficiency of 60%
$(N_1)_{60CS}$ = equivalent clean sand $(N_1)_{60}$ value
CSR = cyclic stress ratio
CRR = cyclic resistance ratio
r_d = stress reduction coefficient (spreadsheet uses average value)
K_σ = correction factor for confining stress
f = exponent for calculation of K_σ
K_α = correction factor for sloping ground
FS = factor of safety against liquefaction

ARCADIS

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30158182**

Calc No.: **D-4** **Subject:** **Veneer Stability Analysis**

Prepared By: **Maeve Tucker** **Date:** **February 2024**

Reviewed By: **Mandy Giampaolo/Brian M. Stone** **Date:** **February 2024**

Objective

Evaluate the veneer stability of the proposed final cover system of the Upland Disposal Facility (UDF) to determine the minimum interface friction angle required to provide an acceptable factor of safety during construction (short-term) and normal (long-term) operating conditions.

References

1. Arcadis. 2024. Upland Disposal Facility Final Design Plan. General Electric Company, Pittsfield, Massachusetts. February 2024.
2. Holtz, Robert D. and Kovacs William D. *An Introduction to Geotechnical Engineering.* Prentice Hall Inc. Upper Saddle River, New Jersey. 1981.
3. Koerner, R.M. and Dhani Narejo. 2005. *Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces.*
4. Koerner, Robert M. and T. Soong, "Analysis and Design of Veneer Cover Soils," *Sixth International Conference on Geosynthetics,* 2005.
5. USGS Earthquake Hazards Program - Unified Hazard Tool.

Attachments

1. Critical Section Location and Cross Section
2. Seismic and Equipment Reference Sheets
3. Veneer Stability Calculations

Assumptions

1. Critical Section: Final closure configuration and slope for the critical section is determined from Reference 1. From review of Reference 1, the worst-case slope condition (i.e., steepest slope over the longest distance) is approximately 33.5% (surface slope, approximately 18.5 degrees) over a length of approximately 105 feet.
2. Cover System: The final cover system, from top to bottom, consists of 24 inches of cover soil (consisting of 6 inches of topsoil and 18 inches of general fill), a geocomposite drainage layer, a 60

mil textured HDPE, a geosynthetic clay liner, and a 6 inch separation layer (final cover subbase), over consolidated material.

3. No adhesion is assumed between the soils and the geosynthetics.
4. The final cover system is freely drained (i.e., adequate subsurface drainage is provided to avoid a buildup of seepage forces at the soil/geosynthetic surface).
5. A horizontal seismic coefficient of 0.084g was used to evaluate the stability of the UDF under pseudo-static conditions. The coefficient was based on the site location entered into the USGS Unified Hazard Tool (Reference 5, Attachment 2).
6. The stability for the short-term scenario reflects conditions expected during placement of the first lift of soil over the geosynthetics, including a 1-foot-thick soil cover layer in place and operation of a D6 low-ground pressure tracked dozer (refer to Attachment 2).
7. Acceleration and deceleration forces due to equipment operations are not considered.
8. Factors of Safety: The minimum acceptable factor of safety (FOS) values used for this calculation include:
    a. 1.50 (long-term static, peak strength)
    b. 1.20 (long-term static, residual)
    c. 1.00 (seismic)
    d. 1.30 (short-term with construction loads, peak strength)
    e. 1.00 (short-term with construction loads, residual)

Calculations

The critical (weakest) interface governs the veneer stability of the proposed cover system. Therefore, the minimum internal friction angle of the cover soils will be no less than the minimum required peak interface friction angle. The weakest interface is assumed to occur between the geosynthetic clay liner layer and HDPE geomembrane. Because the strength of this interface is an unknown until specific products are selected at time of construction, the stability analyses herein are completed by solving for the minimum required interface shear strength needed to achieve the minimum acceptable FOS values.

A procedure developed by Koerner and Soong (Reference 4) for finite slope lengths is used to evaluate stability for the short-term (both peak and residual) and seismic conditions. This method is often referred to as the GRI-215 method and is performed by evaluating the gravitational forces acting on a finite length of the cover system, including the buttressing effects of soil at the bottom of the slope. The force diagram and calculations are summarized in Attachment 3. Calculations are performed as outlined in Reference 4 and shown in Attachment 3.

Summary

The veneer slope stability of the proposed final cover is evaluated for the worst-case slope condition. Table 1 below summarize the minimum acceptable interface/internal friction angles necessary to achieve the minimum required FOS values for 1.) long-term and seismic conditions; and 2.) short-term conditions expected during final cover construction.

Table 1 – Veneer Stability Required Interface/Internal Friction Angles

Case	Required Factor of Safety	Min. Acceptable Interface/Internal Friction Angle
Long-Term, Static – Peak Strength	1.50	25.5
Long-Term, Static – Residual Strength	1.20	20.6
Short-Term, Static – Peak Strength	1.30	23.1
Short-Term, Static – Residual Strength	1.00	18.1
Seismic – Residual Strength	1.00	21.9

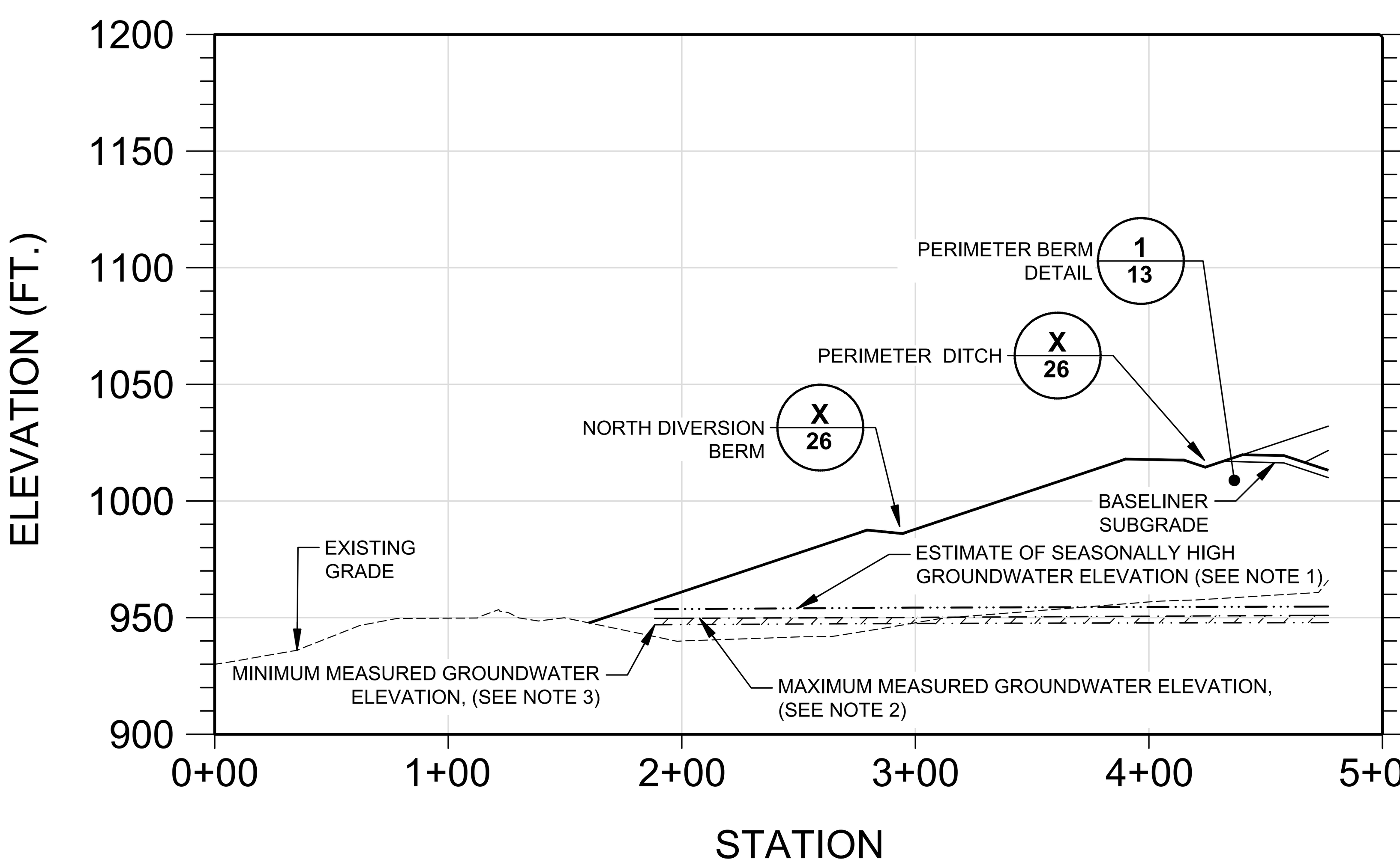
In order to achieve the minimum factors of safety under long-term static conditions, a minimum shear strength equivalent to a friction angle of 25.5 degrees (peak) and 20.6 degrees (residual) over normal loads ranging from 250 psf to 1,000 psf is required. Additionally, in order to achieve the minimum factors of safety during cover construction (short-term), a minimum shear strength equivalent to a friction angle of 23.1 degrees (peak) and 18.1 degrees (residual) over normal loads ranging from 250 psf to 1,000 psf is required. For the seismic case, a minimum shear strength equivalent to a friction angle of 21.9 degrees (residual) over normal loads ranging from 250 psf to 1,000 psf is required. The lower end of the normal load range (i.e., 250 psf) is based on the presence of 2 feet of cover soil, and the upper end of this range is based on the presence of 2 feet of cover soil and a D6 LGP dozer, during construction, and undefined future surface loads, such as mowing equipment.

Acceptability of the proposed cover system materials will be determined by laboratory testing of each soil-to-geosynthetic and geosynthetic-to-geosynthetic interface (ASTM D5321 or ASTM D6243, as appropriate for interface) and by direct shear testing (internal friction angle) of fill materials (ASTM D3080). Testing will occur at representative normal loads (as discussed above) to establish shear resistance over the range of conditions. To simulate seismic conditions more closely, the minimum value should be obtained using a high strain rate (minimum 0.5 in/min).

Laboratory test results will be required to demonstrate interface and internal shear strengths equal to or greater than the minimum acceptable friction angles summarized above, prior to material acceptance. Testing shall be in accordance with project specifications. Note, higher friction angles from laboratory testing than those summarized in Table 1 would result in greater factors of safety.

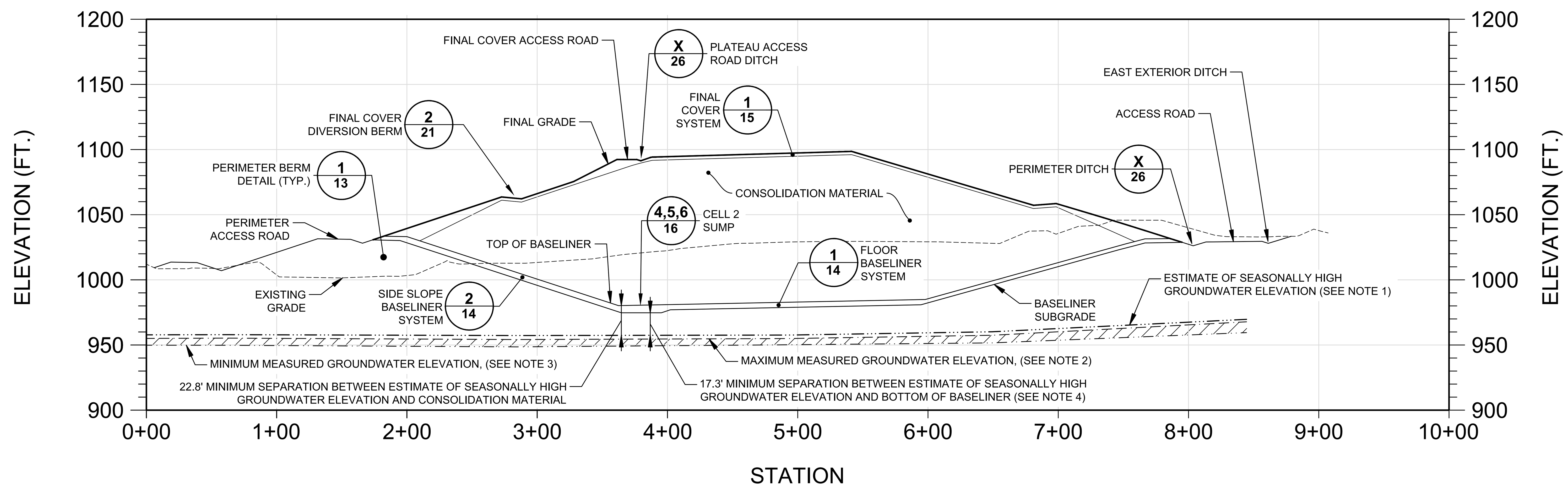
Attachment 1

Critical Section Location and Cross Section



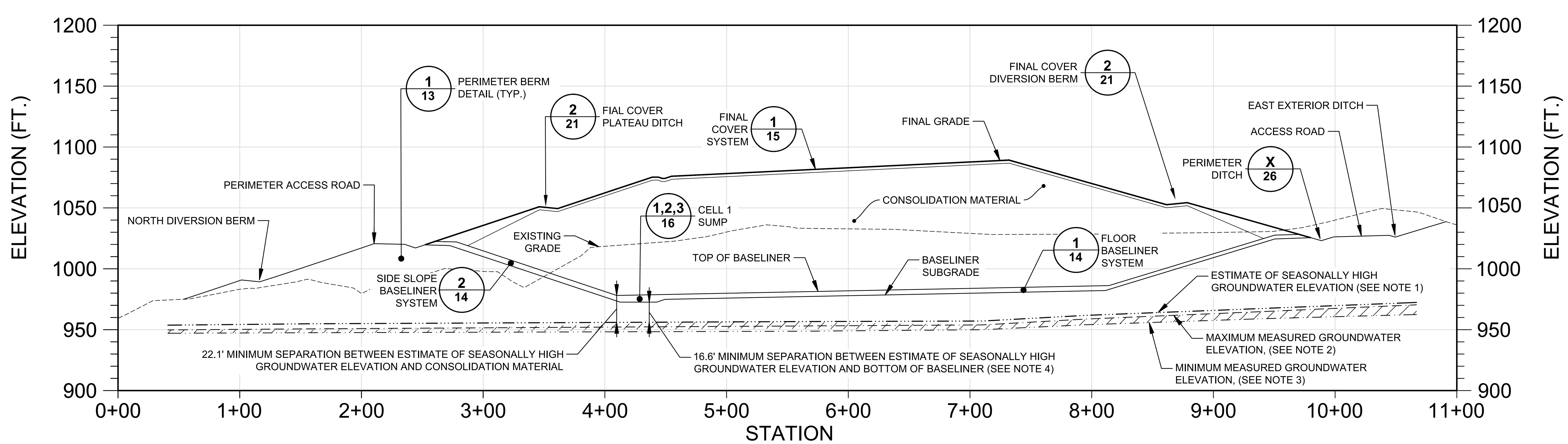
SITE CROSS SECTION C/12

SCALE: 1' = 60'
(NO VERTICAL EXAGGERATION)



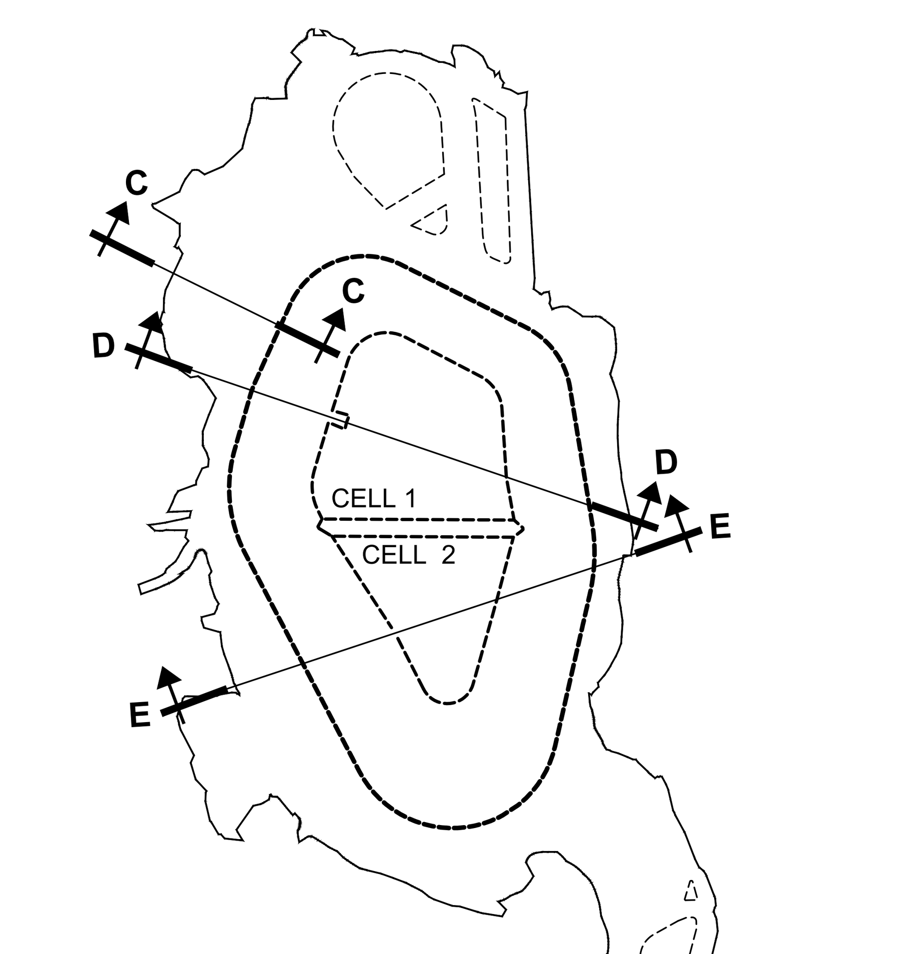
SITE CROSS SECTION E/12

SCALE: 1' = 60'
(NO VERTICAL EXAGGERATION)



SITE CROSS SECTION D/12

SCALE: 1' = 60'
(NO VERTICAL EXAGGERATION)



CROSS SECTION LOCATION PLAN

NOT TO SCALE

NOTES:

1. THE ESTIMATE OF SEASONALLY HIGH GROUNDWATER ELEVATION SHOWN IS BASED ON THE METHODOLOGY AND RESULTING CALCULATIONS DESCRIBED IN SECTION 3.6.2 OF THE FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024).

2. MINIMUM MEASURED GROUNDWATER ELEVATION IS BASED ON TRANSDUCER AND MANUAL GROUNDWATER ELEVATION GAUGING CONDUCTED FROM JUNE 2022 THROUGH JUNE 2023 AS DESCRIBED IN SECTION 3.6.1 OF THE FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024). THE ELEVATIONS SHOWN REPRESENT THE HIGHEST RECORDED GROUNDWATER ELEVATIONS FOR THE TRANSDUCER GAUGING PERIOD.

3. MAXIMUM MEASURED GROUNDWATER ELEVATION IS BASED ON TRANSDUCER GROUNDWATER ELEVATION GAUGING CONDUCTED FROM JUNE 2022 THROUGH JUNE 2023 AS DESCRIBED IN SECTION 3.6.1 OF THE FINAL PRE-DESIGN INVESTIGATION SUMMARY REPORT FOR UPLAND DISPOSAL FACILITY AREA (ARCADIS 2024). THE ELEVATIONS SHOWN REPRESENT THE HIGHEST RECORDED GROUNDWATER ELEVATIONS FOR THE TRANSDUCER GAUGING PERIOD.

4. SECTION II.B.5.A OF THE REVISED PERMIT SETS FORTH THE PERFORMANCE STANDARDS FOR THE UDF THAT REQUIRES THE BASELINER BE A MINIMUM OF 15 FEET ABOVE A CONSERVATIVE ESTIMATE OF THE SEASONALLY HIGH GROUNDWATER ELEVATION. THE SEASONALLY HIGH GROUNDWATER ELEVATION SHOWN ON THIS DRAWING AND USED FOR DESIGN OF THE UDF IS BASED ON THE FRIMPTER METHOD WHICH PROVIDES A CONSERVATIVE ESTIMATE OF THE GROUNDWATER ELEVATIONS USING SITE-SPECIFIC GROUNDWATER ELEVATION DATA COLLECTED IN THE LOCATION OF THE UDF THAT IS MODIFIED (PROJECTED) TO ACCOUNT FOR HISTORICAL GROUNDWATER LEVEL FLUCTUATIONS AT SIMILARLY SITED OFF-SITE, LONG-TERM MONITORING WELLS IN MASSACHUSETTS.

60' 0 60' 120'
1"=60'

THIS BAR REPRESENTS ONE INCH ON THE ORIGINAL DRAWING: USE TO VERIFY FIGURE REPRODUCTION SCALE

No.	Date	Revisions	By	Ckd

Professional Engineer's Name		
MARK O. GRAVELDING		
Professional Engineer's No. 42983		
State: MA	Date Signed	Project Mgr.: DK
Designed by: BMS	Drawn by: KLS	Checked by: PHB

INTERNAL **DRAFT**

ARCADIS

ARCADIS U.S., INC.

GE-PITTSFIELD/HOUSATONIC RIVER SITE • LEE, MASSACHUSETTS
UPLAND DISPOSAL FACILITY FINAL DESIGN PLAN

SITE CROSS SECTIONS - 2

INTERNAL

ARCADIS Project No. 30158182.3
Date FEBRUARY 2024
ARCADIS
ONE LINCOLN CENTER
110 WEST FAYETTE STREET
SYRACUSE, NEW YORK 13202
TEL. 315.446.9120

Attachment 2

Seismic and Equipment Reference Sheets

Unified Hazard Tool

Please do not use this tool to obtain ground motion parameter values for the design code reference documents covered by the U.S. Seismic Design Maps web tools (e.g., the International Building Code and the ASCE 7 or 41 Standard). The values returned by the two applications are not identical.

Please also see the new USGS Earthquake Hazard Toolbox for access to the most recent NSHMs for the conterminous U.S. and Hawaii.

Input

Edition

Conterminous U.S. 2014 (v4.0.x)

Latitude

Decimal degrees

42.3415

Longitude

Decimal degrees, negative values for western longitudes

-73.23806

Site Class

760 m/s (B/C boundary)

Spectral Period

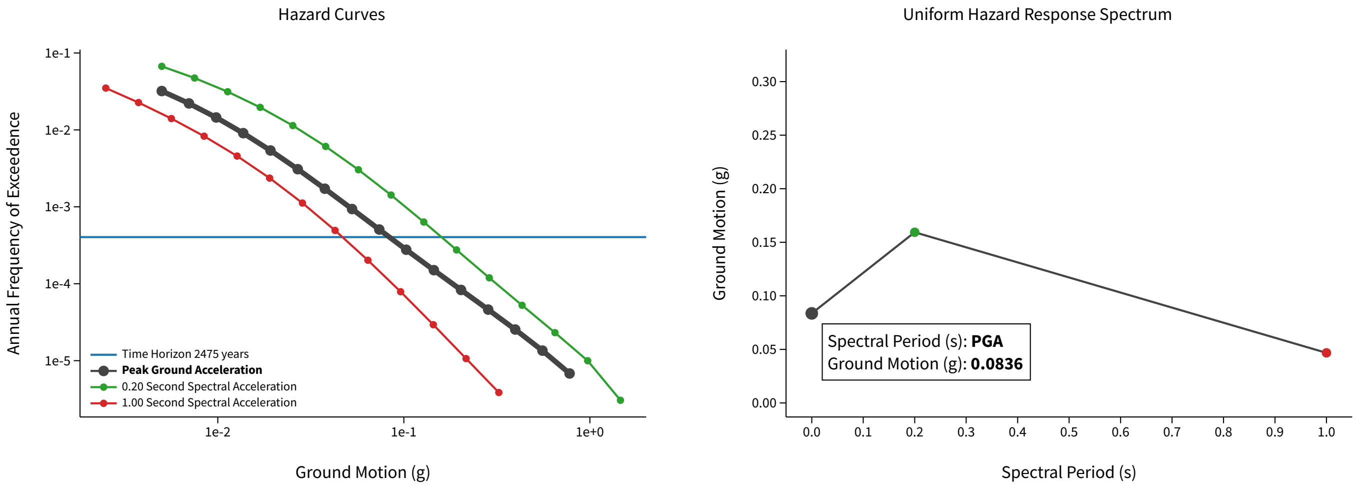
Peak Ground Acceleration

Time Horizon

Return period in years

2475

Hazard Curve



View Raw Data

D6/D6 XE

Track-Type Tractors

Technical Specifications

Engine

Engine Model	Cat® C9.3B	
Emissions	U.S. EPA Tier 4 Final, EU Stage V, Korea Tier 4 Final	
Build Number	20A	
Net Power (Rated) – D6 2,200 rpm/D6 XE 1,700 rpm		
ISO 9249/SAE J1349	161 kW	215 hp
ISO 9249/SAE J1349 (DIN)		219 hp
D6 Engine Power (Maximum) – 1,200 rpm		
ISO 14396	187 kW	251 hp
ISO 14396 (DIN)		254 hp
D6 XE Engine Power (Maximum) – 1,400 rpm		
ISO 14396	177 kW	237 hp
ISO 14396 (DIN)		241 hp
Bore	115 mm	4.5 in
Stroke	149 mm	5.9 in
Displacement	9.3 L	567 in³

- The new Cat C9.3B engine features a new high pressure common rail fuel system, simplified engine system electronics, and simplified air system through the removal of the previously used exhaust gas recirculation (EGR) system.
- The XE drive train allows the engine to operate in a tighter rpm range, 1,400-1,700 rpm, which helps extend engine life and provide improved fuel economy. The increased drive train efficiency also allows the machine to provide more engine power to the ground, resulting in greater machine performance.
- Net power advertised is the power available at the engine flywheel when the engine is equipped with a fan, air cleaner, clean emissions module and alternator.
- No derating required up to 2286 m (7,500 ft). Above this, automatic derating occurs.
- All non-road Tier 4 Interim and Final, Stage IIIB, IV and V and Korea Tier 4 Final diesel engines are required to use only ultra-low sulfur diesel (ULSD) fuels containing 15 ppm (mg/kg) sulfur or less. Biodiesel blends up to B20 (20% blend by volume) are acceptable when blended with 15 ppm (mg/kg) sulfur or less ULSD. B20 should meet ASTM D7467 specification (biodiesel blend stock should meet Cat biodiesel spec, ASTM D6751 or EN 14214). Cat DEO-ULS™ or oils that meet the Cat ECF-3, API CJ-4, and ACEA E9 specification are required. Consult your OMM for further machine specific fuel recommendations.
- Diesel Exhaust Fluid (DEF) used in Cat Selective Catalytic Reduction (SCR) systems must meet the requirements outlined in the International Organization for Standardization (ISO) standard 22241.

D6 XE Drive Train

Type	Electric Drive
Electric Drive System Nominal Voltage	715 Volts

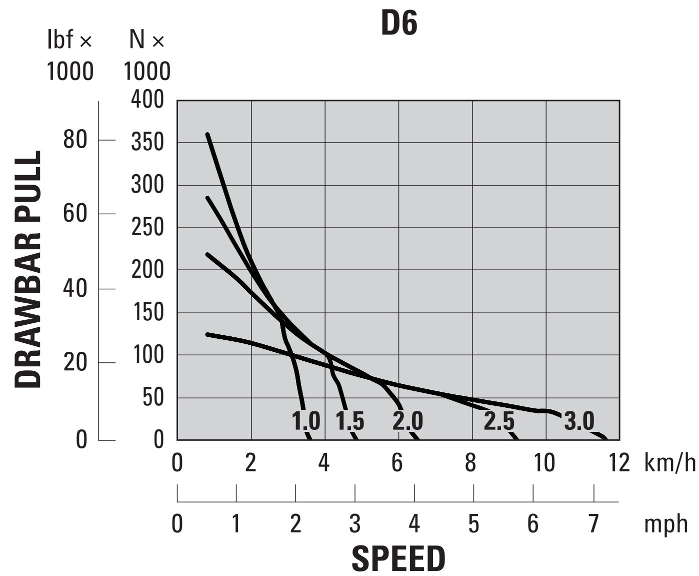
D6/D6 XE Track-Type Tractors Specifications

Maximum Drawbar Power

D6	114 kW	153 hp
D6 XE	119 kW	160 hp

D6 Travel Speed

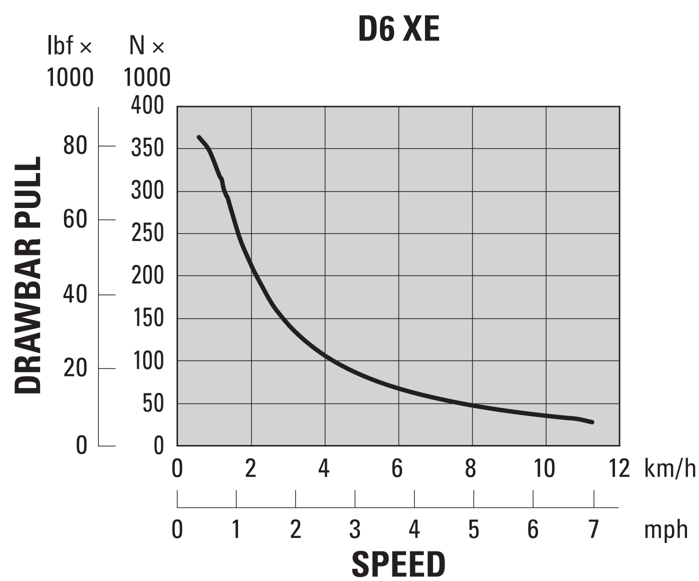
1.0 Forward	3.6 km/h	2.2 mph
1.5 Forward	4.9 km/h	3.0 mph
2.0 Forward	6.5 km/h	4.0 mph
2.5 Forward	9.2 km/h	5.7 mph
3.0 Forward	11.7 km/h	7.2 mph
1.0 Reverse	3.6 km/h	2.2 mph
1.5 Reverse	4.9 km/h	3.0 mph
2.0 Reverse	6.5 km/h	4.0 mph
2.5 Reverse	8.7 km/h	5.4 mph
3.0 Reverse	11.7 km/h	7.2 mph



NOTE: Usable pull will depend on traction and weight of machine.

D6 XE Travel Speed

1.0 Forward	3.6 km/h	2.2 mph
1.5 Forward	4.9 km/h	3.0 mph
2.0 Forward	6.5 km/h	4.0 mph
2.5 Forward	9.2 km/h	5.7 mph
3.0 Forward	11.7 km/h	7.2 mph
1.0 Reverse	3.6 km/h	2.2 mph
1.5 Reverse	4.9 km/h	3.0 mph
2.0 Reverse	6.5 km/h	4.0 mph
2.5 Reverse	9.2 km/h	5.7 mph
3.0 Reverse	11.7 km/h	7.2 mph



NOTE: Usable pull will depend on traction and weight of machine.

- The fully automatic D6 4-speed transmission, with lock-up clutch torque divider, continuously optimizes gear and engine speed for the application.
- The D6 XE Electric Drive power train has no gears to shift. The dozer automatically optimizes power and efficiency for the application and provides constant power to the ground.
- Thirty ground speed selections are available for both power trains, from 0.0 to 3.0 in 0.1 increments.

Hydraulic Controls – Maximum Operating Flows

	D6 (1,900 rpm engine speed*)		D6 XE (1,700 rpm engine speed*)	
Implement Pump Maximum Flow	212 L/min	56 gal/min	212 L/min	56 gal/min
Steering Pump Maximum Flow	198 L/min	52 gal/min	240 L/min	63 gal/min
Fan Pump Flow at Maximum Fan (1,550 rpm)	42 L/min	11 gal/min	—	—
Fan Pump Flow at Maximum Fan (1,625 rpm)	—	—	44 L/min	12 gal/min

*Engine speed varies with load and travel speed. A high idle/low working load speed shown.

Hydraulic Controls – Maximum Operating Pressures

Implement Relief*	27 600 ± 500 kPa	4,000 ± 73 psi
Steering – D6 (89 cc pump)**		
Electronic Relief	42 500 ± 1000 kPa	6,168 ± 145 psi
System Maximum Relief	47 800 ± 1000 kPa	6,938 ± 145 psi
Steering – D6 XE (100 cc pump)***		
Electronic Relief	44 500 ± 1000 kPa	6,459 ± 145 psi
System Maximum Relief	47 800 ± 1000 kPa	6,938 ± 145 psi

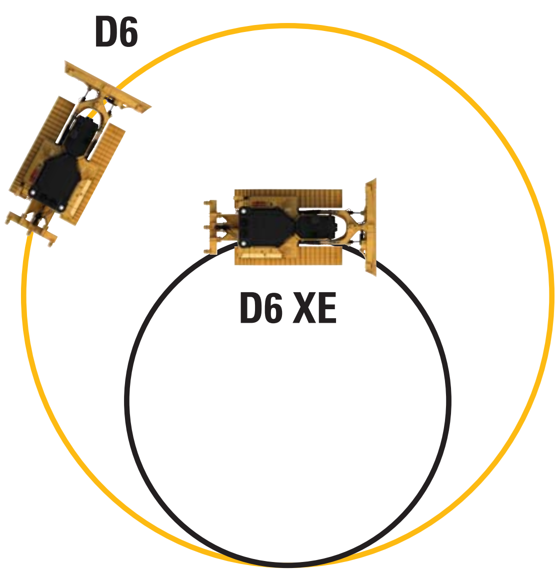
*Implement relief pressure increased over prior model D6 tractors. Consult with your dealer prior to using older vintage or third party implements.

**The same differential steering system is used for both power trains. This system maintains full power to both tracks to provide best-in-class turning with a loaded blade.

***The D6 XE power train utilizes a larger steering pump and enhanced steering controls to provide more steering power, compared to the D6 power train, to turn larger loads and to improve maneuverability. This includes the ability to counter-rotate in gear.

Steering

The D6 XE power train provides up to a 45 percent steering radius reduction compared to the D6. The D6 XE offers in-gear counter rotation for increased maneuverability.



D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE

	Configuration	D6/D6 XE*	
	Operating Weight**	22 000 kg	48,500 lb
	Shipping Weight***	19 060 kg	42,020 lb
	Ground Pressure (ISO 16754)	54 kPa	7.9 psi
	Undercarriage (Standard)	42 Section with 7 Bottom Rollers	
1	Track Gauge	1.930 m	76 in
2	Width of Maximum Track Shoe	0.610 m	24 in
3	Width over Tracks	2.540 m	100 in
	Width over Trunnions	2.692 m	106 in
4	Length of Track on Ground	2.964 m	116.7 in
	Ground Contact Area (ISO 16754)	3.992 m²	6188 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.361 m	14.2 in
	Oscillation at Front Idler	0.103 m	4.0 in
5	Machine Height****	3.172 m	124.9 in
6	Length of Machine without Blade	4.730 m	186.2 in

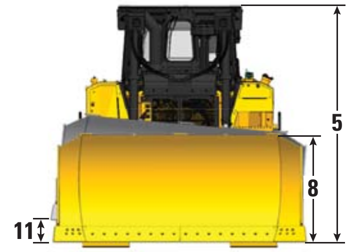
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, 6 SU blade, and calculated per ISO 16754 unless otherwise specified.

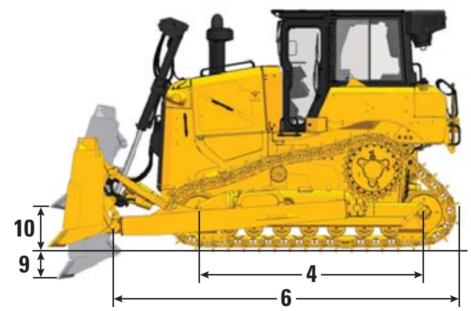
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

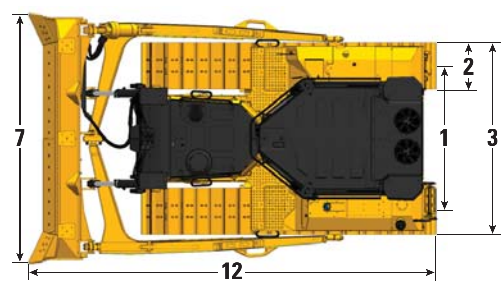
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link™ Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blades

	Configuration	6 SU		6 SU Landfill		6A	
	Capacity (ISO 9246)	5.7 m³	7.5 yd³	11.2 m³	14.6 yd³	4.2 m³	5.5 yd³
7	Width across End Bits	3.312 m	10 ft 10.4 in	3.312 m	10 ft 10.4 in	4.389 m	14 ft 4.8 in
	Width without End Bits	3.246 m	10 ft 7.8 in	3.246 m	10 ft 7.8 in	4.250 m	13 ft 11.3 in
	Width across End Bits (Blade Angled)	N/A		N/A		3.982 m	13 ft 0.8 in
	Width without End Bits (Blade Angled)	N/A		N/A		3.858 m	12 ft 7.9 in
	Maximum Blade Angle	N/A		N/A		25 degrees	
8	Height	1.408 m	4 ft 7.4 in	2.027 m	6 ft 7.8 in	1.150 m	3 ft 9.3 in
9	Dig Depth	0.502 m	19.8 in	0.502 m	19.8 in	0.595 m	23.4 in
10	Lift Height	1.180 m	46.5 in	1.180 m	46.5 in	1.084 m	42.7 in
11	Maximum Tilt at Blade Corner	0.564 m	22.2 in	0.564 m	22.2 in	0.599 m	23.6 in
	Maximum Tilt Angle	9.8 degrees		9.8 degrees		7.8 degrees	
	Pitch Adjustment	±4.2 degrees		±4.2 degrees		N/A	
12	Length of Machine (Blade Straight)	5.436 m	17 ft 10.0 in	5.436 m	17 ft 10.0 in	5.377 m	17 ft 7.7 in
	Length of Machine (Blade Angled)	N/A		N/A		6.418 m	21 ft 0.7 in
	Weight (Blade)	1373 kg	3,027 lb	1592 kg	3,510 lb	1253 kg	2,762 lb
	Weight (Blade and Push Arms)	2608 kg	5,750 lb	2827 kg	6,232 lb	3394 kg	7,842 lb

Configuration Tables – D6/D6 XE LGP (30 in)

	Configuration	D6/D6 XE*	
	Operating Weight**	22 740 kg	50,130 lb
	Shipping Weight***	19 580 kg	43,165 lb
	Ground Pressure (ISO 16754)	46 kPA	6.6 psi
	Undercarriage (Standard)	42 Section with 7 Bottom Rollers	
1	Track Gauge	2.080 m	82 in
2	Width of Maximum Track Shoe	0.760 m	30 in
3	Width over Tracks	2.840 m	111.8 in
	Width over Trunnions	2.994 m	117.9 in
4	Length of Track on Ground	2.964 m	116.7 in
	Ground Contact Area (ISO 16754)	4.990 m²	7,735 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.361 m	14.2 in
	Oscillation at Front Idler	0.100 m	3.9 in
5	Machine Height****	3.172 m	124.9 in
6	Length of Machine without Blade	4.730 m	186.2 in

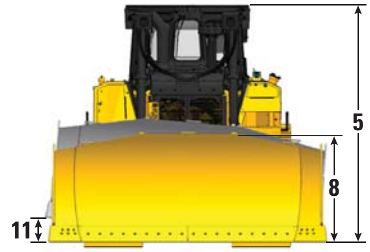
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, 6 SU blade, and calculated per ISO 16754 unless otherwise specified.

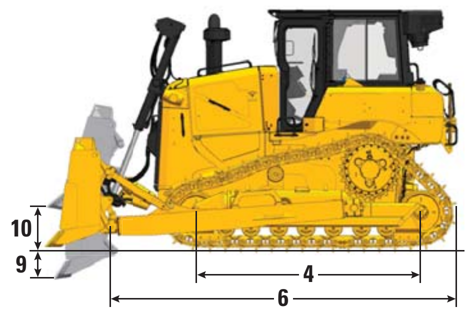
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

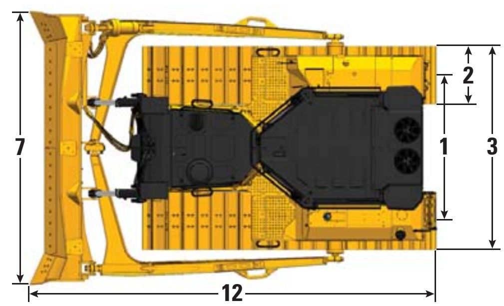
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blades

	Configuration	6 SU LGP (30 in)		6 SU LGP (30 in) Landfill		6A LGP (30 in)	
	Capacity (ISO 9246)	5.8 m³	7.6 yd³	12.3 m³	16.1 yd³	4.6 m³	6.0 yd³
7	Width across End Bits	3.613 m	11 ft 10.2 in	3.613 m	11 ft 10.2 in	4.735 m	15 ft 6.4 in
	Width without End Bits	3.551 m	11 ft 7.8 in	3.551 m	11 ft 7.8 in	4.596 m	15 ft 1.0 in
	Width across End Bits (Blade Angled)	N/A		N/A		4.295 m	14 ft 1.1 in
	Width without End Bits (Blade Angled)	N/A		N/A		4.172 m	13 ft 8.3 in
	Maximum Blade Angle	N/A		N/A		25 degrees	
8	Height	1.408 m	4 ft 7.4 in	2.027 m	6 ft 7.8 in	1.150 m	3 ft 9.3 in
9	Dig Depth	0.502 m	19.8 in	0.502 m	19.8 in	0.568 m	22.3 in
10	Lift Height	1.180 m	46.5 in	1.180 m	46.5 in	1.125 m	44.3 in
11	Maximum Tilt at Blade Corner	0.551 m	21.7 in	0.551 m	21.7 in	0.640 m	25.2 in
	Maximum Tilt Angle	8.8 degrees		8.8 degrees		7.8 degrees	
	Pitch Adjustment	±4.2 degrees		±4.2 degrees		N/A	
12	Length of Machine (Blade Straight)	5.436 m	17 ft 10.0 in	5.436 m	17 ft 10.0 in	5.448 m	17 ft 10.5 in
	Length of Machine (Blade Angled)	N/A		N/A		6.561 m	21 ft 6.3 in
	Weight (Blade)	1446 kg	3,188 lb	1700 kg	3,748 lb	1350 kg	2,976 lb
	Weight (Blade and Push Arms)	2827 kg	6,232 lb	2973 kg	6,554 lb	3414 kg	7,527 lb

D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE LGP (36 in)

	Configuration	D6/D6 XE*	
	Operating Weight**	23 866 kg	52,615 lb
	Shipping Weight***	21 165 kg	46,660 lb
	Ground Pressure (ISO 16754)	35 kPa	5.1 psi
	Undercarriage (Standard)	45 Section with 8 Bottom Rollers	
1	Track Gauge	2.286 m	90 in
2	Width of Maximum Track Shoe	0.915 m	36 in
3	Width over Tracks	3.200 m	126.0 in
	Width over Trunnions	3.491 m	137.4 in
4	Length of Track on Ground	3.247 m	127.8 in
	Ground Contact Area (ISO 16754)	6.505 m²	10,083 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.411 m	16.2 in
	Oscillation at Front Idler	0.116 m	4.6 in
5	Machine Height****	3.222 m	126.9 in
6	Length of Machine without Blade	5.040 m	198.4 in

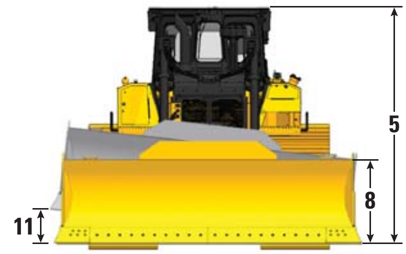
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, 6 S blade, and calculated per ISO 16754 unless otherwise specified.

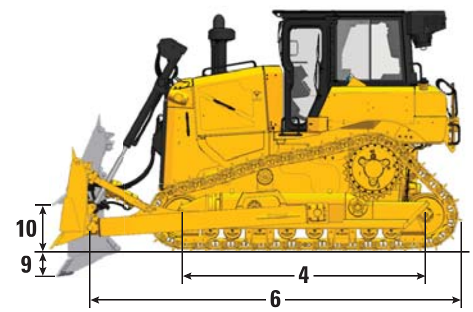
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

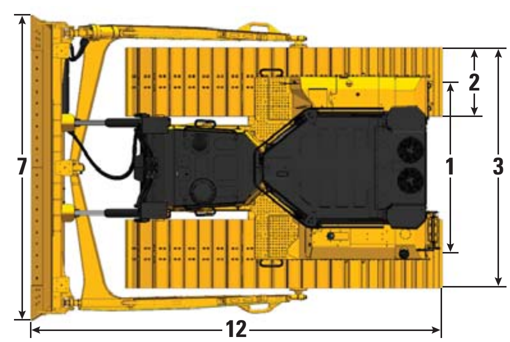
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blades

	Configuration	6 S LGP (36 in)		6 S LGP (36 in) Landfill		6A LGP (36 in)	
	Capacity (ISO 9246)	3.8 m³	5.0 yd³	9.40 m³	12.3 yd³	5.0 m³	6.5 yd³
7	Width across End Bits	4.063 m	13 ft 4 in	4.063 m	13 ft 4 in	5.100 m	16 ft 8.8 in
	Width without End Bits	3.917 m	12 ft 10.2 in	3.917 m	12 ft 10.2 in	4.961 m	16 ft 3.3 in
	Width across End Bits (Blade Angled)	N/A		N/A		4.626 m	15 ft 2.1 in
	Width without End Bits (Blade Angled)	N/A		N/A		4.502 m	14 ft 9.2 in
	Maximum Blade Angle	N/A		N/A		25 degrees	
8	Height	1.108 m	3 ft 7.6 in	1.767 m	3 ft 7.6 in	1.150 m	3 ft 9.3 in
9	Dig Depth	0.600 m	1 ft 11.6 in	0.600 m	1 ft 11.6 in	0.719 m	28.3 in
10	Lift Height	1.080 m	3 ft 6.5 in	1.080 m	3 ft 6.5 in	1.173 m	46.2 in
11	Maximum Tilt at Blade Corner	0.500 m	1 ft 7.7 in	0.500 m	1 ft 7.7 in	0.689 m	27.1 in
	Maximum Tilt Angle	8.8 degrees		8.8 degrees		7.8 degrees	
	Pitch Adjustment	±4.2 degrees		±4.2 degrees		N/A	
12	Length of Machine (Blade Straight)	5.483 m	17 ft 11.9 in	5.483 m	17 ft 11.9 in	5.960 m	19 ft 6.6 in
	Length of Machine (Blade Angled)	N/A		N/A		6.996 m	22 ft 10.3 in
	Weight (Blade)	1220 kg	2,690 lb	1432 kg	3,157 lb	1453 kg	3,203 lb
	Weight (Blade and Push Arms)	2370 kg	5,225 lb	2582 kg	5,692 lb	3618 kg	7,976 lb

Configuration Tables – D6/D6 XE VPAT

	Configuration	D6/D6 XE*	
	Operating Weight**	22 240 kg	49,030 lb
	Shipping Weight***	20 500 kg	45,195 lb
	Ground Pressure (ISO 16754)	49 kPa	7.1 psi
	Undercarriage (Standard)	45 Section with 8 Bottom Rollers	
1	Track Gauge	2.080 m	82 in
2	Width of Maximum Track Shoe	0.610 m	24 in
3	Width over Tracks	2.690 m	105.9 in
4	Length of Track on Ground	3.247 m	127.8 in
	Ground Contact Area (ISO 16754)	4.473 m²	6,933 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.422 m	16.6 in
	Oscillation at Front Idler	0.112 m	4.4 in
5	Machine Height****	3.222 m	126.9 in
6	Length of Machine without Blade	5.134 m	202.1 in

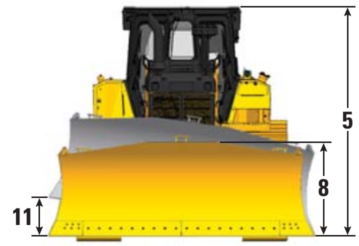
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, VPAT blade, and calculated per ISO 16754 unless otherwise specified.

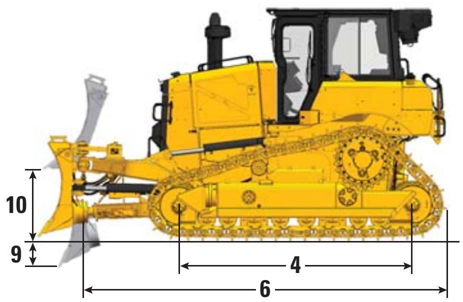
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

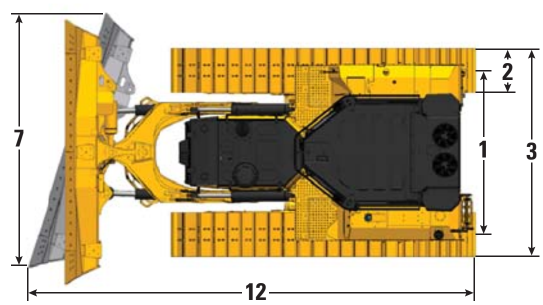
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, C-frame, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blade

	Configuration	6 VPAT	
	Capacity (ISO 9246)	4.1 m³	5.4 yd³
7	Width across End Bits	3.680 m	12 ft 0.9 in
	Width without End Bits	3.570 m	11 ft 8.6 in
	Width across End Bits (Blade Angled)	3.363 m	11 ft 0.4 in
	Width without End Bits (Blade Angled)	3.266 m	10 ft 8.6 in
	Maximum Blade Angle	24.1 degrees	
8	Height	1.312 m	4 ft 3.7 in
9	Dig Depth	0.698 m	27.5 in
10	Lift Height	1.131 m	44.5 in
11	Maximum Tilt at Blade Corner	0.576 m	22.7 in
	Maximum Tilt Angle	9 degrees	
	Pitch Adjustment	+3.1/–2.9 degrees	
12	Length of Machine (Blade Straight)	5.662 m	18 ft 6.9 in
	Length of Machine (Blade Angled)	6.365 m	20 ft 10.6 in
	Weight (Blade)	1414 kg	3,117 lb

D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE LGP VPAT (30 in)

	Configuration	D6/D6 XE*	
	Operating Weight**	22 975 kg	50,650 lb
	Shipping Weight***	21 125 kg	46,575 lb
	Ground Pressure (ISO 16754)	40 kPa	5.8 psi
	Undercarriage (Standard)	46 Section with 8 Bottom Rollers	
	Undercarriage (Optional)	46 Section with 10 Bottom Rollers	
1	Track Gauge	2.286 m	90 in
2	Width of Maximum Track Shoe	0.760 m	30 in
3	Width over Tracks	3.046 m	119.9 in
4	Length of Track on Ground	3.355 m	132.1 in
	Ground Contact Area (ISO 16754)	5.591 m²	8,666 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.390 m	15.4 in
	Oscillation at Front Idler	0.121 m	4.8 in
5	Machine Height****	3.222 m	126.9 in
6	Length of Machine without Blade	5.134 m	202.1 in

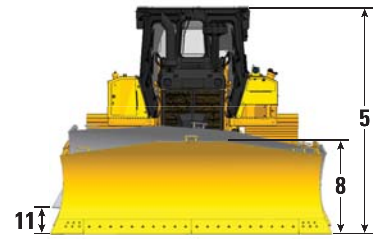
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, VPAT blade, and calculated per ISO 16754 unless otherwise specified.

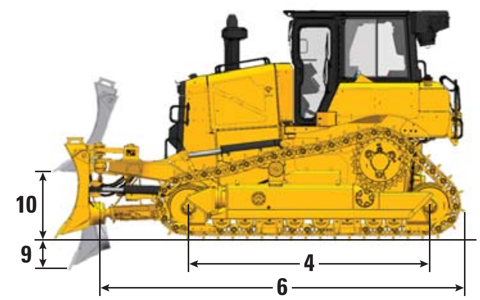
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

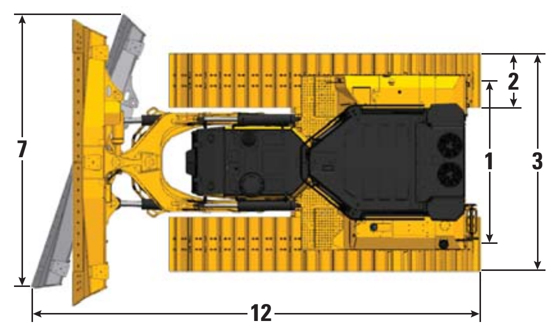
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, C-frame, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blade

	Configuration	6 VPAT LGP (30 in)	
	Capacity (ISO 9246)	4.5 m³	5.9 yd³
7	Width across End Bits	4.000 m	13 ft 1.5 in
	Width without End Bits	3.890 m	12 ft 9.1 in
	Width across End Bits (Blade Angled)	3.655 m	11 ft 11.9 in
	Width without End Bits (Blade Angled)	3.554 m	11 ft 7.9 in
	Maximum Blade Angle	24.1 degrees	
8	Height	1.312 m	4 ft 3.7 in
9	Dig Depth	0.698 m	27.5 in
10	Lift Height	1.131 m	44.5 in
11	Maximum Tilt at Blade Corner	0.625 m	24.6 in
	Maximum Tilt Angle	9 degrees	
	Pitch Adjustment	+3.1/–2.9 degrees	
12	Length of Machine (Blade Straight)	5.662 m	18 ft 6.9 in
	Length of Machine (Blade Angled)	6.430 m	21 ft 1.1 in
	Weight (Blade)	1516 kg	3,342 lb

Configuration Tables – D6/D6 XE LGP VPAT (36 in)

	Configuration	D6/D6 XE*	
	Operating Weight**	23 530 kg	51,875 lb
	Shipping Weight***	21 580 kg	47,575 lb
	Ground Pressure (ISO 16754)	35 kPa	5.0 psi
	Undercarriage (Standard)	46 Section with 8 Bottom Rollers	
	Undercarriage (Optional)	46 Section with 10 Bottom Rollers	
1	Track Gauge	2.39 m	94 in
2	Width of Maximum Track Shoe	0.915 m	36 in
3	Width over Tracks	3.305 m	130.1 in
4	Length of Track on Ground	3.355 m	132.1 in
	Ground Contact Area (ISO 16754)	6.709 m²	9,510 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.383 m	15.1 in
	Oscillation at Front Idler	0.121 m	4.8 in
5	Machine Height****	3.222 m	126.9 in
6	Length of Machine without Blade	5.134 m	202.1 in

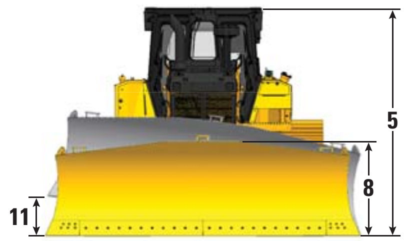
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, VPAT blade, and calculated per ISO 16754 unless otherwise specified.

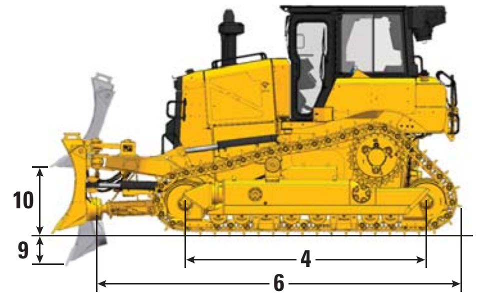
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

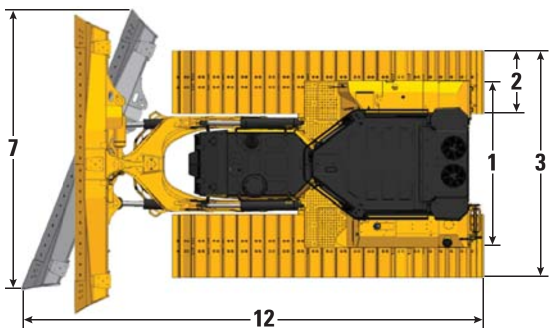
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, tow point, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, C-frame, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and tow point.

****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blade

	Configuration	6 VPAT LGP (36 in)	
	Capacity (ISO 9246)	4.86 m³	6.5 yd³
7	Width across End Bits	4.340 m	14 ft 2.9 in
	Width without End Bits	4.230 m	13 ft 10.5 in
	Width across End Bits (Blade Angled)	3.966 m	13 ft 0.1 in
	Width without End Bits (Blade Angled)	3.868 m	12 ft 8.3 in
	Maximum Blade Angle	24.1 degrees	
8	Height	1.312 m	4 ft 3.7 in
9	Dig Depth	0.698 m	27.5 in
10	Lift Height	1.131 m	44.5 in
11	Maximum Tilt at Blade Corner	0.684 m	26.9 in
	Maximum Tilt Angle	9 degrees	
	Pitch Adjustment	+3.1/–2.9 degrees	
12	Length of Machine (Blade Straight)	5.662 m	18 ft 6.9 in
	Length of Machine (Blade Angled)	6.500 m	21 ft 3.9 in
	Weight (Blade)	1617 kg	3,565 lb

D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE LGP Folding VPAT (30 in) – *EU only*

	Configuration	D6/D6 XE*	
	Operating Weight**	23 405 kg	51,600 lb
	Shipping Weight***	20 820 kg	45,900 lb
	Ground Pressure (ISO 16754)	48 kPa	6.9 psi
	Undercarriage (Standard)	46 Section with 8 Bottom Rollers	
	Undercarriage (Optional)	46 Section with 10 Bottom Rollers	
1	Track Gauge	2.286 m	90 in
2	Width of Standard Track Shoe****	0.660 m	26 in
	Optional Maximum Track Shoe****	0.760 m	30 in
3	Width over Tracks	2.946 m	116.0 in
4	Length of Track on Ground	3.355 m	132.1 in
	Ground Contact Area (ISO 16754)	4.845 m²	7,510 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.390 m	15.4 in
	Oscillation at Front Idler	0.121 m	4.8 in
5	Machine Height*****	3.222 m	126.9 in
6	Length of Machine without Blade	5 134 m	202.1 in

All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of standard width for configuration, Foldable VPAT blade, and calculated per ISO 16754 unless otherwise specified.

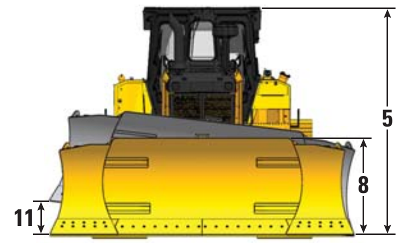
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

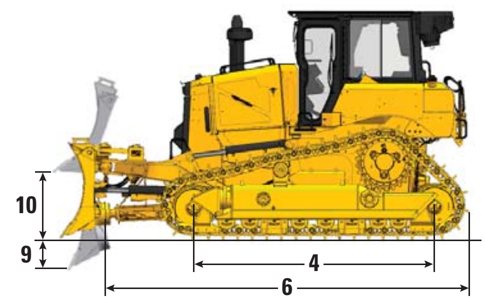
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

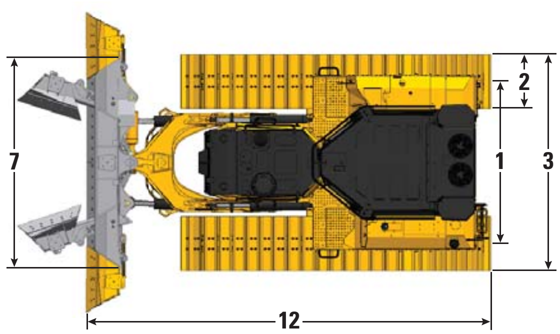
***Shipping weight includes blade lift cylinders, C-frame, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Standard track shoe width ensures 3.0 m shipping width with blade folded. Optional 30 inch track shoes provide lower ground pressure of 45 kPa (6.5 psi). Increases shipping width to 3.046 m (120.0 in).

*****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blade

	Configuration	6 VPAT LGP Folding (30 in)	
	Capacity (ISO 9246)	5.2 m³	6.8 yd³
7	Width across End Bits	4.229 m	13 ft 10.5 in
	Width without End Bits	4.115 m	13 ft 6.0 in
	Width of Folded Blade	2.960 m	9 ft 8.5 in
	Maximum Blade Angle	24.1 degrees	
8	Height	1.312 m	4 ft 3.7 in
9	Dig Depth	0.698 m	27.5 in
10	Lift Height	1.131 m	44.5 in
11	Maximum Tilt at Blade Corner	0.659 m	26.0 in
	Maximum Tilt Angle	9 degrees	
	Pitch Adjustment	+3.1/–2.9 degrees	
12	Length of Machine (Blade Straight)	5.662 m	18 ft 6.9 in
	Length of Machine (Blade Angled)	6.643 m	21 ft 9.5 in
	Length of Machine (Blade Folded)	6.637 m	21 ft 9.3 in
	Weight (Blade)	2254 kg	4,969 lb

Dimensions – Rear Attachments

Add the following to the total length of the machine when these rear attachments are installed.

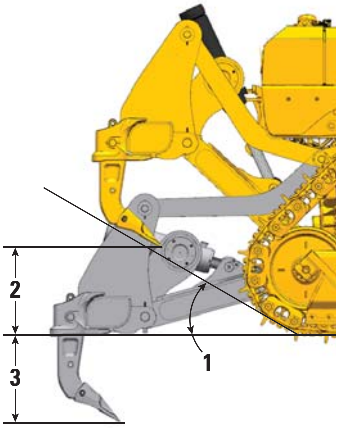
		Winch		Ripper		Drawbar or Counterweight*		Waste Striker Box	
Push Arm and Angle Dozers	D6, D6 LGP (30 in)	441 mm	17.4 in	1179 mm	46.4 in	249 mm	9.8 in	478 mm	18.8 in
	D6 LGP (36 in)	416 mm	16.4 in	1154 mm	45.4 in	224 mm	8.8 in	453 mm	17.8 in
VPAT Dozers		416 mm	16.4 in	1154 mm	45.4 in	224 mm	8.8 in	453 mm	17.8 in

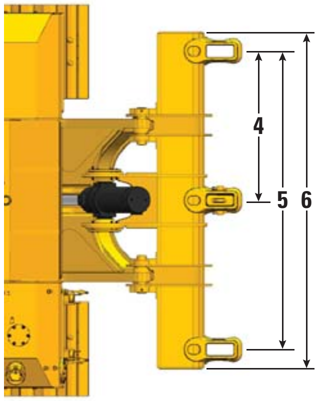
*Drawbar weight 119 kg (262 lb), 331 kg (730 lb) for each counterweight slab. The new D6 dozer design provides improved balance. Counterweights are only recommended with heavier aftermarket blades.

Ripper

	Type	Fixed Parallelogram	
	Number of Pockets	3	
1	Ramp Angle	31 degrees	
2	Maximum Clearance Raised (under tip)	664 mm	26.1 in
3	Maximum Penetration	571 mm	22.5 in
4	Pocket Spacing	1000 mm	39.4 in
5	Shank Gauge	2000 mm	78.8 in
	Shank Section	74 mm × 175 mm	2.9 in × 6.9 in
6	Overall Beam Width	2190 mm	86 in
	Beam Cross Section	219 mm × 304 mm	8.8 in × 12 in
	Maximum Penetration Force*	68.8 kN	15,470 lbf
	Pryout Force	126 kN	28,350 lbf
	Ripper Weight		
	With One Shank	1550 kg	3,417 lb
	Each Additional Shank	73 kg	161 lb

Specifications based on D6 tractor configuration with Heavy Duty undercarriage, MS shoes, and straight ripper shanks.
*May vary based on configuration and machine weight.





Winches

The D6 and D6 XE expand industry-leading winch capability with the introduction of available high pressure (27 600 kPa/4,000 psi) hydraulics capable of powering high performance hydraulic winches. These winches provide exceptional controllability for applications that require precise load placement. The D6 retains compatibility with PTO-driven winches for maximum power and efficiency. Winches of both styles are available from Caterpillar for factory or dealer installation, and integrate with the tractor's electronic and control system.

Tractor Model	**D6**		**D6 and D6 XE**	
Winch Model	PA56 (Low Speed)		PA85	
Winch Drive	Mechanical		Hydraulic	
Control	Electrical		Electrical	
Operating Weight*	1582 kg	3,487 lb	1530 kg	3,374 lb
Oil Capacity	43.5 L	11.5 gal	19 L	5 gal
Increased Tractor Length				
Standard/LGP	516 mm	20.4 in	516 mm	20.4 in
LGP (36 in)	365 mm	14.4 in	365 mm	14.4 in
Drum Diameter	254 mm	10 in	254 mm	10 in
Rope Diameter				
Recommended	22 mm	0.88 in	22 mm	0.88 in
Optional	25 mm	1 in	25 mm	1 in
Drum Working Capacity				
22 mm (0.88 in)	55 m	180 ft	55 m	180 ft
25 mm (1.0 in)	50 m	163 ft	50 m	163 ft
Cable Ferrule Size (O.D. × Length)	54 mm × 67 mm	2.1 in × 2.6 in	54 mm × 67 mm	2.1 in × 2.6 in
Maximum Bare Drum				
Line Pull**	40 700 kg	89,800 lb	40 000 kg	88,000 lb
Line Speed***	18 m/min	58 ft/min	27 m/min	89 ft/min
Maximum Full Drum****				
Line Pull**	34 600 kg	76,300 lb	24 000 kg	52,800 lb
Line Speed***	31 m/min	103 ft/min	44 m/min	145 ft/min

*Operating Weight includes winch, mounting hardware, oil, and recommended wire rope.

**Maximum line pull is lesser of calculated line pull at maximum tractor PTO output torque/hydraulic power or catalog breaking strength of maximum optional size new IWRC IPS wire rope.

***Maximum line speed is calculated no-load line speed at maximum tractor engine PTO output speed or maximum hydraulic power.

****Full drum as defined by SAE J1158.

Track Shoes

Available as Heavy Duty or SystemOne™. Some track shoes not available in all regions. Please consult your Cat dealer for details.

	Moderate Service	Extreme Service	Extreme Service Trapezoidal	Self-Cleaning	Quad/ Quad Ready
D6/D6 XE – 42 Link					
560 mm (22 in)	✓	✓			
610 mm (24 in)	✓	✓	✓		
D6 LGP/D6 XE LGP – 42 Link					
610 mm (24 in)	✓	✓	✓		
760 mm (30 in)	✓	✓	✓		
D6 LGP/D6 XE LGP (36 in) – 45 Link					
760 mm (30 in)	✓	✓	✓		
915 mm (36 in)	✓	✓	✓		HDXL only
1000 mm (39 in)				HDXL only	
D6 VPAT/D6 XE VPAT – 45 Link					
610 mm (24 in)	✓	✓	✓		
D6 LGP VPAT/D6 XE LGP VPAT – 46 Link					
610 mm (24 in)	✓	✓	✓		
660 mm (26 in)	EU only				
760 mm (30 in)	✓	✓	✓		
D6 LGP VPAT/D6 XE LGP VPAT (36 in) – 46 Link					
760 mm (30 in)	✓	✓	✓		
915 mm (36 in)	✓	✓	✓		HDXL only

Fluid/Refill Capacities

Fuel Tank	341 L	90 gal
DEF Tank	28 L	7.4 gal
Cooling System – D6	63 L	16.6 gal
Cooling System – D6 XE	77 L	20.3 gal
Engine Crankcase	24.5 L	6.5 gal
Power Train Oil – D6	148 L	39.1 gal
Power Train Oil – D6 XE	210 L	55.5 gal
Final Drives (each)	18.2 L	4.8 gal
Roller Frames (each)	65-85 L	17.2-22.5 gal
Pivot Shaft Compartment	2.8 L	0.74 gal
Hydraulic Tank Oil	60 L	15.8 gal
Hydraulic System	77 L	20.3 gal

Waste Handlers

	D6/D6 XE*		D6/D6 XE* LGP (30 in)		D6/D6 XE* LGP (36 in)	
Operating Weight	23 662 kg	52,166 lb	23 927 kg	52,751 lb	25 253 kg	55,674 lb
Shipping Weight**	21 072 kg	46,456 lb	21 229 kg	46,803 lb	22 823 kg	50,317 lb

Waste Handler operating weight varies by options selected. Published weights for each configuration include Heavy Duty waste undercarriage with shoes of maximum width, waste blade, fuel tank guards, guarded final drives, high debris cab, chassis bars, striker box, full fuel tank, lubricants, and 75 kg (165 lb) operator.

*XE power train adds 273 kg (600 lb) to the published weights.

**Shipping weight is calculated based on operating weight, minus blade/push arms, less operator, and 10% fuel.

Air Conditioning System

The air conditioning system on this machine contains the fluorinated greenhouse gas refrigerant R134a (Global Warming Potential = 1430). The system contains 1.36 kg of refrigerant which has a CO_2 equivalent of 1.946 metric tonnes.

Advanced Cabin Filtration

Operator Cabin

- Distributed HVAC ducting with automatic temperature control and blower speed provides ultimate operator comfort with less user input.
- Reduced maintenance of the condenser core with automatic reversing fans.
- Cat Advanced Cabin Filtration is standard.

Cat Advanced Cabin Filtration

- Operator protection from respirable particulate (0.3-10 micron size).
- Sustainably pressurized cab (US Silica compliant).
- Reduced maintenance with longer life, high efficiency filters.
- Protection for all cabin components: electronics, etc.
- Helps meet U.S. Occupational Safety and Health Administration Silica Rule Table 1 requirements for operator cabs.
- Multi-tiered filter offerings for optional efficiency upgrades. Contact Cat dealer for availability.
  - MERV 16 – Standard Equipment
  - HEPA
  - Activated Carbon + HEPA
  - ABEK1 + HEPA

Standards

Rollover Protective Structure (ROPS)/ Falling Object Protective Structure (FOPS)

- ROPS meets ISO 3471:2008, FOPS meets ISO 3449:2005 Level II.

Brakes

- Brakes meet the International Standard ISO 10265:2008.

Cab

Meets appropriate standards as listed below.

- The average dynamic spectator sound power level when "ISO 6395:2008" is used to measure the value for a machine is shown below. The measurement was conducted at 70% of the maximum engine cooling fan speed. The sound level may vary at different engine cooling fan speeds.

  NOTE: The dynamic sound power level uncertainty is ± 2 dB(A).

D6	111 dB(A)
D6 XE	109 dB(A)

- The average dynamic operator sound pressure level when "ISO 6396:2008" is used to measure the value for an enclosed cab is shown below. The measurement was conducted at 70% of the maximum engine cooling fan speed. The sound level may vary at different engine cooling fan speeds. The cab was properly installed and maintained. The measurement was conducted with the cab doors and the cab windows closed.

  NOTE: The dynamic operator sound pressure level uncertainty is ± 2 dB(A).

D6	76 dB(A)
D6 XE	73 dB(A)

- Hearing protection may be needed when the machine is operated with an open operator station for extended periods, in a noisy environment, or with a cab that is not properly maintained.
- Sound level information for machines in European Union countries and in countries that adopt the "European Union Directives" is shown below. If equipped, the certification label is used to verify the environmental sound certification of the machine to the requirements of the European Union. The value that is listed on the label indicates the guaranteed exterior sound power level (L_{WA}) at the time of manufacture for the conditions that are specified in "2000/14/EC."

D6	111 dB(A)
D6 XE	111 dB(A)

Standard and Optional Equipment

Standard and optional equipment may vary. Consult your Cat dealer for details.

	Standard	Optional
POWER TRAIN		
Fully-automatic 4-speed Transmission with Lock Up Clutch (LUC) torque divider	D6	
XE Electric Drive Power Train	D6 XE	
Differential Steering System	✓	
Cat C9.3B diesel engine with turbo, with engine mounted aftertreatment to meet U.S. EPA Tier 4 Final, EU Stage V, Korea Tier 4 Final emission standards	✓	
Cat C9.3B diesel engine with thermal shield and liquid cooled turbo, with engine mounted aftertreatment to meet U.S. EPA Tier 4 Final, EU Stage V, Korea Tier 4 Final emission standards		✓
Engine air precleaner with dust ejection	✓	
Engine air precleaner with dust ejection and screen for high debris applications		✓
Double reduction planetary final drives	✓	
Double reduction planetary final drives, guarded		✓
Automatic ether starting aid	✓	
Electric fuel priming pump	✓	
Electronic parking brake	✓	
Engine air filter with electronic service indicator	✓	
Fuel water separator with electronic service indicator	✓	
Jacket water heater, 110V OR 220V based on sales region	✓	
Diesel Exhaust Fluid (DEF) System – Electronic fill indicator, heated lines/tank	✓	
CAT CONNECT TECHNOLOGY		
Slope Indicate	✓	
Stable Blade	✓	
Attachment Ready Option (ARO)	✓	
Cat GRADE with Slope Assist™	✓	
Cat GRADE with 3D		✓
Product Link, cellular PLE641	✓	
Product Link Elite PLE631 – dual cellular/satellite		✓

	Standard	Optional
OPERATOR ENVIRONMENT		
Cab (STD), Fully Redesigned with Integrated ROPS and FOPS, single pane door glass, sliding windows, with Cat Advanced Cabin Filtration	✓	
Cab (High Debris), Fully Redesigned with Integrated ROPS and FOPS, impact resistant polycarbonate doors, solid side windows for improved sealing, powered precleaner with Cat Advanced Cabin Filtration for improved performance and filter life		✓
Cab (Forestry), Fully Redesigned with Integrated ROPS and FOPS, impact resistant polycarbonate doors, sliding windows, with Cat Advanced Cabin Filtration		✓
Full-color 254 mm (10 inch) liquid crystal touch screen display	✓	
Integrated rearview camera	✓	
Adjustable operator controls/armrests	✓	
Cloth seat with mechanical adjustable lumbar support	✓	
Deluxe leather heated/ventilated seat with electronic adjustable lumbar support		✓
Cab mounted modular HVAC system with automatic reversing fans. Automatic temperature and blower control with distributed ducting.	✓	
Viscous cab mounts for improved ride	✓	
Entertainment radio with Bluetooth® and microphone	✓	
USB and AUX ports	✓	
Glove box (removed if Cat GRADE with 3D is selected)	✓	
Enhanced Cab Storage Solutions	✓	
Window shades (front and door)*		✓
Sound suppressed floor plates with adjustable foot pegs	✓	
Quick opening floor plate arrangement with sound suppression and adjustable foot pegs*		✓
Fifth percentile operator floor plate arrangement*		✓
Screen ready, side and rear	✓	
Operator presence switch	✓	

*Please check with your Cat dealer for availability dates.

(continued on next page)

Standard and Optional Equipment *(continued)*

Standard and optional equipment may vary. Consult your Cat dealer for details.

	Standard	Optional
UNDERCARRIAGE		
Structurally improved track roller frame designed to allow conversion between HD and S1	✓	
Undercarriage with 7 or 8 bottom rollers (configuration dependent)	✓	
Undercarriage with 10 bottom rollers for fine grading applications		✓
Waste undercarriage		HD UC only
Partially guided undercarriage		✓
Fully guided undercarriage		✓
Heavy Duty (HDXL with DuraLink™)	✓	
SystemOne track		✓
Moderate service track shoes (see chart on page 13)	✓	
Extreme service track shoes (see chart on page 13)		✓
Carrier roller	✓	
Hydraulically adjustable track	✓	
Replaceable sprocket rim segments	✓	
BLADES		
Semi-Universal, ARO mounts		✓
Semi-Universal, LGP with ARO mounts		✓
Semi-Universal, Waste		✓
Semi-Universal, LGP Waste		✓
Straight blade, LGP with ARO mounts		✓
Straight blade, LGP Waste		✓
VPAT, ARO mounts		✓
VPAT, LGP with ARO mounts		✓
VPAT, LGP (36 in) with ARO mounts		✓
Foldable VPAT, LGP with ARO mounts		EU only
Angle blade		NA only
Caterpillar Performance cutting edges		Dealer only

	Standard	Optional
HYDRAULICS		
Load sensing hydraulics – dozer lift and tilt	✓	
Independent steering hydraulics	✓	
Ripper ready rear hydraulics	D6	
Ripper and winch ready rear hydraulics	D6 XE	D6
Single axis ripper control	✓	
Dual axis ripper/winch control		✓
Hydraulic automatically reversing, zero speed capable cooling fan	✓	
Electronic Hydraulic lockout switch	✓	
ELECTRICAL		
Lights – 6 LED	✓	
Premium lights – 12 LED for 360 degree light coverage		✓
Backup alarm	✓	
Integrated beacon warning light (does not impact shipping height)		✓
Brushless alternator	✓	
Brushless alternator, ducted for high debris applications		✓
Communication radio ready	✓	
Converter: two 10 Amp, 12V outlets	✓	
Diagnostic connector	✓	
Forward warning horn	✓	
Fuse panel and main power relay located inside cab	✓	

(continued on next page)

Standard and Optional Equipment *(continued)*

Standard and optional equipment may vary. Consult your Cat dealer for details.

	Standard	Optional
SERVICE AND MAINTENANCE		
30-minute cab removal	✓	
Ecology drains	✓	
Ecology drains with high speed oil power train and engine oil change		✓
Ground level service center with remote electrical disconnect, access light, secondary shutdown switch and hour meter	✓	
Fuel tank, 341 L (90 gal)	✓	
Fuel tank, 341 L (90 gal), fast fill ready	D6 XE	D6
Wiggins style fast fill nozzle		✓
Mounting provision for grease gun and fire extinguisher	✓	
Perforated radiator doors, louvered and hinged	✓	
Rear access ladder	✓	
Refilling fuel pump		EU only
Removable engine enclosures, perforated and hinged, with under hood work light	✓	
Removable engine enclosures, sound suppressed and hinged, with under hood work light		EU only
S·O·S[SM] sampling ports	✓	
Shovel holder	✓	
Maintenance free equalizer bar	✓	
Certified ISO 14567 tie off points (3)	✓	
Vandalism protection for fluid compartments and battery box	✓	
Dedicated shipping tie downs, rear	✓	
Shipping tie downs, front bracket		EU only
BATTERIES, STARTERS, ALTERNATORS AND FLUIDS		
150 Amp alternator	✓	
150 Amp ducted alternator		✓
Heavy duty batteries, two maintenance-free 12V (1,400 CCA) (24V system)	✓	
Heavy duty, 24V starter	✓	
Extended Life Engine coolant, –37° C (–35° F)	✓	
Extended Life Arctic engine coolant, –51° C (–60° F)		✓
Bio hydraulic oil, –37° C (–35° F)		EU only

	Standard	Optional
ATTACHMENTS		
Drawbar	✓	
High lift multi-shank ripper with straight or curved shanks		✓
Lightweight rear tow point		✓
Striker bar box		✓
Counterweights (not recommended unless using heavier aftermarket blades)		✓
PACCAR PA56 winch, low speed PTO		D6
PACCAR PA85 winch, variable speed hydraulic		✓
PACCAR PA56 winch, standard speed PTO		D6 Dealer only
Allied H6H winch, variable speed hydraulic		Dealer only
Fairlead Assembly; 3-roller, fits PA55, PA56, and PA85 winches		✓
Retrofit kit (4th roller); fits PA55, PA56, and PA85 winches		✓
GUARDING AND SCREENS		
Bottom guards	✓	
Heavy duty sealed bottom guards		Push Arm only
Heavy duty sealed quick access bottom guards*		Push Arm only
Standard duty grab handles	✓	
Heavy duty grab handles		✓
Open Sweeps guarding		✓
Forestry Sweeps guarding with full canopy		✓
Hinged rear screen		✓
Hinged side screens		✓
Fuel tank guard (with or without fast fill)		✓
Guards for premium lights, front and side		✓
Machine seals for high debris		✓
Front and rear striker bars		Dealer only

*Please check with your Cat dealer for availability dates.

For more complete information on Cat products, dealer services, and industry solutions, visit us on the web at **www.cat.com**

Materials and specifications are subject to change without notice. Featured machines in photos may include additional equipment. See your Cat dealer for available options.

AEXQ2470-01 (12-2018)
Replaces AEXQ2470
Build Number: 20A
(North America, Europe, ANZ, Turkey, Korea)

Attachment 3

Veneer Stability Calculations

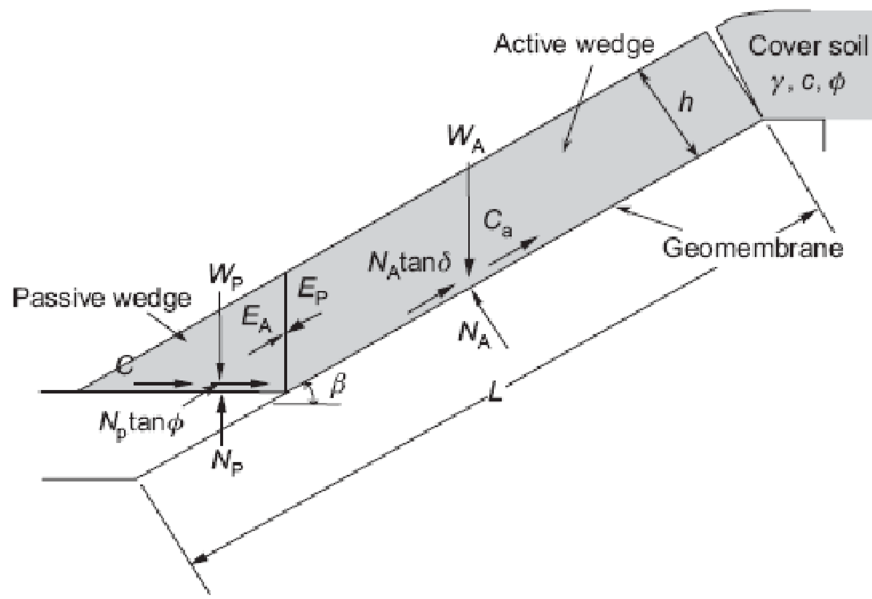
Purpose:

Assess veneer stability due to gravitational forces to determine minimum interface friction angle to achieve a Factor of Safety of 1.50 for peak strength.

Methodology:

Used limit-equilibrium analysis procedure developed by Koerner and Soong (2005).

Assumptions/Input Parameters



Dry Unit Weight of Cover Soil (pcf)	$\gamma_1 := 110$
Vertical Height of Slope (ft)	$H_1 := 35$
Thickness of Cover Soil (in)	$h_1 := 24$
Angle of Slope (degrees)	$\beta_1 := 18.5$
Friction Angle of Cover Soil (degrees)	$\phi_1 := 32$
Angle of Shearing Resistance (degrees)	$\delta_1 := 25.5$
Seismic Coefficient (Unitless)	$C_s := 0$
Adhesion between the Cover Soil of Active Wedge and Geomembrane	$c_a := 0$
Cohesion of the Cover Soil	$c_c := 0$

Conversions:

$H := H_1 \cdot 0.3047$ $\qquad h := h_1 \cdot .0254$ $\qquad \gamma := \gamma_1 \cdot .1571$

$\beta := \beta_1 \cdot \frac{2 \cdot 3.141592}{360}$ $\qquad \phi := \phi_1 \cdot \frac{2 \cdot 3.141592}{360}$ $\qquad \delta := \delta_1 \cdot \frac{2 \cdot 3.141592}{360}$

Calculations:

Length of Slope along Geomembrane $\quad L := \frac{H}{\sin(\beta)} = 33.61$

Total Weight of the Active Wedge $\quad Wa := \gamma \cdot h^2 \cdot \left(\frac{L}{h} - \frac{1}{\sin(\beta)} - \frac{\tan(\beta)}{2}\right)$

Effective Force Normal to the Failure Plane of the Active Wedge $\quad Na := Wa \cdot \cos(\beta)$

Adhesive Force between Cover Soil and Geomembrane $\quad C_{aa} := c_a \cdot \left(L - \frac{h}{\sin(\beta)}\right)$

Total Weight of the Passive Wedge $\quad Wp := \frac{\gamma \cdot h^2}{\sin(2 \cdot \beta)}$

Cohesive Force along the Failure Plain of the Passive Wedge $\quad C_h := \frac{c_c \cdot h}{\sin(\beta)}$

$$a := (C_s \cdot Wa + Na \cdot \sin(\beta)) \cdot \cos(\beta) + C_s \cdot Wp \cdot \sin(\beta)$$

$$b := -((C_s \cdot Wa + Na \cdot \sin(\beta)) \cdot \sin(\beta) \cdot \tan(\phi) + (Na \cdot \tan(\delta) + C_{aa}) \cdot \cos(\beta) \cdot \cos(\beta) + (C_h + Wp \cdot \tan(\phi)) \cdot \cos(\beta))$$

$$c_1 := (Na \cdot \tan(\delta) + C_{aa}) \cdot \cos(\beta) \cdot \sin(\beta) \cdot \tan(\phi)$$

Safety Factor: $\quad FS := \frac{-b + \sqrt{b^2 - 4 \cdot a \cdot c_1}}{2 \cdot a} = 1.503$

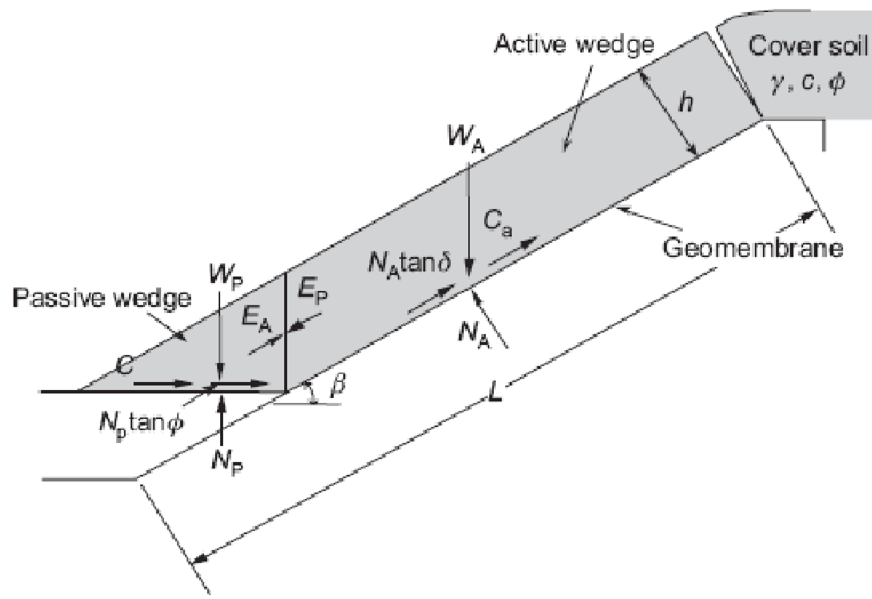
Purpose:

Assess veneer stability due to gravitational forces to determine minimum interface friction angle to achieve a Factor of Safety of 1.20 for residual strength.

Methodology:

Used limit-equilibrium analysis procedure developed by Koerner and Soong (2005).

Assumptions/Input Parameters



Dry Unit Weight of Cover Soil (pcf) $\gamma_1 := 110$

Vertical Height of Slope (ft) $H_1 := 35$

Thickness of Cover Soil (in) $h_1 := 24$

Angle of Slope (degrees) $\beta_1 := 18.5$

Friction Angle of Cover Soil (degrees) $\phi_1 := 32$

Angle of Shearing Resistance (degrees) $\delta_1 := 20.6$

Seismic Coefficient (Unitless) $C_s := 0$

Adhesion between the Cover Soil of Active Wedge and Geomembrane $c_a := 0$

Cohesion of the Cover Soil $c_c := 0$

Conversions:

$H := H_1 \cdot 0.3047$ $\quad h := h_1 \cdot .0254$ $\quad \gamma := \gamma_1 \cdot .1571$

$\beta := \beta_1 \cdot \frac{2 \cdot 3.141592}{360}$ $\quad \phi := \phi_1 \cdot \frac{2 \cdot 3.141592}{360}$ $\quad \delta := \delta_1 \cdot \frac{2 \cdot 3.141592}{360}$

Calculations:

Length of Slope along Geomembrane $\quad L := \frac{H}{\sin(\beta)} = 33.61$

Total Weight of the Active Wedge $\quad Wa := \gamma \cdot h^2 \cdot \left(\frac{L}{h} - \frac{1}{\sin(\beta)} - \frac{\tan(\beta)}{2}\right)$

Effective Force Normal to the Failure Plane of the Active Wedge $\quad Na := Wa \cdot \cos(\beta)$

Adhesive Force between Cover Soil and Geomembrane $\quad C_{aa} := c_a \cdot \left(L - \frac{h}{\sin(\beta)}\right)$

Total Weight of the Passive Wedge $\quad Wp := \frac{\gamma \cdot h^2}{\sin(2 \cdot \beta)}$

Cohesive Force along the Failure Plain of the Passive Wedge $\quad C_h := \frac{c_c \cdot h}{\sin(\beta)}$

$$a := (C_s \cdot Wa + Na \cdot \sin(\beta)) \cdot \cos(\beta) + C_s \cdot Wp \cdot \sin(\beta)$$

$$b := -((C_s \cdot Wa + Na \cdot \sin(\beta)) \cdot \sin(\beta) \cdot \tan(\phi) + (Na \cdot \tan(\delta) + C_{aa}) \cdot \cos(\beta) \cdot \cos(\beta) + (C_h + Wp \cdot \tan(\phi)) \cdot \cos(\beta))$$

$$c_1 := (Na \cdot \tan(\delta) + C_{aa}) \cdot \cos(\beta) \cdot \sin(\beta) \cdot \tan(\phi)$$

Safety Factor: $\quad FS := \frac{-b + \sqrt{b^2 - 4 \cdot a \cdot c_1}}{2 \cdot a} = 1.204$

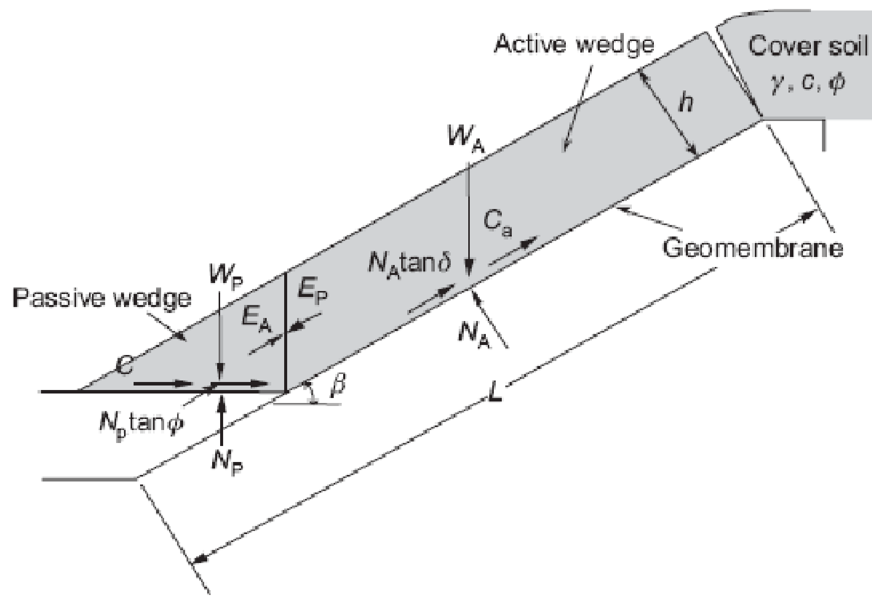
Purpose:

Assess veneer stability due to gravitational forces for interface friction angle of 18.5 degrees.

Methodology:

Used limit-equilibrium analysis procedure developed by Koerner and Soong (2005).

Assumptions/Input Parameters



Dry Unit Weight of Cover Soil (pcf)	$\gamma_1 := 120$
Vertical Height of Slope (ft)	$H_1 := 35$
Thickness of Cover Soil (in)	$h_1 := 24$
Angle of Slope (degrees)	$\beta_1 := 18.5$
Friction Angle of Cover Soil (degrees)	$\phi_1 := 32$
Angle of Shearing Resistance (degrees)	$\delta_1 := 21.9$
Seismic Coefficient (Unitless)	$C_s := 0.084$
Adhesion between the Cover Soil of Active Wedge and Geomembrane	$c_a := 0$
Cohesion of the Cover Soil	$c_c := 0$

Conversions:

$H := H_1 \cdot 0.3047$ $h := h_1 \cdot .0254$ $\gamma := \gamma_1 \cdot .1571$

$\beta := \beta_1 \cdot \frac{2 \cdot 3.141592}{360}$ $\phi := \phi_1 \cdot \frac{2 \cdot 3.141592}{360}$ $\delta := \delta_1 \cdot \frac{2 \cdot 3.141592}{360}$

Calculations:

Length of Slope along Geomembrane $L := \frac{H}{\sin(\beta)} = 33.61$

Total Weight of the Active Wedge $Wa := \gamma \cdot h^2 \cdot \left(\frac{L}{h} - \frac{1}{\sin(\beta)} - \frac{\tan(\beta)}{2}\right)$

Effective Force Normal to the Failure Plane of the Active Wedge $Na := Wa \cdot \cos(\beta)$

Adhesive Force between Cover Soil and Geomembrane $C_{aa} := c_a \cdot \left(L - \frac{h}{\sin(\beta)}\right)$

Total Weight of the Passive Wedge $Wp := \frac{\gamma \cdot h^2}{\sin(2 \cdot \beta)}$

Cohesive Force along the Failure Plain of the Passive Wedge $C_h := \frac{c_c \cdot h}{\sin(\beta)}$

$$a := (C_s \cdot Wa + Na \cdot \sin(\beta)) \cdot \cos(\beta) + C_s \cdot Wp \cdot \sin(\beta)$$

$$b := -((C_s \cdot Wa + Na \cdot \sin(\beta)) \cdot \sin(\beta) \cdot \tan(\phi) + (Na \cdot \tan(\delta) + C_{aa}) \cdot \cos(\beta) \cdot \cos(\beta) + (C_h + Wp \cdot \tan(\phi)) \cdot \cos(\beta))$$

$$c_1 := (Na \cdot \tan(\delta) + C_{aa}) \cdot \cos(\beta) \cdot \sin(\beta) \cdot \tan(\phi)$$

Safety Factor: $FS := \frac{-b + \sqrt{b^2 - 4 \cdot a \cdot c_1}}{2 \cdot a} = 1.002$

GE Lee UDF
Short-Term Condition

Short-Term Peak Veneer Stability
Initial Lift of Cover Soil with Equipment Loads

Input	Units	UOM	Units	UOM
Thickness of cover soil, h	1	ft		
Soil slope angle beneath the geomembrane, beta	18.5	degrees	0.32	radians
Length of slope measured along the geomembrane, L	105	ft		
Unit weight of the cover soil, gamma	110	pcf		
Friction angle of the cover soil, theta	32	degrees	0.56	radians
Cohesion of the cover soil, c	0	psf		
Minimum interface friction angle in the cover system, delta	**23.1**	**degrees**	**0.40**	**radians**
Adhesion between cover soil and geomembrane, ca	0	psf		
Equipment weight, Wb	51,875	lb		
Equipment ground pressure (weight of equipment/(2wb)), q	785	psf		
Length of each equipment track, w	11.0	ft		
Width of each equipment track, b	3	ft		
Influence factor at geomembrane interface, I	1			
Acceleration/deceleration of the bulldozer, a	0	g		
b/h	3			
Output	Units	UOM	Units	UOM
Equivalent equipment force per unit width at the geomembrane interface, We	8,646	lb		
Total weight of the active wedge, Wa	19,831	lb		
Total weight of the passive wedge, Wp	183	lb		
Effective force normal to the failure plane of the active wedge, Na	18,806	lb		
a=	1,893			
b=	-2,850			
c=	506			
Factor of Safety =	**1.30**			

Notes:

(1) The above calculations are based on reference 4 "Analysis and Design of Veneer Cover Soils" by R.M. Koerner and Te-Yang Soong, published in Sixth International Conference on Geosynthetics (2005).

(2) The above calculation does not account for acceleration/deceleration of the bulldozer.

(3) The Influence Factor, I, is estimated from Figure 7 of referenced article.

(4) The friction angle of the cover material, the minimum interface friction angle of the cover material, and equipment weight are assumed input parameters.

GE Lee UDF
Short-Term Condition

Short-Term Residual Veneer Stability
Initial Lift of Cover Soil with Equipment Loads

Input	Units	UOM	Units	UOM
Thickness of cover soil, h	1	ft		
Soil slope angle beneath the geomembrane, beta	18.5	degrees	0.32	radians
Length of slope measured along the geomembrane, L	105	ft		
Unit weight of the cover soil, gamma	110	pcf		
Friction angle of the cover soil, theta	32	degrees	0.56	radians
Cohesion of the cover soil, c	0	psf		
Minimum interface friction angle in the cover system, delta	**18.1**	**degrees**	**0.32**	**radians**
Adhesion between cover soil and geomembrane, ca	0	psf		
Equipment weight, Wb	51,875	lb		
Equipment ground pressure (weight of equipment/(2wb)), q	785.39	psf		
Length of each equipment track, w	11.0083	ft		
Width of each equipment track, b	3	ft		
Influence factor at geomembrane interface, I	1			
Acceleration/deceleration of the bulldozer, a	0	g		
b/h	3			
Output	Units	UOM	Units	UOM
Equivalent equipment force per unit width at the geomembrane interface, We	8,646	lb		
Total weight of the active wedge, Wa	19,831	lb		
Total weight of the passive wedge, Wp	183	lb		
Effective force normal to the failure plane of the active wedge, Na	18,806	lb		
a=	1,893			
b=	-2,280			
c=	386			
Factor of Safety =	**1.00**			

Notes:

(1) The above calculations are based on reference 4 "Analysis and Design of Veneer Cover Soils" by R.M. Koerner and Te-Yang Soong, published in Sixth International Conference on Geosynthetics (2005).

(2) The above calculation does not account for acceleration/deceleration of the bulldozer.

(3) The Influence Factor, I, is estimated from Figure 7 of referenced article.

(4) The friction angle of the cover material, the minimum interface friction angle of the cover material, and equipment weight are assumed input parameters.

Appendix E

Leachate Management System Calculations

ARCADIS

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **E-1** **Subject:** **Leachate Collection Layer Design**

Prepared By: **CSH** **Date:** **February 2024**

Reviewed By: **BMS** **Date:** **February 2024**

Objective

Determine the minimum required transmissivities for the geocomposite on the cell floor and sideslopes of the UDF baseliner system. Estimate the maximum anticipated applied loading on the geocomposite under installed conditions. Identify the laboratory transmissivity testing conditions necessary to determine material acceptability.

References

1. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 5: Baseliner Grading Plan.* February 2024.
2. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 8: Final Grading Plan.* February 2024.
3. Giroud, J.P., Zornberg, J.G., and A. Zhao. *Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers*, technical paper presented in Geosynthetics International - Special Issue on Liquid Collection Systems. 2000.
4. Waterloo Hydrogeologic, Inc. *Visual HELP v3.07* (Windows-based implementation of HELP model v. 3.07).
5. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix D-4. *Floor Settlement Calculation*. February 2024.

Assumptions

1. All geocomposite transmissivity calculations ignore the transmissivity contribution of the overlying granular drainage and operations stone layers of the baseliner system and are, therefore, conservative. The minimum geocomposite transmissivity calculated herein is based on conditions in the primary leachate collection system. Although the geocomposite in the secondary leachate collection system is anticipated to have lesser leachate flowrates, the same performance requirements are also applied to that system for conservatism (i.e., the geocomposite in the primary and secondary leachate collection systems must meet the same performance requirements).
2. The minimum required transmissivity for the exposed cell sideslope is based on the longest maximum sideslope length of the UDF cells (Cell 1 based on Reference 1). The minimum required transmissivity for the cell sideslope is based on Giroud's equation (presented in Reference 3) and the following parameters:

- Slope = 155 feet at 33%
- Maximum allowable head is limited to the thickness of the drainage layer (i.e., the thickness of the geonet core which is assumed to be 0.76 cm based on a 300-mil geonet core)
- Impingement rate (i.e., rate at which leachate infiltrates to geocomposite layer) from Reference 4
- Typical reduction factors and overall design factor of safety from Reference 3 (see attached calculations for specific values)

3. The impingement rate for the exposed cell sideslope is the peak daily infiltration value for the geocomposite layer calculated using Reference 4. The impingement rate for the exposed cell sideslope assumes a 2-foot layer of operations stone (well-graded aggregate base) is placed above the geocomposite and the following parameters:

    - Representative weather data is from Albany, New York
    - Fraction of area allowing runoff = 0.0%
    - Maximum leaf area index = 0.0 (bare ground)
    - Evaporative zone depth = 6 inches (based on the guidance values for gravels as presented in the User's Guide for HELP Model v.3)
    - Permeability of materials are as follows (from top to bottom of model profile):

      Operations layer = 1 x 10^{-2} cm/s

      Geocomposite drainage layer = 33 cm/s

      High-density polyethylene (HDPE) geomembrane = 2.0 x 10^{-13} cm/s

4. The minimum required transmissivity for the cell floor is evaluated for three scenarios: (1) active condition with minimal (10 ft) consolidation material in place, (2) active condition with full buildout of consolidation material (43 ft based on a weighted average over the UDF footprint using References 1 and 2), and (3) closed (i.e., capped) cell conditions. The minimum required transmissivity is based on the geometry of Cell 1 because it exhibits the longest drainage length (based on Reference 1). The minimum required transmissivity for the cell floor is based on Giroud's equation and the following parameters:

    - Total drainage length = 375 ft = 284 feet at 2.8% (pre-consolidation based on Reference 1 and measured perpendicular to the cell floor contour lines) + 91 ft at 33% (from upgradient sideslope)
    - Maximum allowable head is limited to the thickness of the drainage layer (i.e., the thickness of the geocomposite core which is 0.76 cm)
    - Impingement rate from Reference 4
    - Typical reduction factors and overall factor of safety from Reference 3 (see attached calculations for specific values)

5. The impingement rate for the cell floor under active conditions with minimal consolidation material is the peak daily infiltration value to the geocomposite layer calculated using Reference 4 based on an

in-place consolidation material thickness of approximately 10 feet and the following parameters:

- Representative weather data is from Albany, New York
- Fraction of area allowing runoff = 0.0%
- Maximum leaf area index = 0.0 (bare ground)
- Evaporative zone depth = 8 inches (based on the guidance values for silty soils as presented in the User's Guide for HELP Model v.3)
- Permeability of materials are as follows (from top to bottom of model profile):

  Consolidation material = 1 x 10^{-3} cm/s

  Operations layer = 1.0 x 10^{-2} cm/s

  Granular drainage material = 1.0 x 10^{-2} cm/s

  Geocomposite drainage layer = 33 cm/s

  HDPE geomembrane = 2.0 x 10^{-13} cm/s

6. The impingement rate for the cell floor under active conditions with full buildout is the peak daily infiltration value to the geocomposite layer calculated using Reference 4 based on an average in-place consolidation material thickness of approximately 43 feet and the following parameters:

   - Representative weather data is from Albany, New York
   - Fraction of area allowing runoff = 0.0%
   - Maximum leaf area index = 0.0 (bare ground)
   - Evaporative zone depth = 8 inches (based on the guidance values for silty soils as presented in the User's Guide for HELP Model v.3)
   - Permeability of materials are as follows (from top to bottom of model profile):

     Consolidation material = 1 x 10^{-3} cm/s

     Operations layer = 1.0 x 10^{-2} cm/s

     Granular drainage material = 1.0 x 10^{-2} cm/s

     Geocomposite drainage layer = 33 cm/s

     HDPE geomembrane = 2.0 x 10^{-13} cm/s

7. The impingement rate for the cell floor under closed conditions is less due to the presence of the final cover system. The impingement rate for the closed cell floor condition is based on an average in-place thickness of consolidation material of approximately 43 feet and the following parameters:

   - Representative weather data is from Albany, New York
   - Fraction of area allowing runoff = 100%
   - Maximum leaf area index = 2.0 (fair stand of grass)
   - Evaporative zone depth = 12 inches (based on the guidance values for silty soils as

presented in the User's Guide for HELP Model v.3)

- Permeability of materials are as follows (from top to bottom of model profile):

  Topsoil = 3.7×10^{-4} cm/s (HELP model default for silty loam)

  General soil fill = 1.7×10^{-2} cm/s (HELP model default for fine sand)

  Geocomposite drainage layer = 33 cm/s

  HDPE geomembrane = 2.0×10^{-13} cm/s

  GCL = 5×10^{-9} cm/s

  Consolidation material = 1×10^{-3} cm/s

  Operations layer = 1.0×10^{-2} cm/s

  Granular drainage material = 1.0×10^{-2} cm/s

  Geocomposite drainage layer = 33 cm/s

  HDPE geomembrane = 2.0×10^{-13} cm/s

8. When determining the impingement rates for each of the above cases, the initial moisture contents for the various layers are calculated by Reference 4 under nearly steady-state conditions.
9. Assumed unit weights of consolidated material and baseliner and final cover system materials is 120 lb/ft^3.

Calculations

1. Minimum Required Transmissivity for the Cell Sideslope

Leachate is conveyed down the cell sideslopes through a geocomposite layer and a 2-foot-thick operations stone layer. Per Assumption 1, the transmissivity of the operations layer is not considered. The minimum required transmissivity for the geocomposite on the cell sideslope is based on Giroud's equation. Giroud's equation is as follows:

$$\Theta = \frac{TSF q_h L}{\sin\beta + \frac{t_{LCL}/L}{TSF}\cos^2\beta}$$

where,

Θ = minimum required transmissivity

TSF = total serviceability factor = 7.23 (see attached calculations for individual factors of safety)

q_h = impingement rate (calculated using Reference 4 based on Assumption 3) = 1.89 inches/day = 5.6×10^{-5} cm/s

L = maximum drainage length = 155 ft = 47.2 m (Assumption 2)

β = slope angle of drainage layer = 18.4^o (33%) (Assumption 2)

t_{LCL} = thickness of geonet core of geocomposite = 0.76 cm (Assumption 2)

∴ Θ = 6.06 x 10^{-4} m^2/s = 6.06 cm^2/s = Minimum Required Transmissivity for Cell Sideslope

Output from Reference 4 for the impingement rate is included as an attachment.

2. Minimum Required Transmissivity for the Cell Floor with Minimal Consolidation Material in Place (Active Condition)

Leachate is conveyed along the cell floor through a geocomposite layer and a 1-foot-thick granular drainage layer. Per Assumption 1, the transmissivity of the granular drainage layer is ignored; therefore, the geocomposite transmissivity must be large enough to convey the peak leachate flow. The minimum required transmissivity for the active condition with minimal consolidation material in place is:

$$\Theta = \frac{TSFq_h L}{\sin\beta + \frac{t_{LCL}/L}{TSF}\cos^2\beta}$$

where,

Θ = minimum required transmissivity

TSF = total serviceability factor = 7.23 (see attached calculations for individual factors of safety)

q_h = impingement rate (calculated using Reference 4 based on Assumption 5) = 0.42 inches/day = 1.2 x 10^{-5} cm/s

L = maximum drainage length = 375 ft = 114.3 m (Assumption 4)

β = slope angle of drainage layer in cell floor = 1.6^o (2.8%) (Assumption 4)

t_{LCL} = thickness of geonet core of geocomposite = 0.76 cm (Assumption 4)

∴ Θ = 3.62 x 10^{-3} m^2/s = 36.2 cm^2/s = Minimum Required Transmissivity for Active Condition

Output from Reference 4 for the impingement rate is included as an attachment.

3. Minimum Required Transmissivity for the Cell Floor Under Final Buildout (Active Condition)

Leachate is conveyed along the cell floor through a geocomposite layer and a 1-foot-thick granular drainage layer. Per Assumption 1, the transmissivity of the granular drainage layer is ignored; therefore, the geocomposite transmissivity must be large enough to convey the peak leachate flow. The minimum required transmissivity for the active condition with minimal consolidation material in place is:

$$\Theta = \frac{TSFq_h L}{\sin\beta + \frac{t_{LCL}/L}{TSF}\cos^2\beta}$$

where,

Θ = minimum required transmissivity

TSF = total serviceability factor = 7.23 (see attached calculations for individual factors of safety)

q_h = impingement rate (calculated using Reference 4 based on Assumption 6) = 0.15 inches/day

$= 4.41 \times 10^{-6}$ cm/s

L = maximum drainage length = 375 ft = 114.3 m (Assumption 4)

β = slope angle of drainage layer in cell floor = 1.6^{o} (2.8%) (Assumption 4)

t_{LCL} = thickness of geonet core of geocomposite = 0.76 cm (Assumption 4)

∴ Θ = 1.29×10^{-3} m^2/s = 12.9 cm^2/s = Minimum Required Transmissivity for Active Condition

Output from Reference 4 for the impingement rate is included as an attachment.

4. Minimum Required Transmissivity for the Cell Floor (Closed Condition)

The minimum required transmissivity calculated above is also checked for the closed (i.e., capped) condition using a larger total serviceability factor that is more typical of leachate collection systems (as opposed to the reduced value used above for the active condition). The minimum required transmissivity for the closed condition is:

$$\Theta = \frac{TSFq_h L}{\sin\beta + \frac{t_{LCL}/L}{TSF}\cos^2\beta}$$

where,

Θ = minimum required transmissivity

TSF = total serviceability factor = 24.0 (see attached calculations for individual factors of safety)

q_h = impingement rate (calculated using Reference 4 based on Assumption 7) = 0.00037 inches/day = 0.0 cm/s

L = maximum drainage length = 375 ft (Assumption 4)

β = slope angle of drainage layer in cell floor = 1.6^{o} (2.8%) (Assumption 4)

t_{LCL} = thickness of geonet core of geocomposite = 0.76 cm (Assumption 4)

∴ Θ = 0.0 m^2/s = 0.0 cm^2/s = Minimum Required Transmissivity for Closed Condition

Based on Reference 4, no measurable amount of liquid is predicted to reach the liner system geocomposite under the closed condition on a daily basis. This leads to a minimum required transmissivity of zero for the closed condition. Because the required transmissivity is zero for the closed condition, the required transmissivities for the active cell floor condition govern for all geocomposite installed in the baseliner system.

Output from Reference 4 for the impingement rate is included as an attachment.

5. Maximum Applied Load on the Geocomposite

Since the in-place transmissivity of the geocomposite is partly a function of the applied loading, it is necessary to estimate the maximum load that will be applied to the geocomposite. To coincide with the two transmissivity requirements determined for the geocomposite on the cell floor under active conditions, two applied loadings are similarly calculated. A single applied loading is calculated for the geocomposite on the cell sideslopes.

For the active cell floor condition with minimal consolidation material, the geocomposite in the secondary leachate collection system will experience a maximum load of about 1,500 psf due to the presence of 10 feet of consolidation material, 1 foot of operations layer stone, 1 foot of granular drainage layer in the primary leachate collection system, and 1 foot of granular drainage layer in the secondary leachate collection system (13 feet x 120 pcf = 1,560 psf). A factor of safety of 2 is included account for the increase in loading associated with vehicle traffic to yield a design loading of 3,000 psf for the active cell floor condition with minimal consolidation material.

For the active full buildout floor condition, the geocomposite in the secondary leachate collection system will experience a maximum load of about 14,000 psf due to the presence of 113 feet of consolidation material and 3 feet of baseliner system materials (116 feet x 120 pcf = 13,920 psf). It is important to note that this load will only be experienced under the peak fill depth areas and any surface surcharges (e.g increases in pressure on the geocomposite due to vehicle loading) are negligible. For this reason, no factor of safety is applied to the design loading.

For the active full buildout cell sideslope condition, the geocomposite in the secondary leachate collection system will experience about 13,000 psf due to the presence of 104 feet of consolidation material and 2 feet of operations layer stone (106 feet x 120 pcf = 12,720 psf).

Summary

The liner system geocomposite must provide the following minimum transmissivities:

- Θ = 36.2 cm^2/s with a hydraulic gradient = 0.1 and an applied loading of 3,000 psf (cell floor)
- Θ = 12.9 cm^2/s with a hydraulic gradient = 0.1 and an applied loading of 14,000 psf (cell floor)
- Θ = 6.06 cm^2/s with a hydraulic gradient = 0.33 and an applied loading of 13,000 psf (cell sideslopes)

A hydraulic gradient of 0.1 is approximately representative of the cell floor slope of 2.8% and is more easily attained and controlled in the laboratory. Because geocomposite transmissivity decreases with increasing hydraulic gradient, using a value of 0.1 rather than the 0.028 value will yield a conservative measurement of the geocomposite's transmissivity. The hydraulic gradient of 0.33 is representative of the 33% sideslope. Although a geocomposite with a 300-mil thick geonet core is assumed for these calculations, any thickness of geonet core is acceptable for the UDF liner system assuming it meets or exceeds the above transmissivities with the loading and gradients presented above.

Attachments

1. HELP Model Output
2. Transmissivity Calculation Sheets

Attachment 1

HELP Model Output

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 November 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:     C:\WHI\UNSAT22\data\P212.VHP\_weather1.dat
TEMPERATURE DATA FILE:       C:\WHI\UNSAT22\data\P212.VHP\_weather2.dat
SOLAR RADIATION DATA FILE:   C:\WHI\UNSAT22\data\P212.VHP\_weather3.dat
EVAPOTRANSPIRATION DATA:     C:\WHI\UNSAT22\data\P212.VHP\_weather4.dat
SOIL AND DESIGN DATA FILE:   C:\WHI\UNSAT22\data\P212.VHP\I_385921.inp
OUTPUT DATA FILE:            C:\WHI\UNSAT22\data\P212.VHP\O_385921.prt

TIME:  10:29     DATE:  10/ 5/2023

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TITLE: Exposed Cell Sideslope

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******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                 LAYER  1
                                 --------
                   TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   5
          THICKNESS                  =    60.96   CM
          POROSITY                   =     0.4530 VOL/VOL
          FIELD CAPACITY             =     0.1900 VOL/VOL
          WILTING POINT              =     0.0850 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.3019 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.100000000000E-01 CM/SEC

                                LAYER  2
                                 --------
                     TYPE 2 - LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  20
          THICKNESS                  =     0.50   CM
          POROSITY                   =     0.8500 VOL/VOL
          FIELD CAPACITY             =     0.0100 VOL/VOL
          WILTING POINT              =     0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.0210 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =   10.0000000000     CM/SEC
          SLOPE                      =    33.00   PERCENT
          DRAINAGE LENGTH            =    47.2    METERS

                                 LAYER  3
                                 --------
                     TYPE 4 - FLEXIBLE MEMBRANE LINER
                       MATERIAL TEXTURE NUMBER  35
```

THICKNESS	=	0.10 CM
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.200000000000E-12 CM/SEC
FML PINHOLE DENSITY	=	2.00 HOLES/HECTARE
FML INSTALLATION DEFECTS	=	2.00 HOLES/HECTARE
FML PLACEMENT QUALITY	=	2 - EXCELLENT

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 5 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 33.% AND A SLOPE LENGTH OF 47. METERS.

SCS RUNOFF CURVE NUMBER	=	85.29
FRACTION OF AREA ALLOWING RUNOFF	=	0.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	0.4047 HECTARES
EVAPORATIVE ZONE DEPTH	=	15.2 CM
INITIAL WATER IN EVAPORATIVE ZONE	=	6.904 CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.904 CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.295 CM
INITIAL SNOW WATER	=	0.000 CM
INITIAL WATER IN LAYER MATERIALS	=	18.417 CM
TOTAL INITIAL WATER	=	18.417 CM
TOTAL SUBSURFACE INFLOW	=	0.00 MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Albany NY

STATION LATITUDE	=	42.67 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	123
END OF GROWING SEASON (JULIAN DATE)	=	282
EVAPORATIVE ZONE DEPTH	=	6.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	8.90 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	74.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.39	2.26	3.01	2.94	3.31	3.29
3.00	3.34	3.23	2.93	3.04	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
21.10	23.40	33.80	46.60	57.50	66.70
71.40	69.20	61.20	50.50	39.30	26.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Albany NY
AND STATION LATITUDE = 42.38 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.06	2.39	3.25	2.93	3.26	2.98
	2.87	2.76	3.69	2.89	3.07	2.71
STD. DEVIATIONS	0.84	1.06	1.32	1.19	1.25	1.29
	1.01	0.99	2.05	1.56	1.35	1.18
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.567	0.507	0.585	2.116	2.334	2.116
	2.188	2.050	1.955	1.506	1.166	0.566
STD. DEVIATIONS	0.097	0.082	0.240	0.725	0.809	0.884
	0.827	0.691	0.785	0.496	0.212	0.145
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.2598	0.4776	5.1808	2.7430	0.8918	0.8371
	0.7482	0.7158	1.6267	1.3642	1.5678	0.7138
STD. DEVIATIONS	0.6602	0.7549	2.1392	1.5621	0.8013	0.6706
	0.5029	0.4468	1.4610	1.1784	1.3604	0.5306
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0020	0.0025	0.0246	0.0154	0.0070	0.0064

	0.0063	0.0063	0.0103	0.0096	0.0112	0.0071
STD. DEVIATIONS	0.0044	0.0035	0.0076	0.0076	0.0048	0.0037
	0.0037	0.0031	0.0078	0.0068	0.0077	0.0046

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0001	0.0002	0.0015	0.0008	0.0003	0.0003
	0.0002	0.0002	0.0005	0.0004	0.0005	0.0002
STD. DEVIATIONS	0.0002	0.0002	0.0006	0.0005	0.0002	0.0002
	0.0001	0.0001	0.0004	0.0003	0.0004	0.0002

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	34.86	(5.272)	126543.9	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	17.655	(2.2641)	64085.58	50.643
LATERAL DRAINAGE COLLECTED FROM LAYER 2	17.12667	(3.60347)	62168.456	49.12798
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.10877	(0.01926)	394.810	0.31199
AVERAGE HEAD ON TOP OF LAYER 3	0.000	(0.000)		
CHANGE IN WATER STORAGE	-0.029	(1.7650)	-104.96	-0.083

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30 and their dates (DDDYYYY)

	(INCHES)	(CU. FT.)	
PRECIPITATION	3.20	11615.74682	2620015
RUNOFF	0.000	0.00000	0
DRAINAGE COLLECTED FROM LAYER 2	1.89268	6870.27784	950006

PERCOLATION/LEAKAGE THROUGH LAYER 3	0.003425	12.43094	950006
AVERAGE HEAD ON TOP OF LAYER 3	0.017		
MAXIMUM HEAD ON TOP OF LAYER 3	0.035		
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET		
SNOW WATER	6.59	23929.3540	690020

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4530
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0850

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	6.1380	0.2557
2	0.0020	0.0100
3	0.0000	0.0000
SNOW WATER	0.243	

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 **                                                                          **
 **                                                                          **
 **              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
 **                HELP MODEL VERSION 3.07  (1 November 1997)                **
 **                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
 **                    USAE WATERWAYS EXPERIMENT STATION                     **
 **             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
 **                                                                          **
 **                                                                          **
 ******************************************************************************
 ******************************************************************************

 PRECIPITATION DATA FILE:    C:\WHI\UNSAT22\data\P212.VHP\_weather1.dat
 TEMPERATURE DATA FILE:      C:\WHI\UNSAT22\data\P212.VHP\_weather2.dat
 SOLAR RADIATION DATA FILE:  C:\WHI\UNSAT22\data\P212.VHP\_weather3.dat
 EVAPOTRANSPIRATION DATA:    C:\WHI\UNSAT22\data\P212.VHP\_weather4.dat
 SOIL AND DESIGN DATA FILE:  C:\WHI\UNSAT22\data\P212.VHP\I_385483.inp
 OUTPUT DATA FILE:           C:\WHI\UNSAT22\data\P212.VHP\O_385483.prt

 TIME:   9:37     DATE:  10/ 5/2023

 ******************************************************************************

      TITLE:  Uncapped Min Waste

 ******************************************************************************

      NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                   LAYER  1
                                   --------
                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   5
           THICKNESS                  =   304.80   CM
           POROSITY                   =     0.4530 VOL/VOL
           FIELD CAPACITY             =     0.1900 VOL/VOL
           WILTING POINT              =     0.0850 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.2622 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000000000E-02 CM/SEC

                                   LAYER  2
                                   --------
                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   5
           THICKNESS                  =    60.96   CM
           POROSITY                   =     0.4530 VOL/VOL
           FIELD CAPACITY             =     0.1900 VOL/VOL
           WILTING POINT              =     0.0850 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.2071 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000000000E-01 CM/SEC

                                   LAYER  3
                                   --------
                      TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  20
           THICKNESS                  =     0.50   CM
           POROSITY                   =     0.8500 VOL/VOL
```

```
   FIELD CAPACITY               =     0.0100 VOL/VOL
   WILTING POINT                =     0.0050 VOL/VOL
   INITIAL SOIL WATER CONTENT   =     0.0605 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =   10.0000000000     CM/SEC
   SLOPE                        =     2.50   PERCENT
   DRAINAGE LENGTH              =    91.4    METERS

                           LAYER  4
                           --------
               TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  35
   THICKNESS                    =     0.10   CM
   POROSITY                     =     0.0000 VOL/VOL
   FIELD CAPACITY               =     0.0000 VOL/VOL
   WILTING POINT                =     0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =     0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.200000000000E-12 CM/SEC
   FML PINHOLE DENSITY          =     2.00   HOLES/HECTARE
   FML INSTALLATION DEFECTS     =     2.00   HOLES/HECTARE
   FML PLACEMENT QUALITY        =  2 - EXCELLENT


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
          A SLOPE LENGTH OF   91. METERS.

SCS RUNOFF CURVE NUMBER                =     83.60
FRACTION OF AREA ALLOWING RUNOFF       =      0.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE     =      0.4047 HECTARES
EVAPORATIVE ZONE DEPTH                 =     20.3    CM
INITIAL WATER IN EVAPORATIVE ZONE      =      9.205  CM
UPPER LIMIT OF EVAPORATIVE STORAGE     =      9.205  CM
LOWER LIMIT OF EVAPORATIVE STORAGE     =      1.727  CM
INITIAL SNOW WATER                     =      0.000  CM
INITIAL WATER IN LAYER MATERIALS       =     92.565  CM
TOTAL INITIAL WATER                    =     92.565  CM
TOTAL SUBSURFACE INFLOW                =      0.00   MM/YR


            EVAPOTRANSPIRATION AND WEATHER DATA
            -----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          Albany               NY

     STATION LATITUDE                            =  42.67 DEGREES
     MAXIMUM LEAF AREA INDEX                     =   0.00
     START OF GROWING SEASON (JULIAN DATE)       =    123
     END OF GROWING SEASON (JULIAN DATE)         =    282
     EVAPORATIVE ZONE DEPTH                      =   8.0  INCHES
     AVERAGE ANNUAL WIND SPEED                   =   8.90 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY       =  68.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY       =  66.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY       =  74.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY       =  74.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.39	2.26	3.01	2.94	3.31	3.29
3.00	3.34	3.23	2.93	3.04	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
21.10	23.40	33.80	46.60	57.50	66.70
71.40	69.20	61.20	50.50	39.30	26.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY AND STATION LATITUDE = 42.38 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.06	2.39	3.25	2.93	3.26	2.98
	2.87	2.76	3.69	2.89	3.07	2.71
STD. DEVIATIONS	0.84	1.06	1.32	1.19	1.25	1.29
	1.01	0.99	2.05	1.56	1.35	1.18
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.567	0.507	0.606	2.443	2.693	2.470
	2.557	2.404	2.221	1.684	1.196	0.573
STD. DEVIATIONS	0.097	0.082	0.282	0.764	0.927	0.971
	0.942	0.826	0.829	0.505	0.223	0.149

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	1.0634	0.7928	0.8539	3.2367	2.3718	1.2131
	0.9318	0.6707	0.5192	0.6817	0.8183	0.9812
STD. DEVIATIONS	0.4878	0.3222	0.7132	1.4738	0.6248	0.3407
	0.2865	0.2614	0.1855	0.4856	0.6722	0.7839

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0738	0.0612	0.0550	0.1179	0.1130	0.0789
	0.0700	0.0585	0.0493	0.0535	0.0579	0.0650
STD. DEVIATIONS	0.0194	0.0142	0.0208	0.0344	0.0150	0.0109
	0.0109	0.0129	0.0109	0.0191	0.0259	0.0279

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0073	0.0059	0.0058	0.0229	0.0162	0.0086
	0.0064	0.0046	0.0037	0.0047	0.0058	0.0067
STD. DEVIATIONS	0.0033	0.0024	0.0049	0.0104	0.0043	0.0024
	0.0020	0.0018	0.0013	0.0033	0.0047	0.0054

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	34.86	(5.272)	126543.9	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	19.922	(2.3750)	72316.38	57.147
LATERAL DRAINAGE COLLECTED FROM LAYER 3	14.13444	(3.17052)	51306.893	40.54474
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.85406	(0.09913)	3100.171	2.44988
AVERAGE HEAD ON TOP OF LAYER 4	0.008	(0.002)		
CHANGE IN WATER STORAGE	-0.049	(2.4676)	-179.56	-0.142

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30 and their dates (DDDYYYY)

	(INCHES)	(CU. FT.)	
PRECIPITATION	3.20	11615.74682	2620015
RUNOFF	0.000	0.00000	0
DRAINAGE COLLECTED FROM LAYER 3	0.42234	1533.04726	840002
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.008881	32.23622	840002
AVERAGE HEAD ON TOP OF LAYER 4	0.089		
MAXIMUM HEAD ON TOP OF LAYER 4	0.177		
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	2.9 FEET		
SNOW WATER	6.59	23929.3540	690020

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4530

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0850

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	30.1214	0.2510
2	4.5857	0.1911
3	0.0086	0.0438
4	0.0000	0.0000
SNOW WATER	0.243	

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 **                                                                          **
 **              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
 **                HELP MODEL VERSION 3.07 (1 November 1997)                 **
 **                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
 **                    USAE WATERWAYS EXPERIMENT STATION                     **
 **              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
 **                                                                          **
 **                                                                          **
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PRECIPITATION DATA FILE:    C:\WHI\UNSAT22\data\P212.VHP\_weather1.dat
 TEMPERATURE DATA FILE:      C:\WHI\UNSAT22\data\P212.VHP\_weather2.dat
 SOLAR RADIATION DATA FILE:  C:\WHI\UNSAT22\data\P212.VHP\_weather3.dat
 EVAPOTRANSPIRATION DATA:    C:\WHI\UNSAT22\data\P212.VHP\_weather4.dat
 SOIL AND DESIGN DATA FILE:  C:\WHI\UNSAT22\data\P212.VHP\I_385737.inp
 OUTPUT DATA FILE:           C:\WHI\UNSAT22\data\P212.VHP\O_385737.prt

TIME:  10: 2     DATE:  10/ 5/2023

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TITLE: Uncapped Full Waste

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      NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
               COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                    LAYER  1
                                    --------
                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   5
            THICKNESS                  =   1310.64   CM
            POROSITY                   =      0.4530 VOL/VOL
            FIELD CAPACITY             =      0.1900 VOL/VOL
            WILTING POINT              =      0.0850 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2194 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.100000000000E-02 CM/SEC

                                    LAYER  2
                                    --------
                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   5
            THICKNESS                  =     60.96   CM
            POROSITY                   =      0.4530 VOL/VOL
            FIELD CAPACITY             =      0.1900 VOL/VOL
            WILTING POINT              =      0.0850 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.1900 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.100000000000E-01 CM/SEC

                                    LAYER  3
                                    --------
                        TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER  20
            THICKNESS                  =      0.50   CM
            POROSITY                   =      0.8500 VOL/VOL
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   FIELD CAPACITY              =      0.0100 VOL/VOL
   WILTING POINT               =      0.0050 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC
   SLOPE                       =      2.50   PERCENT
   DRAINAGE LENGTH             =     91.4    METERS

                         LAYER  4
                         --------
              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
   THICKNESS                   =      0.10   CM
   POROSITY                    =      0.0000 VOL/VOL
   FIELD CAPACITY              =      0.0000 VOL/VOL
   WILTING POINT               =      0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.200000000000E-12 CM/SEC
   FML PINHOLE DENSITY         =      2.00   HOLES/HECTARE
   FML INSTALLATION DEFECTS    =      2.00   HOLES/HECTARE
   FML PLACEMENT QUALITY       =  2 - EXCELLENT


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 5 WITH BARE
         GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
         A SLOPE LENGTH OF   91. METERS.

 SCS RUNOFF CURVE NUMBER              =     83.60
 FRACTION OF AREA ALLOWING RUNOFF     =      0.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE  =      0.4047 HECTARES
 EVAPORATIVE ZONE DEPTH               =     20.3    CM
 INITIAL WATER IN EVAPORATIVE ZONE   =      9.205  CM
 UPPER LIMIT OF EVAPORATIVE STORAGE  =      9.205  CM
 LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.727  CM
 INITIAL SNOW WATER                   =      0.000  CM
 INITIAL WATER IN LAYER MATERIALS    =    299.148  CM
 TOTAL INITIAL WATER                  =    299.148  CM
 TOTAL SUBSURFACE INFLOW              =      0.00   MM/YR


            EVAPOTRANSPIRATION AND WEATHER DATA
            -----------------------------------

  NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         Albany               NY

     STATION LATITUDE                        =  42.67 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   0.00
     START OF GROWING SEASON (JULIAN DATE)   =    123
     END OF GROWING SEASON (JULIAN DATE)     =    282
     EVAPORATIVE ZONE DEPTH                  =   8.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =   8.90 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  68.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  66.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  74.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  74.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.39	2.26	3.01	2.94	3.31	3.29
3.00	3.34	3.23	2.93	3.04	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
21.10	23.40	33.80	46.60	57.50	66.70
71.40	69.20	61.20	50.50	39.30	26.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY AND STATION LATITUDE = 42.38 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.06	2.39	3.25	2.93	3.26	2.98
	2.87	2.76	3.69	2.89	3.07	2.71
STD. DEVIATIONS	0.84	1.06	1.32	1.19	1.25	1.29
	1.01	0.99	2.05	1.56	1.35	1.18
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.567	0.507	0.606	2.443	2.693	2.470
	2.557	2.404	2.221	1.684	1.196	0.573
STD. DEVIATIONS	0.097	0.082	0.282	0.764	0.927	0.971
	0.942	0.826	0.829	0.505	0.223	0.149

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	1.1639	1.1624	0.9560	0.5783	1.6340	1.5711
	1.5582	1.3635	1.1545	0.9335	0.8669	0.8077
STD. DEVIATIONS	0.4929	0.3734	0.3327	0.3485	0.5977	0.4318
	0.4143	0.4217	0.3092	0.3568	0.3558	0.3648

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0776	0.0751	0.0670	0.0460	0.0913	0.0902
	0.0919	0.0856	0.0761	0.0667	0.0628	0.0609
STD. DEVIATIONS	0.0198	0.0159	0.0151	0.0162	0.0207	0.0132
	0.0125	0.0142	0.0126	0.0162	0.0177	0.0183

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0080	0.0087	0.0065	0.0041	0.0112	0.0111
	0.0106	0.0093	0.0082	0.0064	0.0061	0.0055
STD. DEVIATIONS	0.0034	0.0028	0.0023	0.0025	0.0041	0.0030
	0.0028	0.0029	0.0022	0.0024	0.0025	0.0025

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	34.86	(5.272)	126543.9	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	19.922	(2.3750)	72316.38	57.147
LATERAL DRAINAGE COLLECTED FROM LAYER 3	13.75004	(3.25871)	49911.544	39.44208
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.89113	(0.12273)	3234.729	2.55621
AVERAGE HEAD ON TOP OF LAYER 4	0.008	(0.002)		
CHANGE IN WATER STORAGE	0.298	(4.3063)	1081.23	0.854

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30 and their dates (DDDYYYY)

	(INCHES)	(CU. FT.)	
PRECIPITATION	3.20	11615.74682	2620015
RUNOFF	0.000	0.00000	0
DRAINAGE COLLECTED FROM LAYER 3	0.15079	547.36756	1440003
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.005261	19.09728	1440003
AVERAGE HEAD ON TOP OF LAYER 4	0.032		
MAXIMUM HEAD ON TOP OF LAYER 4	0.064		
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	1.1 FEET		
SNOW WATER	6.59	23929.3540	690020
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4530	
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0850	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	121.9048	0.2362
2	4.5600	0.1900
3	0.0028	0.0141
4	0.0000	0.0000
SNOW WATER	0.243	

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 **                                                                          **
 **              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
 **                HELP MODEL VERSION 3.07  (1 November 1997)                **
 **                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
 **                  USAE WATERWAYS EXPERIMENT STATION                       **
 **              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
 **                                                                          **
 **                                                                          **
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 PRECIPITATION DATA FILE:    C:\WHI\UNSAT22\data\P318.VHP\_weather1.dat
 TEMPERATURE DATA FILE:      C:\WHI\UNSAT22\data\P318.VHP\_weather2.dat
 SOLAR RADIATION DATA FILE:  C:\WHI\UNSAT22\data\P318.VHP\_weather3.dat
 EVAPOTRANSPIRATION DATA:    C:\WHI\UNSAT22\data\P318.VHP\_weather4.dat
 SOIL AND DESIGN DATA FILE:  C:\WHI\UNSAT22\data\P318.VHP\I_385775.inp
 OUTPUT DATA FILE:           C:\WHI\UNSAT22\data\P318.VHP\O_385775.prt

TIME:  13:28     DATE:   9/11/2023

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TITLE: Full Buildout Post-Closure - Steady-State Moisture Content

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      NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                  LAYER  1
                                  --------
                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   8
            THICKNESS                  =     15.24   CM
            POROSITY                   =      0.4630 VOL/VOL
            FIELD CAPACITY             =      0.2320 VOL/VOL
            WILTING POINT              =      0.1160 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.4630 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.370000000000E-03 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
               FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

                                  LAYER  2
                                  --------
                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   4
            THICKNESS                  =     45.72   CM
            POROSITY                   =      0.4370 VOL/VOL
            FIELD CAPACITY             =      0.1050 VOL/VOL
            WILTING POINT              =      0.0470 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.1908 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.170000000000E-02 CM/SEC

                                  LAYER  3
                                  --------
                      TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  20
```

```
THICKNESS                    =      0.50   CM
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0171 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   10.0000000000     CM/SEC
SLOPE                        =      5.00   PERCENT
DRAINAGE LENGTH              =    106.7    METERS

                        LAYER  4
                        --------
            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.10   CM
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.200000000000E-12 CM/SEC
FML PINHOLE DENSITY          =      2.47   HOLES/HECTARE
FML INSTALLATION DEFECTS     =      2.47   HOLES/HECTARE
FML PLACEMENT QUALITY        =  2 - EXCELLENT

                        LAYER  5
                        --------
          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   5
THICKNESS                    =   1310.64   CM
POROSITY                     =      0.4530 VOL/VOL
FIELD CAPACITY               =      0.1900 VOL/VOL
WILTING POINT                =      0.0850 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1900 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000000000E-02 CM/SEC

                        LAYER  6
                        --------
          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   5
THICKNESS                    =     60.96   CM
POROSITY                     =      0.4530 VOL/VOL
FIELD CAPACITY               =      0.1900 VOL/VOL
WILTING POINT                =      0.0850 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1900 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000000000E-01 CM/SEC

                        LAYER  7
                        --------
            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  20
THICKNESS                    =      0.50   CM
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   10.0000000000     CM/SEC
SLOPE                        =      2.50   PERCENT
DRAINAGE LENGTH              =    118.9    METERS
```

LAYER 8

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.10 CM
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.200000000000E-12 CM/SEC
FML PINHOLE DENSITY	=	2.00 HOLES/HECTARE
FML INSTALLATION DEFECTS	=	2.00 HOLES/HECTARE
FML PLACEMENT QUALITY	=	2 - EXCELLENT

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 107. METERS.

SCS RUNOFF CURVE NUMBER	=	79.57	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	0.4047	HECTARES
EVAPORATIVE ZONE DEPTH	=	30.5	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	10.540	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.716	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.484	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	276.398	CM
TOTAL INITIAL WATER	=	276.398	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Albany NY

STATION LATITUDE	=	42.67	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	123	
END OF GROWING SEASON (JULIAN DATE)	=	282	
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	8.90	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	66.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	74.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.39	2.26	3.01	2.94	3.31	3.29
3.00	3.34	3.23	2.93	3.04	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
21.10	23.40	33.80	46.60	57.50	66.70
71.40	69.20	61.20	50.50	39.30	26.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Albany NY
AND STATION LATITUDE = 42.38 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.06	2.39	3.25	2.93	3.26	2.98
	2.87	2.76	3.69	2.89	3.07	2.71
STD. DEVIATIONS	0.84	1.06	1.32	1.19	1.25	1.29
	1.01	0.99	2.05	1.56	1.35	1.18
RUNOFF						
TOTALS	0.205	0.681	4.349	0.631	0.013	0.014
	0.001	0.004	0.068	0.032	0.013	0.173
STD. DEVIATIONS	0.394	0.840	2.170	0.881	0.057	0.036
	0.002	0.016	0.145	0.086	0.029	0.367
EVAPOTRANSPIRATION						
TOTALS	0.567	0.508	0.608	2.612	2.953	2.819
	2.831	2.557	2.064	1.534	1.055	0.548
STD. DEVIATIONS	0.096	0.081	0.266	0.673	1.019	0.967
	1.052	0.835	0.799	0.427	0.179	0.129
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.1992	0.0818	0.3716	1.8790	0.6067	0.3997
	0.2349	0.1855	0.7318	1.0091	1.3564	0.9567
STD. DEVIATIONS	0.0765	0.0162	0.5872	0.6638	0.5873	0.3184
	0.0983	0.0570	0.8796	1.0224	1.1810	0.5399

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0001	0.0000	0.0001	0.0004	0.0001	0.0001
	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002
STD. DEVIATIONS	0.0000	0.0000	0.0001	0.0002	0.0001	0.0001
	0.0000	0.0000	0.0002	0.0002	0.0002	0.0001

LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0001	0.0001	0.0001	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 8

TOTALS	0.0001	0.0000	0.0001	0.0003	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002
STD. DEVIATIONS	0.0000	0.0000	0.0001	0.0001	0.0001	0.0000
	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0008	0.0004	0.0021	0.0211	0.0031	0.0016
	0.0009	0.0007	0.0067	0.0068	0.0070	0.0038
STD. DEVIATIONS	0.0003	0.0001	0.0050	0.0169	0.0056	0.0013
	0.0004	0.0002	0.0152	0.0137	0.0093	0.0022

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	34.86	(5.272)	126543.9	100.00
RUNOFF	6.184	(1.9496)	22447.88	17.739
EVAPOTRANSPIRATION	20.657	(2.3790)	74982.49	59.254
LATERAL DRAINAGE COLLECTED	8.01218	(2.52876)	29083.581	22.98300

FROM LAYER 3				
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00168 (	0.00046)	6.100	0.00482
AVERAGE HEAD ON TOP OF LAYER 4	0.005 (	0.003)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	0.00037 (	0.00018)	1.343	0.00106
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.00131 (	0.00030)	4.757	0.00376
AVERAGE HEAD ON TOP OF LAYER 8	0.000 (	0.000)		
CHANGE IN WATER STORAGE	0.007 (	1.6760)	23.83	0.019

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30 and their dates (DDDYYYY)

	(INCHES)	(CU. FT.)	
PRECIPITATION	3.20	11615.74682	2620015
RUNOFF	2.784	10104.08636	690003
DRAINAGE COLLECTED FROM LAYER 3	1.17275	4256.98078	2710023
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000693	2.51476	2710023
AVERAGE HEAD ON TOP OF LAYER 4	2.162		
MAXIMUM HEAD ON TOP OF LAYER 4	3.027		
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	16.4 FEET		
DRAINAGE COLLECTED FROM LAYER 7	0.00037	1.32932	2710023
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000245	0.88879	2710023
AVERAGE HEAD ON TOP OF LAYER 8	0.000		
MAXIMUM HEAD ON TOP OF LAYER 8	0.000		
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	0.0 FEET		
SNOW WATER	6.59	23929.3540	690020

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4183

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0815

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2.7780	0.4630
2	3.3890	0.1883
3	0.0028	0.0140
4	0.0000	0.0000
5	98.0400	0.1900
6	4.5600	0.1900
7	0.0020	0.0100
8	0.0000	0.0000
SNOW WATER	0.243	

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Attachment 2

Transmissivity Calculation Sheets

General Electric Company
Town of Lee, MA
UDF

Giroud's Equation for Minimum Required Geocomposite Transmissivity
Exposed Cell Sideslope

Input

Drainage Length [m]:	47.2
Drainage Layer Thickness [cm]:	0.76
Slope of Drainage Layer:	0.33
Impingement Rate, q_h, [cm/s][1]:	5.6E-05

Factor of Safety

		Typical Range for Factor of Safety		
		Surface Water	Leachate Collection	Leachate Detection
Intrusion Reduction Factor, RF_{in}	1.0	1.0-1.2	1.0-1.2	1.0-1.2
Creep Reduction Factor, RF_{cr}:	1.0	1.1-1.4	1.4-2.0	1.4-2.0
Chemical Clogging Reduction Factor, RF_{cc}	1.7	1.0-1.2	1.5-2.0	1.5-2.0
Biological Clogging Reduction Factor, RF_{bc}	1.7	1.2-1.5	1.5-2.0	1.5-2.0
Overall FS for Drainage, FS_d:	2.5	2.0-3.0	2.0-3.0	2.0-3.0

Output

Total Serviceability Factor[2]	7.23
Required Transmissivity [cm^2/s]:	**6.06**

Note:

1. Impingement rate is equal to the peak daily value for lateral drainage collected by the geocomposite layer as calculated using Visual HELP. The amount of lateral drainage (in cm) is converted into a daily average infiltration rate to the geocomposite.

General Electric Company
Town of Lee, MA
UDF

Giroud's Equation for Minimum Required Geocomposite Transmissivity
Cell Floor (Active Condition - Minimal Consolidation Material)

Input

Drainage Length [m]:	114.3
Drainage Layer Thickness [cm]:	0.76
Slope of Drainage Layer:	0.028
Impingement Rate, q_h, [cm/s][1]:	1.2E-05

Factor of Safety		Typical Range for Factor of Safety: Surface Water	Leachate Collection	Leachate Detection
Intrusion Reduction Factor, RF_{in}	1.0	1.0-1.2	1.0-1.2	1.0-1.2
Creep Reduction Factor, RF_{cr}:	1.0	1.1-1.4	1.4-2.0	1.4-2.0
Chemical Clogging Reduction Factor, RF_{cc}	1.7	1.0-1.2	1.5-2.0	1.5-2.0
Biological Clogging Reduction Factor, RF_{bc}	1.7	1.2-1.5	1.5-2.0	1.5-2.0
Overall FS for Drainage, FS_d:	2.5	2.0-3.0	2.0-3.0	2.0-3.0

Output

Total Serviceability Factor[2]	7.23
Required Transmissivity [cm^2/s]:	**36.2**

Notes:

1. Impingement rate is equal to the peak daily value for lateral drainage collected by the geocomposite layer as calculated using Visual HELP. The amount of lateral drainage (in cm) is converted into a daily average infiltration rate to the geocomposite.

General Electric Company
Town of Lee, MA
UDF

Giroud's Equation for Minimum Required Geocomposite Transmissivity
Cell Floor (Active Condition - Full Build-Out)

Input

Drainage Length [m]:	114.3
Drainage Layer Thickness [cm]:	0.76
Slope of Drainage Layer:	0.028
Impingement Rate, q_h, [cm/s][1]:	4.4E-06

Factor of Safety		Typical Range for Factor of Safety Surface Water	Leachate Collection	Leachate Detection
Intrusion Reduction Factor, RF_{in}	1.0	1.0-1.2	1.0-1.2	1.0-1.2
Creep Reduction Factor, RF_{cr}:	1.0	1.1-1.4	1.4-2.0	1.4-2.0
Chemical Clogging Reduction Factor, RF_{cc}	1.7	1.0-1.2	1.5-2.0	1.5-2.0
Biological Clogging Reduction Factor, RF_{bc}	1.7	1.2-1.5	1.5-2.0	1.5-2.0
Overall FS for Drainage, FS_d:	2.5	2.0-3.0	2.0-3.0	2.0-3.0

Output

Total Serviceability Factor[2]	7.23
Required Transmissivity [cm^2/s]:	**12.9**

Notes:

1. Impingement rate is equal to the peak daily value for lateral drainage collected by the geocomposite layer as calculated using Visual HELP. The amount of lateral drainage (in cm) is converted into a daily average infiltration rate to the geocomposite.

General Electric Company

Town of Lee, MA

UDF

Giroud's Equation for Minimum Required Transmissivity

Cell Floor - Post-Closure (Full Build-Out)

Input

Drainage Length [m]:	114.3
Drainage Layer Thickness [cm]:	0.76
Slope of Drainage Layer:	0.028
Impingement Rate, q_h, [cm/s][1]:	0.0E+00

Factor of Safety		Typical Range for Factor of Safety: Surface Water	Leachate Collection	Leachate Detection
Intrusion Reduction Factor, RF_{in}	1.0	1.0-1.2	1.0-1.2	1.0-1.2
Creep Reduction Factor, RF_{cr}:	2.0	1.1-1.4	1.4-2.0	1.4-2.0
Chemical Clogging Reduction Factor, RF_{cc}	2.0	1.0-1.2	1.5-2.0	1.5-2.0
Biological Clogging Reduction Factor, RF_{bc}	2.0	1.2-1.5	1.5-2.0	1.5-2.0
Overall FS for Drainage, FS_d:	3.0	2.0-3.0	2.0-3.0	2.0-3.0

Output

Total Serviceability Factor[2]	24.00
Required Transmissivity [cm^2/s]:	**0.00**

Note:

1. Impingement rate is equal to the peak daily value for lateral drainage collected by the geocomposite layer as calculated using Visual HELP. The amount of lateral drainage (in cm) is converted into a daily average infiltration rate to the geocomposite.

ARCADIS

Calculation Brief

Client: General Electric Company

Project Location: Pittsfield/Housatonic River Site - Town of Lee, Massachusetts

Project: Upland Disposal Facility Area **Arcadis Project No.: 30197838**

Calc No.: E-2 **Subject: Leachate Collection Pipe Design**

Prepared By: CSH **Date: February 2024**

Reviewed By: BMS **Date: February 2024**

Objective

Determine the required diameter and perforation pattern for the leachate collection pipe along the cell centerline in the primary and secondary leachate collection systems. Demonstrate that the leachate collection pipe is capable of withstanding the applied loading associated with final buildout. Determine the minimum required cover for the leachate collection pipe to allow the operation of truck traffic across the pipe.

References

1. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 5: Baseliner Grading Plan.* February 2024.
2. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 8: Final Grading Plan.* February 2024.
3. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix E-1. *Leachate Collection Layer Design.* February 2024.
4. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix D-4. *Floor Settlement Calculation*. February 2024.
5. *Engineer-in-Training Reference Manual*, 8th Edition, Lindeburg, Michael R., P.E., pp. A-38 and A-47, 1992 (attached).
6. Literature from Performance Pipe, Bulletin: pp 152-4710 (attached).
7. Goddard, J.B. *The Structural Performance of Polyethylene Pipe*. *Geotechnical Fabrics Report.* September 1991.
8. Paruvakat, N. *Deflection Analysis of Polyethylene Leachate Collection Pipes*. Geosynthetics '93. Vancouver, Canada.
9. U.S. Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). *National Engineering Handbook*, Chapter 52 – Structural Design of Flexible Conduits, pp. 52-8, 52-10, 52-11, 52-12, and 52C-1 (attached).
10. Principles of Geotechnical Engineering, 2nd Edition, Das, Braja M., pp 195-196, 1990 (attached).
11. U.S. Department of the Interior, Bureau of Reclamation Technical Service Center. *Physical Properties*

of Plastic Pipe Used in Reclamation Toe Drains. Report DSO-09-01. September 2009.

Assumptions

1. The hydraulic capacity of the leachate collection pipe and its perforations must equal or exceed the flowrate from the geocomposite draining to it. The flowrate from the geocomposite is based on the design transmissivity value for the active condition with minimal consolidation material in place (from Reference 3), the slope of the cell floor perpendicular to the leachate collection pipe, and the length of the collection pipe. To be conservative, the longest collection pipe length and the steepest post-consolidation slope perpendicular to the leachate collection pipe within the UDF are used. Reference 1 indicates that Cell 1 has approximately 404 feet of geocomposite draining to the leachate collection pipe. Reference 1 indicates that both cells are constructed with a 2% slope perpendicular to the cell centerline. Reference 4 indicates the steepest post-settlement slope perpendicular to the cell centerline will be 2.14%. For the purposes of this calculation, a perpendicular slope of 2% is used.
2. The hydraulic capacity of the leachate collection pipe is, among other parameters, a function of pipe slope. Since the leachate collection pipe will be installed directly on the geocomposite, the post-settlement centerline slope is used. To be conservative, the flattest post-settlement centerline slope within the UDF is used to determine the hydraulic capacity and size of the leachate collection pipe. Reference 4 indicates that the flattest post-settlement slope along the cell centerline will be 2.03%. For the purposes of this calculation, a centerline slope of 2% is used.
3. The hydraulic capacity of the perforations in the leachate collection pipe is determined using the orifice equation, the perforation pattern (i.e., the location, diameter, and spacing of the holes), and assuming 1 foot of head above the geomembrane layer. An orifice coefficient of 0.3 is used (instead of a more typical value of 0.6) to account for the partial blockage of the perforation open area by the drainage stone surrounding the leachate collection pipe.
4. The maximum recommended vertical deflection of HDPE pipe is 5.0% (References 7 and 9).
5. Assumed unit weights of consolidated material and baseliner and final cover system materials is 120 lb/ft^3.
6. The structural performance of the leachate collection pipe is assessed based on ring (vertical) deflection and wall crushing and considers both the prism load associated with overlying soil and consolidation material and vehicular loads.
7. For the minimum cover depth requirement, vehicle traffic is assumed to consist of a semi-truck with a maximum single axle load of 40,000 pounds (lbs) (based on American Association of State Highway and Transportation Officials HS-25 loading). The tire inflation pressure is assumed to be 120 pounds per square inch (psi). The ground contact pressure beneath a pneumatic tire equals the tire inflation pressure. A wheel impact factor (Reference 9) is applied to the static load carried by each axle to account for dynamic effects due to vehicles traveling at speed over an uneven road surface.
8. In addition to ring deflection, pipe wall crushing potential is also evaluated. The maximum allowable long-term compressive stress of HDPE pipe (material designation PE3408) is 800 psi (Reference 9).

Calculations

1. Required Pipe Diameter

The required pipe diameter is determined using the Hazen-Williams equation and the maximum flowrate from the geocomposite that drains to the leachate collection pipe. The maximum flowrate from the geocomposite is determined using Darcy's law, the definition of transmissivity, and the design transmissivity value from Reference 3:

$$Q = kiA$$

$$k = \frac{\Phi}{t}$$

$$A = 2Lt$$

$$\therefore Q = 2L\Phi i$$

where,

L = length of leachate collection pipe from Reference 1 (multiplied by 2 to account for inflow from both sides of pipe). To be conservative, the longest leachate collection pipe length in the UDF is used = 404 ft

Φ = design transmissivity of geocomposite = 36.2 cm^2/s = 0.0390 ft^2/s (Assumption 1)

i = steepest hydraulic gradient perpendicular to the leachate collection pipe = 2.0% (Assumption 1)

Thus,

$$Q = (2)(404\ \text{ft})(0.0390\ \text{ft}^2/\text{s})(0.02) \ = \ 0.630\ \text{cfs}$$

The Hazen-Williams equation is:

$$Q = 1.318 A C_h R^{0.63} S^{0.54}$$

where,

Q = maximum flowrate from the geocomposite (from above)

A = cross sectional area of pipe flowing full = $\pi D^2/4$

C_h = Hazen-Williams friction coefficient for plastic pipe = 150 (Reference 5)

R = hydraulic radius = A/P

P = wetted perimeter of pipe flowing full = πD

S = longitudinal slope of pipe = 2.0% (Assumption 2)

Thus,

$$0.630 = 1.318\left(\frac{\pi D^2}{4}\right)(150)\left(\frac{D}{4}\right)^{0.63}(0.020)^{0.54}$$

Solving for D,

$$D = 0.383\ ft\ (4.60\ inches)$$

To be conservative, an 8-inch-diameter pipe will be used for the leachate collection pipe. An 8-inch-diameter DR 7.3 pipe has an average inside diameter of 6.119 inches (0.510 feet). The pipe-full capacity for this pipe is determined using the Hazen-Williams equation:

$$Q = 1.318\left(\frac{\pi 0.510^2}{4}\right)(150)\left(\frac{0.510}{4}\right)^{0.63}(0.020)^{0.54} = 1.334\ cfs$$

Consequently, an 8-inch-diameter leachate collection pipe provides a factor of safety of approximately 2.12 (i.e., 1.334/0.630). Since the maximum flowrate from the geocomposite and the capacity of the leachate collection pipe are based on worst-case values (per Assumptions 1 and 2), this is the smallest anticipated factor of safety for both UDF cells. Additionally, the required pipe diameter is based on the design transmissivity of the contributing geocomposite, which is significantly greater than the actual flowrate through the geocomposite to the leachate collection pipe (i.e., the design transmissivity also incorporates a factor of safety).

The actual flow depth in the leachate collection pipe for the design flowrate (0.630 cfs) can be calculated using the ratio of the design flowrate to the pipe-full flowrate:

$$\frac{Q}{Q_o} = \frac{0.630\ cfs}{1.334\ cfs} = 0.472$$

Based on Reference 5, this flowrate ratio corresponds to a ratio of depth to pipe diameter of about 0.47. Therefore, the flow depth in the leachate collection pipe for the design flowrate is about 0.24 feet or 2.9 inches (0.47*0.510 feet = 0.24 feet).

2. Required Perforation Pattern

Similar to the required pipe diameter calculations above, the required perforation pattern is based on the maximum flowrate from the geocomposite (using the design transmissivity). Since the perforation pattern is specified as a number of perforations per foot, the maximum flowrate from the geocomposite is redefined as an inflow per foot of leachate collection pipe:

- Maximum Inflow to Each Foot of Pipe from Geocomposite = 0.630 cfs/404 ft = 0.00156 cfs/ft

This is the inflow to the pipe from both sides of the cell (the flow into each side of the pipe is one half of the above value).

Assuming 5/8-inch-diameter holes are used, the flowrate through each set of perforations is calculated using the orifice equation and the effective head (1 foot of head on the geomembrane minus either the height of the center of the holes above the geomembrane or the height of the water surface inside the pipe during the design flow depth above the geomembrane, whichever is greater). Four rows of holes will be installed in the pipe, with two rows offset from the bottom pipe centerline by 45^o and the remaining two rows offset from the top pipe centerline by 45^o. The centerline of each hole in the lower two rows will be approximately 1.3 inches above the outside bottom of the pipe (i.e., approximately 1.3 inches above the geomembrane). The centerline of each hole in the upper two rows will be approximately 7.3 inches above the outside bottom of the pipe. As calculated above, the design flow depth is 2.9 inches. This flow depth, combined with an average wall thickness of 1.182 inches, means that the design water surface inside the pipe is approximately 4.08 inches above the geomembrane. Thus, the effective head on each hole in the lower two rows is 7.92 inches (12 inches – 4.08 inches) and the effective head on each hole in the upper two rows is 4.7 inches (12 inches – 7.3 inches). The flowrate through each set of 4 holes is calculated as follows:

$$Q = 2CA\sum\sqrt{2gH_{eff}}$$

where,

Q = flowrate through each set of 4 holes (unknown)

C = orifice coefficient = 0.3 (Assumption 3)

A = cross sectional area of each hole = $\pi D^2/4$ = 0.00213 ft^2

H_{eff} = effective head on each hole = 7.92 in = 0.66 ft for lower holes and 4.7 in = 0.39 ft for upper holes (see above)

The multiplier of 2 in the above equation accounts for the fact that two holes in each set of 4 holes are at identical elevations and therefore have identical inflow capacities.

Thus,

$$Q = 2(0.3)(0.00213\ \text{ft}^2)\left[\sqrt{2(32.2\ \text{ft/s}^2)(0.66\ \text{ft})} + \sqrt{2(32.2\text{ft/s}^2)(0.39\ \text{ft})}\right] = 0.0147\ \text{cfs}$$

The required number of perforation sets per foot of pipe is:

$$n = (0.00156\ \text{cfs/ft})/(0.0147\text{cfs})\ =\ 0.106\ (\text{i.e., 1 perforation set per 9.4 feet of pipe})$$

To be conservative, the perforation sets will be spaced 6 inches apart on center, yielding a total of 2 perforation sets per foot of pipe. This provides an inflow capacity of 0.0294 cfs per foot of pipe (2x0.0147 cfs), and a factor of safety of 20.0 (0.0294 cfs/0.00147 cfs). In terms of resistance to failure of the leachate collection pipe due to clogging of the perforations, this factor of safety allows for up to 96% clogging of the perforations before the inflow capacity of the leachate collection pipe is reduced to the point that it equals the maximum possible flowrate able to be conveyed through the geocomposite.

3. Structural Performance of Pipe Under Final Landfill Buildout

The leachate collection pipe is designed to withstand the applied loading associated with final buildout. A comparison of the top of the baseliner (Reference 1) and the top of the final cover (Reference 2) indicates that the maximum consolidation material thickness of 115 feet combined with the final cover thickness of 2.5 feet (above the top of the consolidation material) equates to117.5 feet. The leachate collection pipe in the secondary leachate collection system is 3 feet beneath the top of the baseliner (1 foot of operations layer plus 1 foot of granular drainage layer in each of the primary and secondary leachate collection systems). This yields a total depth of cover of 120.5 feet of material above the leachate collection pipe which produces an overburden pressure of 14,460 psf (120.5 ft x 120 lb/ft^3) or 100.4 psi.

Based on laboratory testing of pipe stiffness, drilling holes through solid wall HDPE pipe reduces the pipe stiffness by 15% for every 1% of open area created by the holes (Reference 13). Each 5/8-inch-diameter perforation creates 0.307 in^2 of open area. Eight holes per foot of pipe creates 2.46 in^2 of open area. Each linear foot of pipe has 302 in^2 of pipe wall area. The open area percentage is therefore 0.81% (2.46 in^2/302 in^2 = 0.0081). The pipe stiffness is estimated to reduce by 12% due to the proposed perforation pattern.

The pipe deflection is determined with the Modified Iowa formula (Reference 9). The denominator consists of two components- the pipe stiffness (left hand term) and soil modulus (right hand term). The pipe stiffness includes a 0.88 multiplier to account for the expected 12% reduction due to the pipe perforations:

$$\Delta \mathrm{y} = \frac{D\sigma k_b}{(0.88)\frac{2}{3}E\left(\frac{1}{\mathrm{SDR}-1}\right)^3 + 0.061\mathrm{E'}}$$

where,

Δy = vertical deflection of pipe = unknown

D = average pipe diameter = 7.37 in (average of inside and outside diameter, Reference 6)

σ = 100.4 psi

k_b = bedding factor = 0.1 (Reference 9)

E = long-term modulus of elasticity for HDPE = 22,000 psi (Reference 7)

SDR = standard diameter ratio of pipe (pipe OD/wall thickness) = 7.3

E' = soil modulus of pipe bedding = 3,000 psi (compacted crushed rock, Reference 7)

Using the Modified Iowa Formula, the vertical deflection of the pipe is 0.30 inches, which corresponds to a 4.1% deflection (as compared to the average diameter). Since a deflection of up to 5.0% is acceptable (Assumption 4), the calculated pipe deflection does not exceed the manufacturer's recommendations.

Pipe Wall Crushing

In addition to vertical deflection, the potential for pipe wall crushing is evaluated based on Reference 9 by dividing the normal load on the pipe by the wall cross section in a horizontal plane on a unit length basis as follows:

$$\sigma_{PW} = \frac{PD_o}{2t}$$

where,

σ_{PW} = pipe wall compressive stress (psi) = unknown

P = load applied to pipe = 100.4 psi (calculated previously)

D_o = pipe outside diameter = 8.625 in

t = pipe wall thickness = 1.182 in

Thus,

σ_{PW} = 366 psi < 800 psi allowable

The calculated wall compressive stress is less than the maximum allowable compressive stress.

4. Minimum Cover to Allow Truck Operation Over the Pipe

In addition to final buildout, pipe performance is also evaluated under another scenario to determine the minimum required cover to allow operation of truck traffic over the pipe. Because the granular layers of the primary leachate collection system are 2-feet-thick, there will be approximately 15 inches of granular cover over the pipe (24 in – 8.625 in = 15.375 in) prior to any consolidation material placement in the cell. As a first trial, this amount of cover is evaluated to determine if it is sufficient to protect the pipe from damage. The resulting load on the pipe is the sum of the prism load from the granular material in the baseliner system plus the at-depth pressure increase from vehicular traffic.

The prism load from the baseliner aggregate layers equals the product of the overlying layer thickness (15.375 inches) and the unit weight of the granular material (120 lb/ft^3), which is153.75 psf or 1.1 psi.

As stated in Assumption 7, vehicle traffic over the top of the pipe is assumed to consist of loaded semi-trucks with a maximum axle load of 40,000 lbs. For a cover thickness of 15 inches, a wheel impact factor of 1.2 (Reference 9) is applied to this static load to yield a dynamic axle load of 48,000 lbs. Using an assumed tire inflation pressure of 120 psi, the ground contact area is approximated as follows:

Axle Load = 48,000 lbs (dynamic)

Load at Each End of Each Axle = 24,000 lbs (dynamic)

Ground Contact Area Beneath Set of Tires at Each End of Axle = (24,000 lbs)/(120 psi) = 200 in^2

Radius of Assumed Circular Ground Contact Area = R = $(200\ in^2/\pi)^{1/2}$ = 8.0 in

The at-depth pressure increase, Δp, caused by a surface load, q, decreases with increasing burial depth due to load dissipation. Boussineq's stress distribution theory for a point below the center of a uniformly loaded circular area is used to determine the at-depth increase in normal stress on the top of the pipe as follows (Reference 10):

$$\Delta p = q\left[1 - \frac{1}{\left[\left(R/z\right)^2 + 1\right]^{3/2}}\right]$$

The estimated at-depth increase in pressure, Δp, due to traffic loads is as follows:

R/z = 8.0 in/15.375 in = 0.52

At-depth pressure increase (static load) = 36.2 psi

Summing the prism load from the baseliner aggregate (1.1 psi) and the at-depth pressure increase from vehicular traffic (36.2 psi) a total load of 37.3 psi results for the minimal cover condition.

Ring Deflection

The pipe deflection is determined with the Modified Iowa formula (Reference 9). The denominator consists of two components- the pipe stiffness (left hand term) and soil modulus (right hand term). The pipe stiffness includes a 0.88 multiplier to account for the expected 12% reduction due to the pipe perforations:

$$\Delta y = \frac{D\sigma k_b}{(0.88)\frac{2}{3}E\left(\frac{1}{\mathrm{SDR}-1}\right)^3 + 0.061E'}$$

where,

Δy = vertical deflection of pipe = unknown

D = average pipe diameter = 7.37 in

σ = overburden pressure based on prism loading from the baseliner aggregate plus the at-depth pressure increase from vehicular traffic = 37.3 psi (see calculation above)

k_b = bedding factor = 0.1 (Reference 9)

E = long-term modulus of elasticity for HDPE = 22,000 psi (Reference 7)

SDR = standard diameter ratio of pipe (pipe OD/wall thickness) = 7.3

E' = soil modulus of pipe bedding = 3,000 psi (compacted crushed rock, Reference 7)

Using the Modified Iowa Formula, the vertical deflection of the pipe is 0.12 inches, which corresponds to a 1.6% deflection (as compared to the average diameter). Since a deflection of up to 5.0% is acceptable (Assumption 4), the calculated pipe deflection does not exceed the manufacturer's recommendations.

Pipe Wall Crushing

In addition to vertical deflection, the potential for pipe wall crushing is evaluated based on Reference 9 by dividing the normal load on the pipe by the wall cross section in a horizontal plane on a unit length basis as follows:

$$\sigma_{PW} = \frac{(P)(D_o)}{2t}$$

where,

σ_{PW} = pipe wall compressive stress (psi)

P = load applied to pipe = 37.3 psi (calculated previously)

D_o = pipe outside diameter = 8.625 in

t = pipe wall thickness = 1.182 in

σ_{PW} = 136 psi < 800 psi allowable

The calculated wall compressive stress is less than the maximum allowable compressive stress for the minimal cover scenario. Therefore, no additional material is required above the top of the baseliner system before vehicular traffic can operate over the leachate collection pipe.

Summary

Based on a hydraulic analysis of conditions anticipated for the cell primary and secondary leachate collection systems, an 8-inch-diameter DR 7.3 HDPE pipe with two sets of four 5/8-inch-diameter perforations per foot of pipe (eight holes total per foot of pipe) is sufficient for the leachate collection pipe. A structural analysis indicates that the selected pipe is adequate under final buildout based on ring deflection and wall crushing. A separate structural analysis demonstrates that the baseliner system provides adequate cover to protect the pipe from excessive deflection and wall crushing under vehicle loading by a fully loaded hauling truck.

Attachments

1. Reference Excerpts

Attachment 1:

Reference Excerpts

ENGINEER-IN-TRAINING REFERENCE MANUAL

8th Edition

Current for the 1992-93 Exam Format
Expanded New Edition

Intended for EXAM USE

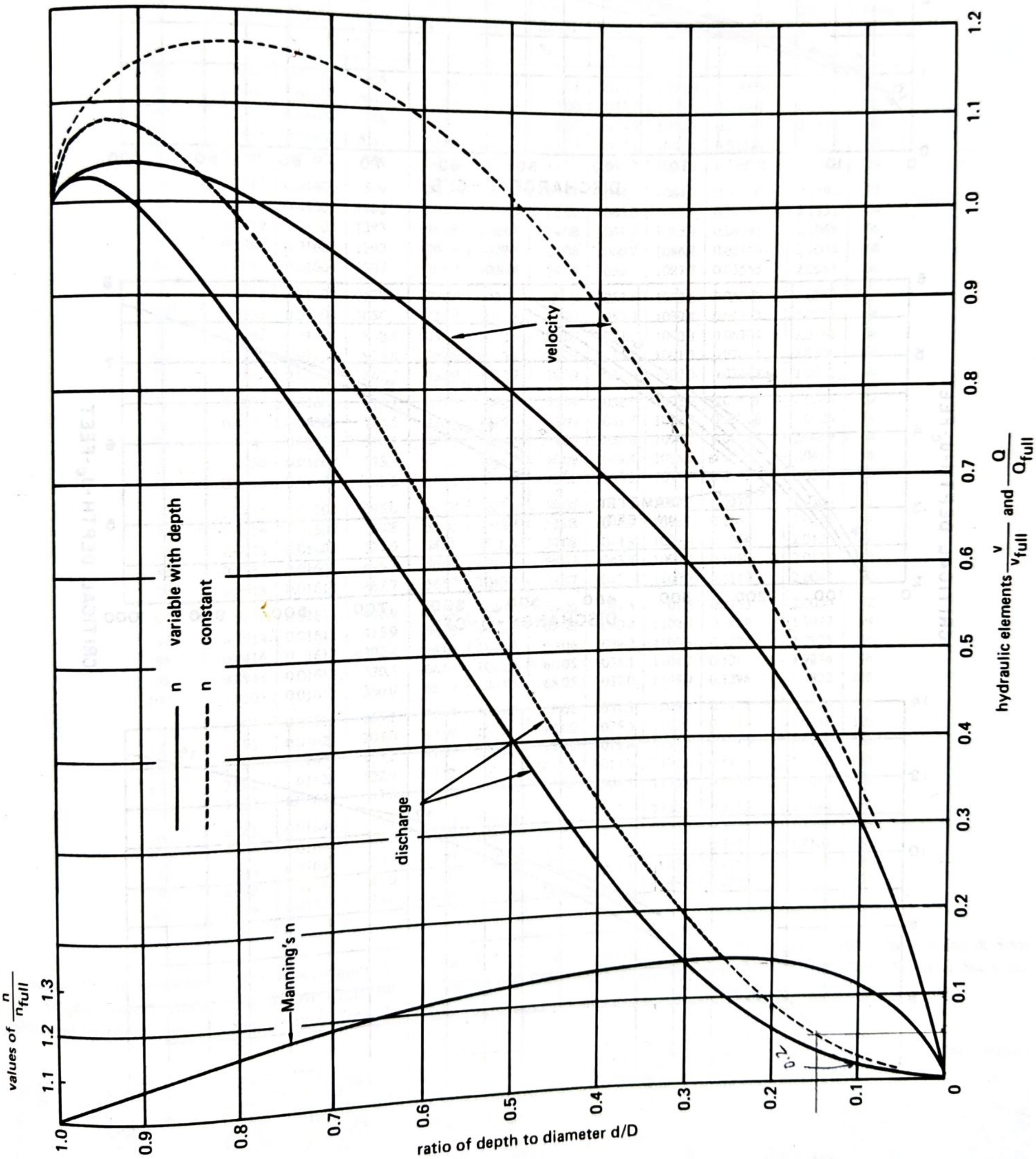
In English and SI Units

The Only Review Series Endorsed By The National Society Of Professional Engineers

Michael R. Lindeburg, P.E.

APPENDIX 19.C
Circular Channel Ratios

Experiments have shown that n varies slightly with depth. This figure gives velocity and flow rate ratios for varying n (solid line) and constant n (broken line) assumptions.



PERFORMANCE PIPE
A Division of Chevron Phillips Chemical Company LP

Revised 04-07-2009

IPS Size and Dimension Data

PE4710 (PE3408)

DriscoPlex® Municipal & Industrial & Energy Series/IPS Pipe Data

Pressure Ratings are calculated using 0.63 design factor for HDS at 73°F as listed in PPI TR-4 for PE 4710 materials.
Temperature, Chemical, and Environmental use considerations may require use of additional design factors.

Pressure Rating		317 psi DR 7.3			250 psi DR 9.0			200 psi DR 11.0			160 psi DR 13.5			
IPS Pipe Size	Nominal OD (in)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	IPS Pipe Size
1 1/4"	1.660	0.227	1.179	0.45	0.184	1.270	0.37	0.151	1.340	0.31	0.123	1.399	0.26	1 1/4"
1 1/2"	1.900	0.260	1.349	0.59	0.211	1.453	0.49	0.173	1.533	0.41	0.141	1.601	0.34	1 1/2"
2"	2.375	0.325	1.686	0.92	0.264	1.815	0.77	0.216	1.917	0.64	0.176	2.002	0.53	2"
3"	3.500	0.479	2.485	1.99	0.389	2.675	1.66	0.318	2.826	1.39	0.259	2.951	1.16	3"
4"	4.500	0.616	3.194	3.29	0.500	3.440	2.75	0.409	3.633	2.31	0.333	3.794	1.92	4"
6"	6.625	0.908	4.700	7.12	0.736	5.065	5.96	0.602	5.349	5.00	0.491	5.584	4.15	6"
8"	8.625	1.182	6.119	12.07	0.958	6.594	10.11	0.784	6.963	8.47	0.639	7.270	7.04	8"
10"	10.750	1.473	7.627	18.75	1.194	8.219	15.70	0.977	8.679	13.16	0.796	9.062	10.93	10"
12"	12.750	1.747	9.046	26.38	1.417	9.746	22.08	1.159	10.293	18.51	0.944	10.749	15.38	12"
14"	14.000	1.918	9.934	31.81	1.556	10.701	26.63	1.273	11.301	22.32	1.037	11.802	18.54	14"
16"	16.000	2.192	11.353	41.55	1.778	12.231	34.78	1.455	12.915	29.15	1.185	13.488	24.22	16"
18"	18.000	2.466	12.772	52.58	2.000	13.760	44.02	1.636	14.532	36.89	1.333	15.174	30.65	18"
20"	20.000	2.740	14.191	64.91	2.222	15.289	54.34	1.818	16.146	45.54	1.481	16.860	37.84	20"
22"	22.000	3.014	15.610	78.55	2.444	16.819	65.75	2.000	17.760	55.10	1.630	18.544	45.79	22"
24"	24.000	3.288	17.029	93.48	2.667	18.346	78.25	2.182	19.374	65.58	1.778	20.231	54.49	24"
26"	26.000				2.889	19.875	91.84	2.364	20.988	76.96	1.926	21.917	63.95	26"
28"	28.000				3.111	21.405	106.51	2.545	22.605	89.26	2.074	23.603	74.17	28"
30"	30.000				3.333	22.934	122.27	2.727	24.219	102.47	2.222	25.289	85.14	30"
32"	32.000							2.909	25.833	116.58	2.370	26.976	96.87	32"
34"	34.000							3.091	27.447	131.61	2.519	28.660	109.36	34"
36"	36.000							3.273	29.061	147.55	2.667	30.346	122.60	36"
42"	42.000										3.111	35.405	166.88	42"
48"	48.000													48"
54"	54.000													54"

Pipe weights are calculated in accordance with PPI TR-7. Average inside diameter is calculated using nomnal OD and Minimum wall plus 6% for use in estimating fluid flows. Actual ID will vary. When designing components to fit the pipe ID, refer to pipe dimension and tolerances in the applicable pipe manufacturing specification.

Visit www.performancepipe.com for the most current literature.

Bulletin: PP 152-4710

April 2009 Supersedes all previous publications

Flow Resistance

DriscoPlex® piping for M & I applications has a hydraulically smooth, non-wetting inside surface. Higher flow capacity and reduced friction loss can result in lower operating costs from reduced pumping costs and reduced maintenance. DriscoPlex® piping does not rust, rot, corrode, or tuberculate. When combined with outstanding abrasion resistance, DriscoPlex® piping provides excellent flow properties throughout its service life. For pressure water and wastewater flows, a Hazen-Williams "C' factor of 150-155 is typically used, and for gravity flows, an "n" factor of 0.009 is typically used with the Manning formula. See the *Performance Pipe Engineering Manual* for additional information.

Joining

DriscoPlex® pipe and fittings are joined using heat fusion, flanges, mechanical connections that are designed for PE pipe, and electrofusion. Heat fusion is a simple procedure that utilizes controlled temperature and pressure to melt and fuse PE pipe materials together. Butt fusion is used to join components end to end; saddle fusion to attach a branch outlet to a main pipe, and socket fusion to join smaller pipes to socket fittings. When properly made, heat fusion joints are reliable, leak-free, fully restrained, and as strong as the pipe itself. Contact Performance Pipe for recommended joining procedures.

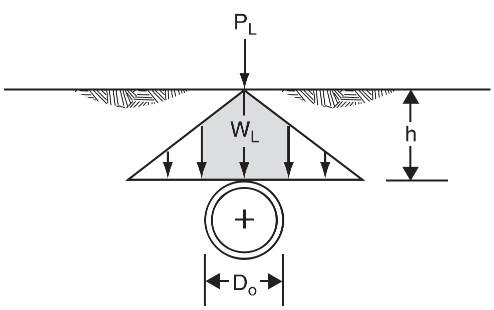
A leakage allowance common to gasketed-bell-and-spigot joined pressure pipes is unnecessary with the DriscoPlex® pressure piping system. With heat fusion, there are no gaskets to leak, joint restraints are not required, and thrust blocks are necessary only under unusual circumstances. Long lengths - 40 feet or more - mean fewer joints.

DriscoPlex® pipe and fittings may also be joined together or transitioned to other materials with flanges, mechanical connections that are designed for PE pipe, or electrofusion. These connections must be made in accordance with the connection manufacturer's instructions. Some connections such as mechanical OD compression couplings may require a stiffener in the pipe bore.

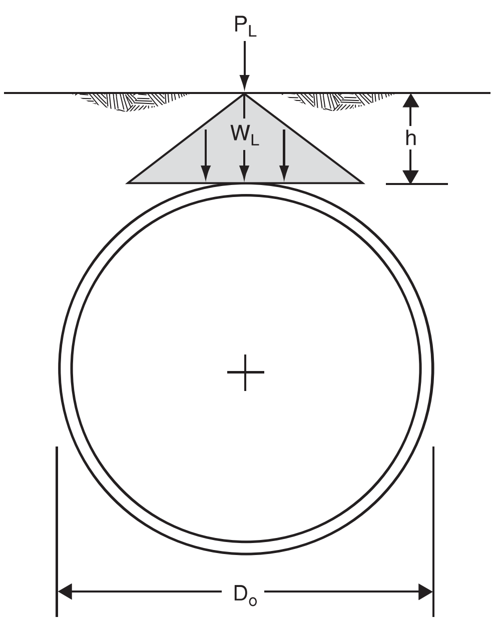
DriscoPlex® piping products cannot be joined with adhesive or solvent cement. Threaded joining, and joining by hot air (hot gas), or extrusion welding techniques are not recommended for pressure service.

Depth of cover	Impact factor
< 1'0"	1.3
1'1" – 2'0"	1.2
2'0" – 2'11"	1.1
≥ 3'0"	1.0

Figure 52–9 Load pressure distribution



(a) D_o-t < 2.67hx12



(b) D_o-t ≥ 2.67hx12

The pressure on the pipe from the wheel load may be determined by:

$$P_W = \frac{W_L}{\left(\frac{D_o}{12}\right)} \quad (52\text{–}21)$$

where:
P_w = pressure on pipe from wheel load, lb/ft²
D_o = outside diameter of pipe, in

When the depth of fill is 2 feet or more, wheel loads may be considered as uniformly distributed over a square with sides equal to 1 3/4 times the depth of fill.

$$P_w = \frac{P_L}{(1.75h)^2} \quad (52\text{–}22)$$

(c) Vacuum pressure

Pipe may be subject to an effective external pressure because of an internal vacuum pressure, P_v. Sudden valve closures, shutoff of a pump, or drainage from high points within the system often create a vacuum in pipelines. Siphons will all be subject to negative pressures.

Vacuum pressure should be incorporated into the design of buried and aboveground pipes as described in this chapter. The vacuum pressure may be intermittent (short term), for long durations, or continuously (long term).

The vacuum load per length of pipe may be determined by:

$$W_V = P_V \times \frac{D_i}{12} \quad (52\text{–}23)$$

where:
W_v = vacuum load per linear foot of pipe, lb/ft
P_v = internal vacuum pressure, lb/ft²
D_i = inside pipe diameter, in

(a) Plastic pipe

Plastic pipe materials consist of poly-vinyl chloride (PVC), acrylonitrile-butadiene-styrene (ABS), and polyethylene (PE). Each type of material is supplied in several grades as shown in appendix 52C.

Design of buried plastic pipe includes analyses of the wall crushing, buckling resistance, allowable long-term deflection, and allowable strain.

At a constant load, the plastic modulus of elasticity of the plastic pipe decreases with time. With any increase in load, the plastic reacts with the short-term modulus of elasticity. The ratio of the short-term to long-term modulus of elasticity varies from approximately 3 for PVC to 5 for PE. The short-term modulus of elasticity is recommended for conditions that change through time, such as deflection. The pipe-soil interaction that occurs as discrete events is similar to a new load (Chevron Chemical, 1998). The long-term modulus of elasticity is often recommended for buckling since the loads and reaction of the pipe are considered static.

(1) Wall crushing

The design pressure and ring compression thrust in the pipe wall is determined by:

$$P = P_s + P_w + P_v \tag{52–25}$$

where:
- P = pressure on pipe, lb/ft^2
- P_s = pressure due to weight of soil, lb/ft^2
- P_w = pressure on pipe due to wheel load, lb/ft^2
- P_v = internal vacuum pressure, lb/ft^2

$$T_{pw} = \frac{P \times \frac{D_o}{12}}{2} \tag{52–26}$$

where:
- T_{pw} = thrust in pipe wall, lb/ft
- D_o = outside pipe diameter, in

The required wall cross-sectional area is determined by:

$$A_{pw} = \frac{\frac{T_{pw}}{12}}{\sigma} \tag{52–27}$$

where:
- A_{pw} = required wall area, in^2/in
- T_{pw} = thrust in pipe wall, lb/ft
- σ = allowable long-term compressive stress, lb/in^2 (see appendix 52C, table 52C–1)

The area of a solid-wall pipe wall may be computed as:

$$A_{pw} = \frac{(D_o - D_i)}{2} \quad \text{or } t \tag{52–28}$$

where:
- A_{pw} = area of pipe wall, in^2/in
- D_o = outside pipe diameter, in
- D_i = inside pipe diameter, in
- t = pipe wall thickness, in

The average area of pipe wall for corrugated and profile wall pipe should be obtained from the manufacturer.

(2) Deflection

The Modified Iowa Equation may be transposed and rewritten to compute the percent deflection of each type of pipe. The properties of a pipe section are expressed as the standard dimension ratio (SDR) or standard inside dimension ratio (SIDR) for solid wall pipe, pipe stiffness (PS) for corrugated plastic pipe, and the ring stiffness constant (RSC) for profile wall pipe.

Solid-wall plastic pipe as:

$$\frac{\%\Delta X}{D} = \frac{(D_L P_S + P_w + P_V)\left(\frac{1}{144}\right)K(100)}{\left[\left(\frac{2E}{3(SDR-1)^3}\right) + 0.061E'\right]} \tag{52–29}$$

or

$$\frac{\%\Delta X}{D} = \frac{(D_L P_S + P_w + P_V)\left(\frac{1}{144}\right)K(100)}{\left[\left(\frac{2E}{3(SIDR+1)^3}\right) + 0.061E'\right]} \tag{52–30}$$

Corrugated-plastic pipe as:

$$\frac{\%\Delta X}{D} = \frac{\left(D_L P_S + P_w + P_V\right)\left(\frac{1}{144}\right)K(100)}{\left[0.149PS + 0.061E'\right]} \qquad (52–31)$$

Profile-wall pipe:

$$\frac{\%\Delta X}{D} = \frac{\left(D_L P_S + P_w + P_V\right)\left(\frac{1}{144}\right)K(100)}{\left[\left(\frac{1.24(RSC)}{D_i}\right) + 0.061E'\right]} \qquad (52–32)$$

where:

$\frac{\%\Delta X}{D}$ = percent deflection
D_L = deflection lag factor (1.0 to 1.5)
K = bedding constant (0.1)
P_s = pressure on pipe from soil (lb/ft^2)
P_w = pressure on pipe from wheel load (lb/ft^2)
P_v = internal vacuum pressure (lb/ft^2)
E = modulus of elasticity of pipe material (as shown below)
SDR = D_o dimension ratio
  SDR = D_o/t
  D_o = pipe outside diameter, in
  t = minimum wall thickness, in
SIDR = D_i dimension ratio
  SIDR = D_i/t
  D_i = pipe inside diameter, in
  t = minimum wall thickness, in
PS = pipe stiffness
RSC = ring stiffness constant
D_i = inside pipe diameter, in
E' = modulus of soil reaction, lb/in^2 (see table 52–2)

Material	Modulus of elasticity* (lb/in^2)
PVC	400,000 (short term)
ABS	300,000 (short term)
Polyethylene	110,000 (short term)

* Short-term modulus of elasticity varies with the cell class of each plastic. Specific values may be obtained from the manufacturer.

The modulus of soil reaction, E', is an interactive modulus representing support of the soil in reaction to the lateral pipe deflection under load. Amster Howard of the Bureau of Reclamation (Howard, 1977) developed recommended E' values based on the soil prism load described above. The recommended values are provided in table 52–2.

The allowable deflections for plastic pipe typically are limited to 5 percent for a spillway/outlet conduit in embankment dam practice and 7.5 percent in water or liquid conveyance practice and drains in embankment dam practice.

(3) Wall buckling

Plastic pipe embedded in soil may buckle because of excessive loads and deformations. The total permanent pressure must be less than the allowable buckling pressure. The permanent load should consist of the soil pressure, groundwater pressure, and any internal long-term vacuum pressures. The allowable buckling pressure may be determined from:

$$q_a = \frac{1}{FS}\left(32R_w B'E'\frac{E_{long}I_{pw}}{D_o^{\,3}}\right)^{1/2} \qquad (52–33)$$

(Moser, 2001)

where:

q_a = allowable buckling pressure, lb/in^2
FS = design factor of safety
  = 2.5 for (h/(D_o/12) > 2
  = 3.0 for (h/(D_o/12) < 2
  where:
  h = height of ground surface above top of pipe, ft
  D_o = outside diameter of the pipe, in
R_w = water buoyancy factor
  = 1–0.33(h_w/h), 0<h_w<h
  where:
  h = height of ground surface above top of pipe, ft
  h_w = height of water above top of pipe, ft
B'= empirical coefficient of elastic support

$$= \frac{4\left(h^2 + \left(\frac{D_o}{12}\right)h\right)}{1.5\left(2h + \left(\frac{D_o}{12}\right)\right)^2}$$

E_{long} = long term modulus of elasticity, lb/in^2 (see table below)
The long term modulus of elasticity is recommended if the pipe is subject to the pressure in the normal operations. If the pipe is subject to the pressure for short time periods and infrequently, the use of the short-term modulus of elasticity is acceptable.

E' = modulus of soil reaction, lb/in^2 (table 52–2)

I_{pw} = pipe wall moment of inertia

$= \frac{t^3}{12}, \text{in}^4/\text{in}$ (for solid wall pipe)

where:
t = pipe wall thickness, in

D_o = outside pipe diameter, in

Material	Modulus of elasticity* (lb/in^2)
PVC	140,000 (long term)
ABS	65,000 (long term)
Polyethylene	22,000 (long term)

* Long-term modulus of elasticity varies with the cell class of each plastic. Specific values may be obtained from the manufacturer.

Pipes that are out-of-round or deflected increase in bending moment and have less allowable buckling pressure. The allowable buckling pressure should be reduced by the following factor:

$$C = \left[\frac{\left(1 - \frac{\%\Delta X}{D}\frac{1}{100}\right)}{\left(1 + \frac{\%\Delta X}{D}\frac{1}{100}\right)^2} \right]^3 \quad (52\text{–}34)$$

where:
C = reduction factor for buckling pressure

$\frac{\%\Delta X}{D}$ = percent deflection

Table 52–2 Average values of the modulus of soil reaction for the Modified Iowa Equation

Soil type – pipe bedding material (Unified Soil Classification – ASTM D2487)	E' for degree of compaction of bedding, lb/in^2 1/			
	Dumped	Slight, < 85% proctor, < 40% relative density	Moderate, 85-95% proctor, 40-70% relative density	High, > 95% proctor, > 70% relative density
Fine-grained soil (LL>50) 2/ Soil with medium to high plasticity CH, MH, CH-MH	No data available, use E' = 0 or consult with a geotechnical engineer			
Fine-grained soil (LL<50) soil with medium to no plasticity CL, ML, ML-CL, with less than 25% coarse-grained particles	50	200	400	1,000
Fine-grained soil (LL<50) soil with medium to no plasticity CL, ML, ML-CL, with more than 25% coarse-grained particles. Coarse-grained soil with fines GM, GC, SM, SC contains more than 12% fines	100	400	1,000	2,000
Coarse-grained soil with little or no fines GW, GP, SW, SP contains less than 12% fines	200	1,000	2,000	3,000
Crushed rock	1,000	3,000	3,000	3,000

1/ Source ASCE Journal of Geotechnical Engineering Division, January 1977
2/ LL = liquid limit

Appendix 52C Material Properties, Pressure Ratings, and Pipe Dimensions for Plastic Pipe

*(**Note:** The source of the information in this appendix is subject to periodic updating. The source documents should be referenced for any updated information.)*

Table 52C–1 Hydrostatic design basis, allowable long-term compressive stress, short-term hoop strength, and designation of plastic pipe

Plastic pipe material	Hydrostatic design basis (lb/in²)	Allowable long-term compressive stress (lb/in²)	Short-term hoop strength (lb/in²)	Designation
PVC Type I, Grade 1 (12454-B)	4,000	2,000	6,400	PVC1120
PVC Type I, Grade 2 (12454-C)	4,000	2,000	6,400	PVC1220
PVC Type II, Grade 1 (14333-D)	4,000	2,000	6,400	PVC2120
PVC Type II, Grade 1 (14333-D)	3,200	1,600	5,000	PVC2116
PVC Type II, Grade 1 (14333-D)	2,500	1,250	5,000	PVC2112
PVC Type II, Grade 1 (14333-D)	2,000	1,000	5,000	PVC2110
ABS Type 1, Grade 2	1,600	800	3,300	ABS1208
ABS Type 1, Grade 2	2,000	1,000	5,240	ABS1210
ABS Type 2, Grade 1	2,700	1,350	6,600	ABS2112
ABS Type 1, Grade 3	3,200	1,600	6,000	ABS1316
PE Grade P 14	800	400	1,250	PE1404
PE Grade P 23	1,000	500	2,000	PE2305
PE Grade P 23	1,260	630	2,520	PE2306
PE Grade P 24	1,260	630	2,520	PE2406
PE Grade P 33	1,260	630	2,520	PE3306
PE Grade P 34	1,260	630	2,520	PE3406
PE Grade P 34	1,600	800	3,200	PE3408

Source: ASTM D 1527, D 1785, D 2104, D 2239, D 2241, D 2282, and D 3035.

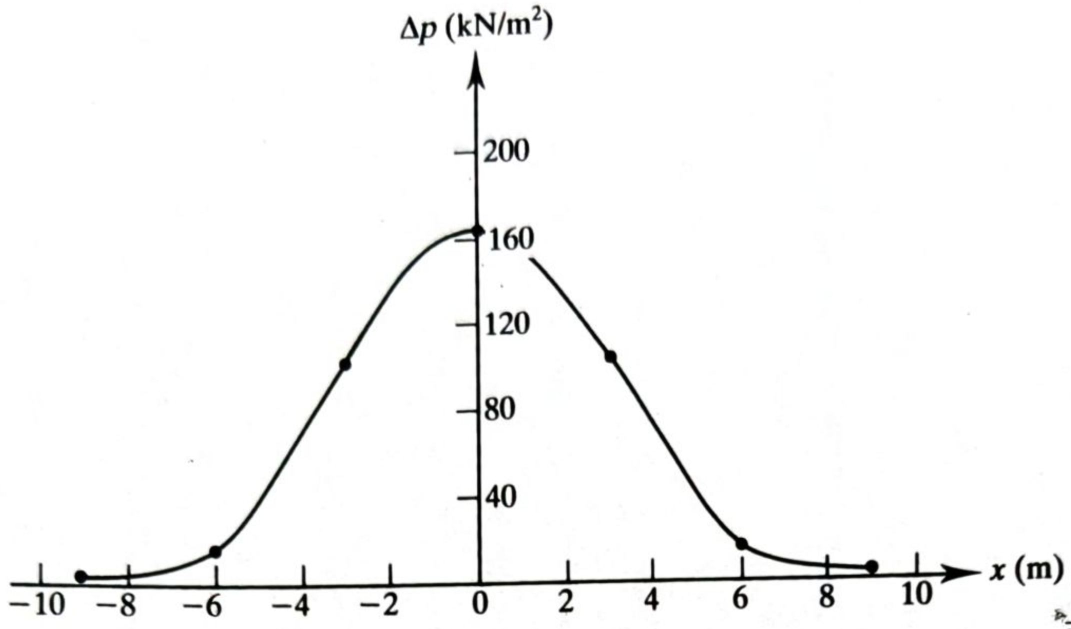


Figure 6.13 Plot of Δp against distance x

6.7 Vertical Stress Below the Center of a Uniformly Loaded Circular Area

Using Boussinesq's solution for vertical stress Δp_z due to a point load [Eq. (6.11)], one can also develop an expression for the vertical stress below the center of a uniformly loaded flexible circular area.

Referring to Figure 6.14, let the intensity of pressure on the circular area of radius R be equal to q. The total load on the elementary area (shaded

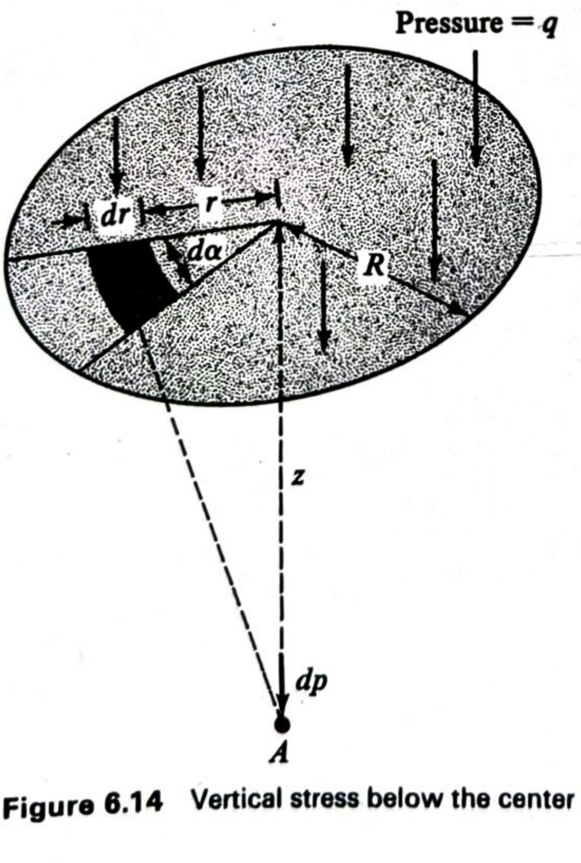


Figure 6.14 Vertical stress below the center of a uniformly loaded flexible circular area

in the figure) $= qr\,dr\,d\alpha$. The vertical stress, dp, at point A due to the load on the elementary area (which may be assumed to be a concentrated load) can be obtained from Eq. (6.11):

$$dp = \frac{3(qr\,dr\,d\alpha)}{2\pi} \frac{z^3}{(r^2 + z^2)^{5/2}} \tag{6.23}$$

The increase of stress at A due to the entire loaded area can be found by integrating Eq. (6.23), or

$$\Delta p = \int dp = \int_{\alpha=0}^{\alpha=2\pi} \int_{r=0}^{r=R} \frac{3q}{2\pi} \frac{z^3 r}{(r^2 + z^2)^{5/2}}\,dr\,d\alpha$$

So

$$\boxed{\Delta p = q\left\{1 - \frac{1}{[(R/z)^2 + 1]^{3/2}}\right\}} \tag{6.24}$$

The variation of $\Delta p/q$ with z/R as obtained from Eq. (6.24) is given in Table 6.3. A plot of this is also shown in Figure 6.15. The value of Δp decreases rapidly with depth; and, at $z = 5R$, it is about 6% of q, which is the intensity of pressure at the ground surface.

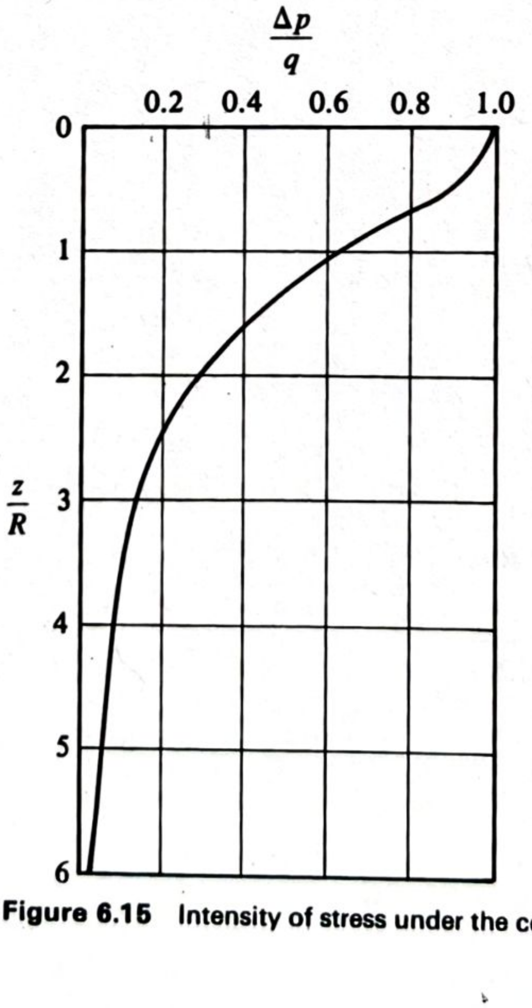


Figure 6.15 Intensity of stress under the center of a uniformly loaded flexible area

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **E-3** **Subject:** **Sideriser Pipe Design**

Prepared By: **CSH** **Date:** **February 2024**

Reviewed By: **BMS** **Date:** **February 2024**

Objective

Determine the required perforation pattern for the horizontal portion of the sideslope riser pipe in the sump of the primary and secondary leachate collection systems. Demonstrate that the sideslope riser pipe is capable of withstanding the applied loading associated with final landfill buildout.

References

1. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 5: Baseliner Grading Plan.* February 2024.
2. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 8: Final Grading Plan.* February 2024.
3. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 16: Leachate Sump Partial Plans.* February 2024.
4. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 17: Leachate Sump Sections and Details.* February 2024.
5. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix D-4. *Floor Settlement Calculation*. February 2024.
6. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix E-1. *Leachate Collection Layer Design*. February 2024.
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9. Paruvakat, N. *Deflection Analysis of Polyethylene Leachate Collection Pipes*. Geosynthetics '93. Vancouver, Canada.
10. Goddard, J. B., N.E. Kampbell, and D.P. Kozman. *Structural Performance of Corrugated PE Pipe Using the Burns and Richard Solution.* Technical Note 2.130 Advanced Drainage Systems, Inc.
11. Literature from Performance Pipe, PP 102 (attached).

12. U.S. Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). *National Engineering Handbook*, Chapter 52 – Structural Design of Flexible Conduits, pp. 52-8, 52-10, 52-11, 52-12, and 52C-1 (attached).

13. U.S. Department of the Interior, Bureau of Reclamation Technical Service Center. *Physical Properties of Plastic Pipe Used in Reclamation Toe Drains*. Report DSO-09-01. September 2009.

Assumptions

1. The horizontal segment of the primary sideslope riser pipe will be a 24-inch-diameter DR 11 high-density polyethylene (HDPE) pipe with a minimum length of 25 feet and have ⅝ inch-diameter holes regularly installed along its length to admit flow from the primary leachate collection system to the interior of the pipe for removal from the cell by pumping.

2. The horizontal segment of the secondary sideslope riser pipe will be an 18-inch-diameter DR 11 high-density polyethylene (HDPE) pipe with a minimum length of 25 feet and have ⅝ inch-diameter holes regularly installed along its length to admit flow from the secondary leachate collection system to the interior of the pipe for removal from the cell by pumping.

3. The hydraulic capacity of the perforations in the sideslope riser pipe must equal or exceed the maximum anticipated inflow to the sump.

4. The maximum anticipated inflow to the sump consists of flowrates from two sources: the leachate collection pipe along the cell centerline and the geocomposite that drains directly into the sump.

5. Leachate inflow potential to the sump from the geocomposite at the fringe of the sump is estimated based on the design transmissivity value of the geocomposite (from Reference 6), the slope of the cell floor perpendicular to the sump fringe (from Reference 1), and the distance around the sump fringe (Reference 3). Although floor settlement is predicted (Reference 5), the design slope is assumed for conservatism because it yields a greater potential inflow to the sump. The distance around the sump of the secondary leachate collection system is greater than that for the primary leachate collection system. Therefore, the dimensions of the sump in the secondary are used to determine the leachate inflow potential from the geocomposite at the sump fringe. There are slight differences in geometry between the sumps of the two UDF cells. The largest perimeter from the two sumps is used for conservatism. The perimeter of the secondary sump (at the top of the slope leading into the sump) for Cell 2 is approximately 39.9 feet long (i.e., parallel to the cell centerline), 31.8 feet wide (i.e., perpendicular to the cell centerline) along the interior side of the cell, and 26.6 feet wide along the toe of the perimeter berm slope.

6. The hydraulic capacity of the perforations in the sideslope riser pipe is determined using the orifice equation, the perforation pattern (i.e., the location, diameter, and spacing of the holes), and assuming 1 foot of head above the lowest edge of the sump rim. Based on the sump geometry depicted in Reference 1, the secondary sump is 1.82 feet deep. Therefore, 1 foot of head above the sump rim equates to 2.82 feet of head above the sump floor. An orifice coefficient of 0.3 is used instead of a more typical value of 0.6 to account for the partial blockage of the perforation open area by the drainage stone surrounding the sideslope riser pipe.

7. The maximum allowable vertical deflection of HDPE pipe is 5.0%.

8. Assumed unit weights of consolidated material and baseliner and final cover system materials is 120 lb/ft^3.

9. The effect of perforations in the structural performance of the pipe is accounted for by reducing the pipe stiffness (Reference 13).

Calculations

1. Maximum Flowrate to the Sump

As discussed in Assumption 3, inflow to the sump occurs via two sources: the leachate collection pipe and the portion of the geocomposite that drains directly into the sump (i.e., at the sump fringe).

The maximum potential flowrate from the leachate collection pipe based on the geocomposite design transmissivity is estimated to be 0.630 cubic feet per second (cfs, Reference 7). The maximum flowrate from the geocomposite at the sump fringe is calculated using the following equation:

$$Q = kiA$$

$$k = \frac{\Phi}{t}$$

$$A = Lt$$

$$\therefore Q = L\Phi i$$

where:

L = length of geocomposite draining directly into the sump based on Assumption 5 (varies depending on which of the four sump edges is analyzed)

Φ = design geocomposite transmissivity from Reference 6

= 36.2 cm^2/s = 0.0390 ft^2/s (for cell floor areas)

= 6.06 cm^2/s = 0.0065 ft^2/s (for cell sideslopes)

i = hydraulic gradient perpendicular to the rim of the sump (varies depending on which of the four sump edges is analyzed)

The slope of the geocomposite along the two sides that are parallel to the cell centerline is 2.0% (Reference 1). The slope of the geocomposite along the sump edge at the toe of the perimeter berm sideslope is 33%. The slope of the geocomposite along the fourth sump edge (across the sump from the 33% perimeter berm sideslope) is 2.0% (Reference 1).

Thus, the maximum flowrate from the geocomposite at the sump fringe is:

$$Q = 0.039\ ft^2/s[(2)(39.9\ ft)(0.020) + (31.8ft)(\ 0.020)] + (0.0065\ ft^2/s)(26.6\ ft)(0.33) = 0.144\ cfs$$

The maximum potential flowrate to the sump is the sum of these two flowrates, which is 0.774 cfs (0.630 + 0.144). Since this value is based on the design transmissivity and flowrate from the contributing geocomposite and leachate collection pipe, respectively, no additional factor of safety is incorporated (i.e., the design transmissivity and pipe flowrate already incorporate factors of safety).

2. Required Perforation Pattern

The horizontal segment of the sideslope riser pipe will be perforated with 5/8-inch-diameter holes spaced at regular intervals. In order to determine the required spacing, the maximum potential flowrate from above (0.774 cfs) is divided by the length of the perforated pipe section (approximately 25 feet) to obtain a required flowrate per foot of pipe:

Maximum Inflow per Foot of Perforated Sideslope Riser Pipe = 0.774 cfs/25 ft = 0.0310 cfs/ft

The flowrate through each perforation is calculated using the orifice equation and the effective head on the perforation:

$$Q = CA\sqrt{2gH_{eff}}$$

where,

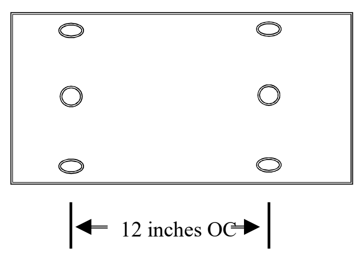
Q = flowrate through each hole in the leachate collection pipe (unknown)

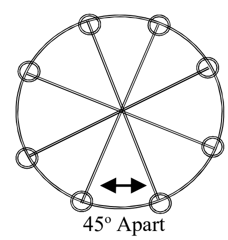
C = orifice coefficient = 0.3 (Assumption 6)

A = cross sectional area of each hole = $\pi D^2/4$ = 0.00213 ft^2

H_{eff} = effective head on each hole (varies according to location)

A satisfactory perforation pattern is one in which the cumulative flowrate through all of the orifices equals or exceeds the maximum potential inflow to the sump of 0.774 cfs (or alternatively, yields at least 0.0310 cfs/ft of pipe). The pattern shown below is proposed for the perforated portion of the sideslope riser pipe:





The hydraulic performance of the above pattern is evaluated using the orifice equation and assuming 3.0 feet of liquid above the floor of the sump (equivalent to 1 foot of liquid above the cell floor adjacent to the secondary sump). The resulting flowrate into the pipe (on a unit length basis) is as follows:

$$Q = 2CA\sum\sqrt{2gH_{eff}}$$

$$Q = 2(0.3)(0.00213\ \text{ft}^2)\sqrt{2(32.2\,)}\left[\sqrt{(2.82\text{-}0.26)} + \sqrt{(2.82\text{-}0.80)} + \sqrt{(2.82\text{-}1.56)} + \sqrt{(2.82\text{-}2.10)}\right]$$

$$= 0.051\ \text{cfs/ft}$$

The multiplier of 2 in the above equation accounts for the symmetry of the perforation pattern with respect to the vertical axis. Note that the effective head on a given perforation is dependent on the leachate elevation above the sump floor (assumed to be 2.82 feet in this case based on Assumption 6) and the elevation of the perforation with respect to the sump floor (varies depending on the perforation).

Because the calculated flowrate through the perforations per foot of pipe (0.051 cfs/ft) exceeds the maximum potential inflow to the sump per foot of pipe (0.0310 cfs/ft), the proposed perforation pattern is acceptable.

3. Pipe Deflection Due to Final Buildout

The sideslope riser pipe is designed to withstand the applied loading associated with final buildout. A comparison of the design elevations for the sump floors (Reference 3) and the final grade above the sumps (Reference 2) indicates that the Cell 2 sump will experience the greatest fill depth with a maximum of 118.5 feet of baseliner, consolidation, and final cover materials. Based on the outside diameter of the primary sideslope riser pipe of 24 inches, this equals 116.5 feet of material above the crown of the pipe, which creates an overburden pressure of 13,980 psf (116.5 ft x 120 lb/ft^3 = 13,980) or 97.1 psi.

Based on laboratory testing of pipe stiffness, drilling holes through solid wall HDPE pipe reduces the pipe stiffness by 15% for every 1% of open area created by the holes (Reference 13). Each 5/8-inch-diameter perforation creates 0.307 in^2 of open area. Eight holes per foot of pipe creates 2.45 in^2 of open area. Each linear foot of pipe has 905 in^2 of pipe wall area. The open area percentage is therefore 0.27% (2.45 in^2/905 in^2 = 0.0027). The pipe stiffness is estimated to reduce by 4% due to the proposed perforation pattern.

The pipe deflection is determined with the Modified Iowa formula (Reference 12). The denominator consists of two components- the pipe stiffness (left hand term) and soil modulus (right hand term). The pipe stiffness includes a 0.96 multiplier to account for the expected 4% reduction due to the pipe perforations:

$$\Delta y = \frac{D\sigma k_b}{(0.96)\frac{2}{3}E\left(\frac{1}{\mathrm{DR}-1}\right)^3 + 0.061\mathrm{E'}}$$

where:

Δy = vertical deflection of pipe

D = average pipe diameter = 21.17 inches

σ = 97.1 psi

k_b = bedding factor = 0.1 (Reference 12)

E = long-term modulus of elasticity for HDPE = 22,000 psi (Reference 12)

DR = diameter ratio of pipe (pipe OD/wall thickness) = DR 7

E’ = soil modulus of pipe bedding = 3,000 psi (Reference 12, compacted crushed rock)

Based on the Modified Iowa Formula, the vertical deflection of the pipe is 0.80 inches, which corresponds to a 3.8% deflection (as compared to the average diameter). Since a deflection of up to 5% is acceptable (Assumption 7), the calculated pipe deflection does not exceed the manufacturer’s recommendations.

Summary

Based on a hydraulic analysis of conditions possible for the cell primary and secondary leachate collection systems, a 24-inch-diameter, DR 7 HDPE pipe with one set of eight 5/8-inch perforations per foot of pipe is adequate for the sideslope riser pipe. Each set of 8 holes are spaced 45^{o} apart around the circumference of the pipe. The pipe deflection analysis indicates that the selected pipe is adequate based on an estimated deflection of less than 5%.

Attachments

1. Reference Excerpts

Attachment 1:

Reference Excerpts

PERFORMANCE PIPE
A Division of Chevron Phillips Chemical Company LP

Revised 04-07-2009

IPS Size and Dimension Data

PE4710 (PE3408)

DriscoPlex® Municipal & Industrial & Energy Series/IPS Pipe Data

Pressure Ratings are calculated using 0.63 design factor for HDS at 73°F as listed in PPI TR-4 for PE 4710 materials.
Temperature, Chemical, and Environmental use considerations may require use of additional design factors.

Pressure Rating		317 psi DR 7.3			250 psi DR 9.0			200 psi DR 11.0			160 psi DR 13.5			
IPS Pipe Size	Nominal OD (in)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	IPS Pipe Size
1 1/4"	1.660	0.227	1.179	0.45	0.184	1.270	0.37	0.151	1.340	0.31	0.123	1.399	0.26	1 1/4"
1 1/2"	1.900	0.260	1.349	0.59	0.211	1.453	0.49	0.173	1.533	0.41	0.141	1.601	0.34	1 1/2"
2"	2.375	0.325	1.686	0.92	0.264	1.815	0.77	0.216	1.917	0.64	0.176	2.002	0.53	2"
3"	3.500	0.479	2.485	1.99	0.389	2.675	1.66	0.318	2.826	1.39	0.259	2.951	1.16	3"
4"	4.500	0.616	3.194	3.29	0.500	3.440	2.75	0.409	3.633	2.31	0.333	3.794	1.92	4"
6"	6.625	0.908	4.700	7.12	0.736	5.065	5.96	0.602	5.349	5.00	0.491	5.584	4.15	6"
8"	8.625	1.182	6.119	12.07	0.958	6.594	10.11	0.784	6.963	8.47	0.639	7.270	7.04	8"
10"	10.750	1.473	7.627	18.75	1.194	8.219	15.70	0.977	8.679	13.16	0.796	9.062	10.93	10"
12"	12.750	1.747	9.046	26.38	1.417	9.746	22.08	1.159	10.293	18.51	0.944	10.749	15.38	12"
14"	14.000	1.918	9.934	31.81	1.556	10.701	26.63	1.273	11.301	22.32	1.037	11.802	18.54	14"
16"	16.000	2.192	11.353	41.55	1.778	12.231	34.78	1.455	12.915	29.15	1.185	13.488	24.22	16"
18"	18.000	2.466	12.772	52.58	2.000	13.760	44.02	1.636	14.532	36.89	1.333	15.174	30.65	18"
20"	20.000	2.740	14.191	64.91	2.222	15.289	54.34	1.818	16.146	45.54	1.481	16.860	37.84	20"
22"	22.000	3.014	15.610	78.55	2.444	16.819	65.75	2.000	17.760	55.10	1.630	18.544	45.79	22"
24"	24.000	3.288	17.029	93.48	2.667	18.346	78.25	2.182	19.374	65.58	1.778	20.231	54.49	24"
26"	26.000				2.889	19.875	91.84	2.364	20.988	76.96	1.926	21.917	63.95	26"
28"	28.000				3.111	21.405	106.51	2.545	22.605	89.26	2.074	23.603	74.17	28"
30"	30.000				3.333	22.934	122.27	2.727	24.219	102.47	2.222	25.289	85.14	30"
32"	32.000							2.909	25.833	116.58	2.370	26.976	96.87	32"
34"	34.000							3.091	27.447	131.61	2.519	28.660	109.36	34"
36"	36.000							3.273	29.061	147.55	2.667	30.346	122.60	36"
42"	42.000										3.111	35.405	166.88	42"
48"	48.000													48"
54"	54.000													54"

Pipe weights are calculated in accordance with PPI TR-7. Average inside diameter is calculated using nomnal OD and Minimum wall plus 6% for use in estimating fluid flows. Actual ID will vary. When designing components to fit the pipe ID, refer to pipe dimension and tolerances in the applicable pipe manufacturing specification.

Visit www.performancepipe.com for the most current literature.

Bulletin: PP 152-4710

April 2009 Supersedes all previous publications

Flow Resistance

DriscoPlex® piping for M & I applications has a hydraulically smooth, non-wetting inside surface. Higher flow capacity and reduced friction loss can result in lower operating costs from reduced pumping costs and reduced maintenance. DriscoPlex® piping does not rust, rot, corrode, or tuberculate. When combined with outstanding abrasion resistance, DriscoPlex® piping provides excellent flow properties throughout its service life. For pressure water and wastewater flows, a Hazen-Williams "C' factor of 150-155 is typically used, and for gravity flows, an "n" factor of 0.009 is typically used with the Manning formula. See the *Performance Pipe Engineering Manual* for additional information.

Joining

DriscoPlex® pipe and fittings are joined using heat fusion, flanges, mechanical connections that are designed for PE pipe, and electrofusion. Heat fusion is a simple procedure that utilizes controlled temperature and pressure to melt and fuse PE pipe materials together. Butt fusion is used to join components end to end; saddle fusion to attach a branch outlet to a main pipe, and socket fusion to join smaller pipes to socket fittings. When properly made, heat fusion joints are reliable, leak-free, fully restrained, and as strong as the pipe itself. Contact Performance Pipe for recommended joining procedures.

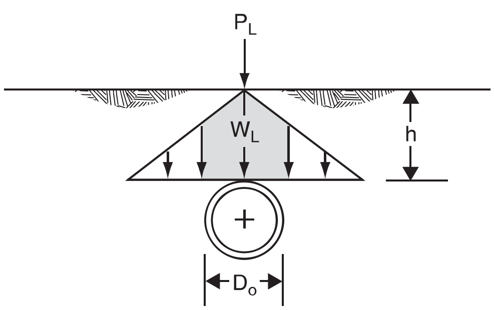
A leakage allowance common to gasketed-bell-and-spigot joined pressure pipes is unnecessary with the DriscoPlex® pressure piping system. With heat fusion, there are no gaskets to leak, joint restraints are not required, and thrust blocks are necessary only under unusual circumstances. Long lengths - 40 feet or more - mean fewer joints.

DriscoPlex® pipe and fittings may also be joined together or transitioned to other materials with flanges, mechanical connections that are designed for PE pipe, or electrofusion. These connections must be made in accordance with the connection manufacturer's instructions. Some connections such as mechanical OD compression couplings may require a stiffener in the pipe bore.

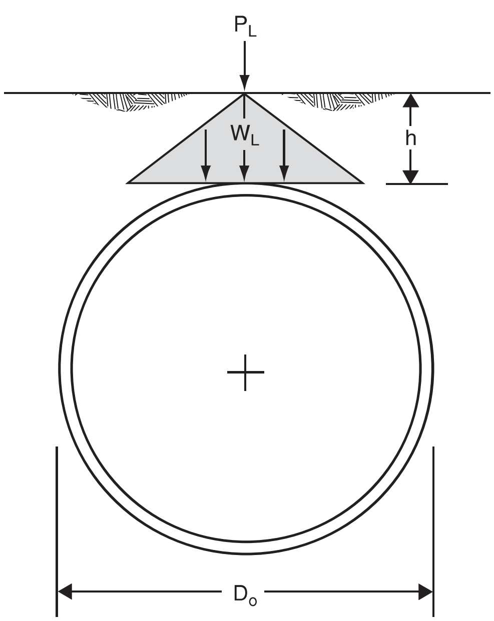
DriscoPlex® piping products cannot be joined with adhesive or solvent cement. Threaded joining, and joining by hot air (hot gas), or extrusion welding techniques are not recommended for pressure service.

Depth of cover	Impact factor
< 1'0"	1.3
1'1" – 2'0"	1.2
2'0" – 2'11"	1.1
≥ 3'0"	1.0

Figure 52–9 Load pressure distribution



(a) D_o-t < 2.67hx12



(b) D_o-t ≥ 2.67hx12

The pressure on the pipe from the wheel load may be determined by:

$$P_W = \frac{W_L}{\left(\frac{D_o}{12}\right)} \quad (52–21)$$

where:
P_w = pressure on pipe from wheel load, lb/ft^2
D_o = outside diameter of pipe, in

When the depth of fill is 2 feet or more, wheel loads may be considered as uniformly distributed over a square with sides equal to 1 3/4 times the depth of fill.

$$P_w = \frac{P_L}{(1.75h)^2} \quad (52–22)$$

(c) Vacuum pressure

Pipe may be subject to an effective external pressure because of an internal vacuum pressure, P_v. Sudden valve closures, shutoff of a pump, or drainage from high points within the system often create a vacuum in pipelines. Siphons will all be subject to negative pressures.

Vacuum pressure should be incorporated into the design of buried and aboveground pipes as described in this chapter. The vacuum pressure may be intermittent (short term), for long durations, or continuously (long term).

The vacuum load per length of pipe may be determined by:

$$W_V = P_V \times \frac{D_i}{12} \quad (52–23)$$

where:
W_v = vacuum load per linear foot of pipe, lb/ft
P_v = internal vacuum pressure, lb/ft^2
D_i = inside pipe diameter, in

(a) Plastic pipe

Plastic pipe materials consist of poly-vinyl chloride (PVC), acrylonitrile-butadiene-styrene (ABS), and polyethylene (PE). Each type of material is supplied in several grades as shown in appendix 52C.

Design of buried plastic pipe includes analyses of the wall crushing, buckling resistance, allowable long-term deflection, and allowable strain.

At a constant load, the plastic modulus of elasticity of the plastic pipe decreases with time. With any increase in load, the plastic reacts with the short-term modulus of elasticity. The ratio of the short-term to long-term modulus of elasticity varies from approximately 3 for PVC to 5 for PE. The short-term modulus of elasticity is recommended for conditions that change through time, such as deflection. The pipe-soil interaction that occurs as discrete events is similar to a new load (Chevron Chemical, 1998). The long-term modulus of elasticity is often recommended for buckling since the loads and reaction of the pipe are considered static.

(1) Wall crushing

The design pressure and ring compression thrust in the pipe wall is determined by:

$$P = P_s + P_w + P_v \qquad (52\text{–}25)$$

where:
P = pressure on pipe, lb/ft^2
P_s = pressure due to weight of soil, lb/ft^2
P_w = pressure on pipe due to wheel load, lb/ft^2
P_v = internal vacuum pressure, lb/ft^2

$$T_{pw} = \frac{P \times \frac{D_o}{12}}{2} \qquad (52\text{–}26)$$

where:
T_{pw} = thrust in pipe wall, lb/ft
D_o = outside pipe diameter, in

The required wall cross-sectional area is determined by:

$$A_{pw} = \frac{\frac{T_{pw}}{12}}{\sigma} \qquad (52\text{–}27)$$

where:
A_{pw} = required wall area, in^2/in
T_{pw} = thrust in pipe wall, lb/ft
σ = allowable long-term compressive stress, lb/in^2 (see appendix 52C, table 52C–1)

The area of a solid-wall pipe wall may be computed as:

$$A_{pw} = \frac{(D_o - D_i)}{2} \text{ or } t \qquad (52\text{–}28)$$

where:
A_{pw} = area of pipe wall, in^2/in
D_o = outside pipe diameter, in
D_i = inside pipe diameter, in
t = pipe wall thickness, in

The average area of pipe wall for corrugated and profile wall pipe should be obtained from the manufacturer.

(2) Deflection

The Modified Iowa Equation may be transposed and rewritten to compute the percent deflection of each type of pipe. The properties of a pipe section are expressed as the standard dimension ratio (SDR) or standard inside dimension ratio (SIDR) for solid wall pipe, pipe stiffness (PS) for corrugated plastic pipe, and the ring stiffness constant (RSC) for profile wall pipe.

Solid-wall plastic pipe as:

$$\frac{\%\Delta X}{D} = \frac{(D_L P_S + P_w + P_V)\left(\frac{1}{144}\right)K(100)}{\left[\left(\frac{2E}{3(SDR-1)^3}\right) + 0.061E'\right]} \qquad (52\text{–}29)$$

or

$$\frac{\%\Delta X}{D} = \frac{(D_L P_S + P_w + P_V)\left(\frac{1}{144}\right)K(100)}{\left[\left(\frac{2E}{3(SIDR+1)^3}\right) + 0.061E'\right]} \qquad (52\text{–}30)$$

Corrugated-plastic pipe as:

$$\frac{\%\Delta X}{D} = \frac{\left(D_L P_S + P_w + P_V\right)\left(\frac{1}{144}\right)K(100)}{\left[0.149PS + 0.061E'\right]} \quad (52–31)$$

Profile-wall pipe:

$$\frac{\%\Delta X}{D} = \frac{\left(D_L P_S + P_w + P_V\right)\left(\frac{1}{144}\right)K(100)}{\left[\left(\frac{1.24(RSC)}{D_i}\right) + 0.061E'\right]} \quad (52–32)$$

where:

$\frac{\%\Delta X}{D}$ = percent deflection
D_L = deflection lag factor (1.0 to 1.5)
K = bedding constant (0.1)
P_s = pressure on pipe from soil (lb/ft^2)
P_w = pressure on pipe from wheel load (lb/ft^2)
P_v = internal vacuum pressure (lb/ft^2)
E = modulus of elasticity of pipe material (as shown below)
SDR = D_o dimension ratio
 SDR = D_o/t
 D_o = pipe outside diameter, in
 t = minimum wall thickness, in
SIDR = D_i dimension ratio
 SIDR = D_i/t
 D_i = pipe inside diameter, in
 t = minimum wall thickness, in
PS = pipe stiffness
RSC = ring stiffness constant
D_i = inside pipe diameter, in
E' = modulus of soil reaction, lb/in^2 (see table 52–2)

Material	Modulus of elasticity* (lb/in^2)
PVC	400,000 (short term)
ABS	300,000 (short term)
Polyethylene	110,000 (short term)

* Short-term modulus of elasticity varies with the cell class of each plastic. Specific values may be obtained from the manufacturer.

The modulus of soil reaction, E', is an interactive modulus representing support of the soil in reaction to the lateral pipe deflection under load. Amster Howard of the Bureau of Reclamation (Howard, 1977) developed recommended E' values based on the soil prism load described above. The recommended values are provided in table 52–2.

The allowable deflections for plastic pipe typically are limited to 5 percent for a spillway/outlet conduit in embankment dam practice and 7.5 percent in water or liquid conveyance practice and drains in embankment dam practice.

(3) Wall buckling

Plastic pipe embedded in soil may buckle because of excessive loads and deformations. The total permanent pressure must be less than the allowable buckling pressure. The permanent load should consist of the soil pressure, groundwater pressure, and any internal long-term vacuum pressures. The allowable buckling pressure may be determined from:

$$q_a = \frac{1}{FS}\left(32R_w B'E' \frac{E_{long} I_{pw}}{D_o^{\,3}}\right)^{1/2} \quad (52–33)$$

(Moser, 2001)

where:

q_a = allowable buckling pressure, lb/in^2
FS = design factor of safety
 = 2.5 for (h/(D_o/12) > 2
 = 3.0 for (h/(D_o/12) < 2
 where:
 h = height of ground surface above top of pipe, ft
 D_o = outside diameter of the pipe, in
R_w = water buoyancy factor
 = 1–0.33(h_w/h), 0<h_w<h
 where:
 h = height of ground surface above top of pipe, ft
 h_w = height of water above top of pipe, ft
B'= empirical coefficient of elastic support

$$= \frac{4\left(h^2 + \left(\frac{D_o}{12}\right)h\right)}{1.5\left(2h + \left(\frac{D_o}{12}\right)\right)^2}$$

E_{long} = long term modulus of elasticity, lb/in^2 (see table below)
The long term modulus of elasticity is recommended if the pipe is subject to the pressure in the normal operations. If the pipe is subject to the pressure for short time periods and infrequently, the use of the short-term modulus of elasticity is acceptable.

E' = modulus of soil reaction, lb/in^2 (table 52–2)

I_{pw} = pipe wall moment of inertia

$= \frac{t^3}{12}, in^4/in$ (for solid wall pipe)

where:
t = pipe wall thickness, in

D_o = outside pipe diameter, in

Material	Modulus of elasticity* (lb/in^2)
PVC	140,000 (long term)
ABS	65,000 (long term)
Polyethylene	22,000 (long term)

* Long-term modulus of elasticity varies with the cell class of each plastic. Specific values may be obtained from the manufacturer.

Pipes that are out-of-round or deflected increase in bending moment and have less allowable buckling pressure. The allowable buckling pressure should be reduced by the following factor:

$$C = \left[\frac{\left(1 - \frac{\%\Delta X}{D} \frac{1}{100}\right)}{\left(1 + \frac{\%\Delta X}{D} \frac{1}{100}\right)^2} \right]^3 \quad (52\text{–}34)$$

where:
C = reduction factor for buckling pressure

$\frac{\%\Delta X}{D}$ = percent deflection

Table 52–2 Average values of the modulus of soil reaction for the Modified Iowa Equation

Soil type – pipe bedding material (Unified Soil Classification – ASTM D2487)	E' for degree of compaction of bedding, lb/in^2 1/ Dumped	Slight, < 85% proctor, < 40% relative density	Moderate, 85-95% proctor, 40-70% relative density	High, > 95% proctor, > 70% relative density
Fine-grained soil (LL>50) 2/ Soil with medium to high plasticity CH, MH, CH-MH	No data available, use E' = 0 or consult with a geotechnical engineer			
Fine-grained soil (LL<50) soil with medium to no plasticity CL, ML, ML-CL, with less than 25% coarse-grained particles	50	200	400	1,000
Fine-grained soil (LL<50) soil with medium to no plasticity CL, ML, ML-CL, with more than 25% coarse-grained particles. Coarse-grained soil with fines GM, GC, SM, SC contains more than 12% fines	100	400	1,000	2,000
Coarse-grained soil with little or no fines GW, GP, SW, SP contains less than 12% fines	200	1,000	2,000	3,000
Crushed rock	1,000	3,000	3,000	3,000

1/ Source ASCE Journal of Geotechnical Engineering Division, January 1977
2/ LL = liquid limit

Appendix 52C Material Properties, Pressure Ratings, and Pipe Dimensions for Plastic Pipe

*(**Note:** The source of the information in this appendix is subject to periodic updating. The source documents should be referenced for any updated information.)*

Table 52C–1 Hydrostatic design basis, allowable long-term compressive stress, short-term hoop strength, and designation of plastic pipe

Plastic pipe material	Hydrostatic design basis (lb/in²)	Allowable long-term compressive stress (lb/in²)	Short-term hoop strength (lb/in²)	Designation
PVC Type I, Grade 1 (12454-B)	4,000	2,000	6,400	PVC1120
PVC Type I, Grade 2 (12454-C)	4,000	2,000	6,400	PVC1220
PVC Type II, Grade 1 (14333-D)	4,000	2,000	6,400	PVC2120
PVC Type II, Grade 1 (14333-D)	3,200	1,600	5,000	PVC2116
PVC Type II, Grade 1 (14333-D)	2,500	1,250	5,000	PVC2112
PVC Type II, Grade 1 (14333-D)	2,000	1,000	5,000	PVC2110
ABS Type 1, Grade 2	1,600	800	3,300	ABS1208
ABS Type 1, Grade 2	2,000	1,000	5,240	ABS1210
ABS Type 2, Grade 1	2,700	1,350	6,600	ABS2112
ABS Type 1, Grade 3	3,200	1,600	6,000	ABS1316
PE Grade P 14	800	400	1,250	PE1404
PE Grade P 23	1,000	500	2,000	PE2305
PE Grade P 23	1,260	630	2,520	PE2306
PE Grade P 24	1,260	630	2,520	PE2406
PE Grade P 33	1,260	630	2,520	PE3306
PE Grade P 34	1,260	630	2,520	PE3406
PE Grade P 34	1,600	800	3,200	PE3408

Source: ASTM D 1527, D 1785, D 2104, D 2239, D 2241, D 2282, and D 3035.

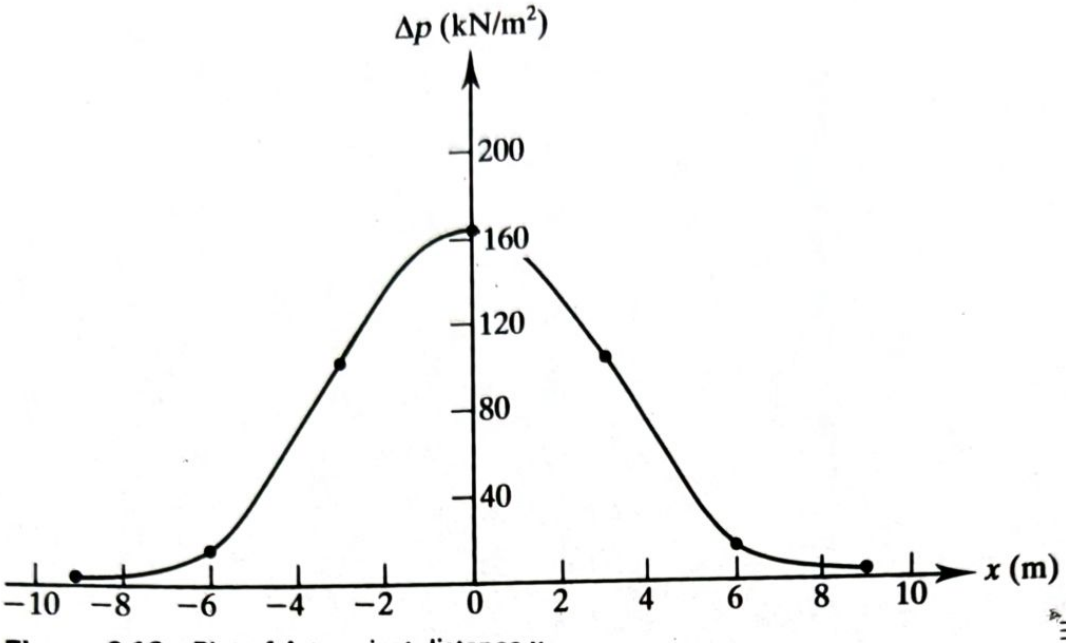


Figure 6.13 Plot of Δp against distance x

6.7 Vertical Stress Below the Center of a Uniformly Loaded Circular Area

Using Boussinesq's solution for vertical stress Δp_z due to a point load [Eq. (6.11)], one can also develop an expression for the vertical stress below the center of a uniformly loaded flexible circular area.

Referring to Figure 6.14, let the intensity of pressure on the circular area of radius R be equal to q. The total load on the elementary area (shaded

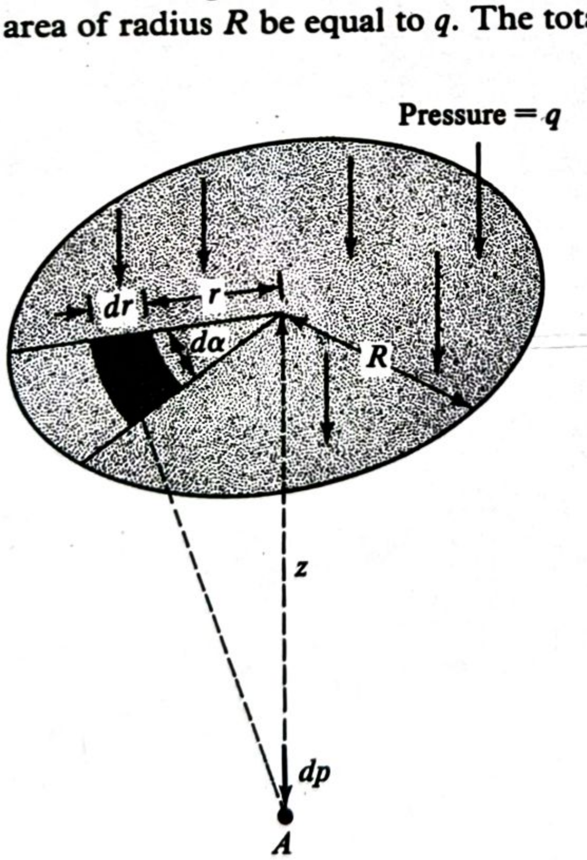


Figure 6.14 Vertical stress below the center of a uniformly loaded flexible circular area

in the figure) $= qr\,dr\,d\alpha$. The vertical stress, dp, at point A due to the load on the elementary area (which may be assumed to be a concentrated load) can be obtained from Eq. (6.11):

$$dp = \frac{3(qr\,dr\,d\alpha)}{2\pi}\frac{z^3}{(r^2 + z^2)^{5/2}} \tag{6.23}$$

The increase of stress at A due to the entire loaded area can be found by integrating Eq. (6.23), or

$$\Delta p = \int dp = \int_{\alpha=0}^{\alpha=2\pi}\int_{r=0}^{r=R} \frac{3q}{2\pi}\frac{z^3 r}{(r^2 + z^2)^{5/2}}\,dr\,d\alpha$$

So

$$\boxed{\Delta p = q\left\{1 - \frac{1}{[(R/z)^2 + 1]^{3/2}}\right\}} \tag{6.24}$$

The variation of $\Delta p/q$ with z/R as obtained from Eq. (6.24) is given in Table 6.3. A plot of this is also shown in Figure 6.15. The value of Δp decreases rapidly with depth; and, at $z = 5R$, it is about 6% of q, which is the intensity of pressure at the ground surface.

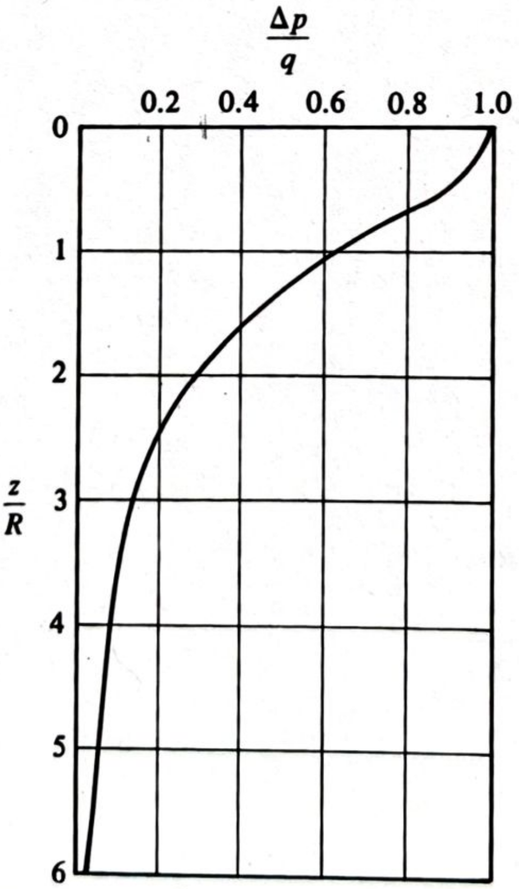


Figure 6.15 Intensity of stress under the center of a uniformly loaded flexible area

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **E-4** **Subject:** **Leachate Transfer System Design**

Prepared By: **MA** **Date:** **February 2024**

Reviewed By: **BMS** **Date:** **February 2024**

Objective

Evaluate hydraulic conditions associated with the UDF primary leachate transfer system during operational scenarios. Determine the minimum performance requirements (flow rate and total head) for the pumps in the leachate collection sumps under anticipated worst-case flowrate scenario. Ensure that the pressures within the system are satisfactory with respect to the pressure rating of the proposed pipe size and wall thickness. Demonstrate that the proposed piping is capable of withstanding applied loading associated with burial and anticipated vehicle traffic.

References

1. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 6: Leachate Collection Plan".* February 2024.
2. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 7: Consolidation Grading Plan".* February 2024.
3. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 18: Leachate Transfer and Storage System Plan"* February 2024.
4. WaterCAD CONNECT, Version 10.3, pressure network analysis software, 2020.
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7. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 16: Leachate Sump Partial Plans".* February 2024.
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14. U.S. Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). *National Engineering Handbook,* Chapter 52 – Structural Desing of Flexible Conduits, pp. 52-8, 52-10, 52-11, 52-12, and 52C. (Attached)
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16. FlexPVC, PVC Distributors, LLC, *Flexible & Rigid PVC Pipe Size Table with Dimensions & Pressure Ratings Chart for Identified and Use Classification. https://flexpvc.com/Reference/PVCPipeSize.shtml* 2002.
17. Goddard, J.B. *The Structural Performance of Polyethylene Pipe. Geotechnical Fabrics Report.* September 1991.
18. Principles of Geotechnical Engineering, 2nd Edition, Das, Braja M., pp 195-196, 1990 (attached).

Assumptions

1. The UDF leachate transfer system consists of submersible pumps within each cell and piping from the pumps to the leachate storage tanks. The cells have both primary and secondary leachate collection systems, each with dedicated sumps. The flow from the pumps (both primary and secondary) within the sumps of each cell can be directed into either or both of two identical and parallel leachate force mains buried in the UDF perimeter berm. For this calculation, it is assumed that the flow from the primary sump in each cell is directed into only one of the two force mains.
2. Piping within the leachate riser vault of each cell includes both primary and secondary systems, which utilize identical pipe sizes and configurations and are depicted in Reference 8. The capacity of the secondary system is therefore identical to the primary system although smaller pumps are typically used for secondary sumps due to lower inflows. Because of the lesser flows and corresponding infrequent operation of the pumps in the secondary systems, this analysis assumes that only the primary pumps in each cell are operating.
3. Sideslope riser pipes provide access to the primary and secondary sumps of each cell for insertion and removal of submersible pumps. Flex hose is used to connect the submersible pumps to rigid piping within the riser vault for each cell. The riser vault piping connects to the leachate force mains within the UDF perimeter berm. Leachate conveyance piping outside of the UDF and the riser vault is dual contained high-density polyethylene (HDPE) with an inner carrier pipe and an outer containment pipe to provide for containment and detection of leaks within the inner carrier pipe.
4. The hydraulic calculations (i.e., flowrates, system heads and pressures, etc.) are based on the interior pipe diameters of the proposed piping and, in the case of dual-contained piping, the interior pipe diameter of the inner carrier pipe. The structural calculations for piping buried in the UDF perimeter berm are based on the diameter and wall thicknesses of the outer containment pipe because only the outer pipe is subject to burial and vehicular loads.

5. The sumps are modeled as constant head reservoirs with a liquid level equal to the lowest sump rim elevation for the primary sump in each cell (Reference 7). The pumps are set at the sump floor elevations (Reference 7).

6. The flow rate into the primary sump of each cell is determined from Reference 6 based on the single highest day of leachate production during the simulation period with minimal waste in place. This results in 115,891 gallons of leachate per day, which is equivalent to approximately 80 gallons per minute (gpm) based on a steady flow over the course of the day. The pumps in the primary sumps of each cell must therefore deliver an in-service flowrate (inclusive of losses and elevation changes in the piping system) of at least 80 gpm.

7. To allow intermittent operation of the pumps and provide additional flow capacity, the in-service flowrate provided by the primary sumps should exceed 80 gpm. A flowrate of 160 gpm provides a factor of safety of 2 and is the minimum in-service flowrate desired. The in-service flowrate from the sump of each cell is determined using WaterCAD, which accounts for energy losses within piping networks as well as elevation changes in the system. The model is run iteratively using different pipe diameters and pump models until the target in-service flowrate of 160 gpm from each cell (both assumed to be running simultaneously) is achieved. Currently available submersible pumps are used in the iterative model runs. It is noted that although specific pump models are assumed to be used, other brands and models may be used assuming they provide at least the minimum in-service flowrate of 160 gpm.

8. The leachate inflows to the sumps are based on conditions associated with conventional transport (i.e., trucks) of consolidation material that can pass a paint filter test. Transport of dredged sediments to the UDF may also be achieved in whole or in part via hydraulic slurry, which is a mixture of solids (typically about 5%) and river water (typically about 95%). In the event dredged sediment is conveyed into the UDF via slurry, the liquid inflow to the UDF will be greater than 80 gpm, and a separate, temporary system will be used to convey the river water component from the slurry to an on-site water treatment plant. Although the leachate transfer system evaluated herein would remain operational during slurry operations but would not be relied upon to manage the additional contribution associated with those operations.

9. As shown in Reference 1, the force main servicing Cell 1 connects to the piping from Cell 2 at a junction manhole. The combined flow from both cells continues to the leachate storage tanks.

10. The primary leachate pumps for both cells are assumed to be running simultaneously.

11. Apart from flex hose connecting the submersible pumps to the riser vault piping, all piping is pressure-rated Iron Pipe Size (IPS) HDPE. Piping beyond (downstream) of the riser vaults will have double containment with leak detection provided at each manhole along the force mains. Piping within the riser vaults will be single contained because the riser vaults provide secondary containment and leak detection. All HDPE pipe has a diameter ratio (DR) of 21 (Reference 9).

12. The long-term strength properties of PE pipe are affected by internal pipe temperature, with higher temperatures reduces allowable pressure in pipes (Reference 11). As shown in Table A.2 in Reference 11, a temperature compensation multiplier must be determined to later be used in calculating the pressure rating of the pipe. Groundwater is assumed to be approximately 50 degrees Fahrenheit. However, since higher temperatures yield a lesser allowable pressure and therefore are more conservative, the pipe environment is assumed to contain leachate at the standard temperature

of 73°F (Reference 11)

13. Assumed unit weights of material is 120 lb/ft^3 (Reference 13).
14. Vehicle traffic is assumed to consist of semi-truck traffic with a maximum single axle load of 40,000 pounds (based on the American Association of State highway and Transportation Official HS-25 loading). The tire inflation pressure is assumed to be 120 psi. Ground contact pressure beneath pneumatic tire is equivalent to tire inflation pressure. A wheel impact factor is applied to each axle. A wheel impact factor of 1.0 is used (Reference 14).
15. The minimum depth of cover for the leachate transfer pipes is 3 feet below grade, per Lee, Massachusetts' municipal code for pipe installation and frost depth (Reference 15). To be conservative, minimum 3.5 feet is provided above the pipe.
16. The maximum allowable ring (vertical) deflection for PE4710 piping is 5.0%. (Reference 14).
17. The maximum allowable long-term compressive stress of HDPE pipe is 800 psi (Reference 9).

Calculations

1. Hydraulic Calculations

WaterCAD (Reference 4) is used to evaluate the transfer of leachate from the cell sumps, through the force main, and to the storage tanks. The losses associated with pipe fittings are based on individual loss coefficients and quantities for the types of fittings proposed, as depicted in References 3 and 8. WaterCAD calculates the energy losses through the fittings based on the fitting inventory and the calculated flow velocities in the system.

Based on iterative simulations with different pipe sizes, the flex hose and HDPE piping within the riser vaults for both Cells 1 and 2 will be 4-inch-diameter (inner diameter is 4.05 inches for rigid piping and 4.03 inches for flex hose, Reference 9 and 16) in diameter. HDPE piping from the Cell 1 riser vault to the force main within the UDF perimeter berm will also utilize 4-inch-diameter piping but will be double-contained (e.g., 4-inch-diameter carrier pipe within a larger, containment pipe). This piping tees into the force main through an HDPE manhole (MH-1). From MH-1, the 4-inch-diameter force main extends downstream to the intersection with piping from the Cell 2 riser vault at MH-4. With the additional flow from Cell 2, the force main size remains 4-inch-diameter and is utilized for the remainder of the force main to the leachate storage tanks. The pump selected for the primary sump of both cells model is the Godwin GSP130HH (Reference 10). The GSP130HH pump is produced by Godwin Pumps and is an electric, submersible pump for industrial applications. The pump runs on 3 phase power at 230/460 voltage. The pump will be automated with a level sensor. The "on" switch of the pump is set to the lowest rim elevation of the sump, while the "off" switch is set to the minimum operating level for the pump model being used. Note that other models/brands of pump can be utilized but must provide adequate flowrates according to the constraints set by this analysis.

A schematic and detailed output from the WaterCAD model is provided in Attachment 1. A summary of the WaterCAD model is presented below.

Table 1- Modeled Flows to Leachate Tanks

Cell	Pump Type	In-Service Flowrate (gpm)	Head at Pump (ft)
1	**GSP130HH**	**198**	**132**
2	**GSP130HH**	**210**	**120**

The total flow at the leachate tanks is 408 gpm.

This scenario represents the worst-case flow scenario for the force main due to assumptions made in Reference 6.

2. Pressure Rating Calculations (Inner Containment Pipe Only)

As stated in Assumption 11, a pipe with DR 21 is used for modeling. Pressure rating calculations are provided below to confirm that the speculative pipe used herein will be capable of withstanding the resultant pressure from the modeled system.

$$PR = \frac{2HDSF_T A_F}{DR - 1} \; (Equation\ 1)$$

Where,

PR = Pressure Rating

HDS = Hydrostatic Design Stress = 1,000 psi (Reference 12)

A_F = Environmental Application Factor = 1.0 (Reference 12, Assumption 12)

F_T = Service Temperature Design Factor = 1.0 (Reference 11, Assumption 12)

DR = 21 (Assumption 11)

So,

PR = 100 psi

The maximum pressure allowable in the system is 100 psi. From the model, the maximum pressure in the system at any given time is less than 100 psi, with the maximum pressure at a node in the system being 57 psi (See Attachment 1). This ensures that the DR 21 pipe is adequate. See Attachment 1 for pressure listings in the system.

3. Structural Calculations for Burial and Vehicular Loads (Outer Containment Pipe Only)

Pipe performance is evaluated to determine if the minimum cover over the pipe allows for truck traffic on the access roads around the UDF. There will be approximately 42 inches of granular cover over the pipe (Reference 15). The 42 inches will first be tested to see if this depth is sufficient to protect the pipe. The resulting load on the pipe is the sum of the load from material plus the at-depth pressure increase from vehicular traffic.

The load from the material is the product of the overlaying thickness of 42 inches (minimal cover condition) and the weight of the material (120 lb/ft^3, Assumption 13). This results in 420 psf (2.92 psi). This 2.92 psi will be used to calculate the total load.

As stated in Assumption 14, the maximum axle load in 40,000 pounds and the wheel impact factor is 1.0.

The wheel impact factor is applied to the static load of 40,000 pounds, resulting in a dynamic load of 40,000 pounds. Using the assumed tire inflation pressure of 120 psi, the ground contact area is calculated as follows:

Axle load = 40,000 lbs

Load at each end of axle = 40,000 lbs/2 = 20,000 lbs

Ground contact area beneath set of tires at each end of axle = 20,000 lbs/120 psi = 166.67 in^2

Radius of assumed circular ground contact area = R = $(166.67^2/\pi)^{1/2}$ = 7.28 in

The at-depth pressure increase (Δp) caused by surface load, q (120 lb/ft^3, Assumption 13), utilizes Boussineq's stress distribution theory. Boussineq's stress distribution theory calculates the at-depth pressure increase on the top of the pipe as follows (Reference 18):

$$\Delta p = q\left(1 - \frac{1}{\left[\left(\frac{R}{z}\right)^2 + 1\right]^{\frac{3}{2}}}\right) (Equation\ 2)$$

Where,

R/z = 7.28 in (Calculated above) / 42 in = 0.17

Δp =5.02 psi

The resulting load of the minimum cover and the at-depth pressure increase is 7.94 psi.

<u>Ring Deflection</u>

Vertical pipe deflection is determined with the Modified Iowa Formula (Reference 14). The denominator contains the pipe stiffness and the soil modulus.

$$\Delta y = \frac{D\sigma k_b}{\frac{2}{3}E(\frac{1}{SDR-1})^3 + 0.061E'}\ (Equation\ 3)$$

Where,

Δy = vertical deflection of pipe = unknown

D = average pipe diameter = 8.19 inches (average of inner and outer diameter) (Reference 9)

σ =Overburden pressures based on loading from cover plus the at-depth pressure increase from vehicular traffic = 7.94 psi (Calculations above)

k_b = bedding factor = 0.1 (Reference 14)

E = long-term modulus of elasticity for HDPE = 22,000 psi (Reference 14)

SDR = Standard diameter ratio of pipe = 21

E' = soil modulus of pipe bedding = 3,000 psi (Reference 14)

Using the Modified Iowa formula, the vertical deflection of the 8-inch pipe is 0.035 inches or 0.44%. The pipe deflection is below the acceptable maximum deflection of 5% (Assumption 16).

<u>Pipe Wall Crushing</u>

In addition to vertical deflection, the potential for pipe wall crushing is evaluated per Reference 14 below:

$$\sigma_{PW} = \frac{(P)(D_o)}{2t} \; (Equation\ 4)$$

Where,

σ_{PW} = pipe wall compressive stress (psi)

P = load applied to pipe = 7.94 psi (calculations above)

D_o = pipe outside diameter = 8.625 inches (Reference 9)

t = pipe wall thickness = 0.411 inches

8-inch Diameter Pipe: σ_{PW} = 83.31 psi < 800 psi

Both the vertical deflection and the pipe wall compressive stress for pipe wall compressive stress are less than the maximum allowable values, thus indicating adequate pipe strength for leachate transfer.

Summary

The individual cell pumping rates are evaluated under the worst-case scenario of a nominal flow rate of 160 gpm. The new pumps to be installed in the Cell 1 and Cell 2 cells must be able to provide an in-service minimum of 160 gpm at each pump. Using pump model GSP130HH, pipe sizes were determined in the WaterCAD model, resulting in a 4-inch diameter leachate force main from Cell 1 to the tanks. A pressure rating analysis of the internal pipes (4-inch diameter) was performed to assess adequacy. A structural analysis of the external 8-inch diameter pipe indicates that the selected pipe is adequate under final buildout based on ring deflection and wall crushing. Ring deflection includes the influence of fill material and vehicle traffic. Pump models capable of meeting or exceeding this minimum condition are acceptable.

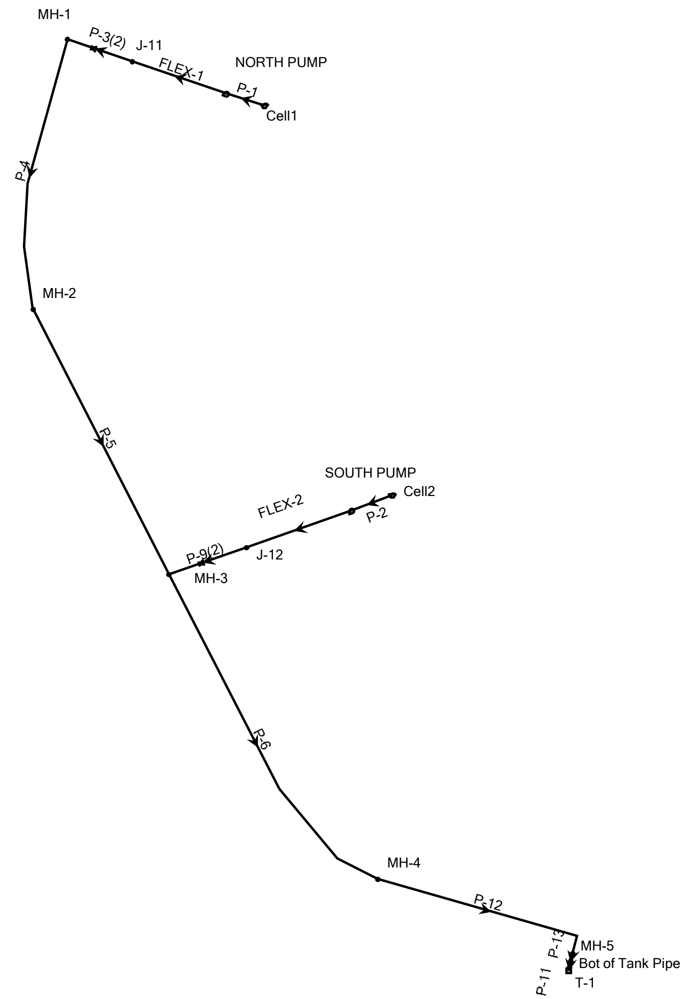
Attachments

1. WaterCAD Report
2. ISP HDPE Spec Sheet
3. Godwin Pump Spec Sheet
4. Reference Excerpts

Attachment 1

WaterCAD Report

Scenario: Base



FlexTable: Pipe Table

ID	Label	Length (Scaled) (ft)	Start Node	Stop Node	Diameter (in)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (gpm)	Velocity (ft/s)	Headloss Gradient (ft/ft)	Status (Initial)	Status (Calculated)
34	P-1	45	Cell1	NORTH PUMP	12.0	PVC	150.0	False	0.000	198	0.56	0.000	Open	Open
35	P-2	49	Cell2	SOUTH PUMP	12.0	PVC	150.0	False	0.000	210	0.60	0.000	Open	Open
43	P-4	308	MH-1	MH-2	4.1	HDPE	155.0	False	0.000	198	4.93	0.018	Open	Open
44	P-5	332	MH-2	MH-3	4.1	HDPE	155.0	False	0.000	198	4.93	0.018	Open	Open
45	P-6	422	MH-3	MH-4	4.1	HDPE	155.0	False	0.000	408	10.16	0.070	Open	Open
56	FLEX-1	111	NORTH PUMP	J-11	4.0	flex hose	120.0	False	0.000	198	5.05	0.031	Open	Open
57	P-3(2)	76	J-11	MH-1	4.1	HDPE	155.0	True	0.390	198	4.81	0.074	Open	Open
59	FLEX-2	124	SOUTH PUMP	J-12	4.0	flex hose	120.0	False	0.000	210	5.36	0.034	Open	Open
60	P-9(2)	91	J-12	MH-3	4.1	HDPE	155.0	True	12.170	210	5.10	0.073	Open	Open
69	P-11	11	Bot of Tank Pipe	T-1	4.1	HDPE	155.0	False	0.370	408	9.91	0.119	Open	Open
79	P-12	251	MH-4	MH-5	4.1	HDPE	155.0	False	0.550	408	9.91	0.068	Open	Open
80	P-13	9	MH-5	Bot of Tank Pipe	4.1	HDPE	155.0	False	0.000	408	9.91	0.065	Open	Open

FlexTable: Junction Table

ID	Label	Elevation (ft)	Hydraulic Grade (ft)	Pressure (psi)
37	MH-1	1,016.20	1,097.17	35
38	MH-2	1,021.42	1,091.55	30
39	MH-3	1,027.30	1,085.55	25
40	MH-4	1,034.96	1,055.96	9
48	Bot of Tank Pipe	1,036.93	1,038.25	1
55	J-11	1,001.44	1,102.84	44
58	J-12	1,005.59	1,092.21	37
76	MH-5	1,036.30	1,038.81	1

FlexTable: Tank Table

ID	Label	Zone	Elevation (Base) (ft)	Elevation (Minimum) (ft)	Elevation (Initial) (ft)	Elevation (Maximum) (ft)	Volume (Inactive) (MG)	Diameter (ft)	Flow (Out net) (gpm)	Hydraulic Grade (ft)
68	T-1	<None>	1,036.93	1,036.93	1,037.00	1,066.93	0.00	10.00	-408	1,037.00

FlexTable: Reservoir Table

ID	Label	Elevation (ft)	Zone	Flow (Out net) (gpm)	Hydraulic Grade (ft)
30	Cell1	974.21	<None>	198	974.21
31	Cell2	976.21	<None>	210	976.21

FlexTable: Pump Table

ID	Label	Elevation (ft)	Pump Definition	Status (Initial)	Hydraulic Grade (Suction) (ft)	Hydraulic Grade (Discharge) (ft)	Flow (Total) (gpm)	Pump Head (ft)
32	NORTH PUMP	974.21	GSP130HH	On	974.21	1,106.25	198	132.04
33	SOUTH PUMP	976.21	GSP130HH	On	976.21	1,096.47	210	120.26

Pump Definition Detailed Report: GSP130HH

Element Details

ID	75	Notes	
Label	GSP130HH		

Pump Definition Type

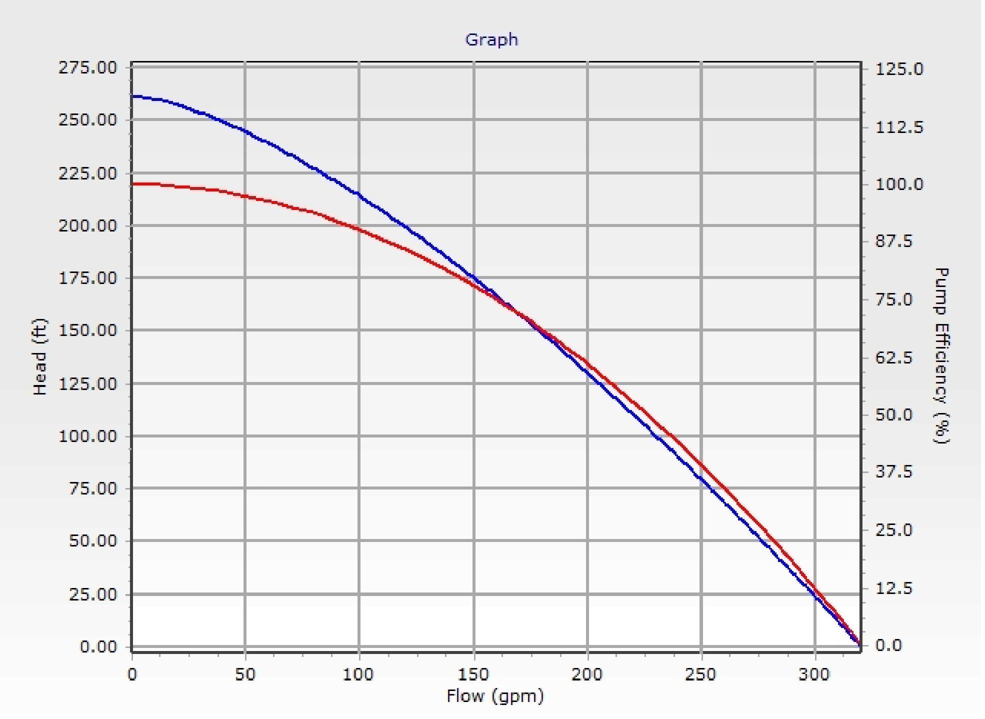
Pump Definition Type	Standard (3 Point)	Design Head	130.00 ft
Shutoff Flow	0 gpm	Maximum Operating Flow	320 gpm
Shutoff Head	262.00 ft	Maximum Operating Head	0.00 ft
Design Flow	200 gpm		

Pump Efficiency Type

Pump Efficiency Type	Best Efficiency Point	Motor Efficiency	100.0 %
BEP Efficiency	100.0 %	Is Variable Speed Drive?	False
BEP Flow	0 gpm		

Transient (Physical)

Inertia (Pump and Motor)	0.000 lb·ft²	Specific Speed	SI=25, US=1280
Speed (Full)	0 rpm	Reverse Spin Allowed?	True



Attachment 2

ISP HDPE Spec. Sheet

JMM HIGH DENSITY POLYETHYLENE (HDPE) PE4710 PRODUCT SPECIFICATION

Description:

JMM manufactures High Density Polyethylene (HDPE) water pressure pipes for municipal and industrial transmission systems. Our pressure pipe is used in many types of applications such as potable water, sewer, drain, mining, irrigation, slip lining, and reclaimed water.

Materials:

JMM HDPE pressure pipe is manufactured with premium, highly engineered PE4710 resin that provides maximum performance benefits to service today's municipal and industrial water needs. The PE4710 material conforms to ASTM D3350 with the cell classification of 445574C/E and is listed with the Plastic Pipe Institute's (PPI) TR4. It is formulated with carbon black and/or ultraviolet stabilizer for maximum protection against UV rays for added assurance.

Size	Type	DR	Standard (If Applicable)
4" – 63"	IPS / DIPS	7 – 41	ASTM F714

Quality Assurance:

JMM takes great pride in the quality and workmanship of all of our products. JMM quality control programs monitor three critical aspects of the manufacturing process: the raw material, pipe production, and the finished goods. Incoming raw material is inspected and tested to ensure the material meets all applicable requirements before its release for production. During production, the pipe will be examined and pipe samples will be collected for physical verification and testing for compliance. The finished product is subjected to further visual inspection to ensure it has met all the appropriate specifications and packaging requirements. Our pipes are continuously monitored throughout the entire manufacturing process to validate that they are in accordance with all applicable specifications. Certificates of Compliance are available upon request.

Lengths & Bending Radius:

Standard laying lengths of HDPE pressure water pipe is 40/50 foot lengths. Pipe sizes under 6" may be coiled at continuous longer lengths upon request.

Marking:

The standard markings printed on JMM pipes generally consist of the JMM logo, nominal size and OD base, material code, dimension ratio, pressure class, current AWWA C906 (if applicable), ASTM F714 (if applicable), and production date (day, month, & year).

Website:

Please visit our website at www.jmm.com for more information.

Note: Information provided here is a general guideline of JMM PE products. JMM reserves the right to modify any information as necessary. For more detailed information, please contact your JMM sales representative. Always follow project specifications and adhere to local rules, codes and regulations

HDPE IRON PIPE SIZE (IPS) PRESSURE PIPE PE4710

		DR 7 (333 psi)			DR 7.3 (318 psi)			DR 9 (250 psi)			DR 9.3 (241 psi)			DR 11 (200 psi)			DR 13.5 (160 psi)		
Pipe Size	Avg OD	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft
1/2	0.840	0.120	0.59	0.12	0.115	0.60	0.11	0.093	0.64	0.10	0.090	0.65	0.09	0.076	0.68	0.08	0.062	0.71	0.07
3/4	1.050	0.150	0.73	0.19	0.144	0.75	0.18	0.117	0.80	0.15	0.113	0.81	0.15	0.095	0.85	0.12	0.078	0.88	0.10
1	1.315	0.188	0.92	0.29	0.180	0.93	0.28	0.146	1.01	0.23	0.141	1.02	0.23	0.120	1.06	0.20	0.097	1.11	0.16
2	2.375	0.339	1.66	0.95	0.325	1.69	0.91	0.264	1.82	0.77	0.255	1.83	0.74	0.216	1.92	0.64	0.176	2.00	0.53
3	3.500	0.500	2.44	2.06	0.479	2.48	1.98	0.389	2.68	1.66	0.376	2.70	1.61	0.318	2.83	1.39	0.259	2.95	1.16
4	4.500	0.643	3.14	3.40	0.616	3.19	3.28	0.500	3.44	2.75	0.484	3.47	2.67	0.409	3.63	2.30	0.333	3.79	1.91
5 3/8	5.375	0.768	3.75	4.85	0.736	3.81	4.68	0.597	4.11	3.92	0.578	4.15	3.81	0.489	4.34	3.29	0.398	4.53	2.73
5	5.563	0.795	3.88	5.20	0.762	3.95	5.02	0.618	4.25	4.20	0.598	4.29	4.08	0.506	4.49	3.52	0.412	4.69	2.92
6	6.625	0.946	4.62	7.36	0.908	4.70	7.12	0.736	5.06	5.96	0.712	5.11	5.79	0.602	5.35	4.99	0.491	5.58	4.15
7	7.125	0.976	5.06	8.23	0.976	5.06	8.23	0.792	5.45	6.89	0.766	5.50	6.70	0.648	5.75	5.78	0.528	6.01	4.80
8	8.625	1.232	6.01	12.48	1.182	6.12	12.06	0.958	6.59	10.09	0.927	6.66	9.81	0.784	6.96	8.46	0.639	7.27	7.03
10	10.750	1.536	7.49	19.40	1.473	7.63	18.74	1.194	8.22	15.68	1.156	8.30	15.24	0.977	8.68	13.14	0.796	9.06	10.92
12	12.750	1.821	8.89	27.28	1.747	9.05	26.36	1.417	9.75	22.07	1.371	9.84	21.44	1.159	10.29	18.49	0.944	10.75	15.36
14	14.000	2.000	9.76	32.90	1.918	9.93	31.78	1.556	10.70	26.61	1.505	10.81	25.85	1.273	11.30	22.30	1.037	11.80	18.52
16	16.000	2.286	11.15	42.97	2.192	11.35	41.51	1.778	12.23	34.75	1.720	12.35	33.76	1.455	12.92	29.12	1.185	13.49	24.19
18	18.000	2.571	12.55	54.37	2.466	12.77	52.53	2.000	13.76	43.97	1.935	13.90	42.73	1.636	14.53	36.84	1.333	15.17	30.61
20	20.000	2.857	13.94	67.13	2.740	14.19	64.85	2.222	15.29	54.28	2.151	15.44	52.77	1.818	16.15	45.49	1.481	16.86	37.79
24	24.000	3.429	16.73	96.68	3.288	17.03	93.39	2.667	18.35	78.18	2.581	18.53	75.98	2.182	19.37	65.52	1.778	20.23	54.44
26	26.000							2.889	19.88	91.75	2.796	20.07	89.17	2.364	20.99	76.89	1.926	21.92	63.89
28	28.000							3.111	21.40	106.40	3.011	21.62	103.42	2.545	22.60	89.15	2.074	23.60	74.09
30	30.000							3.333	22.93	122.13	3.226	23.16	118.72	2.727	24.22	102.35	2.222	25.29	85.04
32	32.000													2.909	25.83	116.46	2.370	26.98	96.76
34	34.000													3.091	27.45	131.48	2.519	28.66	109.26
36	36.000													3.273	29.06	147.41	2.667	30.35	122.49

		DR 15.5 (138 psi)			DR 17 (125 psi)			DR 19 (111 psi)			DR 21 (100 psi)			DR 26 (80 psi)			DR 32.5 (64 psi)		
Pipe Size	Avg OD	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft
1/2	0.840	0.054	0.73	0.07	0.062	0.71	0.07	0.044	0.75	0.05	0.062	0.71	0.07	0.062	0.71	0.07	0.062	0.71	0.07
3/4	1.050	0.068	0.91	0.09	0.062	0.92	0.08	0.055	0.93	0.08	0.062	0.92	0.08	0.062	0.92	0.08	0.062	0.92	0.08
1	1.315	0.085	1.14	0.14	0.077	1.15	0.13	0.069	1.17	0.12	0.063	1.18	0.11	0.062	1.18	0.11	0.062	1.18	0.11
2	2.375	0.153	2.05	0.47	0.140	2.08	0.43	0.125	2.11	0.39	0.113	2.14	0.35	0.091	2.18	0.29	0.073	2.22	0.23
3	3.500	0.226	3.02	1.02	0.206	3.06	0.94	0.184	3.11	0.84	0.167	3.15	0.77	0.135	3.21	0.63	0.108	3.27	0.51
4	4.500	0.290	3.88	1.68	0.265	3.94	1.55	0.237	4.00	1.39	0.214	4.05	1.27	0.173	4.13	1.03	0.138	4.21	0.83
5 3/8	5.375	0.347	4.64	2.40	0.316	4.71	2.21	0.283	4.78	1.99	0.256	4.83	1.81	0.207	4.94	1.48	0.165	5.03	1.19
5	5.563	0.359	4.80	2.58	0.327	4.87	2.36	0.293	4.94	2.13	0.265	5.00	1.94	0.214	5.11	1.58	0.171	5.20	1.27
6	6.625	0.427	5.72	3.65	0.390	5.80	3.35	0.349	5.89	3.02	0.315	5.96	2.74	0.255	6.08	2.24	0.204	6.19	1.81
7	7.125	0.460	6.15	4.23	0.419	6.24	3.88	0.375	6.33	3.49	0.340	6.40	3.18	0.274	6.54	2.59	0.219	6.66	2.09
8	8.625	0.556	7.45	6.19	0.507	7.55	5.68	0.454	7.66	5.12	0.411	7.75	4.66	0.332	7.92	3.80	0.265	8.06	3.06
10	10.750	0.694	9.28	9.62	0.632	9.41	8.82	0.566	9.55	7.95	0.512	9.66	7.24	0.413	9.87	5.90	0.331	10.05	4.77
12	12.750	0.823	11.01	13.53	0.750	11.16	12.41	0.671	11.33	11.18	0.607	11.46	10.17	0.490	11.71	8.30	0.392	11.92	6.69
14	14.000	0.903	12.09	16.31	0.824	12.25	14.97	0.737	12.44	13.49	0.667	12.59	12.28	0.538	12.86	10.00	0.431	13.09	8.08
16	16.000	1.032	13.81	21.30	0.941	14.01	19.55	0.842	14.21	17.61	0.762	14.38	16.03	0.615	14.70	13.07	0.492	14.96	10.54
18	18.000	1.161	15.54	26.95	1.059	15.75	24.75	0.947	15.99	22.29	0.857	16.18	20.28	0.692	16.53	16.54	0.554	16.83	13.36
20	20.000	1.290	17.26	33.28	1.176	17.51	30.53	1.053	17.77	27.52	0.952	17.98	25.03	0.769	18.37	20.43	0.615	18.70	16.47
24	24.000	1.548	20.72	47.92	1.412	21.01	43.99	1.263	21.32	39.63	1.143	21.58	36.06	0.923	22.04	29.42	0.738	22.44	23.72
26	26.000	1.677	22.44	56.24	1.529	22.76	51.61	1.368	23.10	46.51	1.238	23.38	42.31	1.000	23.88	34.53	0.800	24.30	27.86
28	28.000	1.806	24.17	65.22	1.647	24.51	59.87	1.474	24.88	53.94	1.333	25.17	49.07	1.077	25.72	40.05	0.862	26.17	32.33
30	30.000	1.935	25.90	74.87	1.765	26.26	68.74	1.579	26.65	61.92	1.429	26.97	56.36	1.154	27.55	45.98	0.923	28.04	37.09
32	32.000	2.065	27.62	85.23	1.882	28.01	78.18	1.684	28.43	70.45	1.542	28.73	64.11	1.231	29.39	52.31	0.985	29.91	42.22
34	34.000	2.194	29.35	96.21	2.000	29.76	88.27	1.790	30.21	79.54	1.619	30.57	72.36	1.308	31.23	59.06	1.046	31.78	47.63
36	36.000	2.323	31.08	107.86	2.118	31.51	98.98	1.895	31.98	89.17	1.714	32.37	81.12	1.385	33.06	66.22	1.108	33.65	53.42

HDPE IRON PIPE SIZE (IPS) PRESSURE PIPE PE4710

		DR 17 (125 psi)			DR 19 (111 psi)			DR 21 (100 psi)			DR 26 (80 psi)			DR 32.5 (64 psi)			DR 41 (50 psi)		
Pipe Size	Avg OD	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft
36	36.000	2.118	31.510	98.98	1.895	31.983	89.17	1.714	32.366	81.12	1.385	33.064	66.22	1.108	33.651	53.42	0.878	34.139	42.63
42	42.000	2.471	36.761	134.72	2.211	37.314	121.37	2.000	37.760	110.43	1.615	38.576	90.08	1.292	39.261	72.68	1.024	39.830	58.03
48	48.000	2.824	42.013	175.97	2.526	42.644	158.52	2.286	43.154	144.25	1.846	44.086	117.68	1.477	44.869	94.95	1.171	45.517	75.79
54	54.000	3.177	42.265	222.64	2.842	47.975	200.63	2.571	48.549	182.51	2.077	49.597	148.95	1.622	50.477	120.20	1.317	51.208	95.92
63	63.000							3.000	56.640	248.46	2.423	57.863	202.72	1.938	58.891	163.53	1.537	59.742	130.56

HDPE DUCTILE IRON PIPE SIZE (DIPS) PRESSURE PIPE PE4710

		DR 7 (333 psi)			DR 9 (250 psi)			DR 11 (200 psi)			DR 13.5 (160 psi)			DR 17 (125 psi)		
Pipe Size	Avg OD	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft
4	4.800	0.686	3.346	3.87	0.533	3.670	3.13	0.436	3.876	2.62	0.356	4.045	2.18	0.282	4.202	1.76
6	6.900	0.946	4.894	7.99	0.767	5.274	6.46	0.627	5.571	5.41	0.511	5.817	4.50	0.406	6.039	3.64
8	9.050	1.293	6.309	13.75	1.006	6.917	11.12	0.823	7.305	9.32	0.670	7.630	7.74	0.532	7.922	6.25
10	11.100	1.586	7.738	20.68	1.233	8.486	16.72	1.009	8.961	14.01	0.822	9.357	11.64	0.653	9.716	9.41
12	13.200	1.886	9.202	29.24	1.467	10.090	23.65	1.200	10.656	19.82	0.978	11.127	16.47	0.776	11.555	13.30
14	15.300	2.186	10.666	39.29	1.700	11.696	31.77	1.391	12.351	26.63	1.133	12.898	22.12	0.900	13.392	17.88
16	17.400	2.486	12.130	50.81	1.933	13.302	41.09	1.582	14.046	34.44	1.289	14.667	28.61	1.024	15.229	23.13
18	19.500	2.786	13.594	63.82	2.167	14.906	51.61	1.773	15.741	43.25	1.444	16.439	35.92	1.147	17.068	29.04
20	21.600				2.400	16.512	63.32	1.964	17.436	53.07	1.600	18.208	44.09	1.271	18.905	35.64
24	25.800				2.867	19.722	90.34	2.345	20.829	75.69	1.911	21.749	62.90	1.518	22.582	50.84
30	32.000							2.909	25.833	116.46	2.370	26.976	96.76	1.880	28.014	78.18
36	38.300										2.837	32.286	138.62	2.253	33.524	112.02
42	44.500													2.618	38.950	151.24
48	50.800													2.988	44.465	197.05

		DR 19 (111 psi)			DR 21 (100 psi)			DR 26 (80 psi)			DR 32.5 (64 psi)		
Pipe Size	Avg OD	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft	Min Wall	Avg ID	Weight lb/ft
4	4.800	0.253	4.264	1.59	0.229	4.315	1.44	0.185	4.408	1.18	0.148	4.486	0.95
6	6.900	0.363	6.130	3.28	0.329	6.203	2.98	0.265	6.338	2.43	0.212	6.451	1.96
8	9.050	0.476	8.041	5.64	0.431	8.136	5.13	0.348	8.312	4.18	0.278	8.461	3.37
10	11.100	0.584	9.862	8.48	0.529	9.979	7.72	0.427	10.195	6.29	0.342	10.375	5.08
12	13.200	0.695	11.727	11.99	0.629	11.867	10.91	0.508	12.123	8.91	0.406	12.339	7.18
14	15.300	0.805	13.593	16.11	0.729	13.755	14.66	0.588	14.053	11.95	0.471	14.301	9.65
16	17.400	0.916	15.458	20.83	0.829	15.643	18.96	0.669	15.982	15.46	0.536	16.264	12.49
18	19.500	1.026	17.325	26.16	0.929	17.531	23.81	0.750	17.910	19.42	0.600	18.228	15.67
20	21.600	1.137	19.190	32.10	1.029	19.419	29.22	0.831	19.838	23.84	0.665	20.190	19.24
24	25.800	1.358	22.921	45.80	1.229	23.195	41.68	0.992	23.697	33.99	0.794	24.117	27.44
30	32.000	1.684	28.430	70.45	1.524	28.769	64.11	1.231	29.390	52.31	0.985	29.912	42.22
36	38.300	2.016	34.026	100.93	1.824	34.433	91.84	1.473	35.177	74.92	1.179	35.801	60.43
42	44.500	2.342	39.535	136.25	2.119	40.008	123.96	1.712	40.871	101.17	1.370	41.596	81.59
48	50.800	2.674	45.131	177.55	2.419	45.672	161.55	1.954	46.658	131.83	1.563	47.486	106.34

PE 4710 JMM HDPE Typical Primary Properties

Property	Unit	Test Procedure	Typical Value
Material Designation	---	PPI-TR4	PE 4710
Cell Classification	---	ASTM D3350	** 445574C
Density [4]	g/cm^3	ASTM D1505	0.959
Melt Index [4]	g/10 minutes	ASTM D1238	<0.15
Flexural Modulus [5]	psi	ASTM D790	> 120,000
Tensile Strengt [5]	psi	ASTM D638	> 3,600
SCG (PENT) [7]	Hours	ASTM F1473	>100
HDB @ 73.4ºF (23°C)[4] HDB @ 140°F (60°C)	psi psi	ASTM D2837 ASTM D2837	1600 1000
HDS (hydrostatic design stress) @ 73.4ºF HDS @ 140ºF	psi psi	PPI-TR4 PPI-TR4	1000 630
Color; UV Stabilize [C]	---	---	Black with minimum 2% carbon black
Brittleness Temperature	°F	ASTM D746	<-180

** Note: Cell Classification is 445576E for all Blue / Green / Gray Polyethylene Pipes.

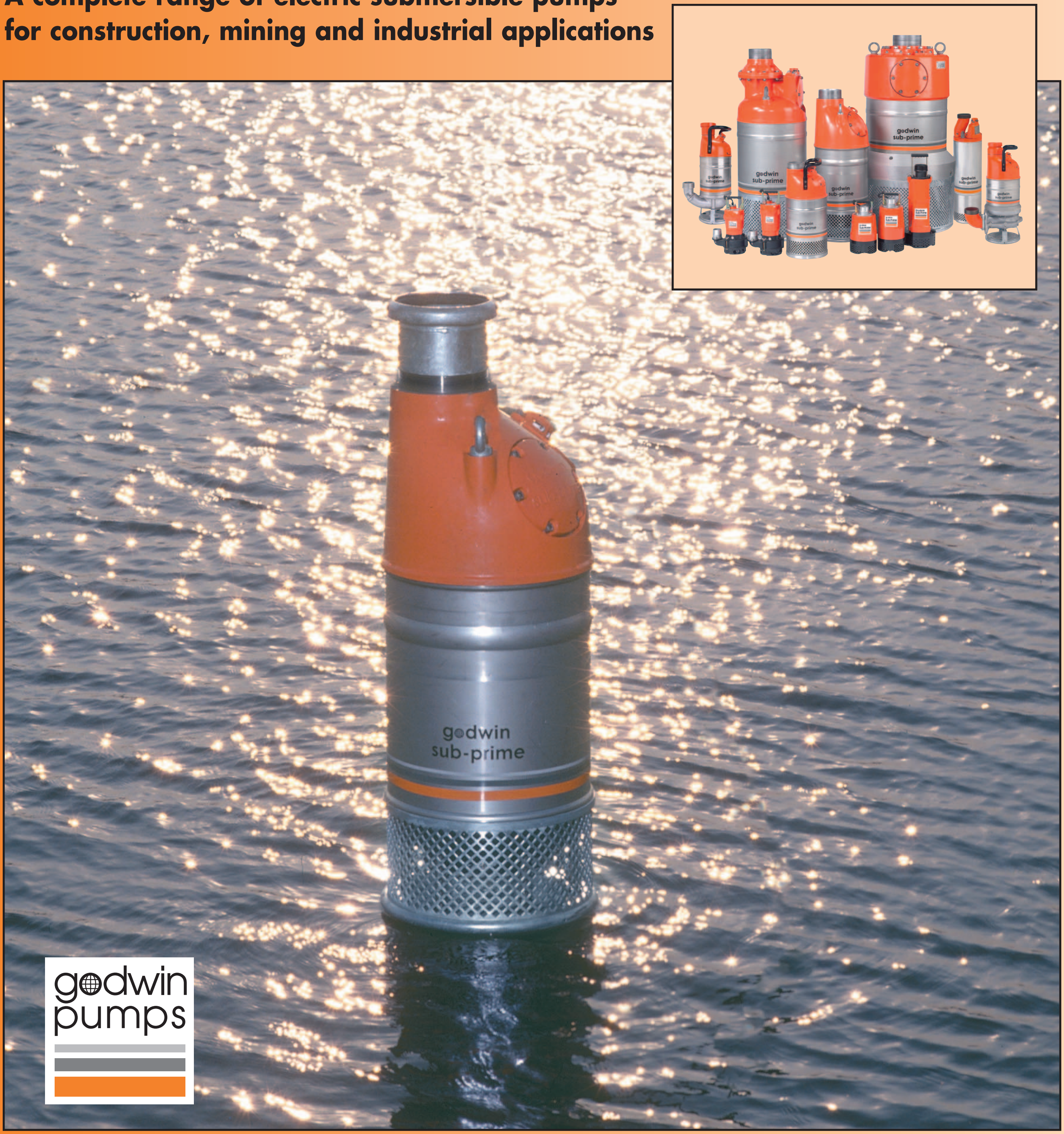
Attachment 3

Godwin Pump Spec Sheet

Godwin

Sub-Prime® Pumps

A complete range of electric submersible pumps for construction, mining and industrial applications



Godwin Sub-Prime® Technical Specifications


GST05


GSP10


GSP35


GSP60SL


GSP300


GSP600

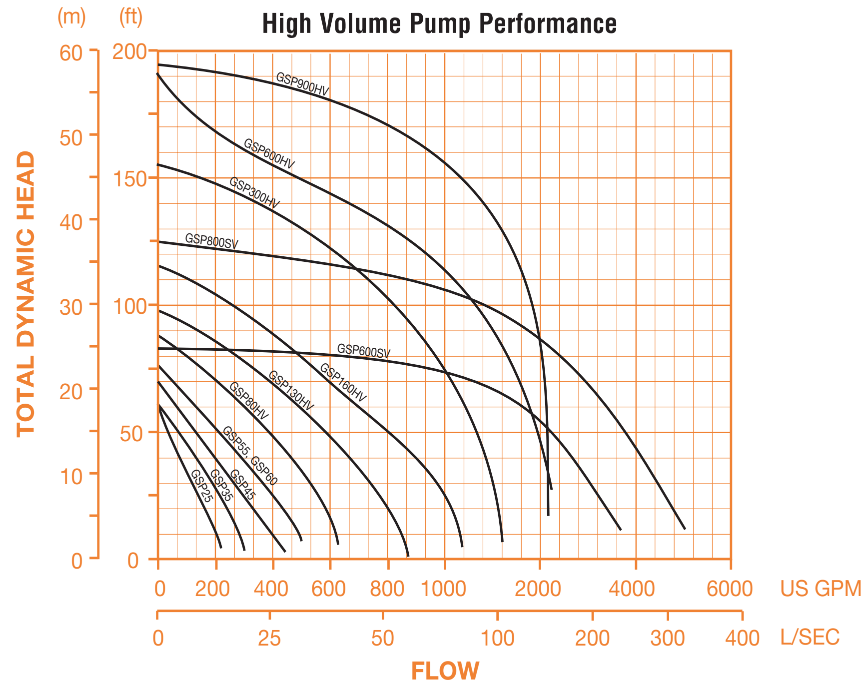
	Rated HP	Speed RPM	Operating Voltage	Rated Current Amps	Discharge Connection	Weight	Maximum Height	Maximum Width	Maximum Solids
GSP Small Dewatering Pumps - Single Phase									
GSP05	0.5 HP	3600	115, 230	5.8, 3.2	2"	20 lbs	12.8"	7.2"	0.33"
GSP10	1.0 HP	3600	115, 230	10.3, 5.11	2"	29 lbs.	14.1"	7.2"	0.33"
GSP20	2.0 HP	3600	115/230	25.9/13.0	3"	61 lbs.	24.5"	9.25"	0.33"
GST Small Trash Pumps - Single Phase									
GST05	0.5 HP	3600	115, 230	5.8, 2.9	2"	22 lbs.	14.7"	9.9"	1"
GST10	1.0 HP	3600	115, 230	10.3, 5.1	2"	29 lbs.	16.4"	9.9"	1"
GSP Large Dewatering Pumps - Single Phase									
GSP25	2.5 HP	3400	230	12.0	3"	57 lbs.	21.5"	9.5"	0.3"
GSP45	4.5 HP	3400	230	20.0	4"	94 lbs.	25.5"	11.0"	0.33"
GSP60	6.0 HP	3400	230	25.0	4"	107 lbs.	25.5"	11.0"	0.33"
GSP Large Dewatering Pumps - Three Phase									
GSP35	3.5 HP	3400	230/460	9.0/4.5	3"	57 lbs.	21.5"	9.5"	0.3"
GSP55	5.5 HP	3400	230/460	14.0/7.0	4"	94 lbs.	25.5"	11.0"	0.33"
GSP80	8.0 HP	3400	230/460	22.0/11.0	4"	107 lbs.	25.5"	11.0"	0.33"
GSP130	13.0 HP	3400	230/460	33.0/16.0	4"	131 lbs.	27.5"	11.0"	0.33"
GSP160	16.0 HP	3500	230/460	41.0/20.0	6"	267 lbs.	34.7"	15.5"	0.5"
GSP300	30.0 HP	3500	230/460	72.0/36.0	6"	355 lbs.	39.5"	16.5"	0.5"
GSP600HV	60.0 HP	3500	460	63.0	8"	628 lbs.	53.5"	20.0"	0.5"
GSP600HH	60.0 HP	3500	460	55.0	6"	628 lbs.	53.5"	20.0"	0.5"
GSP600SV	60.0 HP	1750	460	58.0	8"	628 lbs.	53.5"	20.0"	0.5"
GSP900HV	90.0 HP	1750	460	105.0	8"	1190 lbs.	55.0"	29.5"	0.5"
GSP900HH	90.0 HP	3500	460	105.0	6"	1190 lbs.	55.0"	29.5"	0.5"
GSP900SV	90.0 HP	1750	460	105.0	10"	1190 lbs.	55.0"	29.5"	0.5"
GSP-SL SlimLine Dewatering Pumps									
GSP40SL Single Phase	4.0 HP	3400	230	18.0	3" Std./2" Opt.	68 lbs.	28.19"	7.25"	0.33"
GSP60SL Three Phase	6.0 HP	3400	230/460	16.0/8.0	3" Std./2" Opt.	68 lbs.	28.19"	7.25"	0.33"
GSL Sludge Pumps - Single Phase									
GSL30	3.0 HP	3400	230	16.0	3"	62 lbs.	27.0"	15.0"	2"
GSL60	6.0 HP	3400	230	25.0	3"	129 lbs.	31.0"	18.0"	1.3", 2"
GSL Sludge Pumps - Three Phase									
GSL35	3.5 HP	3400	230/460	9.5/4.8	3"	62 lbs.	27.0"	15.0"	2"
GSL80	8.0 HP	1700/3400	230/460	22.0/11.0	4"*/3"**	129 lbs.	31.0"	19.0"*/18.0"**	1.3", 2", 3.2"

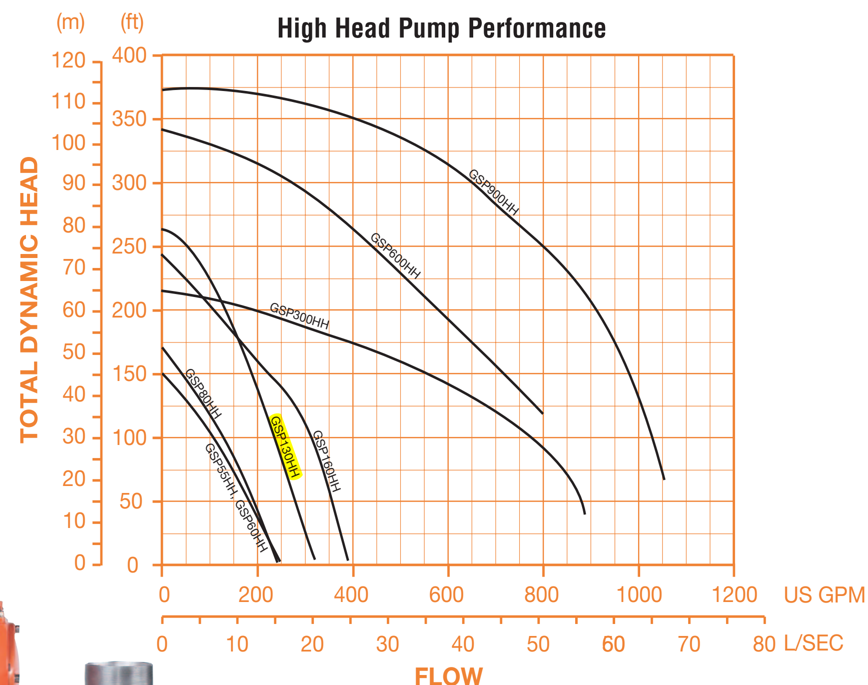
Power cable: 65' standard, except for the following: 30' for GSP05 and GST05; 50' for GSP10, GSP20 and GST10.
* Measurements with standard 4" discharge. **Measurements with optional 3" discharge.

Godwin GSP Sub-Prime® Large Dewatering Pumps

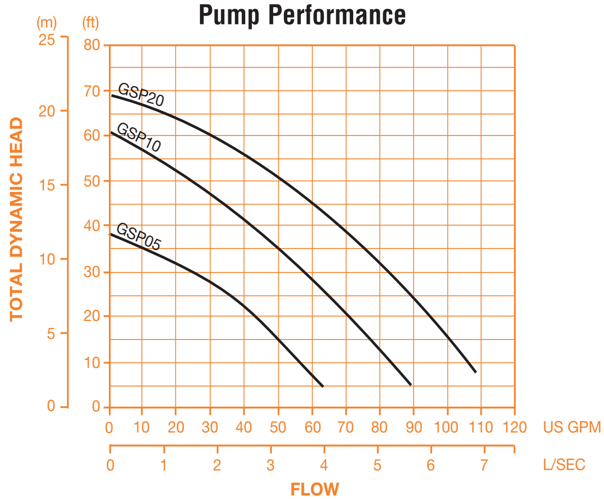
Features and Benefits:

- Compact, slim-line, top discharge design to fit into confined spaces
- Dual voltage junction chamber for convenient voltage changeover in the field
- Dual phase available for electrical supply flexibility (selected models)
- Tandem mechanical seals – silicon carbide on silicon carbide primary seal – for dry running and extra protection against leakage
- Cast chromium steel impeller and heavy duty rubber coated adjustable wear parts for maximum pump life





Godwin GSP Sub-Prime® Small Dewatering Pumps



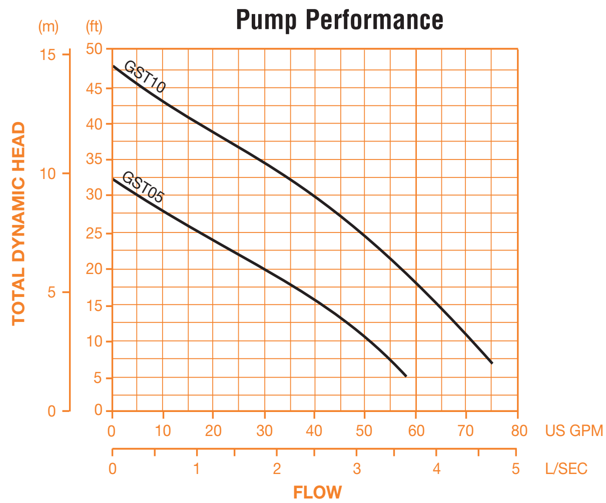
Features and Benefits:

- Compact, slim-line, top discharge design to fit into confined spaces
- Durable silicon carbide upper and lower mechanical seals and external lip seal – protects against leaks and runs dry without damage
- Reliable high-torque, capacitor-start motor with thermal overload protection
- Portable, lightweight and durable
- Non-wicking power cable

Godwin GST Sub-Prime Small Trash Pumps

Features and Benefits:

- Side discharge, semi-vortex impeller and fully removable abrasion-resistant volute – handles solids up to 1" in diameter
- Durable silicon carbide upper and lower mechanical seals and external lip seal – protects against leaks and runs dry without damage
- Reliable high-torque, capacitor-start motor with thermal overload protection
- Portable, lightweight and durable
- Non-wicking power cable

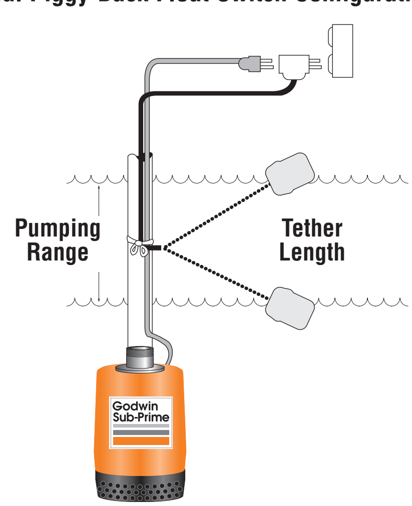


Piggy-Back Float Switches

Features and Benefits:

- Optional Piggy-Back Float Switches available for automatic, remote activation of Sub-Prime pumps
- Package consists of 30'/50' (9M/15M) power cord with piggy-back power plug, variable length float tether, and sealed float (Typical configuration shown)
- Piggy-Back Float Switches available on selected models two horsepower and below
- Optional manual controls or automatic controls available

Typical Piggy-Back Float Switch Configuration

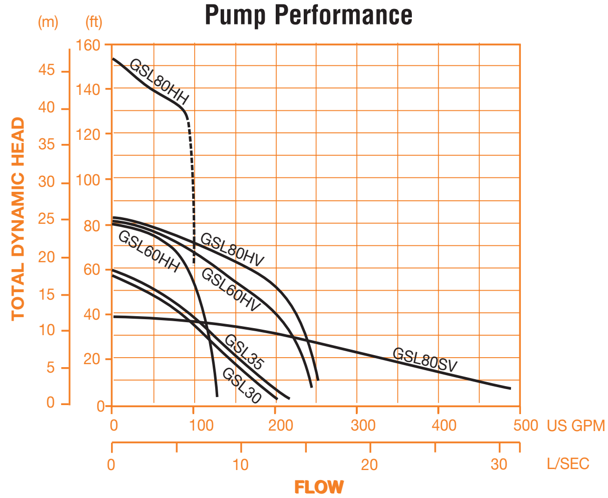


Godwin GSL Sub-Prime Sludge Pumps

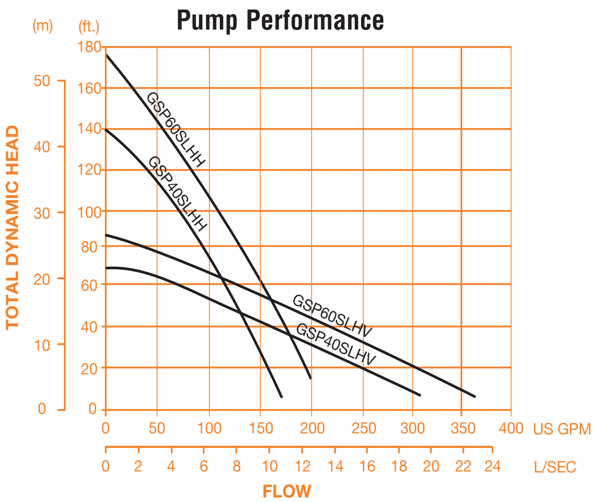
Features and Benefits:

- Side discharge design handles solids up to 3.2" in diameter
- Lightweight cast aluminum construction

- Tandem mechanical seals – silicon carbide on silicon carbide primary seal – for dry running and extra protection against leakage
- Cast chromium steel vortex impeller and heavy-duty polyurethane lined volute for maximum pump life



Godwin GSP SlimLine Sub-Prime Dewatering Pumps



Features and Benefits:

- Convenient top discharge and compact slim-line design for cassion dewatering applications
- Lightweight cast aluminum and corrosion-resistant stainless steel construction
- Tandem mechanical seals – silicon carbide on silicon carbide primary seal – for dry running and extra protection against leakage
- Cast chromium steel impeller and heavy-duty rubber coated adjustable wearparts for maximum pump life

Manual and Automatic Control Panels

Features and Benefits:

- Manual systems provide full electrical, short-circuit and overload protection and starting components
- Automatic systems allow unattended, automatic operation of Sub-Prime electric submersible pumps
- Standard controls are protected in NEMA 3R watertight enclosures; other NEMA enclosures are available

Other Options:

- Zinc anode kits are available for all pump models to help protect against the damaging effects of galvanic corrosion
- Tandem connections allow pumps to be connected in series; available for most models. Consult factory for pressure limitations and other application requirements

Choose Godwin Sub-Prime® Electric Submersible Pumps

... for the Best Service and Parts Availability in the Industry

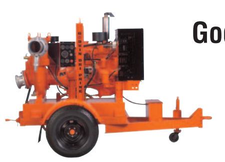
Our Sub-Prime line of electric submersible pumps come with the same commitment to quality and service you've come to expect from Godwin Pumps. There's always a Godwin representative close by and ready to help you. Call us today, we have the right pump for your job.

Service 24 hours-a-day, 7 days-a-week – Godwin Pumps is available to serve you around the clock. Our staff is on call to meet your pumping emergencies no matter when they might occur.

On-Site servicing and repairs – We have experienced, radio-dispatched road mechanics and a fleet of fully-stocked service trucks to service and repair rental and customer-owned equipment on site.

Application specialists – When you choose Godwin Pumps, you have skilled personnel on your side from start to finish. Our application specialists ensure that you rent the right equipment for your job. And we continue to work with you throughout installation and testing, until the pumping system is up and running.

Extraordinary parts, service, testing facility – Our newly expanded parts and service center provides over 30,000 square feet of space dedicated to pump service, testing and parts inventory. Here, our experienced mechanics perform everything from simple repairs to complete pump overhauls, in a timely and cost efficient manner.

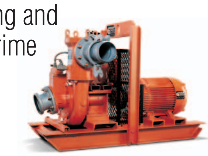


Godwin Dri-Prime® Pumps – The keystone of the Godwin Pumps product line, the Dri-Prime features automatic self-priming to 28 feet of static suction, dry-running capabilities, solids handling and high discharge heads.

Godwin Generators – Diesel-powered portable generators, 20 kW to 350 kW, programmable microprocessor control panel monitors, protects and controls engine and generator operations with remote starting capabilities and automatic warning and shutdown features.

Heidra® Hydraulic Submersible Pumps – Available in sizes from 3" to 12", these diesel driven, hydraulic submersible pumps can meet a variety of flow and head requirements with only simple throttle adjustments.

Electric Drive Dri-Prime Pumps – Long lasting and durable, permanently installed electric drive Dri-Prime pumps provide continuous pumping and reduced costs. For temporary jobs where refueling is difficult, an electric drive Dri-Prime pump is the solution.



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856-467-3636

Gloucestershire, England
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www.godwinpumps.com

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Manchester, NH
603-887-5550

Syracuse, NY
315-536-2317

Buffalo, NY
585-344-3156

New York Metro
201-858-8850

Pittsburgh, PA
724-266-6936

Cleveland, OH
440-357-6868

Wilmington, DE
302-656-9144

Washington, DC
301-390-3806

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708-889-1560

Charleston, WV
304-984-0200

Richmond, VA
804-798-6600

Virginia Beach, VA
757-490-1300

Raleigh, NC
919-661-6061

Charlotte, NC
704-588-4592

N. Charleston, SC
843-818-2266

Atlanta, GA
770-529-7559

Savannah, GA
912-201-9544

Tampa, FL
813-740-0331

Houston, TX
281-864-9200

San Antonio, TX
210-648-9101

Corpus Christi, TX
361-879-0031

Helena, MT
406-495-1335

Seattle, WA
253-395-5450

Los Angeles, CA
951-278-3636

Local Distributor:

Attachment 4

Reference Excerpts

PERFORMANCE PIPE
A Division of Chevron Phillips Chemical Company LP

Revised 04-07-2009

IPS Size and Dimension Data

PE4710 (PE3408)

DriscoPlex® Municipal & Industrial & Energy Series/IPS Pipe Data

Pressure Ratings are calculated using 0.63 design factor for HDS at 73°F as listed in PPI TR-4 for PE 4710 materials.
Temperature, Chemical, and Environmental use considerations may require use of additional design factors.

Pressure Rating		317 psi DR 7.3			250 psi DR 9.0			200 psi DR 11.0			160 psi DR 13.5			
IPS Pipe Size	Nominal OD (in)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	IPS Pipe Size
1 1/4"	1.660	0.227	1.179	0.45	0.184	1.270	0.37	0.151	1.340	0.31	0.123	1.399	0.26	1 1/4"
1 1/2"	1.900	0.260	1.349	0.59	0.211	1.453	0.49	0.173	1.533	0.41	0.141	1.601	0.34	1 1/2"
2"	2.375	0.325	1.686	0.92	0.264	1.815	0.77	0.216	1.917	0.64	0.176	2.002	0.53	2"
3"	3.500	0.479	2.485	1.99	0.389	2.675	1.66	0.318	2.826	1.39	0.259	2.951	1.16	3"
4"	4.500	0.616	3.194	3.29	0.500	3.440	2.75	0.409	3.633	2.31	0.333	3.794	1.92	4"
6"	6.625	0.908	4.700	7.12	0.736	5.065	5.96	0.602	5.349	5.00	0.491	5.584	4.15	6"
8"	8.625	1.182	6.119	12.07	0.958	6.594	10.11	0.784	6.963	8.47	0.639	7.270	7.04	8"
10"	10.750	1.473	7.627	18.75	1.194	8.219	15.70	0.977	8.679	13.16	0.796	9.062	10.93	10"
12"	12.750	1.747	9.046	26.38	1.417	9.746	22.08	1.159	10.293	18.51	0.944	10.749	15.38	12"
14"	14.000	1.918	9.934	31.81	1.556	10.701	26.63	1.273	11.301	22.32	1.037	11.802	18.54	14"
16"	16.000	2.192	11.353	41.55	1.778	12.231	34.78	1.455	12.915	29.15	1.185	13.488	24.22	16"
18"	18.000	2.466	12.772	52.58	2.000	13.760	44.02	1.636	14.532	36.89	1.333	15.174	30.65	18"
20"	20.000	2.740	14.191	64.91	2.222	15.289	54.34	1.818	16.146	45.54	1.481	16.860	37.84	20"
22"	22.000	3.014	15.610	78.55	2.444	16.819	65.75	2.000	17.760	55.10	1.630	18.544	45.79	22"
24"	24.000	3.288	17.029	93.48	2.667	18.346	78.25	2.182	19.374	65.58	1.778	20.231	54.49	24"
26"	26.000				2.889	19.875	91.84	2.364	20.988	76.96	1.926	21.917	63.95	26"
28"	28.000				3.111	21.405	106.51	2.545	22.605	89.26	2.074	23.603	74.17	28"
30"	30.000				3.333	22.934	122.27	2.727	24.219	102.47	2.222	25.289	85.14	30"
32"	32.000							2.909	25.833	116.58	2.370	26.976	96.87	32"
34"	34.000							3.091	27.447	131.61	2.519	28.660	109.36	34"
36"	36.000							3.273	29.061	147.55	2.667	30.346	122.60	36"
42"	42.000										3.111	35.405	166.88	42"
48"	48.000													48"
54"	54.000													54"

Pipe weights are calculated in accordance with PPI TR-7. Average inside diameter is calculated using nomnal OD and Minimum wall plus 6% for use in estimating fluid flows. Actual ID will vary. When designing components to fit the pipe ID, refer to pipe dimension and tolerances in the applicable pipe manufacturing specification.
Visit www.performancepipe.com for the most current literature.

Flow Resistance

DriscoPlex® piping for M & I applications has a hydraulically smooth, non-wetting inside surface. Higher flow capacity and reduced friction loss can result in lower operating costs from reduced pumping costs and reduced maintenance. DriscoPlex® piping does not rust, rot, corrode, or tuberculate. When combined with outstanding abrasion resistance, DriscoPlex® piping provides excellent flow properties throughout its service life. For pressure water and wastewater flows, a Hazen-Williams "C' factor of 150-155 is typically used, and for gravity flows, an "n" factor of 0.009 is typically used with the Manning formula. See the *Performance Pipe Engineering Manual* for additional information.

Joining

DriscoPlex® pipe and fittings are joined using heat fusion, flanges, mechanical connections that are designed for PE pipe, and electrofusion. Heat fusion is a simple procedure that utilizes controlled temperature and pressure to melt and fuse PE pipe materials together. Butt fusion is used to join components end to end; saddle fusion to attach a branch outlet to a main pipe, and socket fusion to join smaller pipes to socket fittings. When properly made, heat fusion joints are reliable, leak-free, fully restrained, and as strong as the pipe itself. Contact Performance Pipe for recommended joining procedures.

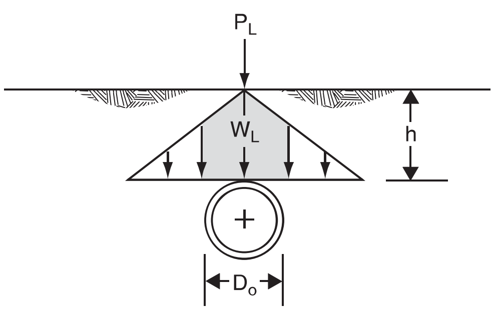
A leakage allowance common to gasketed-bell-and-spigot joined pressure pipes is unnecessary with the DriscoPlex® pressure piping system. With heat fusion, there are no gaskets to leak, joint restraints are not required, and thrust blocks are necessary only under unusual circumstances. Long lengths - 40 feet or more - mean fewer joints.

DriscoPlex® pipe and fittings may also be joined together or transitioned to other materials with flanges, mechanical connections that are designed for PE pipe, or electrofusion. These connections must be made in accordance with the connection manufacturer's instructions. Some connections such as mechanical OD compression couplings may require a stiffener in the pipe bore.

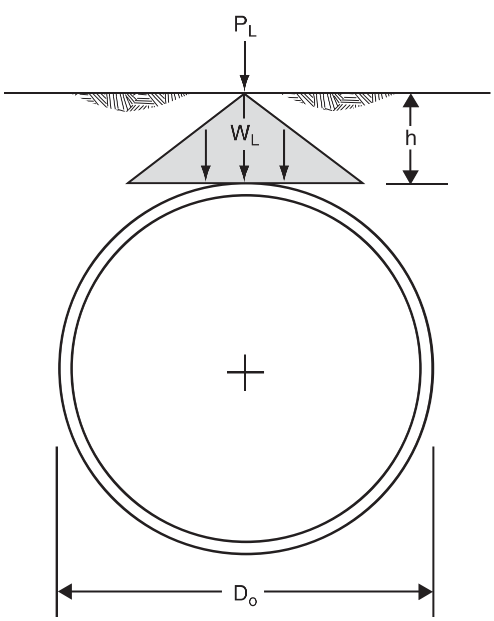
DriscoPlex® piping products cannot be joined with adhesive or solvent cement. Threaded joining, and joining by hot air (hot gas), or extrusion welding techniques are not recommended for pressure service.

Depth of cover	Impact factor
< 1'0"	1.3
1'1" – 2'0"	1.2
2'0" – 2'11"	1.1
≥ 3'0"	1.0

Figure 52–9 Load pressure distribution



(a) D_o-t < 2.67hx12



(b) D_o-t ≥ 2.67hx12

The pressure on the pipe from the wheel load may be determined by:

$$P_W = \frac{W_L}{\left(\frac{D_o}{12}\right)} \qquad (52–21)$$

where:
P_w = pressure on pipe from wheel load, lb/ft^2
D_o = outside diameter of pipe, in

When the depth of fill is 2 feet or more, wheel loads may be considered as uniformly distributed over a square with sides equal to 1 3/4 times the depth of fill.

$$P_w = \frac{P_L}{(1.75h)^2} \qquad (52–22)$$

(c) Vacuum pressure

Pipe may be subject to an effective external pressure because of an internal vacuum pressure, P_v. Sudden valve closures, shutoff of a pump, or drainage from high points within the system often create a vacuum in pipelines. Siphons will all be subject to negative pressures.

Vacuum pressure should be incorporated into the design of buried and aboveground pipes as described in this chapter. The vacuum pressure may be intermittent (short term), for long durations, or continuously (long term).

The vacuum load per length of pipe may be determined by:

$$W_V = P_V \times \frac{D_i}{12} \qquad (52–23)$$

where:
W_v = vacuum load per linear foot of pipe, lb/ft
P_v = internal vacuum pressure, lb/ft^2
D_i = inside pipe diameter, in

(a) Plastic pipe

Plastic pipe materials consist of poly-vinyl chloride (PVC), acrylonitrile-butadiene-styrene (ABS), and polyethylene (PE). Each type of material is supplied in several grades as shown in appendix 52C.

Design of buried plastic pipe includes analyses of the wall crushing, buckling resistance, allowable long-term deflection, and allowable strain.

At a constant load, the plastic modulus of elasticity of the plastic pipe decreases with time. With any increase in load, the plastic reacts with the short-term modulus of elasticity. The ratio of the short-term to long-term modulus of elasticity varies from approximately 3 for PVC to 5 for PE. The short-term modulus of elasticity is recommended for conditions that change through time, such as deflection. The pipe-soil interaction that occurs as discrete events is similar to a new load (Chevron Chemical, 1998). The long-term modulus of elasticity is often recommended for buckling since the loads and reaction of the pipe are considered static.

(1) Wall crushing

The design pressure and ring compression thrust in the pipe wall is determined by:

$$P = P_s + P_w + P_v \qquad (52\text{–}25)$$

where:
- P = pressure on pipe, lb/ft^2
- P_s = pressure due to weight of soil, lb/ft^2
- P_w = pressure on pipe due to wheel load, lb/ft^2
- P_v = internal vacuum pressure, lb/ft^2

$$T_{pw} = \frac{P \times \frac{D_o}{12}}{2} \qquad (52\text{–}26)$$

where:
- T_{pw} = thrust in pipe wall, lb/ft
- D_o = outside pipe diameter, in

The required wall cross-sectional area is determined by:

$$A_{pw} = \frac{\frac{T_{pw}}{12}}{\sigma} \qquad (52\text{–}27)$$

where:
- A_{pw} = required wall area, in^2/in
- T_{pw} = thrust in pipe wall, lb/ft
- σ = allowable long-term compressive stress, lb/in^2 (see appendix 52C, table 52C–1)

The area of a solid-wall pipe wall may be computed as:

$$A_{pw} = \frac{(D_o - D_i)}{2} \text{ or } t \qquad (52\text{–}28)$$

where:
- A_{pw} = area of pipe wall, in^2/in
- D_o = outside pipe diameter, in
- D_i = inside pipe diameter, in
- t = pipe wall thickness, in

The average area of pipe wall for corrugated and profile wall pipe should be obtained from the manufacturer.

(2) Deflection

The Modified Iowa Equation may be transposed and rewritten to compute the percent deflection of each type of pipe. The properties of a pipe section are expressed as the standard dimension ratio (SDR) or standard inside dimension ratio (SIDR) for solid wall pipe, pipe stiffness (PS) for corrugated plastic pipe, and the ring stiffness constant (RSC) for profile wall pipe.

Solid-wall plastic pipe as:

$$\frac{\%\Delta X}{D} = \frac{(D_L P_S + P_w + P_V)\left(\frac{1}{144}\right)K(100)}{\left[\left(\frac{2E}{3(SDR-1)^3}\right) + 0.061E'\right]} \qquad (52\text{–}29)$$

or

$$\frac{\%\Delta X}{D} = \frac{(D_L P_S + P_w + P_V)\left(\frac{1}{144}\right)K(100)}{\left[\left(\frac{2E}{3(SIDR+1)^3}\right) + 0.061E'\right]} \qquad (52\text{–}30)$$

Corrugated-plastic pipe as:

$$\frac{\%\Delta X}{D} = \frac{\left(D_L P_S + P_w + P_V\right)\left(\frac{1}{144}\right)K(100)}{\left[0.149PS + 0.061E'\right]} \quad (52\text{–}31)$$

Profile-wall pipe:

$$\frac{\%\Delta X}{D} = \frac{\left(D_L P_S + P_w + P_V\right)\left(\frac{1}{144}\right)K(100)}{\left[\left(\frac{1.24(RSC)}{D_i}\right) + 0.061E'\right]} \quad (52\text{–}32)$$

where:

$\frac{\%\Delta X}{D}$ = percent deflection
D_L = deflection lag factor (1.0 to 1.5)
K = bedding constant (0.1)
P_s = pressure on pipe from soil (lb/ft^2)
P_w = pressure on pipe from wheel load (lb/ft^2)
P_v = internal vacuum pressure (lb/ft^2)
E = modulus of elasticity of pipe material (as shown below)
SDR = D_o dimension ratio
  SDR = D_o/t
  D_o = pipe outside diameter, in
  t = minimum wall thickness, in
SIDR = D_i dimension ratio
  SIDR = D_i/t
  D_i = pipe inside diameter, in
  t = minimum wall thickness, in
PS = pipe stiffness
RSC = ring stiffness constant
D_i = inside pipe diameter, in
E' = modulus of soil reaction, lb/in^2 (see table 52–2)

Material	Modulus of elasticity* (lb/in^2)
PVC	400,000 (short term)
ABS	300,000 (short term)
Polyethylene	110,000 (short term)

* Short-term modulus of elasticity varies with the cell class of each plastic. Specific values may be obtained from the manufacturer.

The modulus of soil reaction, E', is an interactive modulus representing support of the soil in reaction to the lateral pipe deflection under load. Amster Howard of the Bureau of Reclamation (Howard, 1977) developed recommended E' values based on the soil prism load described above. The recommended values are provided in table 52–2.

The allowable deflections for plastic pipe typically are limited to 5 percent for a spillway/outlet conduit in embankment dam practice and 7.5 percent in water or liquid conveyance practice and drains in embankment dam practice.

(3) Wall buckling

Plastic pipe embedded in soil may buckle because of excessive loads and deformations. The total permanent pressure must be less than the allowable buckling pressure. The permanent load should consist of the soil pressure, groundwater pressure, and any internal long-term vacuum pressures. The allowable buckling pressure may be determined from:

$$q_a = \frac{1}{FS}\left(32R_w B' E' \frac{E_{long} I_{pw}}{D_o^{\,3}}\right)^{1/2} \quad (52\text{–}33)$$

(Moser, 2001)

where:

q_a = allowable buckling pressure, lb/in^2
FS = design factor of safety
 = 2.5 for (h/(D_o/12) > 2
 = 3.0 for (h/(D_o/12) < 2
  where:
  h = height of ground surface above top of pipe, ft
  D_o = outside diameter of the pipe, in
R_w = water buoyancy factor
 = 1–0.33(h_w/h), 0<h_w<h
  where:
  h = height of ground surface above top of pipe, ft
  h_w = height of water above top of pipe, ft
B'= empirical coefficient of elastic support

$$= \frac{4\left(h^2 + \left(\frac{D_o}{12}\right)h\right)}{1.5\left(2h + \left(\frac{D_o}{12}\right)\right)^2}$$

E_{long} = long term modulus of elasticity, lb/in^2 (see table below)
The long term modulus of elasticity is recommended if the pipe is subject to the pressure in the normal operations. If the pipe is subject to the pressure for short time periods and infrequently, the use of the short-term modulus of elasticity is acceptable.

E' = modulus of soil reaction, lb/in^2 (table 52–2)

I_{pw} = pipe wall moment of inertia

$$= \frac{t^3}{12}, \text{in}^4/\text{in} \quad \text{(for solid wall pipe)}$$

where:
t = pipe wall thickness, in

D_o = outside pipe diameter, in

Material	Modulus of elasticity* (lb/in^2)
PVC	140,000 (long term)
ABS	65,000 (long term)
Polyethylene	22,000 (long term)

* Long-term modulus of elasticity varies with the cell class of each plastic. Specific values may be obtained from the manufacturer.

Pipes that are out-of-round or deflected increase in bending moment and have less allowable buckling pressure. The allowable buckling pressure should be reduced by the following factor:

$$C = \left[\frac{\left(1 - \frac{\%\Delta X}{D}\frac{1}{100}\right)}{\left(1 + \frac{\%\Delta X}{D}\frac{1}{100}\right)^2} \right]^3 \qquad (52\text{–}34)$$

where:
C = reduction factor for buckling pressure

$\frac{\%\Delta X}{D}$ = percent deflection

Table 52–2 Average values of the modulus of soil reaction for the Modified Iowa Equation

Soil type – pipe bedding material (Unified Soil Classification – ASTM D2487)	E' for degree of compaction of bedding, lb/in^2 [1/] Dumped	Slight, < 85% proctor, < 40% relative density	Moderate, 85-95% proctor, 40-70% relative density	High, > 95% proctor, > 70% relative density
Fine-grained soil (LL>50) [2/] Soil with medium to high plasticity CH, MH, CH-MH	No data available, use E' = 0 or consult with a geotechnical engineer			
Fine-grained soil (LL<50) soil with medium to no plasticity CL, ML, ML-CL, with less than 25% coarse-grained particles	50	200	400	1,000
Fine-grained soil (LL<50) soil with medium to no plasticity CL, ML, ML-CL, with more than 25% coarse-grained particles. Coarse-grained soil with fines GM, GC, SM, SC contains more than 12% fines	100	400	1,000	2,000
Coarse-grained soil with little or no fines GW, GP, SW, SP contains less than 12% fines	200	1,000	2,000	3,000
Crushed rock	1,000	3,000	3,000	3,000

1/ Source ASCE Journal of Geotechnical Engineering Division, January 1977
2/ LL = liquid limit

Appendix 52C Material Properties, Pressure Ratings, and Pipe Dimensions for Plastic Pipe

*(**Note:** The source of the information in this appendix is subject to periodic updating. The source documents should be referenced for any updated information.)*

Table 52C–1 Hydrostatic design basis, allowable long-term compressive stress, short-term hoop strength, and designation of plastic pipe

Plastic pipe material	Hydrostatic design basis (lb/in²)	Allowable long-term compressive stress (lb/in²)	Short-term hoop strength (lb/in²)	Designation
PVC Type I, Grade 1 (12454-B)	4,000	2,000	6,400	PVC1120
PVC Type I, Grade 2 (12454-C)	4,000	2,000	6,400	PVC1220
PVC Type II, Grade 1 (14333-D)	4,000	2,000	6,400	PVC2120
PVC Type II, Grade 1 (14333-D)	3,200	1,600	5,000	PVC2116
PVC Type II, Grade 1 (14333-D)	2,500	1,250	5,000	PVC2112
PVC Type II, Grade 1 (14333-D)	2,000	1,000	5,000	PVC2110
ABS Type 1, Grade 2	1,600	800	3,300	ABS1208
ABS Type 1, Grade 2	2,000	1,000	5,240	ABS1210
ABS Type 2, Grade 1	2,700	1,350	6,600	ABS2112
ABS Type 1, Grade 3	3,200	1,600	6,000	ABS1316
PE Grade P 14	800	400	1,250	PE1404
PE Grade P 23	1,000	500	2,000	PE2305
PE Grade P 23	1,260	630	2,520	PE2306
PE Grade P 24	1,260	630	2,520	PE2406
PE Grade P 33	1,260	630	2,520	PE3306
PE Grade P 34	1,260	630	2,520	PE3406
PE Grade P 34	1,600	800	3,200	PE3408

Source: ASTM D 1527, D 1785, D 2104, D 2239, D 2241, D 2282, and D 3035.

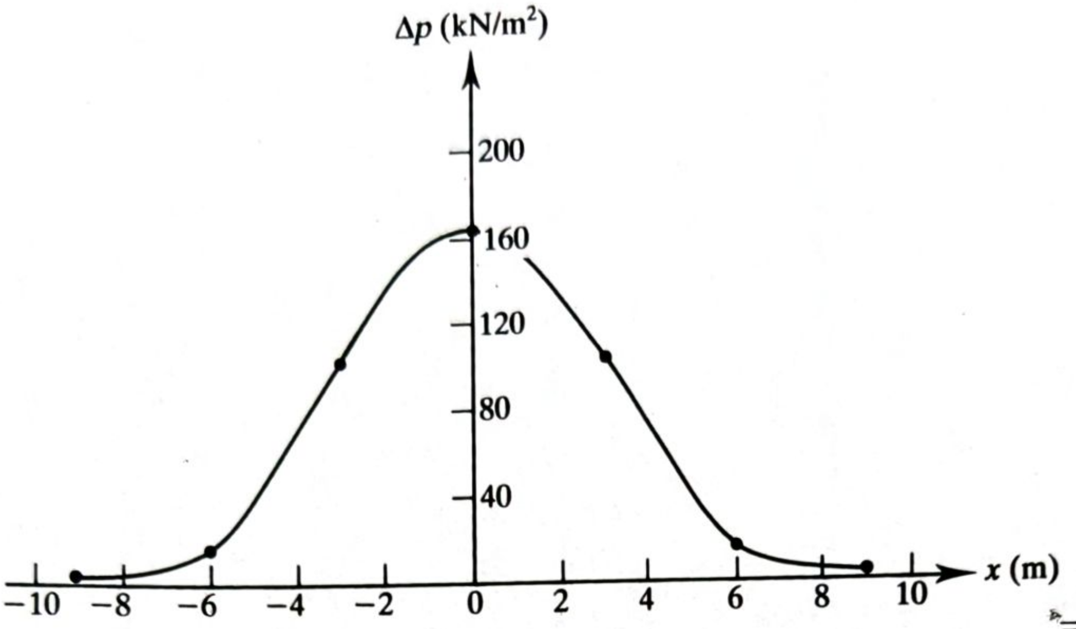


Figure 6.13 Plot of Δp against distance x

6.7 Vertical Stress Below the Center of a Uniformly Loaded Circular Area

Using Boussinesq's solution for vertical stress Δp_z due to a point load [Eq. (6.11)], one can also develop an expression for the vertical stress below the center of a uniformly loaded flexible circular area.

Referring to Figure 6.14, let the intensity of pressure on the circular area of radius R be equal to q. The total load on the elementary area (shaded

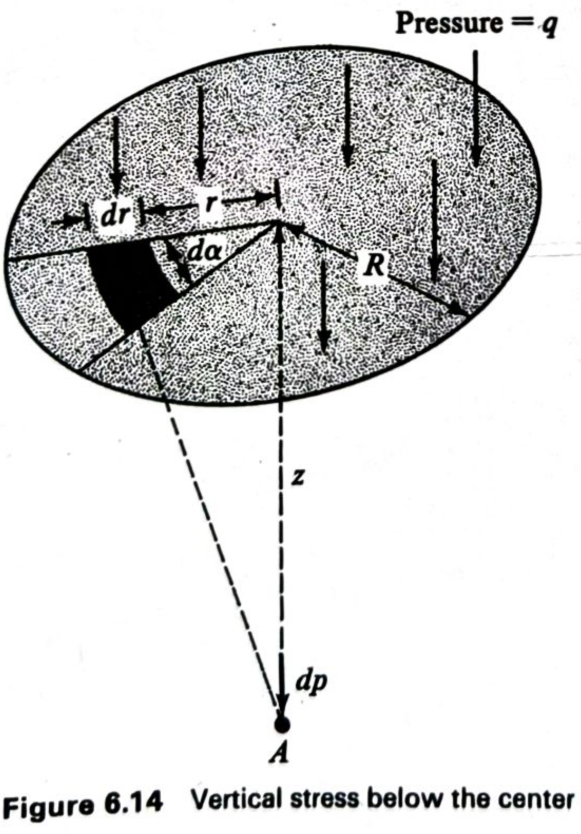


Figure 6.14 Vertical stress below the center of a uniformly loaded flexible circular area

in the figure) $= qr\,dr\,d\alpha$. The vertical stress, dp, at point A due to the load on the elementary area (which may be assumed to be a concentrated load) can be obtained from Eq. (6.11):

$$dp = \frac{3(qr\,dr\,d\alpha)}{2\pi}\frac{z^3}{(r^2+z^2)^{5/2}} \tag{6.23}$$

The increase of stress at A due to the entire loaded area can be found by integrating Eq. (6.23), or

$$\Delta p = \int dp = \int_{\alpha=0}^{\alpha=2\pi}\int_{r=0}^{r=R}\frac{3q}{2\pi}\frac{z^3 r}{(r^2+z^2)^{5/2}}\,dr\,d\alpha$$

So

$$\Delta p = q\left\{1 - \frac{1}{[(R/z)^2+1]^{3/2}}\right\} \tag{6.24}$$

The variation of $\Delta p/q$ with z/R as obtained from Eq. (6.24) is given in Table 6.3. A plot of this is also shown in Figure 6.15. The value of Δp decreases rapidly with depth; and, at $z = 5R$, it is about 6% of q, which is the intensity of pressure at the ground surface.

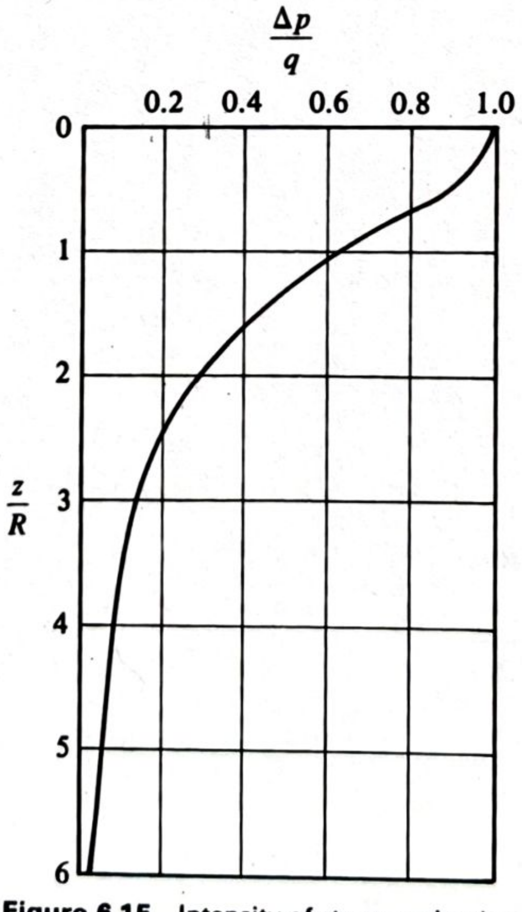


Figure 6.15 Intensity of stress under the center of a uniformly loaded flexible area

ARCADIS

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **E-5** **Subject:** **Leachate Generation Rates and Tank Sizing**

Prepared By: **MA** **Date:** **February 2024**

Reviewed By: **BMS** **Date:** **February 2024**

Objective

Evaluate leachate generation rates based on various stages of UDF operations. Using the worst-case leachate generation scenario, determine minimum holding capacity in the on-site leachate storage system.

References

1. Waterloo Hydrogeologic, Inc. *Visual HELP v3.07* (Windows-based implementation of HELP model v. 3.07).
2. National Oceanic and Atmosphere Administration (NOAA). National Weather Service. *NOAA Atlas 14 Point Precipitation Frequency Estimates: MA.* Pittsfield Municipal Airport. Accessed November 2023.
3. AquaStore Tanks & Domes. *AquaStore Tank Capacity Chart Water Tanks with Concrete Floors.* https://www.cstindustries.com/wp-content/uploads/2020/07/Aquastore-Tank-Capacity-Chart-AWWA-Seismic-0-1-English-Units.pdf. Accessed October 2023.

Assumptions

1. Several simulations are run for leachate generation under various conditions ranging from newly constructed with minimal consolidation material in place through closure with final cover installed.
2. Reference 1 is used to predict leachate generation from the two cells of the UDF. Leachate is defined as the liquid collected from the geocomposite of the primary leachate collection system and is expressed by Reference 1 in terms of inches of drainage. Leachate volumes are calculated outside of Reference 1 as the product of drainage and the planimetric area that drains to the sump of each cell.
3. The thickness of consolidation material affects the rate of leachate generation based on Reference 1 simulations. Modeled consolidation material thicknesses range from initial cell filling with 10 feet of consolidation material in place to advanced filling with 43 feet of material in place, which is based on the average consolidation material thickness under final buildout.
4. Pittsfield Airport (USW00014763) station is used to gather average monthly precipitation data for Lee, Massachusetts (Reference 2).
5. Reference 1 uses precipitation data from Albany, NY, which is the nearest weather station available within the software. To account for the differences in precipitation between Lee, MA and Albany, NY,

the calculated values of leachate generation from Reference 1 are scaled up or down based on annual precipitation ratio between the two weather data sets.

6. The following leachate generation scenarios are evaluated herein:
   - Active conditions with Cell 1 full (43 ft of consolidation material on average) and Cell 2 with minimal (10 ft) consolidation material.
   - Post-closure Year 1.
   - Post-closure Year 2.
   - Post-closure Year 3.
   - Post-closure Year 4.
   - Post-closure Year 5.
7. Leachate will be conveyed via double-contained force main to on-site double-contained leachate storage tanks, which will hold the leachate for off-site disposal via semi tanker truck. The minimum capacity of the leachate storage tanks is calculated herein based on the following criteria:
   - Leachate generation rates predicted using Reference 1 and scaled to account for local rainfall.
   - 1 week holding capacity in the storage tanks to allow for no required off-site trucking and disposal during weekends and/or adverse weather events and to provide storage for other unforeseen circumstances.
8. An equalization pipe connects the tanks at 2.5 feet above the base. This renders the bottom 2.5 feet of the tank as unusable storage volume. It is also assumed that the top 1 foot of the tank is not to be considered as usable storage for conservatism. Therefore, the usable volume provided by Reference 3 will decrease based on the usable height being reduced by 3.5 feet relative to the total tank height.

Calculations

The calculations for each scenario are performed using the HELP Model (Reference 1). Output is reported monthly. Additionally, output is reported on the single worst day of the simulation period. These results are used to find the total volume of leachate produced per day per cell. In-depth results and tables can be found in Attachments 1 and 3.

1. Leachate Volume Adjustment for Lee, MA Rainfall

As mentioned in Assumption 5, the HELP model values are scaled to better reflect the rainfall events in the site area as shown below:

$$Leachate\ Volume\ (Lee, MA) = \frac{Annual\ Precip\ (in)_{Lee,MA}}{Annual\ Precip\ (in)_{Albany,NY}} * Leachate\ Volume_{HELP\ Model,Albany,NY}$$

2. Leachate Volume Prediction – Active Conditions

Attachment 1 includes output for all scenarios run in the HELP model. The table below represents leachate generation with both cells containing consolidation material with no final cover in place. This scenario yields the greatest leachate generation volumes and is therefore used to establish the minimum required tank capacity.

Table 1 – Active Conditions

Month	**Cell 1**		**Cell 2**		**Combined**
	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Total (gal/day)
January	297,899	9,610	258,066	8,325	17,934
February	297,515	10,626	192,397	6,871	17,947
March	244,687	7,893	207,225	6,685	14,578
April	148,015	4,934	785,483	26,183	31,117
May	**418,221**	**13,491**	**575,589**	**18,567**	**32,058**
June	402,122	13,404	294,395	9,813	23,217
July	398,820	12,865	226,129	7,294	20,160
August	348,987	11,258	162,766	5,251	16,508
September	295,493	9,850	126,000	4,200	14,050
October	238,928	7,707	165,435	5,337	13,044
November	221,882	7,396	198,585	6,620	14,016
December	206,730	6,669	238,118	7,681	14,350
Single Worst Day of Simulation		38,595		109,883	148,478

The greatest monthly volume of leachate is predicted in May for this scenario, with a combined daily average of 32,058 gallons from both cells. The peak daily leachate volume predicted is 148,478 gallons, inclusive of both cells. Attachment 1 includes leachate generation calculations for active conditions.

3. Leachate Volume Prediction – Post-Closure Conditions

The HELP model is used to model the UDF under post-closure conditions during the first five years following installation of the final cover system. The following tables summarize the monthly leachate generation for each of the first five years following closure. The leachate volumes generally reduce over time throughout this five year period as the water content in the consolidation material transitions to a steady state condition associated with closure.

Table 2 - Post-Closure, Year 1

Month	**Cell 1**		**Cell 2**		**Combined**
	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Total (gal/day)
January	74,267	2,396	70,417	2,272	4,667
February	122,154	4,363	115,822	4,136	8,499
March	153,428	4,949	145,474	4,693	9,642
April	138,026	4,601	130,871	4,362	8,963
May	133,181	4,296	126,276	4,073	8,370
June	120,795	4,026	114,532	3,818	7,844
July	117,358	3,786	111,274	3,589	7,375
August	110,559	3,566	104,828	3,382	6,948
September	101,165	3,372	95,920	3,197	6,570
October	99,088	3,196	93,951	3,031	6,227
November	91,103	3,037	86,380	2,879	5,916
December	89,545	2,889	84,903	2,739	5,627
Single Worst Day of Simulation		5,142		4,876	10,018

Table 3 - Post-Closure, Year 2

Month	**Cell 1**		**Cell 2**		**Combined**
	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Total (gal/day)
January	79,883	2,577	75,742	2,443	5,020
February	69,062	2,467	65,482	2,339	4,806
March	73,270	2,364	69,472	2,241	4,605
April	67,837	2,261	64,320	2,144	4,405
May	67,328	2,172	63,838	2,059	4,231

Month	Cell 1		Cell 2		Combined
	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Total (gal/day)
June	62,681	2,089	59,431	1,981	4,070
July	62,334	2,011	59,103	1,907	3,917
August	59,999	1,935	56,888	1,835	3,771
September	55,999	1,867	53,096	1,770	3,636
October	55,860	1,802	52,964	1,709	3,510
November	52,184	1,739	49,479	1,649	3,389
December	52,115	1,681	49,413	1,594	3,275
Single Worst Day of Simulation		2,636		2,499	5,135

Table 4 - Post-Closure, Year 3

Month	Cell 1		Cell 2		Combined
	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Total (gal/day)
January	42,677	1,377	40,465	1,305	2,682
February	37,401	1,336	35,462	1,267	2,602
March	40,196	1,297	38,112	1,229	2,526
April	37,734	1,258	35,777	1,193	2,450
May	37,773	1,218	35,814	1,155	2,374
June	35,545	1,185	33,702	1,123	2,308
July	35,740	1,153	33,888	1,093	2,246
August	34,763	1,121	32,961	1,063	2,185
September	32,751	1,092	31,053	1,035	2,127
October	32,966	1,063	31,257	1,008	2,072
November	31,051	1,035	29,441	981	2,016
December	31,265	1,009	29,645	956	1,965
Single Worst Day of Simulation		1,397		1,325	2,722

Table 5 - Post-Closure, Year 4

Month	**Cell 1**		**Cell 2**		**Combined**
	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Total (gal/day)
January	43,095	1,390	40,890	1,318	2,708
February	39,370	1,406	37,329	1,333	2,739
March	41,108	1,326	38,977	1,257	2,583
April	38,873	1,296	36,858	1,229	2,524
May	39,149	1,263	37,120	1,197	2,460
June	37,108	1,237	35,184	1,173	2,410
July	37,494	1,209	35,550	1,147	2,356
August	36,666	1,183	34,765	1,121	2,304
September	34,735	1,158	32,934	1,098	1,098
October	35,176	1,135	33,353	1,076	2,211
November	33,273	1,109	31,548	1,052	2,161
December	33,631	1,085	31,888	1,029	2,114
Single Worst Day of Simulation		1,407		1,334	2,741

Table 6 - Post-Closure, Year 5

Month	**Cell 1**		**Cell 2**		**Combined**
	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Total (gal/day)
January	35,405	1,142	33,570	1,083	2,225
February	31,409	1,122	29,781	1,064	2,185
March	34,132	1,101	32,363	1,044	2,145
April	42,451	1,415	40,250	1,342	2,757
May	592	19	561	18	37
June	0	0	0	0	0
July	0	0	0	0	0
August	0	0	0	0	0
September	0	0	0	0	0
October	0	0	0	0	0

Month	Cell 1		Cell 2		Combined
	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Monthly Leachate Vol (gal)	Ave. Daily Vol. (gal)	Total (gal/day)
November	0	0	0	0	0
December	30	1	28	1	2
Single Worst Day of Simulation		2,140		2,029	4,170

4. Leachate Tank Sizing

The leachate tanks are sized to contain 1-week of leachate generation based on the volumes presented in Table 1. The largest monthly leachate production value from the governing scenario is June, yielding 32,058 gal/day, which is equivalent to a 1-week volume of 224,406 gal.

Two 31-ft-diameter and 33-ft-tall tanks are proposed. Considering the volume reductions identified in Assumption 9, each tank provides the following operating capacity:

$$Tank\ Volume = \pi * \left(\frac{31}{2}\right)^2 * (33 - 2.5 - 1) = 22{,}266\ cubic\ feet = 166{,}550\ gal/tank$$

The usable capacity for both tanks is 333,099 gallons (2 x 166,550 gal/tank). The tanks are connected with an equalization pipe, which is equipped with manual valves to allow each tank to be isolated if necessary for servicing or inspection. These tanks serve as primary containment. Larger secondary containment tanks will be installed around the exterior of the primary containment tanks.

Summary

The HELP model is used to predict leachate volumes during active and post-closure conditions. A number of scenarios are simulated for active conditions, with one yielding the largest leachate volume generation. This scenario is used to size the on-site leachate storage tanks. The proposed leachate storage tanks provide an operating sufficient to hold greater than 1 week of leachate generation associated with the governing leachate condition.

Attachments

1. Leachate Generation Estimates
2. Tank Sizing Reference Chart
3. HELP Model Output

Attachment 1

Leachate Generation Estimates

Cell Areas for Leachate Volumes

Cell 1 (ac)	7.33
Cell 2 (ac)	6.95

Rainfall and Leachate Scaling Factors

	Active Conditions (Ave Annual)	Post-Closure, Year 1	Post-Closure, Year 2	Post-Closure, Year 3	Post-Closure, Year 4	Post-Closure, Year 5
Annual Total (in), Albany, NY (HELP Model)	34.86	36.09	38.59	45.66	32.34	30.14
Annual Total (in), Lee, MA (Pittsfield Airport)	44.83	44.83	44.83	44.83	44.83	44.83
Scaling Factor for Lee, MA	1.29	1.24	1.16	0.98	1.39	1.49

Active Conditions

	Cell 1				Cell 2				Combined
Month	**Leachate (in), HELP Model**	**Leachate (in), Scaled for Lee, MA**	**Leachate Vol (gal), Scaled for Lee, MA**	**Ave. Daily Vol. (gal)**	**Leachate (in), HELP Model**	**Leachate (in), Scaled for Lee, MA**	**Leachate Vol (gal), Scaled for Lee, MA**	**Ave. Daily Vol. (gal)**	**Total (gal/day)**
January	1.164	1.497	297,899	9,610	1.063	1.368	258,066	8,325	17,934
February	1.162	1.495	297,515	10,626	0.793	1.020	192,397	6,871	17,497
March	0.956	1.229	244,687	7,893	0.854	1.098	207,225	6,685	14,578
April	0.578	0.744	148,015	4,934	3.237	4.162	785,483	26,183	31,117
May	1.634	2.101	418,221	13,491	2.372	3.050	575,589	18,567	32,058
June	1.571	2.020	402,122	13,404	1.213	1.560	294,395	9,813	23,217
July	1.558	2.004	398,820	12,865	0.932	1.198	226,129	7,294	20,160
August	1.364	1.753	348,987	11,258	0.671	0.863	162,766	5,251	16,508
September	1.155	1.485	295,493	9,850	0.519	0.668	126,000	4,200	14,050
October	0.934	1.200	238,928	7,707	0.682	0.877	165,435	5,337	13,044
November	0.867	1.115	221,882	7,396	0.818	1.052	198,585	6,620	14,016
December	0.808	1.039	206,730	6,669	0.981	1.262	238,118	7,681	14,350
Annual Totals	*13.750*	*17.683*	*3,519,300*		*14.135*	*18.177*	*3,430,188*		
Single Worst Day of Simulation	0.151	0.194	38,595		0.453	0.582	109,883		148,478

Post Closure, Year 1

	Cell 1				Cell 2				Combined
Month	**Leachate (in), HELP Model**	**Leachate (in), Scaled for Lee, MA**	**Leachate Vol (gal), Scaled for Lee, MA**	**Ave. Daily Vol. (gal)**	**Leachate (in), HELP Model**	**Leachate (in), Scaled for Lee, MA**	**Leachate Vol (gal), Scaled for Lee, MA**	**Ave. Daily Vol. (gal)**	**Total (gal/day)**
January	0.300	0.373	74,267	2,396	0.300	0.373	70,417	2,272	4,667
February	0.494	0.614	122,154	4,363	0.494	0.614	115,822	4,136	8,499
March	0.621	0.771	153,428	4,949	0.621	0.771	145,474	4,693	9,642
April	0.558	0.694	138,026	4,601	0.558	0.694	130,871	4,362	8,963
May	0.539	0.669	133,181	4,296	0.539	0.669	126,276	4,073	8,370
June	0.489	0.607	120,795	4,026	0.489	0.607	114,532	3,818	7,844
July	0.475	0.590	117,358	3,786	0.475	0.590	111,274	3,589	7,375
August	0.447	0.555	110,559	3,566	0.447	0.555	104,828	3,382	6,948
September	0.409	0.508	101,165	3,372	0.409	0.508	95,920	3,197	6,570
October	0.401	0.498	99,088	3,196	0.401	0.498	93,951	3,031	6,227
November	0.369	0.458	91,103	3,037	0.369	0.458	86,380	2,879	5,916
December	0.362	0.450	89,545	2,889	0.362	0.450	84,903	2,739	5,627
Annual Totals	*5.463*	*6.786*	*1,350,670*		*5.463*	*6.786*	*1,280,648*		
Single Worst Day of Simulation	0.0208	0.026	5,142		0.0208	0.026	4,876		10,018

Post Closure, Year 2

	Cell 1				Cell 2				Combined
Month	**Leachate (in), HELP Model**	**Leachate (in), Scaled for Lee, MA**	**Leachate Vol (gal), Scaled for Lee, MA**	**Ave. Daily Vol. (gal)**	**Leachate (in), HELP Model**	**Leachate (in), Scaled for Lee, MA**	**Leachate Vol (gal), Scaled for Lee, MA**	**Ave. Daily Vol. (gal)**	**Total (gal/day)**
January	0.346	0.401	79,883	2,577	0.346	0.401	75,742	2,443	5,020
February	0.299	0.347	69,062	2,467	0.299	0.347	65,482	2,339	4,805
March	0.317	0.368	73,270	2,364	0.317	0.368	69,472	2,241	4,605
April	0.293	0.341	67,837	2,261	0.293	0.341	64,320	2,144	4,405
May	0.291	0.338	67,328	2,172	0.291	0.338	63,838	2,059	4,231
June	0.271	0.315	62,681	2,089	0.271	0.315	59,431	1,981	4,070
July	0.270	0.313	62,334	2,011	0.270	0.313	59,103	1,907	3,917
August	0.260	0.301	59,999	1,935	0.260	0.301	56,888	1,835	3,771
September	0.242	0.281	55,999	1,867	0.242	0.281	53,096	1,770	3,636
October	0.242	0.281	55,860	1,802	0.242	0.281	52,964	1,709	3,510
November	0.226	0.262	52,184	1,739	0.226	0.262	49,479	1,649	3,389
December	0.225	0.262	52,115	1,681	0.225	0.262	49,413	1,594	3,275
Annual Totals	*3.281*	*3.811*	*758,553*		*3.281*	*3.811*	*719,228*		
Single Worst Day of Simulation	0.0114	0.013	2,636		0.0114	0.013	2,499		5,135

Post Closure, Year 3

Month	Cell 1				Cell 2				Combined
	Leachate (in), HELP Model	Leachate (in), Scaled for Lee, MA	Leachate Vol (gal), Scaled for Lee, MA	Ave. Daily Vol. (gal)	Leachate (in), HELP Model	Leachate (in), Scaled for Lee, MA	Leachate Vol (gal), Scaled for Lee, MA	Ave. Daily Vol. (gal)	Total (gal/day)
January	0.218	0.214	42,677	1,377	0.218	0.214	40,465	1,305	2,682
February	0.191	0.188	37,401	1,336	0.191	0.188	35,462	1,267	2,602
March	0.206	0.202	40,196	1,297	0.206	0.202	38,112	1,229	2,526
April	0.193	0.190	37,734	1,258	0.193	0.190	35,777	1,193	2,450
May	0.193	0.190	37,773	1,218	0.193	0.190	35,814	1,155	2,374
June	0.182	0.179	35,545	1,185	0.182	0.179	33,702	1,123	2,308
July	0.183	0.180	35,740	1,153	0.183	0.180	33,888	1,093	2,246
August	0.178	0.175	34,763	1,121	0.178	0.175	32,961	1,063	2,185
September	0.168	0.165	32,751	1,092	0.168	0.165	31,053	1,035	2,127
October	0.169	0.166	32,966	1,063	0.169	0.166	31,257	1,008	2,072
November	0.159	0.156	31,051	1,035	0.159	0.156	29,441	981	2,016
December	0.160	0.157	31,265	1,009	0.160	0.157	29,645	956	1,965
Annual Totals	*2.200*	*2.160*	*429,861*		*2.200*	*2.160*	*407,576*		
Single Worst Day of Simulation	0.00715	0.007	1,397		0.00715	0.007	1,325		2,722

Post Closure, Year 4

Month	Cell 1				Cell 2				Combined
	Leachate (in), HELP Model	Leachate (in), Scaled for Lee, MA	Leachate Vol (gal), Scaled for Lee, MA	Ave. Daily Vol. (gal)	Leachate (in), HELP Model	Leachate (in), Scaled for Lee, MA	Leachate Vol (gal), Scaled for Lee, MA	Ave. Daily Vol. (gal)	Total (gal/day)
January	0.156	0.217	43,095	1,390	0.156	0.217	40,860	1,318	2,708
February	0.143	0.198	39,370	1,406	0.143	0.198	37,329	1,333	2,739
March	0.149	0.207	41,108	1,326	0.149	0.207	38,977	1,257	2,583
April	0.141	0.195	38,873	1,296	0.141	0.195	36,858	1,229	2,524
May	0.142	0.197	39,149	1,263	0.142	0.197	37,120	1,197	2,460
June	0.135	0.186	37,108	1,237	0.135	0.186	35,184	1,173	2,410
July	0.136	0.188	37,494	1,209	0.136	0.188	35,550	1,147	2,356
August	0.133	0.184	36,666	1,183	0.133	0.184	34,765	1,121	2,304
September	0.126	0.175	34,735	1,158	0.126	0.175	32,934	1,098	2,256
October	0.128	0.177	35,176	1,135	0.128	0.177	33,353	1,076	2,211
November	0.121	0.167	33,273	1,109	0.121	0.167	31,548	1,052	2,161
December	0.122	0.169	33,631	1,085	0.122	0.169	31,888	1,029	2,114
Annual Totals	*1.630*	*2.259*	*449,678*		*1.630*	*2.259*	*426,366*		
Single Worst Day of Simulation	0.0051	0.007	1,407		0.0051	0.007	1,334		2,741

Post Closure, Year 5

Month	Cell 1				Cell 2				Combined
	Leachate (in), HELP Model	Leachate (in), Scaled for Lee, MA	Leachate Vol (gal), Scaled for Lee, MA	Ave. Daily Vol. (gal)	Leachate (in), HELP Model	Leachate (in), Scaled for Lee, MA	Leachate Vol (gal), Scaled for Lee, MA	Ave. Daily Vol. (gal)	Total (gal/day)
January	0.120	0.178	35,405	1,142	0.120	0.178	33,570	1,083	2,225
February	0.106	0.158	31,409	1,122	0.106	0.158	29,781	1,064	2,185
March	0.115	0.171	34,132	1,101	0.115	0.171	32,363	1,044	2,145
April	0.143	0.213	42,451	1,415	0.143	0.213	40,250	1,342	2,757
May	0.002	0.003	592	19	0.002	0.003	561	18	37
June	0.000	0.000	0	0	0.000	0.000	0	0	0
July	0.000	0.000	0	0	0.000	0.000	0	0	0
August	0.000	0.000	0	0	0.000	0.000	0	0	0
September	0.000	0.000	0	0	0.000	0.000	0	0	0
October	0.000	0.000	0	0	0.000	0.000	0	0	0
November	0.000	0.000	0	0	0.000	0.000	0	0	0
December	0.000	0.000	30	1	0.000	0.000	28	1	2
Annual Totals	*0.487*	*0.724*	*144,019*		*0.487*	*0.724*	*136,553*		
Single Worst Day of Simulation	0.00723	0.011	2,140		0.00723	0.011	2,029		4,170

Attachment 2

Tank Sizing Reference Chart

AQUASTORE® TANK CAPACITY CHART
WATER TANKS WITH CONCRETE FLOORS (x 1000 US Gallons)

AWWA Seismic 0,1 English Units

Model Diameter	# Sheets	Exact Diameter (feet)	Capacity Per Foot (gallons)	Max Water Depth (Ft) AWWA Z = 0,1 A .375" max.	B .5" max.	5.51 1	10.09 2	14.68 3	19.26 4	23.84 5	28.43 6	33.01 7	37.59 8	42.17 9	46.76 10	51.34 11	55.92 12	60.51 13	65.09 14	69.67 15	74.26 16	78.84 17	83.42 18	88.00 19	92.59 20	97.17 21	101.75 22	106.34 23	110.92 24	115.50 25	120.09 26	124.67 27	129.25 28	133.83 29	138.42 30	31	32
						Actual Sidewall Height (feet) - Number of Rings - Courses																															
11	4	11.19	735	65.1	**65.1**	4	7	10	14	17	20	24	27	30	34	37	41	44	47	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -	- / -
14	5	13.98	1,149	138.4	**138.4**	6	11	16	22	27	32	37	43	48	53	58	64	69	74	80	85	90	95	101	106	111	116	122	127	132	137	143	148	153	159	- / -	- / -
17	6	16.78	1,655	138.4	**138.4**	9	16	24	31	39	47	54	62	69	77	84	92	100	107	115	122	130	138	145	153	160	168	175	183	191	198	206	213	221	229	- / -	- / -
20	7	19.58	2,252	138.4	**138.4**	12	22	33	43	53	64	74	84	94	105	115	125	136	146	156	167	177	187	198	208	218	229	239	249	260	270	280	291	301	311	- / -	- / -
22	8	22.37	2,942	138.4	**138.4**	16	29	43	56	70	83	97	110	124	137	151	164	178	191	204	218	231	245	258	272	285	299	312	326	339	353	366	380	393	407	- / -	- / -
25	9	25.17	3,724	123.2	**138.4**	20	37	54	71	88	105	122	139	157	174	191	208	225	242	259	276	293	310	327	344	361	378	395	413	430	447	460 / 123.79	474 / 127.49	488 / 131.19	502 / 134.89	515 / 138.60	- / -
28	10	27.97	4,597	110.9	**138.4**	25	46	67	88	109	130	151	172	193	214	236	257	278	299	320	341	362	383	404	425	446	467	488	505	522 / 113.74	539 / 117.44	556 / 121.14	573 / 124.84	590 / 128.55	607 / 132.25	624 / 135.95	636 / 139.65
31	11	30.77	5,563	100.8	**134.6**	30	56	81	107	132	158	183	209	234	260	285	311	336	362	387	413	438	464	489	515	540	561 / 100.87	581 / 104.57	602 / 108.27	622 / 111.97	643 / 115.68	664 / 119.38	684 / 123.08	705 / 126.78	725 / 130.48	746 / 134.18	748 / 137.88
34	12	33.56	6,620	92.4	**123.2**	36	66	97	127	157	188	218	248	279	309	339	370	400	430	461	491	521	552	582	607 / 91.71	631 / 95.41	656 / 99.11	680 / 102.81	705 / 106.51	729 / 110.22	754 / 113.92	778 / 117.62	803 / 121.32	815 / 125.02			
36	13	36.36	7,770	85.3	**113.9**	42	78	114	149	185	220	256	292	327	363	398	434	470	505	541	576	612	648	676 / 87.12	705 / 90.82	734 / 94.52	763 / 98.22	791 / 101.93	820 / 105.63	849 / 109.33	878 / 113.03	885 / 116.73					
39	14	39.16	9,011	79.2	**105.7**	49	90	132	173	214	256	297	338	380	421	426	503	545	586	627	669	710	743 / 82.54	777 / 86.24	810 / 89.94	843 / 93.64	877 / 97.34	910 / 101.05	943 / 104.75	952 / 108.45							
42	15	41.96	10,345	73.9	**98.7**	57	104	151	199	246	294	341	388	436	483	531	578	625	673	720	759 / 73.37	797 / 77.07	835 / 80.77	873 / 84.47	912 / 88.17	950 / 91.88	988 / 95.58	1,021 / 99.28									
45	16	44.75	11,770	69.3	**92.5**	64	118	172	226	280	334	388	442	496	550	604	658	712	766	809 / 68.79	853 / 72.49	896 / 76.19	940 / 79.89	983 / 83.59	1,027 / 87.30	1,071 / 91.00	1,088 / 94.70										
48	17	47.55	13,287	65.2	**87.1**	73	134	195	255	316	377	438	499	560	621	682	743	803	864	914 / 68.79	963 / 72.49	1,012 / 76.19	1,061 / 79.89	1,110 / 83.60	1,157 / 87.30												
50	18	50.35	14,896	61.6	**82.2**	82	150	218	286	355	423	491	559	628	696	764	833	901	956 / 64.21	1,011 / 67.91	1,066 / 71.61	1,121 / 75.31	1,176 / 79.01	1,224 / 82.71													
53	19	53.15	16,598	58.3	**77.9**	91	167	243	319	395	471	547	623	700	776	852	928	989 / 59.62	1,051 / 63.33	1,112 / 67.03	1,173 / 70.73	1,235 / 74.43	1,292 / 78.13														
56	20	55.95	18,391	55.4	**74.0**	101	185	269	354	438	522	607	691	775	859	944	1,012 / 55.04	1,080 / 58.74	1,148 / 62.44	1,216 / 66.15	1,284 / 69.85	1,352 / 73.55	1,360 / 77.25														
59	21	58.74	20,276	52.8	**70.5**	111	204	297	390	483	576	669	762	855	948	1,040	1,115 / 55.04	1,191 / 58.74	1,266 / 62.44	1,241 / 66.15	1,416 / 69.85	1,429 / 73.55															
62	22	61.54	22,253	50.4	**67.3**	122	224	326	428	530	632	734	836	938	1,040	1,122 / 50.46	1,205 / 54.16	1,287 / 57.86	1,369 / 61.56	1,452 / 65.26	1,497 / 68.96																
64	23	64.34	24,322	48.2	**64.3**	134	245	356	468	579	691	802	914	1,025	1,137	1,227 / 50.46	1,317 / 54.16	1,407 / 57.86	1,497 / 61.56	1,563 / 65.26																	
67	24	67.13	26,483	46.2	**61.7**	145	267	388	510	631	752	874	995	1,116	1,214 / 45.88	1,313 / 49.58	1,411 / 53.28	1,509 / 56.98	1,606 / 60.68	1,634 / 64.38																	
70	25	69.93	28,736	44.3	**59.2**	158	290	421	553	685	816	948	1,080	1,211	1,318 / 45.88	1,424 / 49.58	1,531 / 53.28	1,637 / 56.98	1,701 / 60.68																		
73	26	72.73	31,081	42.6	**56.9**	171	313	456	598	741	883	1,025	1,168	1,310	1,425 / 45.88	1,540 / 49.58	1,655 / 53.28	1,768 / 56.98																			
76	27	75.53	33,518	41.1	**54.8**	184	338	491	645	799	952	1,106	1,259	1,383 / 41.29	1,507 / 44.99	1,631 / 48.69	1,756 / 52.40	1,836 / 56.09																			
78	28	78.32	36,046	39.6	**52.8**	198	363	529	694	859	1,024	1,189	1,355	1,488 / 41.29	1,621 / 44.99	1,755 / 48.69	1,888 / 52.40	1,903 / 56.10																			
81	29	81.12	38,667	38.2	**51.0**	213	390	567	744	921	1,099	1,276	1,453	1,596 / 41.29	1,739 / 44.99	1,882 / 48.69	1,972 / 52.40																				
84	30	83.92	41,380	37.0	**49.3**	228	417	607	796	986	1,176	1,365	1,519 / 36.71	1,672 / 40.41	1,825 / 44.11	1,978 / 47.81	2,040 / 51.51																				
87	31	86.72	44,184	35.8	**47.7**	246	445	648	850	1,053	1,255	1,458	1,621 / 36.71	1,785 / 40.41	1,948 / 44.11	2,107 / 47.81																					
90	32	89.51	47,081	34.6	**46.2**	259	475	690	906	1,122	1,338	1,554	1,728 / 36.71	1,902 / 40.41	2,076 / 44.11	2,175 / 47.81																					
92	33	92.31	50,070	33.6	**44.8**	275	505	734	964	1,193	1,423	1,652	1,838 / 36.71	2,023 / 40.41	2,208 / 44.11	2,243 / 47.81																					
95	34	95.11	53,150	32.6	**43.5**	292	536	780	1,023	1,267	1,510	1,707 / 32.13	1,904 / 35.83	2,101 / 39.53	2,297 / 43.23	2,312 / 46.93																					
98	35	97.91	56,323	31.7	**42.3**	310	568	826	1,084	1,342	1,600	1,809 / 32.13	2,018 / 35.83	2,226 / 39.53	2,382 / 43.23																						
101	36	100.70	59,587	30.8	**41.1**	328	601	874	1,147	1,420	1,693	1,914 / 32.13	2,135 / 35.83	2,355 / 39.53	2,449 / 43.23																						
104	37	103.50	62,944	30.0	**40.0**	346	635	923	1,212	1,500	1,789	2,022 / 32.13	2,255 / 35.83	2,488 / 39.53	2,517 / 43.23																						

Glass Tanks with a Heart of Steel™

SPLIT-CELL CHART KEY:

1,836 / 56.09	
1,836	1. Top number is tank volume (x 1000) in US Gallons
56.09	2. Bottom number is actual sidewall height with 44" high shell sheets

Notes:
1. 100 mph wind speed
2. 25 psf live snow load
3. Seismic zone 0 & 1
4. Importance Factor, I = 1.25
5. Site Amplification Factor, S = 1.5
6. Specific gravity 1.0 @ STP
7. Structure height limitations dependent upon local soil conditions and construction techniques
8. AWWA Designates AWWA D103-97
9. Model Designation => Model Diameter & Model Sidewall Height
   Example: Model Designation 4228 => 42' diameter & 28' height
10. For steel floor option: Add .678' X Capacity Per Foot (gallons) to listed capacities
11. No freeboard allowance except in the darker gray shaded areas at the far right end of the rows, where the freeboard is variable

Part#: 274400-000
ECN#: 07387

AQUASTORE Tanks & Domes

AQUASTORE® TANK CAPACITY CHART
WATER TANKS WITH CONCRETE FLOORS (x 1000 US Gallons)

Actual Sidewall Height (feet) - Number of Rings - Courses

Model Diameter	# Sheets	Exact Diameter (feet)	Capacity Per Foot (gallons)	Max Water Depth (Ft) AWWA Z = 0,1 A .375" max.	B .5" max.	5.51 1	10.09 2	14.68 3	19.26 4	23.84 5	28.43 6	33.01 7	37.59 8	42.17 9	46.76 10	51.34 11	55.92 12	60.51 13	65.09 14	69.67 15	74.26 16	78.84 17	83.42 18	88.00 19	92.59 20	97.17 21	101.75 22	106.34 23	110.92 24	115.50 25	120.09 26	124.67 27	129.25 28	133.83 29	138.42 30	31	32
106	38	106.30	66,392	29.2	**38.9**	365	670	974	1,278	1,582	1,887	2,133 32.13	2,378 35.83	2,582 39.53																							
109	39	109.10	69,932	28.4	**37.9**	385	705	1,026	1,346	1,667	1,926 27.54	2,184 31.24	2,444 34.95	2,650 38.65																							
112	40	111.90	73,565	27.7	**37.0**	405	742	1,079	1,416	1,753	2,026 27.54	2,298 31.24	2,571 34.95	2,721 38.65																							
115	41	114.69	77,289	27.0	**36.1**	425	780	1,134	1,488	1,842	2,128 27.54	2,414 31.24	2,701 34.95	2,790 38.65																							
117	42	117.49	81,105	26.4	**35.2**	446	818	1,190	1,562	1,933	2,233 27.54	2,533 31.24	2,834 34.95	2,854 38.65																							
120	43	120.29	85,013	25.8	**34.4**	468	858	1,247	1,637	2,026	2,341 27.54	2,655 31.24	2,924 34.95																								
123	44	123.09	89,013	25.2	**33.6**	490	898	1,306	1,714	2,122	2,451 27.54	2,780 31.24	2,990 34.95																								
126	45	125.89	93,105	24.6	**32.9**	513	939	1,366	1,793	2,219	2,564 27.54	2,908 31.24	3,063 34.95																								
129	46	128.68	97,289	24.1	**32.1**	536	981	1,427	1,873	2,319	2,679 27.54	3,039 31.24	3,122 34.95																								
131	47	131.48	101,565	23.6	**31.5**	559	1,025	1,490	1,956	2,331 22.96	2,707 26.66	3,083 30.36	3,199 34.06																								
134	48	134.27	105,933	23.1	**30.8**	583	1,069	1,554	2,040	2,432 22.96	2,824 26.66	3,216 30.36	3,262 34.06																								
137	49	137.07	110,393	22.6	**30.2**	608	1,114	1,620	2,126	2,534 22.96	2,943 26.66	3,333 30.36																									
140	50	139.87	114,945	22.2	**29.6**	633	1,160	1,686	2,213	2,639 22.96	3,064 26.66	3,402 30.36																									
143	51	142.67	119,589	21.7	**29.0**	658	1,207	1,755	2,303	2,745 22.96	3,188 26.66	3,468 30.36																									
145	52	145.46	124,324	21.3	**28.4**	685	1,254	1,824	2,394	2,854 22.96	3,314 26.66	3,530 30.36																									
148	53	148.26	129,152	20.9	**27.9**	711	1,303	1,895	2,487	2,965 22.96	3,443 26.66	3,603 30.36																									
151	54	151.06	134,072	20.5	**27.4**	738	1,353	1,967	2,582	3,078 22.96	3,574 26.66	3,673 30.36																									
154	55	153.86	139,083	20.2	**26.9**	766	1,403	2,041	2,678	3,193 22.96	3,707 26.66	3,741 30.36																									
157	56	156.66	144,187	19.8	**26.4**	794	1,455	2,116	2,776	3,310 22.96	3,806 26.66																										
159	57	159.46	149,382	19.4	**25.9**	823	1,507	2,192	2,876	3,429 22.96	3,868 26.66																										
162	58	162.26	154,670	19.1	**25.5**	852	1,561	2,269	2,842 18.38	3,415 22.08	3,944 25.78																										
171	61	170.65	171,082	18.2	**24.2**	942	1,726	2,510	3,144 18.38	3,777 22.08	4,140 25.78																										
179	64	179.04	188,318	17.3	**23.1**	1,037	1,900	2,763	3,461 18.38	4,158 22.08	4,350 25.78																										
187	67	187.43	206,381	16.5	**22.1**	1,137	2,083	3,028	3,793 18.38	4,556 22.08	4,561 25.78																										
193	69	193.03	218,898	16.1	**21.4**	1,206	2,209	3,212	4,023 18.38	4,684 22.08																											
201	72	201.42	238,340	15.4	**20.5**	1,313	2,405	3,497	4,380 18.38	4,885 22.08																											
210	75	209.81	258,609	14.8	**19.7**	1,424	2,610	3,795	4,753 18.38	5,094 22.08																											
218	78	218.20	279,712	14.2	**18.9**	1,541	2,823	3,858 13.79	4,894 17.50	5,286 21.20																											
227	81	226.59	301,642	13.7	**18.2**	1,662	3,044	4,159 13.79	5,278 17.50	5,489 21.20																											
235	84	234.99	324,399	13.2	**17.6**	1,778	3,274	4,473 13.79	5,676 17.50	5,709 21.20																											
243	87	243.38	347,984	12.7	**17.0**	1,917	3,512	4,798 13.79	5,915 17.50																												

Glass Tanks with a Heart of Steel™

SPLIT-CELL CHART KEY:

1,836 56.09

1. Top number is tank volume (x 1000) in US Gallons
2. Bottom number is actual sidewall height with 44" high shell sheets

Notes:
1. 100 mph wind speed
2. 25 psf live snow load
3. Seismic zone 0 & 1
4. Importance Factor, I = 1.25
5. Site Amplification Factor, S = 1.5
6. Specific gravity 1.0 @ STP
7. Structure height limitations dependent upon local soil conditions and construction techniques
8. AWWA Designates AWWA D103-97
9. Model Designation => Model Diameter & Model Sidewall Height
   Example: *Model Designation 4228 => 42' diameter & 28' height*
10. For steel floor option: Add .678' X Capacity Per Foot (gallons) to listed capacities
11. No freeboard allowance except in the darker gray shaded areas at the far right end of the rows, where the freeboard is variable

Part#: 274400-000
ECN#: 07387

ENGINEERED STORAGE PRODUCTS COMPANY

AWWA Seismic 0,1 English Units

Attachment 3

HELP Model Output

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 ******************************************************************************
  ******************************************************************************
  **                                                                          **
  **                                                                          **
  **              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE              **
  **                HELP MODEL VERSION 3.07  (1 November 1997)                **
  **                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
  **                    USAE WATERWAYS EXPERIMENT STATION                     **
  **             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
  **                                                                          **
  **                                                                          **
  ******************************************************************************
  ******************************************************************************

  PRECIPITATION DATA FILE:    C:\WHI\UNSAT22\data\P212.VHP\_weather1.dat
  TEMPERATURE DATA FILE:      C:\WHI\UNSAT22\data\P212.VHP\_weather2.dat
  SOLAR RADIATION DATA FILE:  C:\WHI\UNSAT22\data\P212.VHP\_weather3.dat
  EVAPOTRANSPIRATION DATA:    C:\WHI\UNSAT22\data\P212.VHP\_weather4.dat
  SOIL AND DESIGN DATA FILE:  C:\WHI\UNSAT22\data\P212.VHP\I_385483.inp
  OUTPUT DATA FILE:           C:\WHI\UNSAT22\data\P212.VHP\O_385483.prt

  TIME:   9:37     DATE:  10/ 5/2023

  ******************************************************************************
```

TITLE: Uncapped Min Waste

```
  ******************************************************************************

       NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
                COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                   LAYER  1
                                   --------
                        TYPE 1 - VERTICAL PERCOLATION LAYER
                            MATERIAL TEXTURE NUMBER   5
            THICKNESS                  =   304.80   CM
            POROSITY                   =     0.4530 VOL/VOL
            FIELD CAPACITY             =     0.1900 VOL/VOL
            WILTING POINT              =     0.0850 VOL/VOL
            INITIAL SOIL WATER CONTENT =     0.2622 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.100000000000E-02 CM/SEC

                                   LAYER  2
                                   --------
                        TYPE 1 - VERTICAL PERCOLATION LAYER
                            MATERIAL TEXTURE NUMBER   5
            THICKNESS                  =    60.96   CM
            POROSITY                   =     0.4530 VOL/VOL
            FIELD CAPACITY             =     0.1900 VOL/VOL
            WILTING POINT              =     0.0850 VOL/VOL
            INITIAL SOIL WATER CONTENT =     0.2071 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.100000000000E-01 CM/SEC

                                   LAYER  3
                                   --------
                          TYPE 2 - LATERAL DRAINAGE LAYER
                            MATERIAL TEXTURE NUMBER  20
            THICKNESS                  =     0.50   CM
            POROSITY                   =     0.8500 VOL/VOL
```

```
   FIELD CAPACITY              =     0.0100 VOL/VOL
   WILTING POINT               =     0.0050 VOL/VOL
   INITIAL SOIL WATER CONTENT  =     0.0605 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  10.0000000000     CM/SEC
   SLOPE                       =     2.50   PERCENT
   DRAINAGE LENGTH             =    91.4    METERS

                          LAYER  4
                          --------
                 TYPE 4 - FLEXIBLE MEMBRANE LINER
                   MATERIAL TEXTURE NUMBER  35
   THICKNESS                   =     0.10   CM
   POROSITY                    =     0.0000 VOL/VOL
   FIELD CAPACITY              =     0.0000 VOL/VOL
   WILTING POINT               =     0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.200000000000E-12 CM/SEC
   FML PINHOLE DENSITY         =     2.00   HOLES/HECTARE
   FML INSTALLATION DEFECTS    =     2.00   HOLES/HECTARE
   FML PLACEMENT QUALITY       =  2 - EXCELLENT


              GENERAL DESIGN AND EVAPORATIVE ZONE DATA
              ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 5 WITH BARE
         GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
         A SLOPE LENGTH OF   91. METERS.

SCS RUNOFF CURVE NUMBER                 =    83.60
FRACTION OF AREA ALLOWING RUNOFF        =     0.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE      =     0.4047 HECTARES
EVAPORATIVE ZONE DEPTH                  =    20.3    CM
INITIAL WATER IN EVAPORATIVE ZONE       =     9.205  CM
UPPER LIMIT OF EVAPORATIVE STORAGE      =     9.205  CM
LOWER LIMIT OF EVAPORATIVE STORAGE      =     1.727  CM
INITIAL SNOW WATER                      =     0.000  CM
INITIAL WATER IN LAYER MATERIALS        =    92.565  CM
TOTAL INITIAL WATER                     =    92.565  CM
TOTAL SUBSURFACE INFLOW                 =     0.00   MM/YR


               EVAPOTRANSPIRATION AND WEATHER DATA
               -----------------------------------

  NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         Albany                NY

     STATION LATITUDE                          =  42.67 DEGREES
     MAXIMUM LEAF AREA INDEX                   =   0.00
     START OF GROWING SEASON (JULIAN DATE)     =    123
     END OF GROWING SEASON (JULIAN DATE)       =    282
     EVAPORATIVE ZONE DEPTH                    =   8.0  INCHES
     AVERAGE ANNUAL WIND SPEED                 =   8.90 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY     =  68.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY     =  66.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY     =  74.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY     =  74.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.39	2.26	3.01	2.94	3.31	3.29
3.00	3.34	3.23	2.93	3.04	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
21.10	23.40	33.80	46.60	57.50	66.70
71.40	69.20	61.20	50.50	39.30	26.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Albany NY
AND STATION LATITUDE = 42.38 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.06	2.39	3.25	2.93	3.26	2.98
	2.87	2.76	3.69	2.89	3.07	2.71
STD. DEVIATIONS	0.84	1.06	1.32	1.19	1.25	1.29
	1.01	0.99	2.05	1.56	1.35	1.18
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.567	0.507	0.606	2.443	2.693	2.470
	2.557	2.404	2.221	1.684	1.196	0.573
STD. DEVIATIONS	0.097	0.082	0.282	0.764	0.927	0.971
	0.942	0.826	0.829	0.505	0.223	0.149

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	1.0634	0.7928	0.8539	3.2367	2.3718	1.2131
	0.9318	0.6707	0.5192	0.6817	0.8183	0.9812
STD. DEVIATIONS	0.4878	0.3222	0.7132	1.4738	0.6248	0.3407
	0.2865	0.2614	0.1855	0.4856	0.6722	0.7839

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0738	0.0612	0.0550	0.1179	0.1130	0.0789
	0.0700	0.0585	0.0493	0.0535	0.0579	0.0650
STD. DEVIATIONS	0.0194	0.0142	0.0208	0.0344	0.0150	0.0109
	0.0109	0.0129	0.0109	0.0191	0.0259	0.0279

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0073	0.0059	0.0058	0.0229	0.0162	0.0086
	0.0064	0.0046	0.0037	0.0047	0.0058	0.0067
STD. DEVIATIONS	0.0033	0.0024	0.0049	0.0104	0.0043	0.0024
	0.0020	0.0018	0.0013	0.0033	0.0047	0.0054

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	34.86	(5.272)	126543.9	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	19.922	(2.3750)	72316.38	57.147
LATERAL DRAINAGE COLLECTED FROM LAYER 3	14.13444	(3.17052)	51306.893	40.54474
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.85406	(0.09913)	3100.171	2.44988
AVERAGE HEAD ON TOP OF LAYER 4	0.008	(0.002)		
CHANGE IN WATER STORAGE	-0.049	(2.4676)	-179.56	-0.142

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30 and their dates (DDDYYYY)

	(INCHES)	(CU. FT.)	
PRECIPITATION	3.20	11615.74682	2620015
RUNOFF	0.000	0.00000	0
DRAINAGE COLLECTED FROM LAYER 3	0.42234	1533.04726	840002
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.008881	32.23622	840002
AVERAGE HEAD ON TOP OF LAYER 4	0.089		
MAXIMUM HEAD ON TOP OF LAYER 4	0.177		
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	2.9 FEET		
SNOW WATER	6.59	23929.3540	690020

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4530

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0850

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	30.1214	0.2510
2	4.5857	0.1911
3	0.0086	0.0438
4	0.0000	0.0000
SNOW WATER	0.243	

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 **                                                                          **
 **                                                                          **
 **              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
 **                HELP MODEL VERSION 3.07 (1 November 1997)                 **
 **                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
 **                    USAE WATERWAYS EXPERIMENT STATION                     **
 **              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
 **                                                                          **
 **                                                                          **
 ******************************************************************************
 ******************************************************************************

PRECIPITATION DATA FILE:    C:\WHI\UNSAT22\data\P212.VHP\_weather1.dat
 TEMPERATURE DATA FILE:      C:\WHI\UNSAT22\data\P212.VHP\_weather2.dat
 SOLAR RADIATION DATA FILE:  C:\WHI\UNSAT22\data\P212.VHP\_weather3.dat
 EVAPOTRANSPIRATION DATA:    C:\WHI\UNSAT22\data\P212.VHP\_weather4.dat
 SOIL AND DESIGN DATA FILE:  C:\WHI\UNSAT22\data\P212.VHP\I_385737.inp
 OUTPUT DATA FILE:           C:\WHI\UNSAT22\data\P212.VHP\O_385737.prt

TIME:  10: 2     DATE:  10/ 5/2023

******************************************************************************
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TITLE: Uncapped Full Waste

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 ******************************************************************************

      NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
               COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                    LAYER  1
                                    --------
                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER   5
            THICKNESS                  =   1310.64   CM
            POROSITY                   =      0.4530 VOL/VOL
            FIELD CAPACITY             =      0.1900 VOL/VOL
            WILTING POINT              =      0.0850 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.2194 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.100000000000E-02 CM/SEC

                                    LAYER  2
                                    --------
                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER   5
            THICKNESS                  =     60.96   CM
            POROSITY                   =      0.4530 VOL/VOL
            FIELD CAPACITY             =      0.1900 VOL/VOL
            WILTING POINT              =      0.0850 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.1900 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.100000000000E-01 CM/SEC

                                    LAYER  3
                                    --------
                         TYPE 2 - LATERAL DRAINAGE LAYER
                           MATERIAL TEXTURE NUMBER  20
            THICKNESS                  =      0.50   CM
            POROSITY                   =      0.8500 VOL/VOL
```

```
   FIELD CAPACITY              =     0.0100 VOL/VOL
   WILTING POINT               =     0.0050 VOL/VOL
   INITIAL SOIL WATER CONTENT  =     0.0100 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  10.0000000000     CM/SEC
   SLOPE                       =     2.50   PERCENT
   DRAINAGE LENGTH             =    91.4    METERS

                        LAYER  4
                        --------
                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
   THICKNESS                   =     0.10   CM
   POROSITY                    =     0.0000 VOL/VOL
   FIELD CAPACITY              =     0.0000 VOL/VOL
   WILTING POINT               =     0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.200000000000E-12 CM/SEC
   FML PINHOLE DENSITY         =     2.00   HOLES/HECTARE
   FML INSTALLATION DEFECTS    =     2.00   HOLES/HECTARE
   FML PLACEMENT QUALITY       =  2 - EXCELLENT


            GENERAL DESIGN AND EVAPORATIVE ZONE DATA
            ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 5 WITH BARE
         GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
         A SLOPE LENGTH OF   91. METERS.

SCS RUNOFF CURVE NUMBER              =    83.60
FRACTION OF AREA ALLOWING RUNOFF     =     0.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =     0.4047 HECTARES
EVAPORATIVE ZONE DEPTH               =    20.3    CM
INITIAL WATER IN EVAPORATIVE ZONE    =     9.205  CM
UPPER LIMIT OF EVAPORATIVE STORAGE   =     9.205  CM
LOWER LIMIT OF EVAPORATIVE STORAGE   =     1.727  CM
INITIAL SNOW WATER                   =     0.000  CM
INITIAL WATER IN LAYER MATERIALS     =   299.148  CM
TOTAL INITIAL WATER                  =   299.148  CM
TOTAL SUBSURFACE INFLOW              =     0.00   MM/YR


             EVAPOTRANSPIRATION AND WEATHER DATA
             -----------------------------------

  NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         Albany                NY

     STATION LATITUDE                            =  42.67 DEGREES
     MAXIMUM LEAF AREA INDEX                     =   0.00
     START OF GROWING SEASON (JULIAN DATE)       =    123
     END OF GROWING SEASON (JULIAN DATE)         =    282
     EVAPORATIVE ZONE DEPTH                      =   8.0  INCHES
     AVERAGE ANNUAL WIND SPEED                   =   8.90 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY       =  68.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY       =  66.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY       =  74.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY       =  74.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.39	2.26	3.01	2.94	3.31	3.29
3.00	3.34	3.23	2.93	3.04	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
21.10	23.40	33.80	46.60	57.50	66.70
71.40	69.20	61.20	50.50	39.30	26.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Albany NY AND STATION LATITUDE = 42.38 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.06	2.39	3.25	2.93	3.26	2.98
	2.87	2.76	3.69	2.89	3.07	2.71
STD. DEVIATIONS	0.84	1.06	1.32	1.19	1.25	1.29
	1.01	0.99	2.05	1.56	1.35	1.18
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.567	0.507	0.606	2.443	2.693	2.470
	2.557	2.404	2.221	1.684	1.196	0.573
STD. DEVIATIONS	0.097	0.082	0.282	0.764	0.927	0.971
	0.942	0.826	0.829	0.505	0.223	0.149

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	1.1639	1.1624	0.9560	0.5783	1.6340	1.5711
	1.5582	1.3635	1.1545	0.9335	0.8669	0.8077
STD. DEVIATIONS	0.4929	0.3734	0.3327	0.3485	0.5977	0.4318
	0.4143	0.4217	0.3092	0.3568	0.3558	0.3648

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0776	0.0751	0.0670	0.0460	0.0913	0.0902
	0.0919	0.0856	0.0761	0.0667	0.0628	0.0609
STD. DEVIATIONS	0.0198	0.0159	0.0151	0.0162	0.0207	0.0132
	0.0125	0.0142	0.0126	0.0162	0.0177	0.0183

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0080	0.0087	0.0065	0.0041	0.0112	0.0111
	0.0106	0.0093	0.0082	0.0064	0.0061	0.0055
STD. DEVIATIONS	0.0034	0.0028	0.0023	0.0025	0.0041	0.0030
	0.0028	0.0029	0.0022	0.0024	0.0025	0.0025

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	34.86 (5.272)	126543.9	100.00
RUNOFF	0.000 (0.0000)	0.00	0.000
EVAPOTRANSPIRATION	19.922 (2.3750)	72316.38	57.147
LATERAL DRAINAGE COLLECTED FROM LAYER 3	13.75004 (3.25871)	49911.544	39.44208
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.89113 (0.12273)	3234.729	2.55621
AVERAGE HEAD ON TOP OF LAYER 4	0.008 (0.002)		
CHANGE IN WATER STORAGE	0.298 (4.3063)	1081.23	0.854

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30 and their dates (DDDYYYY)

	(INCHES)	(CU. FT.)	
PRECIPITATION	3.20	11615.74682	2620015
RUNOFF	0.000	0.00000	0
DRAINAGE COLLECTED FROM LAYER 3	0.15079	547.36756	1440003
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.005261	19.09728	1440003
AVERAGE HEAD ON TOP OF LAYER 4	0.032		
MAXIMUM HEAD ON TOP OF LAYER 4	0.064		
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	1.1 FEET		
SNOW WATER	6.59	23929.3540	690020

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4530
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0850

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	121.9048	0.2362
2	4.5600	0.1900
3	0.0028	0.0141
4	0.0000	0.0000
SNOW WATER	0.243	

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```
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 **                                                                          **
 **                                                                          **
 **              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
 **                HELP MODEL VERSION 3.07 (1 November 1997)                 **
 **                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
 **                    USAE WATERWAYS EXPERIMENT STATION                     **
 **             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
 **                                                                          **
 **                                                                          **
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```
PRECIPITATION DATA FILE:    C:\WHI\UNSAT22\data\P318.VHP\_weather1.dat
TEMPERATURE DATA FILE:      C:\WHI\UNSAT22\data\P318.VHP\_weather2.dat
SOLAR RADIATION DATA FILE:  C:\WHI\UNSAT22\data\P318.VHP\_weather3.dat

EVAPOTRANSPIRATION DATA:    C:\WHI\UNSAT22\data\P318.VHP\_weather4.dat
SOIL AND DESIGN DATA FILE:  C:\WHI\UNSAT22\data\P318.VHP\I_385794.inp

OUTPUT DATA FILE:           C:\WHI\UNSAT22\data\P318.VHP\O_385794.prt

 TIME:  13:28     DATE:   9/11/2023

 ******************************************************************************
```

TITLE: Full Buildout Post-Closure - User-Specified Moisture Content

```
 ******************************************************************************
```

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
SPECIFIED BY THE USER.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER   8

```
THICKNESS                  =     15.24   CM
POROSITY                   =      0.4630 VOL/VOL
FIELD CAPACITY             =      0.2320 VOL/VOL
WILTING POINT              =      0.1160 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.2300 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.370000000000E-03 CM/SEC
```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00

FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 4

THICKNESS	=	45.72 CM
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.1050 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1050 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000000000E-02 CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.50 CM
POROSITY	=	0.8500 VOL/VOL
FIELD CAPACITY	=	0.0100 VOL/VOL
WILTING POINT	=	0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
SLOPE	=	5.00 PERCENT
DRAINAGE LENGTH	=	106.7 METERS

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.10 CM
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.200000000000E-12 CM/SEC
FML PINHOLE DENSITY	=	2.47 HOLES/HECTARE
FML INSTALLATION DEFECTS	=	2.47 HOLES/HECTARE

FML PLACEMENT QUALITY = 2 - EXCELLENT

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 5

THICKNESS	=	1310.64 CM
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1900 VOL/VOL
WILTING POINT	=	0.0850 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2194 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000000000E-02 CM/SEC

LAYER 6

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 5

THICKNESS	=	60.96 CM
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1900 VOL/VOL
WILTING POINT	=	0.0850 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1900 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000000000E-01 CM/SEC

LAYER 7

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.50 CM
POROSITY	=	0.8500 VOL/VOL
FIELD CAPACITY	=	0.0100 VOL/VOL
WILTING POINT	=	0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
SLOPE	=	2.50 PERCENT
DRAINAGE LENGTH	=	118.9 METERS

LAYER 8

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.10 CM
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.200000000000E-12 CM/SEC
FML PINHOLE DENSITY	=	2.00 HOLES/HECTARE
FML INSTALLATION DEFECTS	=	2.00 HOLES/HECTARE
FML PLACEMENT QUALITY	=	2 - EXCELLENT

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A “FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.%" AND A SLOPE LENGTH OF 107. METERS.

SCS RUNOFF CURVE NUMBER	=	79.57	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	0.4047	HECTARES
EVAPORATIVE ZONE DEPTH	=	30.5	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	5.105	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.716	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.484	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	307.453	CM
TOTAL INITIAL WATER	=	307.453	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM

Albany NY

STATION LATITUDE	=	42.67 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	123
END OF GROWING SEASON (JULIAN DATE)	=	282
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	8.90 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	74.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.39	2.26	3.01	2.94	3.31	3.29
3.00	3.34	3.23	2.93	3.04	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Albany NY

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
21.10	23.40	33.80	46.60	57.50	66.70
71.40	69.20	61.20	50.50	39.30	26.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING

COEFFICIENTS FOR Albany NY

AND STATION LATITUDE = 42.38 DEGREES

HEAD #1: AVERAGE HEAD ON TOP OF LAYER 4

DRAIN #1: LATERAL DRAINAGE FROM LAYER 3 (RECIRCULATION AND COLLECTION)

LEAK #1: PERCOLATION OR LEAKAGE THROUGH LAYER 4

HEAD #2: AVERAGE HEAD ON TOP OF LAYER 8

DRAIN #2: LATERAL DRAINAGE FROM LAYER 7 (RECIRCULATION AND COLLECTION)

LEAK #2: PERCOLATION OR LEAKAGE THROUGH LAYER

****

MONTHLY TOTALS (IN INCHES) FOR YEAR 1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	2.46	2.10	3.03	2.21	1.88	3.93
	2.75	2.83	3.98	1.31	5.59	4.02
RUNOFF	0.630	0.150	3.148	0.059	0.000	0.000
	0.000	0.000	0.000	0.000	0.005	1.274
EVAPOTRANSPIRATION	0.363	0.401	0.445	3.287	1.600	3.304
	3.026	2.462	3.001	0.678	1.293	0.472
LATERAL DRAINAGE COLLECTED	0.0000	0.0000	0.0000	1.2705	0.3100	0.1931
FROM LAYER 3	0.2329	0.2469	0.7850	0.3358	2.9609	1.2127
PERCOLATION/LEAKAGE THROUGH	0.0000	0.0000	0.0000	0.0002	0.0001	0.0001
LAYER 4	0.0001	0.0001	0.0002	0.0001	0.0004	0.0002
LATERAL DRAINAGE COLLECTED	0.3004	0.4941	0.6206	0.5583	0.5387	0.4886
FROM LAYER 7	0.4747	0.4472	0.4092	0.4008	0.3685	0.3622
PERCOLATION/LEAKAGE THROUGH	0.0456	0.0566	0.0669	0.0624	0.0623	0.0584
LAYER 8	0.0585	0.0567	0.0534	0.0537	0.0506	0.0510

****

MONTHLY TOTALS (IN INCHES) FOR YEAR 2

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	2.65	2.83	5.63	6.04	2.74	2.29
	2.46	2.21	1.68	2.02	6.51	1.53
RUNOFF	0.000	0.006	8.772	0.001	0.000	0.02
	0.000	0.000	0.000	0.000	0.026	0.000
EVAPOTRANSPIRATION	0.551	0.528	0.438	3.563	3.527	2.741
	1.199	3.275	0.976	0.887	1.013	0.418
LATERAL DRAINAGE COLLECTED	0.2206	0.0883	0.0623	3.3846	1.1769	0.3549
FROM LAYER 3	0.1600	0.1202	0.1080	0.0801	4.0651	1.8091
PERCOLATION/LEAKAGE THROUGH	0.0001	0.0000	0.0000	0.0008	0.0002	0.0001
LAYER 4	0.0001	0.0000	0.0000	0.0000	0.0007	0.0003
LATERAL DRAINAGE COLLECTED	0.3455	0.2987	0.3169	0.2934	0.2912	0.2711
FROM LAYER 7	0.2696	0.2595	0.2422	0.2416	0.2257	0.2254
PERCOLATION/LEAKAGE THROUGH	0.0498	0.0440	0.0477	0.0452	0.0457	0.0434
LAYER 8	0.0440	0.0431	0.0410	0.0416	0.0396	0.0402

****

MONTHLY TOTALS (IN INCHES) FOR YEAR 3

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	2.16	2.28	5.77	4.38	7.07	4.52
	3.02	3.59	3.02	3.43	3.29	3.13
RUNOFF	0.000	0.052	6.655	1.760	0.309	0.158

	0.000	0.000	0.007	0.000	0.000	0.005
EVAPOTRANSPIRATION	0.683	0.573	0.646	2.691	4.727	3.081
	3.488	3.014	1.604	1.876	1.135	0.410
LATERAL DRAINAGE COLLECTED	0.1917	0.0826	0.0596	1.8275	3.0198	1.1740
FROM LAYER 3	0.3079	0.1756	0.2417	0.9133	2.2826	0.6822
PERCOLATION/LEAKAGE THROUGH	0.0001	0.0000	0.0000	0.0003	0.0006	0.0002
LAYER 4	0.0001	0.0001	0.0001	0.0002	0.0004	0.0002
LATERAL DRAINAGE COLLECTED	0.2184	0.1914	0.2057	0.1931	0.1933	0.1819
FROM LAYER 7	0.1829	0.1779	0.1676	0.1687	0.1589	0.1600
PERCOLATION/LEAKAGE THROUGH	0.0396	0.0352	0.0384	0.0366	0.0372	0.0355
LAYER 8	0.0362	0.0357	0.0341	0.0347	0.0332	0.0338

****

MONTHLY TOTALS (IN INCHES) FOR YEAR 4

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	1.43	2.78	2.46	2.25	3.08	3.03
	0.93	1.82	1.60	5.14	3.35	4.47
RUNOFF	0.101	2.591	2.599	1.479	0.000	0.000
	0.000	0.000	0.000	0.030	0.000	1.266
EVAPOTRANSPIRATION	0.590	0.693	0.589	1.741	2.384	2.553
	1.812	1.776	0.924	1.469	1.191	0.484
LATERAL DRAINAGE COLLECTED	0.1484	0.0743	0.0537	1.8666	0.3757	0.2533
FROM LAYER 3	0.2135	0.1262	0.0864	0.9083	3.2419	0.7267

PERCOLATION/LEAKAGE THROUGH	0.0000	0.0000	0.0000	0.0004	0.0001	0.0001
LAYER 4	0.0001	0.0000	0.0000	0.0001	0.0005	0.0002
LATERAL DRAINAGE COLLECTED	0.1562	0.1427	0.1490	0.1409	0.1419	0.1345
FROM LAYER 7	0.1359	0.1329	0.1259	0.1275	0.1206	0.1219
PERCOLATION/LEAKAGE THROUGH	0.0334	0.0309	0.0326	0.0312	0.0319	0.0305
LAYER 8	0.0312	0.0308	0.0295	0.0302	0.0289	0.0295

****

MONTHLY TOTALS (IN INCHES) FOR YEAR 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	1.28	2.71	2.39	3.05	3.94	3.65
	2.73	2.17	1.58	1.25	3.27	2.12
RUNOFF	0.135	2.273	2.409	0.618	0.000	0.012
	0.000	0.000	0.000	0.000	0.007	0.000
EVAPOTRANSPIRATION	0.652	0.451	0.516	2.141	4.104	3.510
	2.813	1.467	2.010	1.302	0.706	0.659
LATERAL DRAINAGE COLLECTED	0.1534	0.0736	0.0550	2.4802	0.6079	0.4280
FROM LAYER 3	0.2356	0.1371	0.1308	0.1678	0.1339	1.5847
PERCOLATION/LEAKAGE THROUGH	0.0001	0.0000	0.0000	0.0005	0.0001	0.0001
LAYER 4	0.0001	0.0000	0.0000	0.0001	0.0000	0.0003
LATERAL DRAINAGE COLLECTED	0.1196	0.1061	0.1153	0.1434	0.0020	0.0000
FROM LAYER 7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001

```
PERCOLATION/LEAKAGE THROUGH      0.0292  0.0262  0.0287  0.0313  0.0006  0.0001
  LAYER  8                       0.0001  0.0000  0.0000  0.0000  0.0000  0.0002

-------------------------------------------------------------------------------
     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   30

-------------------------------------------------------------------------------
                                      INCHES           CU. FEET       PERCENT
                               -------------------   -------------   ---------

 PRECIPITATION                  34.86    (   5.272)     126543.9     100.00


 RUNOFF                          6.127   (  1.9511)      22240.35     17.575


 EVAPOTRANSPIRATION             20.647   (  2.3585)      74947.85     59.227


 LATERAL DRAINAGE COLLECTED      7.98035 (  2.51221)     28968.042   22.89170
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH     0.00167 (  0.00047)         6.058    0.00479
   LAYER  4

 AVERAGE HEAD ON TOP             0.005 (    0.003)
   OF LAYER  4

 LATERAL DRAINAGE COLLECTED      0.43564 (  1.21275)      1581.357    1.24965
   FROM LAYER  7

 PERCOLATION/LEAKAGE THROUGH     0.07170 (  0.17763)       260.280    0.20568
   LAYER  8

 AVERAGE HEAD ON TOP             0.000 (    0.001)
   OF LAYER  8

 CHANGE IN WATER STORAGE        -0.401   (  1.9707)      -1454.00     -1.149
*******************************************************************************

******************************************************************************
```

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30 and their dates (DDDYYYY)

	(INCHES)	(CU. FT.)	
PRECIPITATION	3.20	11615.74682	2620015
RUNOFF	2.784	10104.09064	690003
DRAINAGE COLLECTED FROM LAYER 3	1.16975	4246.09454	2710023
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000693	2.51389	2710023
AVERAGE HEAD ON TOP OF LAYER 4	2.161		
MAXIMUM HEAD ON TOP OF LAYER 4	3.019		
LOCATION OF MAXIMUM HEAD IN LAYER 3			
(DISTANCE FROM DRAIN)	16.4 FEET		
DRAINAGE COLLECTED FROM LAYER 7	0.02075	75.33771	680001
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.002199	7.98202	680001
AVERAGE HEAD ON TOP OF LAYER 8	0.006		
MAXIMUM HEAD ON TOP OF LAYER 8	0.011		
LOCATION OF MAXIMUM HEAD IN LAYER 7			
(DISTANCE FROM DRAIN)	0.1 FEET		
SNOW WATER	6.59	23929.3540	690020
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4183	
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0815	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner

" by Bruce M. McEnroe, University of Kansas"

****

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2.7780	0.4630
2	3.4016	0.1890
3	0.0028	0.0140
4	0.0000	0.0000
5	98.0400	0.1900
6	4.5600	0.1900
7	0.0020	0.0100
8	0.0000	0.0000
SNOW WATER	0.243	

****

Appendix F

Final Cover System Calculations

ARCADIS

Calculation Brief

Client: General Electric Company

Project Location: Pittsfield/Housatonic River Site - Town of Lee, Massachusetts

Project: Upland Disposal Facility Area **Arcadis Project No.:** 30197838

Calc No.: F-1 **Subject:** Final Cover Soil Loss Calculation

Prepared By: MA **Date:** February 2024

Reviewed By: BMS **Date:** February 2024

Objective

Calculate the expected soil loss from the longest uninterrupted slope of the UDF under post-closure conditions relative to the maximum tolerable soil loss rate per year. Calculations will indicate if soil loss rate is acceptable or if additional stabilization techniques are required.

References

1. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 8: Final Grading Plan".* February 2024.
2. US Environmental Protection Agency (USEPA). "Evaluating Cover Systems for Solid and Hazardous Waste (SW-867),", September 1980.
3. US Environmental Protection Agency (USEPA). Rainfall Erosivity Calculator for Small Construction Sites. Web application Accessed September 2023. https://lew.epa.gov/
4. United States Department of Agriculture (USDA) Soil Conservation Service (SCS), National Engineering Handbook, Section 3: Sedimentation, Chapter 3: Erosion, 1978.
5. United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Web Soil Survey. https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Assumptions

1. The anticipated erosion rates for the UDF final cover system are calculated using the Universal Soil Loss Equation (USLE) using factors described herein and the slope of the UDF final cover system (Reference 1).
2. The runoff erosivity factor, R, is a location-specific factor that considers high and medium intensity rainfalls and measures the ability to erode soil. Using the USEPA's erosivity factor calculator (Reference 3), a value of 141 is obtained.
3. The soil erodibility factor, K, is based on the final cover soil type(s) and their erodibility rating using the USDA Web Soil Survey (Reference 5). A K value of 0.43 is estimated using the regional soils that may be sourced for topsoil.
4. The slope-length factor, LS, quantifies the gradient and uninterrupted slope length. For conservatism,

the longest, uninterrupted slope length on the steepest sideslope of the UDF (3H:1V) is used. The longest side slope at 33% is 120' long, resulting in a LS factor on 10 (Reference 4, Figure 3-2).

5. The cover management factor, C, considers how the soil is used and managed on the slope. For conservativism based on land cover of the UDF, a vegetative cover of 95+% of tall grass, weeds, or short brush results in a C factor of 0.003 (Reference 4, Table 3-2).
6. The erosion control support factor, P, compares effect on soil loss due to contouring, contour strip-cropping, or contour irrigated furrows to that with straight row farming, upslope, and downslope. A P value of 1.0 is determined from Reference 2, Table 8 as no support practice is anticipated for the UDF.
7. The soil loss tolerance is 2 tons/acre/year per Reference 2, page 51.

Calculations

The longest uninterrupted slope path is included in Attachment 1. To calculate the annual soil loss from the final cover of the UDF, the USLE (Assumption 1) is used as shown below:

$$A = R * K * LS * C * P$$

Where,

A = Annual soil loss = unknown

R = Runoff Erosivity Factor = 141 (Assumption 2)

K = Soil Erodibility Factor = 0.43 (Assumption 3)

LS = Slope-Length Factor = 10 (Assumption 4)

C = Cover Management Factor = 0.003 (Assumption 5)

P = Erosion Control Support Factor = 1 (Assumption 6)

$$\therefore Annual\ Soil\ Loss = 141 * 0.43 * 10 * 0.003 * 1 = 1.82\ tons/acre/year$$

The worst-case annual soil from the final cover system is 1.82 tons/acre/year, which is less than the soil loss tolerance of 2 tons/acre/year (Assumption 7). Therefore, additional permanent stabilization measures are not required along the longest, uninterrupted slope. Although not required by calculation, erosion control products may be installed on slopes for added protection.

Summary

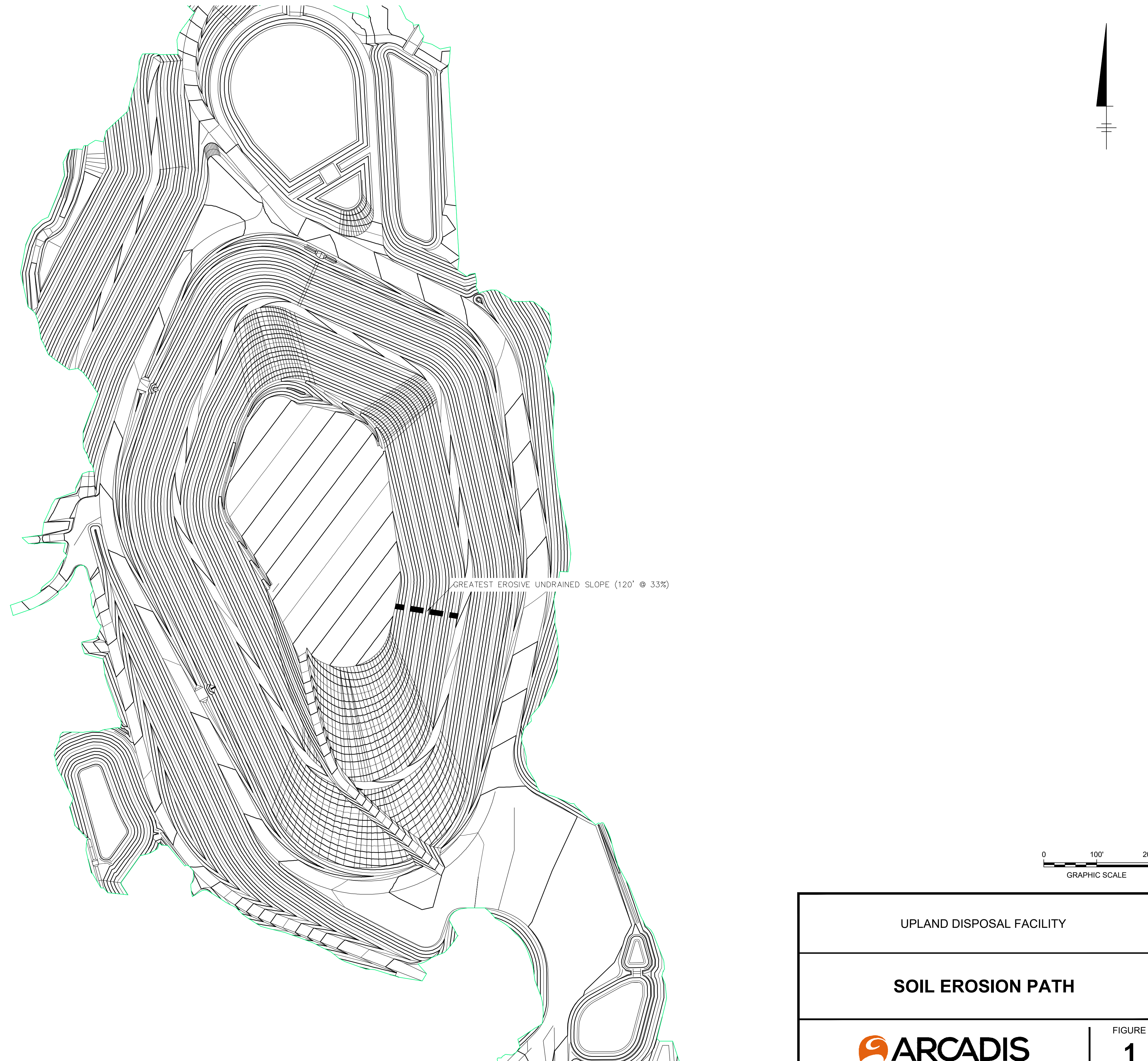
The longest, uninterrupted 3H:1V is 120' long and will not require additional permanent stabilization. Because this analysis was performed on the longest, steepest slope, the outcome is conservative for the remainder of the UDF.

Attachments

1. Soil Erosion Path Figure
2. USLE Calculations Output
3. USDA SCS National Engineering Handbook References (Reference 4)
4. Web Soil Survey (Reference 5)
5. SW-867 (Reference 2)

Attachment 1

Soil Erosion Path Figure



UPLAND DISPOSAL FACILITY

SOIL EROSION PATH

ARCADIS

FIGURE
1

Attachment 2

USLE Calculations Output

Soil Loss Calculation
Solve for the maximum uninterrupted slope length that would cause the greatest erosion on the final cover slope.

Maximum Allowable Slope-Length Factor Using Revised Universal Soil Loss Equation

A = R*K*LS*C*P

	Value	Unit	Description	Assumption	Source
R	141		Rainfall Runoff Erosivity Factor	Total erosivity for a year	USEPA Rainfall Erosivity Calculator
K	0.43		Soil Erodibility Factor	Average value for Topsoil	NRCS Web Soil Survey
LS	10.00		Slope Length Factor	Greatest erosive undrained slope 120' at 33% slope	Interporated from Slope Length Table (attached)
C	0.003		Cover Management Factor	Hay & pasture with no-till	OMAFRA RUSLE Fact Sheet
P	1.0		Erosion Control Support Factor	A value of 1.0 reflects no specific practice is assumed.	OMAFRA RUSLE Fact Sheet
A	**1.82**	**Tons/Ac/Year**	**Average Annual Soil Loss**	**Calculated based on the Universal Soil Loss Equation**	**USDA AH-527 pg. 5**

The approximate soil loss each year is 1.82 Tons per acre per year
Average Annual Soil Loss Value is less than max rate of 2 ton/ac/year

Attachment 3

USDA SCS National Engineering Handbook References

United States
Department of
Agriculture

**Soil
Conservation
Service**

National Engineering Handbook

Section 3

Sedimentation

Chapter 3

Erosion

Contents

Figures

Tables

Chapter 3
Erosion

General

Erosion consists of a series of complex and interrelated natural processes that loosen or dissolve and move earth or rock material. The land surface is worn away through the detachment and transport of soil and rock materials by moving water, wind, or other geologic agents.

Erosion can be divided into two categories according to the conditions under which it occurs. The first category is normal (geologic) erosion, which has been occurring at variable rates, depending on climatic and terrestrial conditions, since the first solid materials formed on earth. Geologic erosion is extremely slow in most places. It is, in fact, an important process in soil formation. The underlying rock is attacked by air and water, and fragments are detached, decomposed, or dissolved. This process is termed weathering. Generally, a rough equilibrium is reached in natural environments between geologic erosion and soil formation. The rates of normal upland erosion and soil formation are determined mainly by climate, parent rocks, soil, precipitation, topography, and vegetal cover.

The second category is accelerated erosion caused by the activities of man. Accelerated erosion has been defined as "erosion occurring at a rate greater than normal for the site, usually through reduction of a vegetal cover" (Roehl 1965). Deforestation, cultivation, and destruction of vegetation accelerate erosion. Soil that normally would take 100 years to be eroded may vanish in 1 year or even a single day (United Nations 1953).

Both categories of erosion can be subdivided into two types: sheet and channel. This classification is helpful in (1) estimating the amount of erosion and sediment yield, (2) determining the relative importance of sediment sources, (3) formulating treatment measures to reduce erosion and sediment yield, and (4) evaluating the effectiveness of treatment measures.

In planning programs to reduce erosion and sediment yield, it is most important that the various types of erosion be thoroughly investigated as sources of sediment. Proper conservation practices and land stabilization measures can then be planned and applied.

Sheet erosion, which includes rill erosion, is the removal of soil or earth material from the land surface by the forces of raindrop impact, overland runoff, or wind. Although it occurs on all land surfaces, sheet erosion is particularly active on cultivated areas of mild slope where the runoff is not concentrated in well-defined channels but consists largely of overland flow. The numerous small but conspicuous rills caused by minor concentration of runoff are obliterated by normal field cultivation. This type of erosion occurs gradually over large areas as though the soil were removed in sheets (Bennett 1939, p. 92–115).

Materials derived from sheet erosion are fine grained because overland flow, which is usually laminar, seldom exceeds a velocity of 2 or 3 ft/s. Flow of this low velocity can transport only the fine particles detached by raindrop impact. Ellison (1945) reported a grain-size diameter of less than 0.05 mm for 95 percent of the sediment in prechannel runoff from a silt loam soil in Ohio.

Factors Involved

The basic factors in sheet erosion are rainfall, soil properties, slope length, slope gradient, and kind and condition of cover. Several equations incorporating these factors can be used to obtain a quantitative estimate of the amount of soil material moved by sheet erosion. These equations, originally developed for the humid areas east of the Rocky Mountains, are particularly well suited for determining the effects of land treatment measures on erosion.

Equations

From the late 1940's until 1972, SCS geologists, who are responsible for estimating yield, used the Musgrave Equation to compute the amount of sheet and rill erosion in a watershed. The Musgrave Equation was part of one of several procedures used to estimate sediment yield. Additional research on erosion resulted in the development of the Universal Soil Loss Equation (USLE) by the Agricultural Research Service (ARS) in cooperation with SCS and certain State experiment stations. In September 1972 the Musgrave Equation was replaced by the USLE for computing sheet erosion for project areas.

Both the Musgrave Equation and the USLE are empirical formulas in which sediment yield from subacre test plots is defined as "erosion" or "soil loss." The computed soil loss from large areas is usually greater than the sediment yield from the same area, and the larger the area, the greater the discrepancy between computed soil loss and sediment yield. Neither equation allows for deposition on upland areas. Soil loss computed by these equations represents nothing that can be located or measured in the field. It therefore is an abstract figure that must not be confused with sediment yield. Computed soil loss, however, is a valuable tool for comparing the soil loss from different areas or the effects of different land treatments on a given area.

The USLE initially was used only for cropland, hayland, and pastures in rotation, because erosion factors reflecting the effect of cover on uncultivated land areas were not available. Because the USLE had been used in much of the country as a tool in planning land treatment on individual operating units, use of this equation with its refined data was recommended for watersheds and other project areas in which SCS has responsibilities. Before this could be done, however, additional plant-cover factors (C) had to be determined for permanent pastureland, rangeland, woodland, and idle land to estimate the effect of these types of cover on soil losses.

In November 1971, SCS and ARS personnel tentatively agreed on the factors for types of cover on uncultivated lands, and subsequent analyses by ARS provided values for them. These factors are used in the USLE to estimate sheet and rill erosion for work in SCS projects such as watersheds, river basin studies, and resource conservation and development (RC&D).

The complete Universal Soil Loss Equation is

$$A = RKLSCP$$

where

A = the computed annual soil loss (sheet and rill erosion) in tons per acre. A is not the sediment yield.

R = the rainfall factor: the number of erosion index units in a normal year's rain.

K = the soil erodibility factor: the erosion rate per erosion index unit for a specific soil in cultivated continuous fallow on

9-percent slope 72.6 ft long.

L = the slope length factor: the ratio of the soil loss from the field slope length to that from a 72.6-ft length on the same soil type and gradient.

S = The slope gradient factor: the ratio of the soil loss from the field gradient to that from a 9-percent slope on the same soil type and slope length.

C = the cropping management factor: the ratio of the soil loss from a field with specified cropping and management to that from the fallow condition from which the K factor is evaluated.

P = the erosion control practice factor: the ratio of the soil loss with contouring, contour stripcropping, or contour-irrigated furrows to that with straight-row farming, upslope and downslope.

Rainfall Factor (R)

The energy of moving water detaches and transports soil materials. The energy intensity (EI) value is the product of the total raindrop energy of a storm and the maximum 30-min intensity. Soil losses are linearly proportional to the number of EI units. The EI values of the storms from a 22-year (maximum) record were summed to obtain an average annual rainfall-erosion index for a given location. This annual index serves as the R factor and can be obtained from figure 3–1, which is figure 1 in Agriculture Handbook 537 (Wischmeier and Smith 1978). This handbook also includes a procedure for determining the effect of snowmelt on the R factor.

Soil Erodibility Factor (K)

The resistance of a soil surface to erosion is a function of the soil's physical and chemical properties. The soil properties most significantly affecting soil erodibility are texture, organic-matter content, structure, and permeability. The K values assigned to named soils can be obtained from soil scientists, technical guides, or published lists.

Slope Length (L) and Slope Gradient (S)

Soil loss is affected by both length and degree of slope. For convenience in field application, these two factors are combined into a single topographic factor, LS.

The LS factor for a gradient as much as 50 percent and a slope length as much as 1,000 ft is obtained from the slope-effect chart (fig. 3–2). Similar data appear in tabular form in table 3–1. Values shown on the chart and table for slopes of less than 3 percent, greater than 20 percent, or longer than 400 feet are extrapolations of the formula to cover conditions beyond the range of research data. Computed soil loss determined from these LS values may need to be adjusted on the basis of experience and judgment.

Plant Cover or Cropping Management Factor (C)

The erosion equation, as applied to cropland and hayland, uses established factor relationships to estimate a basic soil loss that is determined by soil properties, topographic features, certain conservation practices, and expected rainfall patterns for a specific field. The basic soil loss is the rate at which the field would erode if it were continuously in tilled fallow. The C factor value indicates the percentage of this potential soil loss that would occur if the surface were partially protected by a particular combination of cover and management practices. Musgrave cover factors cannot be substituted for the C factor in the USLE because different base conditions were used to develop the cover factors (tilled continuous fallow for the USLE as opposed to uphill and downhill row crops for the Musgrave Equation).

Use of the C factor in other situations depends on three distinct but interrelated zones of influence: vegetal cover in direct contact with the soil surface, canopy cover, and the surface and beneath it.

C factor for cropland and hayland.—The C factor measures the effects of cropping sequences, cover, and management on soil losses from cropland and hayland. It is computed, on a local basis, for conventional and conservation (minimum-tillage) farming systems.

C factor for permanent pasture, grazed forest land, range, and idle land.—The effects of the three zones of influence are used in estimating the C factor for permanent pasture, grazed forest land, range, and idle land. The C factors are given in table 3–2.

C factor for forest land.—Permanent (undisturbed) forest land differs in several respects from the land for which C-factor values are given in table 3–2. A layer of compacted decaying duff or litter is extremely effective against water erosion. Research data, although limited, support a C value

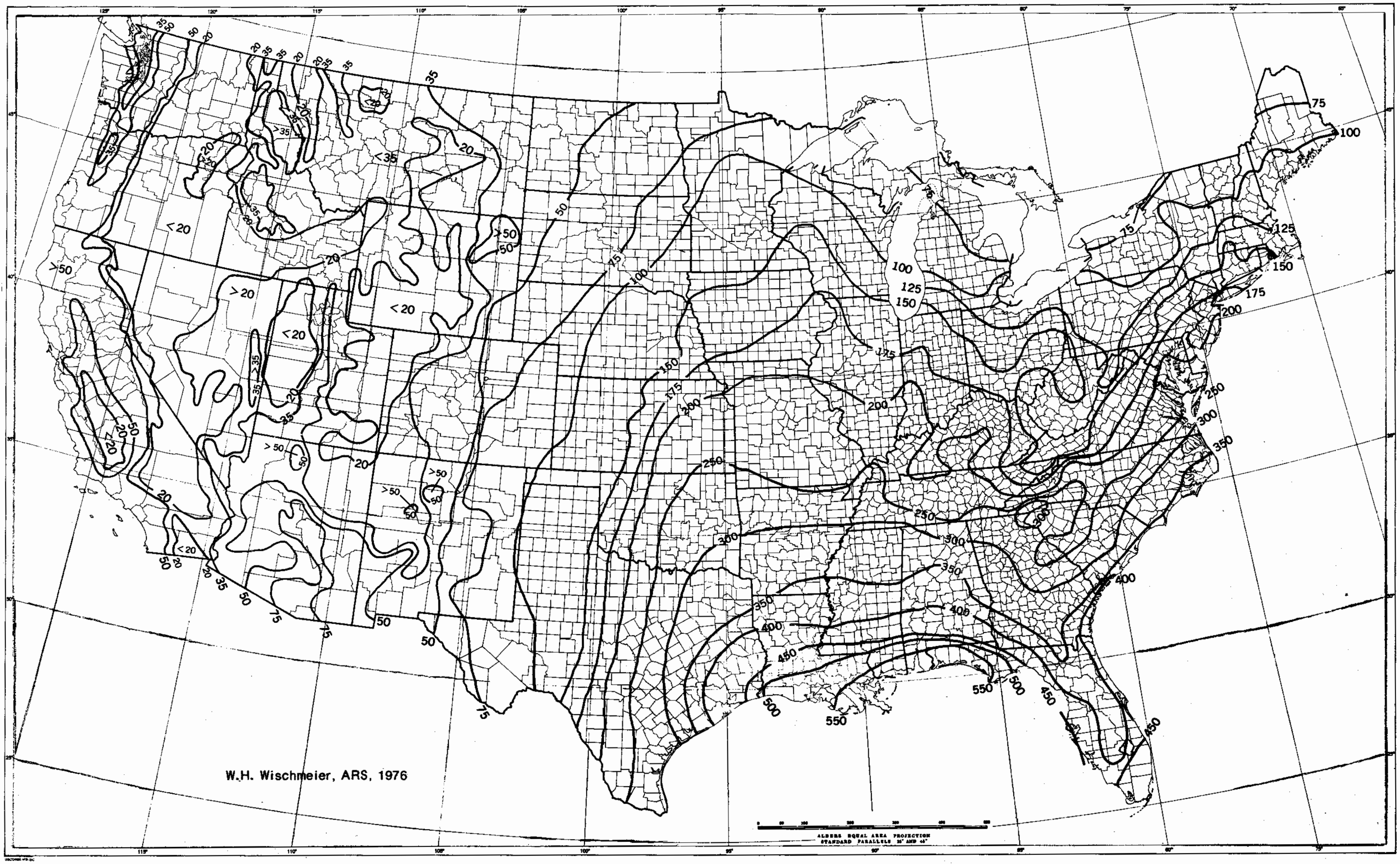
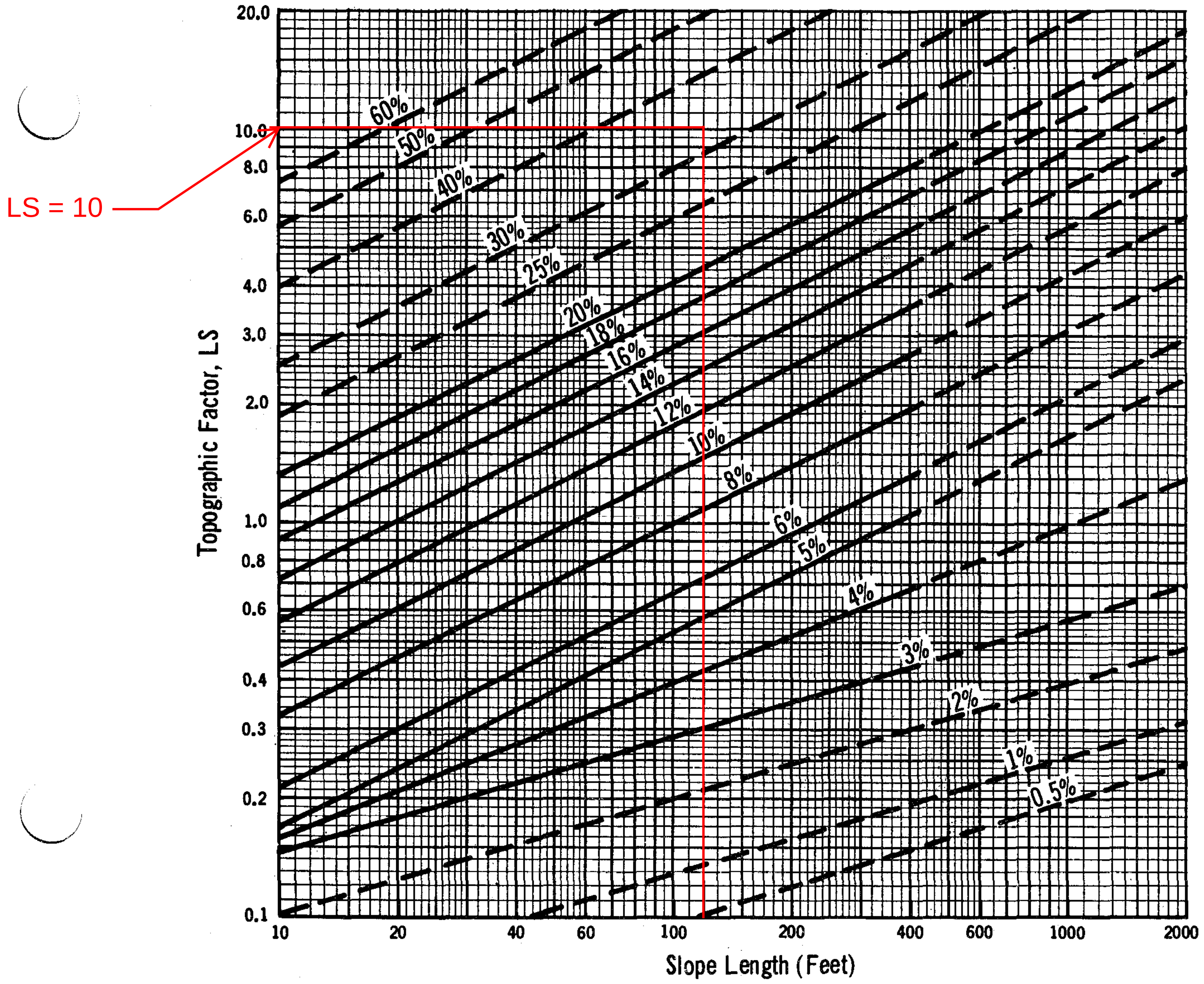


Figure 3-1.—Average annual values of the R factor.



*The dashed lines represent estimates for slope dimensions beyond the range of lengths and steepnesses for which data are available. The curves were derived by the formula:

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{430x^2 + 30x + 0.43}{6.57415}\right)$$

where λ = field slope length in feet and m = 0.5 if s = 5% or greater, 0.4 if s = 4%, and 0.3 if s = 3% or less; and x = sin θ. θ is the angle of slope in degrees.

Figure 3–2.—Slope-effect chart (topographic factor, LS).

Table 3-1.—Values of the topographic factor, LS for specific combinations of slope length and steepness[1]

Percent slope	Slope length (feet)											
	25	50	75	100	150	200	300	400	500	600	800	1,000
0.2	0.060	0.069	0.075	0.080	0.086	0.092	0.099	0.105	0.110	0.114	0.121	0.126
0.5	.073	.083	.090	.096	.104	.110	.119	.126	.132	.137	.145	.152
0.8	.086	.098	.107	.113	.123	.130	.141	.149	.156	.162	.171	.179
2	.133	.163	.185	.201	.227	.248	.280	.305	.326	.344	.376	.402
3	.190	.233	.264	.287	.325	.354	.400	.437	.466	.492	.536	.573
4	.230	.303	.357	.400	.471	.528	.621	.697	.762	.820	.920	1.01
5	.268	.379	.464	.536	.656	.758	.928	1.07	1.20	1.31	1.52	1.69
6	.336	.476	.583	.673	.824	.952	1.17	1.35	1.50	1.65	1.90	2.13
8	.496	.701	.859	.992	1.21	1.41	1.72	1.98	2.22	2.43	2.81	3.14
10	.685	.968	1.19	1.37	1.68	1.94	2.37	2.74	3.06	3.36	3.87	4.33
12	.903	1.28	1.56	1.80	2.21	2.55	3.13	3.61	4.04	4.42	5.11	5.71
14	1.15	1.62	1.99	2.30	2.81	3.25	3.98	4.59	5.13	5.62	6.49	7.26
16	1.42	2.01	2.46	2.84	3.48	4.01	4.92	5.68	6.35	6.95	8.03	8.98
18	1.72	2.43	2.97	3.43	4.21	4.86	5.95	6.87	7.68	8.41	9.71	10.9
20	2.04	2.88	3.53	4.08	5.00	5.77	7.07	8.16	9.12	10.0	11.5	12.9

[1] $LS = (\lambda/72.6)^m (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065)$ where λ = slope length in feet; m = 0.2 for gradients <1 percent, 0.3 for 1- to 3-percent slopes, 0.4 for 3.5- to 4.5-percent slopes, 0.5 for 5-percent slopes and steeper; and θ = angle of slope. (For other combinations of length and gradient, interpolate between adjacent values.)

as low as 0.0001 for woodland with a 100-percent duff cover. Values of the C factor for undisturbed forest land are given in table 3-3. Table 3-4 gives values for forest land that has been harvested and cropland that has been converted to woodland, both of which required some mechanical preparation for planting.

Tables 3-2, 3-3, and 3-4 provide a wide range of values for the C factor. Although some land situations may not fit neatly in any of the three general categories, a representative C factor for most situations can be obtained from these tables.

Erosion Control Practice Factor (P)

The P factor measures the effect of control practices that reduce the erosion potential of the runoff by their influence on drainage patterns, runoff concentration, and runoff velocity. Practices for which P factors have been established are contouring and contour stripcropping. The latter values are also used for contour-irrigated furrows. In contour stripcropping, strips of sod or meadow are alternated with strips of row crops or small grains. Terraces and diversions, where used, reduce the length of slope. The P values for computing sediment yield reduction for terraces and diversions are given in table 3-5.

Water Quality and Sediment Yield

The computed soil loss for large areas is not sediment yield, and it is not directly related to water quality. Overland sediment transport is a complex process of transport and deposition. The USLE estimates the transport component and specifically excludes the deposition component. For example, only 5 percent of the computed soil loss may appear as sediment yield in a drainage area of 500 mi^2. The remaining 95 percent is redistributed and deposited on uplands or flood plains and is not a net soil loss from the area. Procedures for computing sediment yield are given in Chapter 6.

Example of Use of USLE in Watershed Planning

Assume a watershed area of 600 acres above a proposed floodwater-retarding structure in Fountain County, Ind. (fig. 3-3). Compute the average annual soil loss from sheet erosion for present conditions and that for future conditions after the recommended land treatment has been applied on all land in the watershed.

Present conditions.—Cropland: 280 acres of continuous corn with residue removed, cultivated upslope and downslope, average yield of 70 bu/acre; soil is Fayette silt loam; slopes are 8 percent and 200 ft long.

C = 0.003

Table 3–2.—C factors for permanent pasture, grazed forest land, range, and idle land[1]

Vegetative canopy		Cover that contacts the soil surface						
			Percent ground cover					
Type and height[2]	Percent cover[3]	Type[4]	0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall grass, weeds, or short brush with average drop fall height of 20 in. or less	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[1]The listed C values require that the vegetation and mulch are randomly distributed over the entire area. For grazed forest land multiply these values by 0.7.
[2]Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.
[3]Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).
[4]G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter. W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

R = 185
K = 0.37
LS = 1.4
C = 0.43
P = 1.00

A (annual soil loss) = 185 × 0.37 × 1.4 × 0.43 × 1.0
= 41.2 tons/acre

Pasture: 170 acres; 50 percent of area has canopy cover of short brush (0.5-m [1.6-ft] fall height); 80 percent of surface is covered by grass and grasslike plants; soil is Fayette silt loam; slopes are 8 percent and 200 ft long.

R = 185
K = 0.37
LS = 1.4
C = 0.012

A (annual soil loss) = 185 × 0.37 × 1.4 × 0.012
= 1.15 tons/acre

Forest: 150 acres; 30 percent of area has tree; canopy; 50 percent of surface is covered by litter; undergrowth is unmanaged; soil is Bates silt loam; slopes are 12 percent and 100 ft long.

R = 185
K = 0.32
LS = 1.8
C = 0.009

A (annual soil loss) = 185 × 0.32 × 1.8 × 0.009
= 0.96 ton/acre

Future conditions.—Cropland: 280 acres in rotation of wheat, meadow, corn, corn with residue left, contour stripcropped; soil is Fayette silt loam;

Table 3–3.—C factors for undisturbed forest land[1]

Percentage of area covered by canopy of trees and undergrowth	Percentage of area covered by duff[2]	C factor[3]
100–75	100–90	0.0001–0.001
70–45	85–75	.002 - .004
40–20	70–40	.003 - .009

[1]Where effective litter cover is less than 40 percent or canopy cover is less than 20 percent, use table 3–2. Also use table 3–2 where woodlands are being grazed, harvested, or burned.
[2]Percentage of area covered by duff is dominant. Interpolate on basis of duff, not canopy.
[3]The ranges in listed C values are caused by the ranges in the specified forest litter and canopy covers and by variations in effective canopy heights.

Table 3–4.—C factors for mechanically prepared woodland sites

Site preparation	Mulch cover[1]	Excellent NC	Excellent WC	Good NC	Good WC	Fair NC	Fair WC	Poor NC	Poor WC
	Percent								
Disked, raked, or bedded[4]	None	0.52	0.20	0.72	0.27	0.85	0.32	0.94	0.36
	10	.33	.15	.46	.20	.54	.24	.60	.26
	20	.24	.12	.34	.17	.40	.20	.44	.22
	40	.17	.11	.23	.14	.27	.17	.30	.19
	60	.11	.08	.15	.11	.18	.14	.20	.15
	80	.05	.04	.07	.06	.09	.08	.10	.09
Burned[5]	None	.25	.10	.26	.10	.31	.12	.45	.17
	10	.23	.10	.24	.10	.26	.11	.36	.16
	20	.19	.10	.19	.10	.21	.11	.27	.14
	40	.14	.09	.14	.09	.15	.09	.17	.11
	60	.08	.06	.09	.07	.10	.08	.11	.08
	80	.04	.04	.05	.04	.05	.04	.06	.05
Drum chopped[5]	None	.16	.07	.17	.07	.20	.08	.29	.11
	10	.15	.07	.16	.07	.17	.08	.23	.10
	20	.12	.06	.12	.06	.14	.07	.18	.09
	40	.09	.06	.09	.06	.10	.06	.11	.07
	60	.06	.05	.06	.05	.07	.05	.07	.05
	80	.03	.03	.03	.03	.03	.03	.04	.04

(Soil condition[2] and weed cover[3] spans the Excellent, Good, Fair and Poor columns.)

[1]Percentage of surface covered by residue in contact with the soil.
[2]*Excellent* soil condition—Highly stable soil aggregates in topsoil with fine tree roots and litter mixed in. *Good*—Moderately stable soil aggregates in topsoil or highly stable aggregates in subsoil (topsoil removed during raking), only traces of litter mixed in. *Fair*—Highly unstable soil aggregates in topsoil or moderately stable aggregates in subsoil, no litter mixed in. *Poor*—No topsoil, highly erodible soil aggregates in subsoil, no litter mixed in.
[3]NC—No live vegetation. WC—75-percent cover of grass and weeds having an average drop fall height of 20 in. For intermediate percentages of cover, interpolate between columns.
[4]Modify the listed C values as follows to account for effects of surface roughness and aging. *First year after treatment*: multiply listed C values by 0.40 for rough surface (depressions >6 in.); by 0.65 for moderately rough; and by 0.90 for smooth depressions <2 in.) *For 1 to 4 years after treatment*: multiply listed factors by 0.7. *For 4+ to 8 years*: use table 3–2. *More than 8 years*: use table 3–3.
[5]*For first 3 years*: use C values as listed. *For 3+ to 8 years after treatment*: use table 3–2. *More than 8 years after treatment*: use table 3–3.

slopes are 8 percent and 200 ft long.

$$R = 185$$
$$K = 0.37$$
$$LS = 1.4$$
$$C = 0.119$$
$$P = 0.3$$

$$A \text{ (annual soil loss)} = 185 \times 0.37 \times 1.4 \times 0.119 \times 0.3 = 3.4 \text{ tons/acre}$$

Pasture: 170 acres with improved management; 25 percent of area has canopy cover (4-m [13-m] fall height); ground cover in an area not protected by canopy is increased to 95 percent; soil is Fayette silt loam; slopes are 8 percent and 200 ft long.

$$R = 185$$
$$K = 0.37$$
$$LS = 1.4$$
$$C = 0.003$$
$$P = 0.3$$

$$A \text{ (annual soil loss)} = 185 \times 0.37 \times 1.4 \times 0.003 = 0.29 \text{ ton/acre}$$

Forest: 150 acres with improved management; canopy cover increased to 60 percent; litter cover increased to 80 percent; soil is Bates silt loam; slopes are 12 percent and 100 ft long.

$$R = 185$$
$$K = 0.32$$
$$LS = 1.8$$
$$C = 0.003$$

$$A \text{ (annual soil loss)} = 185 \times 0.32 \times 1.8 \times 0.003 = 0.32 \text{ ton/acre}$$

Summary of average annual soil loss.—Present conditions:

Cropland:	280 acres × 41.2 tons/acre =	11,536 tons/year
Pasture:	170 acres × 1.15 tons/acre =	196 tons/year
Forest:	150 acres × 0.96 ton/acre =	144 tons/year

Future conditions:

Cropland:	280 acres × 3.4 tons/acre =	952 tons/year
Pasture:	170 acres × 0.29 ton/acre =	49 tons/year
Forest:	150 acres × 0.32 ton/acre =	48 tons/year

Table 3-5.—P values for contour-farmed terraced fields[1]

Land slope (percent)	Farm planning: Contour factor[3]	Farm planning: Stripcrop factor	Computing sediment yield[2]: Graded channels, sod outlets	Computing sediment yield[2]: Steep backslope, underground outlets
1 to 2	0.60	0.30	0.12	0.05
3 to 8	.50	.25	.10	.05
9 to 12	.60	.30	.12	.05
13 to 16	.70	.35	.14	.05
17 to 20	.80	.40	.16	.06
21 to 25	.90	.45	.18	.06

[1]Slope length is the horizontal terrace interval. The listed values are for contour farming. No additional contouring factor is used in the computation.

[2]These values include entrapment efficiency and are used for control of offsite sediment within limits and for estimating the field's contribution to watershed sediment yield.

[3]Use these values for control of interterrace erosion within specified soil-loss tolerances.

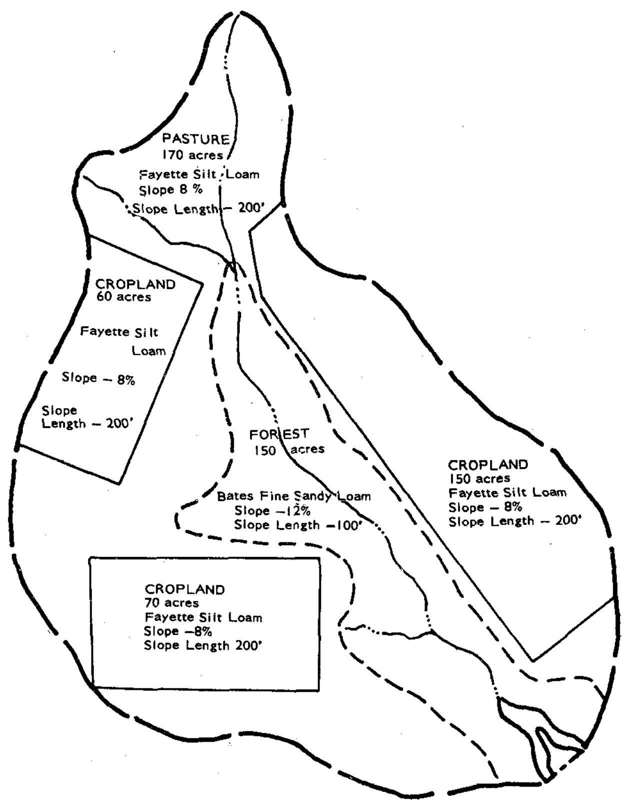


Figure 3-3.—Hypothetical 600-acre watershed used in example.

Enter these values on Form SCS-ENG-309 (Rev. 1974) and follow the procedure set forth in Chapter 8, Sediment-Storage Design Criteria, to obtain the sediment yield at the proposed floodwater-retarding structure.

Channel Erosion

Channel erosion consists of the removal of soil and rock by a concentrated flow of water. Concentrated flow permits a more concerted local attack on the soil and associated materials. Channel erosion includes gully erosion, streambank erosion, streambed degradation, flood-plain scour, valley trenching, and much roadbank erosion.

Factors Involved

Gullies usually follow sheet erosion. They begin in a slight surface depression into which, in time, the concentrated flow cuts a channel a foot or more deep. The shape of the channel is usually determined by the relative resistance of the soil.

Streambank erosion and bed degradation are affected primarily by the bank materials and the resistance of the channel bottom to the character and direction of flow. Removal of the natural vegetation from streambanks increases bank erosion. The presence of coarse bed material that a stream cannot pick up during reduced flows results in an attack on the banks by the flowing water.

When estimating long-term streambank erosion, keep in mind that bank erosion is a natural process and occurs even on streams that tend to maintain a long-term constant width. On these streams, bank erosion is offset by less obvious deposition and accretion. Therefore, streams of this type are not primary sources of sediment.

Streambed erosion is not a significant long-term sediment source because the material subject to this type of erosion is limited in both extent and volume. Compared with other potential sources of sediment, streambed erosion usually is minor.

Flood-plain scour is the removal of flood-plain soil by flows sweeping across the flood plain. It may occur in the form of channelization or sheet removal of the surface soil. This form of sheet erosion cannot be computed by the USLE or similar equations.

Computation Procedures

Methods of determining soil loss by the various types of channel erosion are: (1) comparing aerial photographs of different dates to determine the annual growth rate of channels; (2) rerunning existing cross sections to determine the difference in total channel cross-sectional area; (3) assembling historical data to determine the average age of channels and their average annual growth; and (4) making field studies to estimate the average annual growth rate (volume per unit length of channel).

Formulas for computing annual channel erosion from data obtained in these determinations are:

For bank erosion

$$S = H \times L \times R$$

where

S = annual soil loss from streambank erosion (cubic feet).
H = average height of bank (feet).
L = length of bank being eroded, each side of channel (feet).
R = annual rate of bank recession (feet).

Example: If H = 5 ft, L = 1,800 ft, and R = 0.1 ft,[1]

$$S = 5 \text{ ft} \times 1{,}800 \text{ ft} \times 0.1 \text{ ft} = 900 \text{ ft}^3$$

For channel degradation

$$S = W \times L \times R$$

where

S = volume voided by channel degradation (cubic feet).
W = average bottom width of channel (feet).
L = length of channel bottom being eroded (feet).
R = annual rate of degradation (feet).

Example: If W = 20 ft, L = 900 ft, and R = 0.2 ft,[2]

$$S = 20 \text{ ft} \times 900 \text{ ft} \times 0.2 \text{ ft} = 3{,}600 \text{ ft}^3$$

[1] *Annual recession rates of more than 0.1 ft are common on the outside of bends and meanders. This cut-bank recession is usually offset by sediment accretion on the opposite slip-off slope, which results in channel migration with no substantial change in channel width. Significant long-term changes in channel width cannot occur without equally drastic changes in discharge, slope, or depth.*

[2] *An annual degradation rate of 0.2 ft for 100 years (normal project life) would deepen the channel by 20 ft. This rate is not likely to occur in a perennial stream.*

Figure 3–4 is a nomograph that can be used to estimate the volume of material lost annually because of various types of channel erosion. A procedure for calculating gully erosion is presented in more detail in Technical Release No. 32 (Soil Conservation Service 1966).

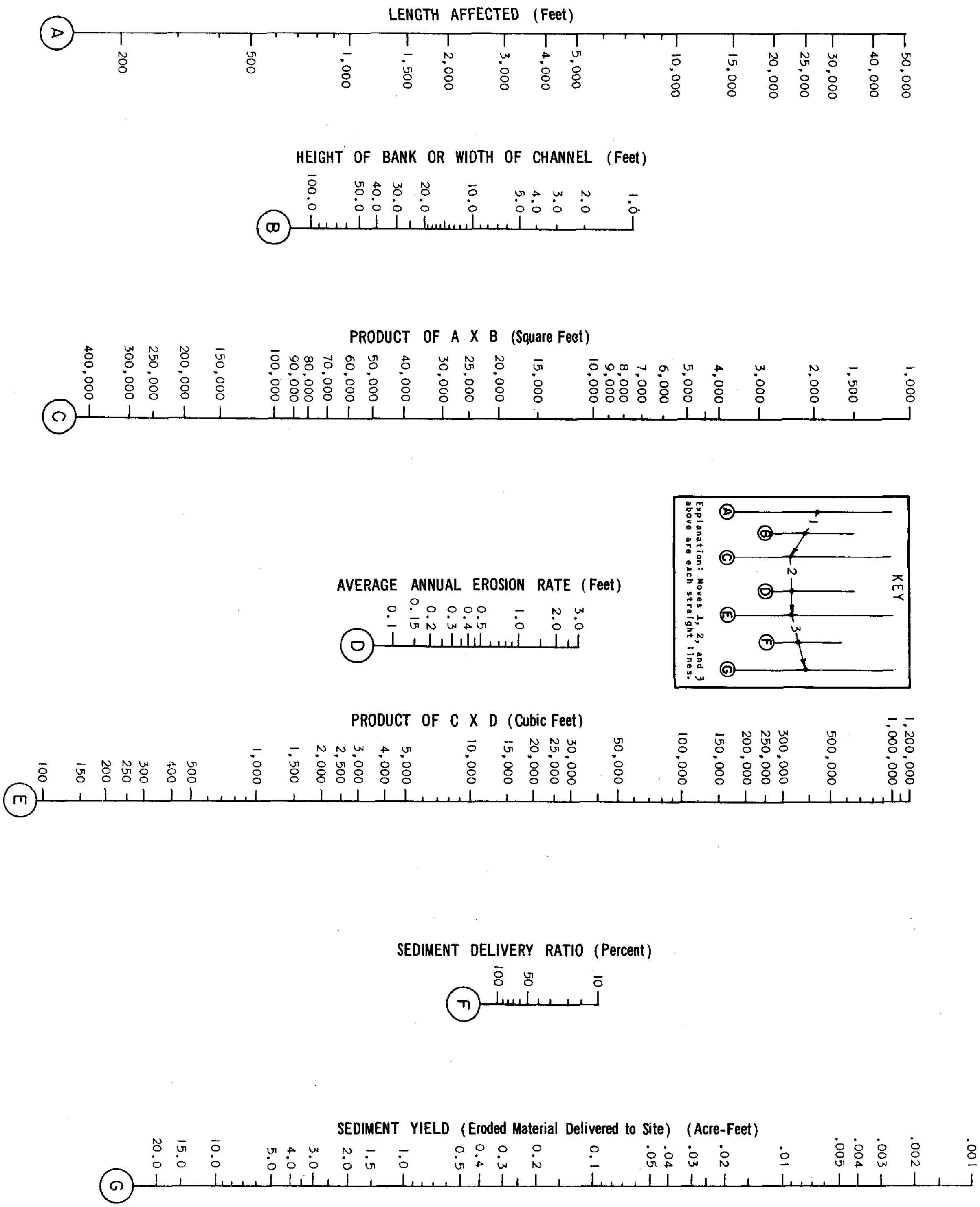


Figure 3–4.—Nomograph for computing average annual gully erosion, streambank erosion, channel entrenchment, and flood-plain scour in acre-feet.

Wind erosion is the detachment and transport of soil material by wind. The process is called deflation, and the resultant deposits are classified as eolian. The rate of erosion depends on the intensity and persistence of the wind, size and availability of soil particles, and amount of protective cover. Dry soil is necessary for maximum deflation rates.

In the United States, the conditions generally most favorable for wind erosion are in semiarid or arid areas west of the 100th meridian, although wind erosion does occur elsewhere. Although water erosion is dominant even in arid areas, wind erosion can approach it in amount in deserts and during periods of intensive drought in other areas.

Eolian deposits are characterized by highly sorted particles, by cross-bedded or lenticular structures, and by dunes oriented by the prevailing winds. A hummocky surface develops when wind-blown sediment lodges around isolated bushes or grass. Fence-line deposits are confined to the area alongside the fence and can be several feet thick.

Deflation areas contain scoured-out depressions or pock-marked surfaces. Such features are usually in exposed places and are not associated with water drainage rills or channels. Remnants of grass or even single pebbles may rest on small pedestals in the eroded zone. Some shrubs or bunches of grass may persist with the root system exposed above ground. In gravelly sands, selective removal of the smaller particles can produce a gravel pavement on the surface.

The amount of deflation can be determined by comparing the voided area with the original ground surface. Measure enough cross sections to delineate an average-sized depression and determine the number of depressions on recent aerial photographs or count the number per unit area.

Wind-deposited materials may have come from outside a watershed. Conversely, a watershed under study may have lost much soil to distant areas. Windblown sediment moves progressively in the direction of the prevailing winds rather than downslope.

The most important aspect of wind erosion to be considered in studies of sediment yield is the deposition of windblown sediment in channels from which it is easily flushed and added to the sediment yield of the watershed. Channels act as natural traps for airborne sediment whether they contain water or not. If eolian deposition in channels is a factor in the watershed being studied, measure the annual volume of deposition. A sampling process will usually be adequate. Unless channel capacity is decreasing because of these deposits, add the volume of these sediments to the sediment yield. The sediment delivery ratio depends on the kind of material. Wind erosion does not occur every year in most areas. Adjust the annual sediment yield rates downward to account for years in which wind erosion does not occur.

In some areas a significant amount of windblown soil may be deposited on snow. During snowmelt the soil is carried by water into streams or drainage ditches. This snow-caught sediment can be measured by pushing metal tubes into the snow and weighing the contents after the snow in the sample melts.

Many factors affect the amount of soil moved by wind erosion. An equation has been developed (Chepil and Woodruff 1963) to predict the average annual soil loss from wind erosion:

$$E = f(I, C, K, L, V)$$

where

E = average annual soil loss (tons per acre).
I = annual soil erodibility (tons per acre).
C = local wind-erosion climatic factor (percent).
K = soil surface roughness (ratio).
L = equivalent width of field (feet).
V = equivalent quantity of vegetal cover (proportionate factor).

Soil erodibility (I) is determined from the percentage of the nonerodible soil fraction greater than 0.84 mm in diameter (Chepil 1962). The local wind-erosion climatic factor (C) is estimated from a wind-erosion climatic map developed by Chepil, Siddoway, and Armbrust (1962). Surface soil roughness (K) is measured in terms of the height of standard ridges spaced at right angles to the wind, with a height-spacing ratio of 1 to 4. The equivalent width of the field (L) is the unsheltered distance along the prevailing wind-erosion direction. The equivalent quantity of vegetation (V) is a proportionate factor determined by the quantity, type, and orientation of the vegetal cover. Instructions for use of these factors, as well as maps, charts, and tables, are in Agriculture Handbook 346 (Agricultural Research Service 1968).

Mass movement includes slumps, mud flows, soil and rock falls, rotational and planar slides, avalanches, and soil creep. Unlike wind and water, mass movement does not carry soil or rock out of the general region in which it formed, but mass movement is often an important factor in soil removal. It can increase or decrease erosion from one source, change a stream channel regime, and alter the drainage area of a watershed.

Factors Involved

Mass movement occurs when shear stress exceeds shear strength. High shear stress can be caused by removal of lateral support; added weight of rain, snow, or talus accumulations; construction or other human activities; transitory earth stresses, such as earthquakes; regional tilting; removal of underlying support; and lateral pressure from water in cracks and caverns, freezing of water, or swelling of clay or anhydrite (Highway Research Board 1958).

Low shear strength can be caused by:

1. Composition. Inherently weak materials such as saturated clay and silt are examples.
2. Texture, such as loose arrangement of particles or roundness of grains.
3. Gross structure, including discontinuities from faults, bedding planes, or joints, or strata inclined toward a free face.
4. Changes resulting from weathering and other physiochemical reactions.
5. Changes in intergranular forces resulting from pore water.
6. Changes in internal structure, such as fissuring in preconsolidated clays or the effect of disturbance or remolding on sensitive materials (Highway Research Board 1958).

Gravity is, of course, the main force in these mass movements. Usually, landslides are precipitated by some combination of the factors listed above. No movement can occur, however, unless the topographic conditions help to create the instability.

Estimation Procedures

No standard procedures for calculating erosion by mass movement have been developed; it must therefore be estimated.

Numerous measurements have been made in the semiarid West to determine the maximum angles at which slopes stand with and without vegetal cover. Nonvegetated talus material stands at gradients between 68 and 80 percent (angles of about 34 to 38 degrees). Vegetated slopes underlain by fine-textured soils derived from the same parent material as the barren talus stand at gradients of as much as 173 percent (angle of 60 degrees). Without vegetation, slopes of fine material would not stand, even at gradients as high as those of coarse talus (Bailey 1941).

The hazard of debris flows can be estimated on the basis of slope. These flows usually originate on slopes of more than 30 percent. The terminal slope of debris flows is between 7 and 10 percent.

A procedure for calculating erosion from mass movement would require measuring the volume of materials moved. For large masses, comparing the findings of a topographic survey of the mass with the original topography (from standard quadrangle sheets if available) provides an estimate of the volume of materials moved. For smaller masses, a grid of hand-auger borings extending into the original soil profile can provide a basis for estimating the volume.

Other types of erosion not described in detail here do occur and must be evaluated if found in areas under study.

Wave Erosion

Caused by wind and water, wave erosion is an important source of sediment along shorelines of oceans, lakes, and rivers. Wave erosion can change shorelines markedly and can be measured in many places (Jones and Rogers 1952, Glymph and Jones 1937). The rate of erosion from wave action can be measured by comparing two sets of aerial photographs taken on different dates, as in estimating channel erosion. Historical data form another basis for estimating wave erosion rates. Unless the shoreline was mechanically shaped during reservoir construction, wave erosion along a reservoir shore can also be determined by comparing the present shore profile with an extrapolation of the slope of the profile above the influence of wave action (fig. 3–5.).

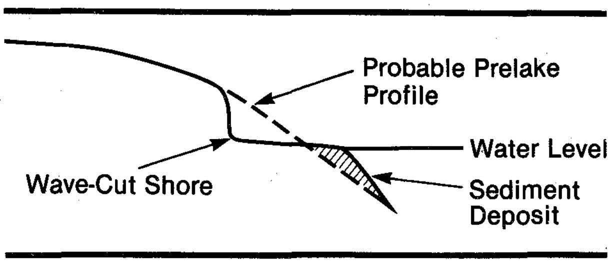


Figure 3–5.—Projecting lines of undisturbed bank to determine probable prelake profile.

Erosion from Strip Mining and Construction

Strip mining or excavating operations and construction of highways, industrial areas, public buildings, housing, shopping centers, and related areas greatly accelerate erosion of exposures and spoil banks. Each condition must be evaluated as a separate problem.

Holeman and Geiger (1959) estimated that the Lake Barcroft, Va., watershed yielded 25 acre-ft of sediment in 1951, when 9 percent of the area (13 mi^2) was under construction, an increase of 21.3 acre-ft over the pre-1938 average annual rate of 3.7 acre-ft. The sediment yield was 16.3 acre-ft/mi^2 for the area under construction and 0.257 acre-ft/mi^2 for the watershed in the earlier period of agricultural use. Before 1938, 18 percent of the watershed was cultivated, 23.5 percent in pasture, 53 percent in woods, and 5.5 percent residential. Construction activities are believed to have increased the sediment yield to more than 63 times the pre-1938 level.

Wolman and Schick (1967) found that the sediment yield in construction areas averaged 72 times that in rural areas. Collier et al. (1964) found that in 1959 a watershed near Somerset, Ky., with 6 percent of its area strip mined, yielded 69 times more sediment than a similar adjacent watershed that was wooded and unmined.

These findings do not mean that areas under construction always yield 70 times the sediment that they would under rural conditions, but the figures do indicate the general size of the increase. In areas undergoing urbanization, the average annual amount of soil exposed can be estimated from such factors as population curves and the number of sewer connections, to determine annual trends.

The USLE is the most promising method for calculating erosion on construction sites or strip-mined areas, but appropriate values for factors of the equation must be carefully selected. Keep in mind that the soil surface is probably not in the same condition as it would be under any agricultural use. The microrelief and soil surface conditions are likely to vary much more over short distances than they do in any agricultural situation. The USLE K values are indexed to "tilled continuous fallow" and a specific microrelief and surface texture that may not be common on construction sites. Topsoil K values are currently determined by use of a nomograph (Wischmeier, Johnson, and Cross 1971). Recent research (Roth, Nelson, and Romkins 1974) indicates that factors other than those considered by Wischmeier et al. may be significant in determining the erodibility of exposed cohesive subsoil.

Sediment yield from construction sites and strip-mined areas can be estimated from the computed erosion and a sediment delivery ratio. Consider projected erosion-control measures realistically when determining the sediment delivery ratio.

Ice Erosion

In watersheds likely to be studied in the SCS small watershed program, erosion by ice probably falls into one of three categories: (1) glacial gouging around the margin of mountain glaciers, (2) erosion by ice along river channels during spring freshets, and (3) erosion by ice shoved along the shores of northern lakes. Ice erosion usually is not an important source of sediment.

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Attachment 4

Web Soil Survey

United States Department of Agriculture

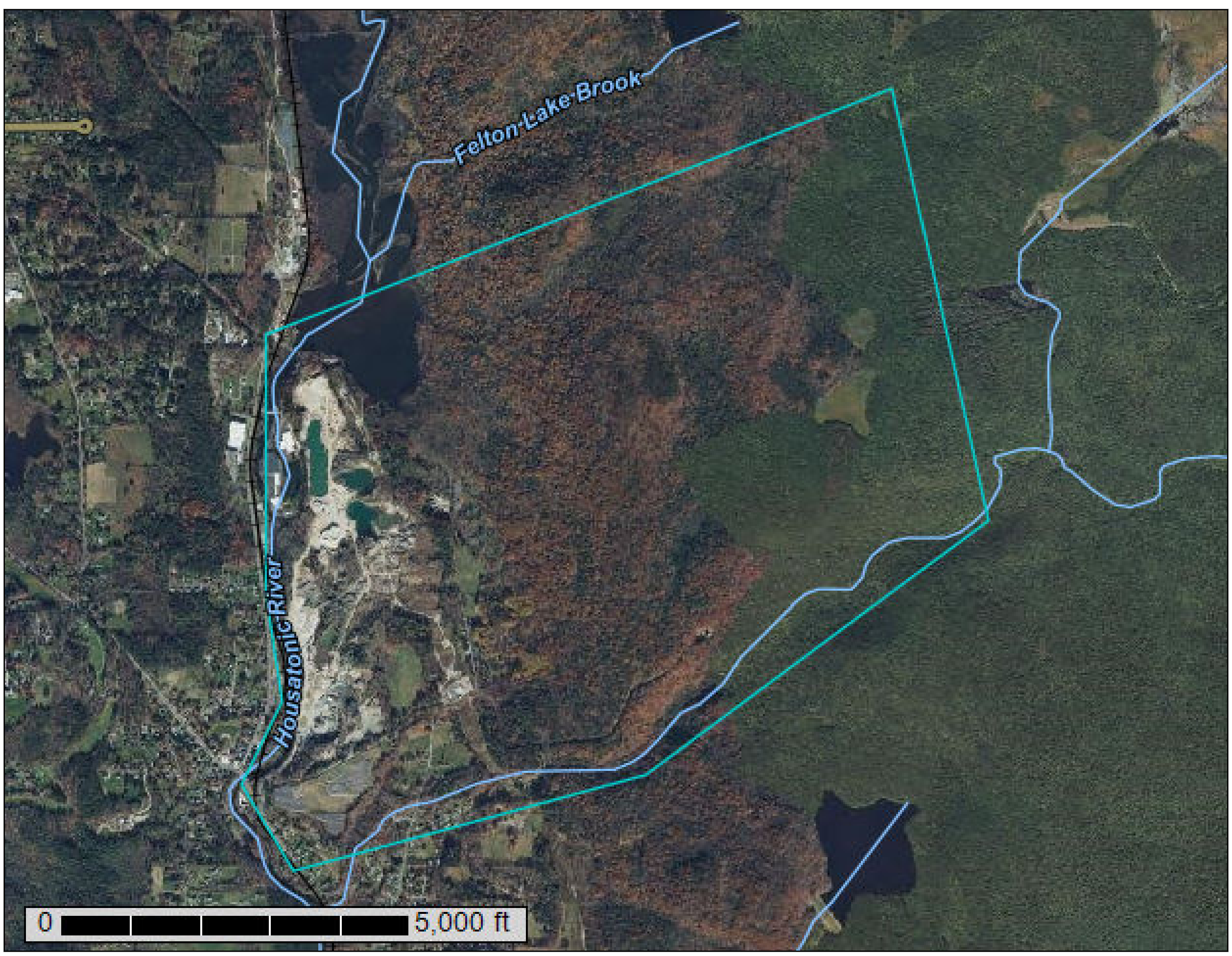
NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Berkshire County, Massachusetts



September 27, 2023

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

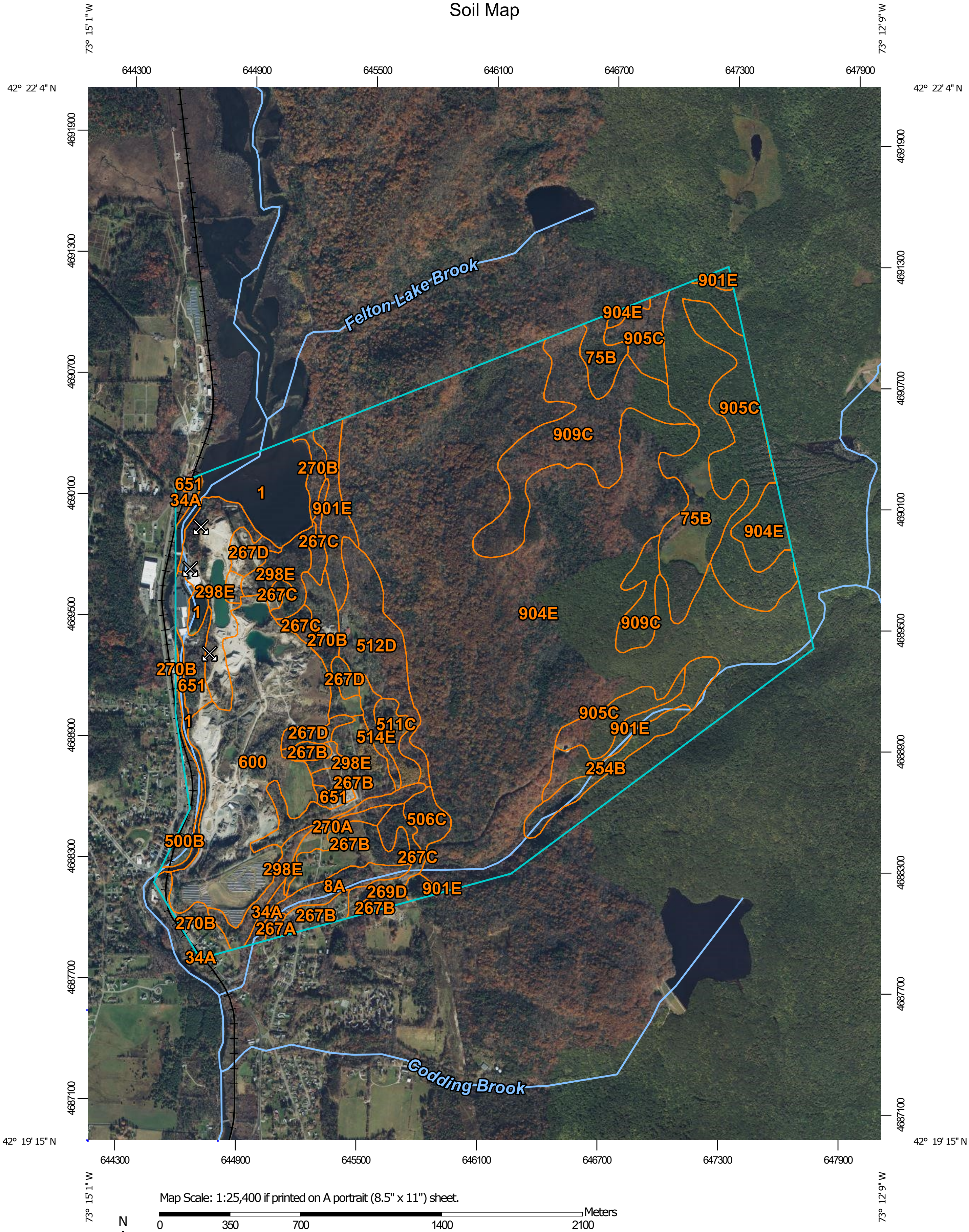
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map



Map Scale: 1:25,400 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 350, 700, 1400, 2100

Feet: 0, 1000, 2000, 4000, 6000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Berkshire County, Massachusetts
Survey Area Data: Version 17, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 15, 2021—Nov 8, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Cwater	61.3	3.4%
8A	Limerick silt loam, 0 to 3 percent slopes, frequently flooded	16.1	0.9%
34A	Fredon fine sandy loam, 0 to 3 percent slopes	7.4	0.4%
75B	Pillsbury fine sandy loam, 0 to 8 percent slopes, very stony	107.9	6.1%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	19.7	1.1%
267A	Copake fine sandy loam, 0 to 3 percent slopes	1.4	0.1%
267B	Copake fine sandy loam, 3 to 8 percent slopes	74.4	4.2%
267C	Copake fine sandy loam, 8 to 15 percent slopes	30.8	1.7%
267D	Copake fine sandy loam, 15 to 25 percent slopes	19.5	1.1%
269D	Groton gravelly sandy loam, 15 to 25 percent slopes	3.5	0.2%
270A	Hero loam, 0 to 3 percent slopes	9.4	0.5%
270B	Hero loam, 3 to 8 percent slopes	38.6	2.2%
298E	Groton and Hinckley soils, 25 to 35 percent slopes	85.4	4.8%
500B	Amenia silt loam, 3 to 8 percent slopes	12.3	0.7%
506C	Nellis loam, 8 to 15 percent slopes, very stony	10.9	0.6%
511C	Pittsfield loam, 8 to 15 percent slopes, very stony	11.3	0.6%
512D	Pittsfield loam, 15 to 25 percent slopes, extremely stony	49.2	2.8%
514E	Pittsfield and Nellis loams, 25 to 35 percent slopes, extremely stony	7.7	0.4%
600	Pits, gravel	168.7	9.5%
651	Udorthents, smoothed	22.1	1.2%
901E	Berkshire-Marlow association, 15 to 45 percent slopes, extremely stony	51.4	2.9%
904E	Lyman-Tunbridge association, 15 to 60 percent slopes, extremely stony	755.4	42.4%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
905C	Peru-Marlow association, 3 to 15 percent slopes, extremely stony	112.7	6.3%
909C	Tunbridge-Lyman association, 3 to 15 percent slopes, extremely stony	106.2	6.0%
Totals for Area of Interest		**1,783.3**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Berkshire County, Massachusetts

1—Cwater

Map Unit Setting

National map unit symbol: 98sq
Mean annual precipitation: 32 to 52 inches
Mean annual air temperature: 37 to 50 degrees F
Farmland classification: Not prime farmland

Map Unit Composition

Cwater: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

8A—Limerick silt loam, 0 to 3 percent slopes, frequently flooded

Map Unit Setting

National map unit symbol: 2zvd3
Elevation: 50 to 500 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Limerick and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Limerick

Setting

Landform: Alluvial flats
Landform position (two-dimensional): Toeslope
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Coarse-silty alluvium

Typical profile

H1 - 0 to 10 inches: silt loam
H2 - 10 to 34 inches: silt loam
H3 - 34 to 65 inches: very fine sandy loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 6 to 10 inches
Frequency of flooding: Frequent

Frequency of ponding: None
Available water supply, 0 to 60 inches: Very high (about 13.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: B/D
Ecological site: F144BY120ME - Small Floodplain Riparian Complex (reserved), F144BY110ME - Broad Floodplain Riparian Complex
Hydric soil rating: Yes

Minor Components

Pootatuck

Percent of map unit: 5 percent

Saco

Percent of map unit: 5 percent
Landform: Alluvial flats
Hydric soil rating: Yes

Winooski

Percent of map unit: 5 percent
Hydric soil rating: No

34A—Fredon fine sandy loam, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 98t1
Elevation: 250 to 1,200 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Fredon and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Fredon

Setting

Landform: Depressions
Landform position (two-dimensional): Footslope
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Friable coarse-loamy eolian deposits over loose sandy and gravelly glaciofluvial deposits derived from slate and/or loose sandy glaciofluvial deposits derived from slate

Typical profile

H1 - 0 to 8 inches: fine sandy loam
H2 - 8 to 26 inches: fine sandy loam
H3 - 26 to 64 inches: stratified sand to loamy fine sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: About 6 to 12 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: B/D
Ecological site: F144BY303ME - Acidic Swamp
Hydric soil rating: Yes

Minor Components

Halsey

Percent of map unit: 10 percent
Landform: Depressions
Hydric soil rating: Yes

Hero

Percent of map unit: 5 percent
Hydric soil rating: No

75B—Pillsbury fine sandy loam, 0 to 8 percent slopes, very stony

Map Unit Setting

National map unit symbol: 2ty6x
Elevation: 360 to 2,070 feet
Mean annual precipitation: 31 to 95 inches
Mean annual air temperature: 27 to 52 degrees F
Frost-free period: 90 to 140 days
Farmland classification: Not prime farmland

Map Unit Composition

Pillsbury, very stony, and similar soils: 79 percent
Minor components: 21 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pillsbury, Very Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainbase, base slope, interfluve
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Loamy lodgment till derived from gneiss and/or loamy lodgment till derived from mica schist and/or loamy lodgment till derived from granite

Typical profile

Oe - 0 to 1 inches: mucky peat
A - 1 to 6 inches: fine sandy loam
Bg1 - 6 to 13 inches: cobbly fine sandy loam
Bg2 - 13 to 23 inches: cobbly fine sandy loam
Cd - 23 to 65 inches: cobbly fine sandy loam

Properties and qualities

Slope: 0 to 8 percent
Surface area covered with cobbles, stones or boulders: 1.1 percent
Depth to restrictive feature: 21 to 43 inches to densic material
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.01 to 1.42 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 3.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: D
Ecological site: F144BY305ME - Wet Loamy Flat
Hydric soil rating: Yes

Minor Components

Peru, very stony

Percent of map unit: 9 percent
Landform: Mountains, hills
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Mountainbase, interfluve, base slope
Microfeatures of landform position: Rises, rises
Down-slope shape: Convex
Across-slope shape: Linear, convex
Hydric soil rating: No

Peacham, very stony

Percent of map unit: 5 percent
Landform: Hills, mountains
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainbase, base slope, interfluve
Microfeatures of landform position: Closed depressions, closed depressions

Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Wonsqueak

Percent of map unit: 4 percent
Landform: Hills, mountains
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainbase, base slope, interfluve
Microfeatures of landform position: Closed depressions, closed depressions
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Lyman, very stony

Percent of map unit: 3 percent
Landform: Mountains, hills
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Mountainbase, interfluve, base slope
Microfeatures of landform position: Rises, rises
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

254B—Merrimac fine sandy loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 2tyqs
Elevation: 0 to 1,290 feet
Mean annual precipitation: 36 to 71 inches
Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 140 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Merrimac and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Merrimac

Setting

Landform: Outwash plains, outwash terraces, moraines, eskers, kames
Landform position (two-dimensional): Backslope, footslope, summit, shoulder
Landform position (three-dimensional): Side slope, crest, riser, tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy glaciofluvial deposits derived from granite, schist, and gneiss over sandy and gravelly glaciofluvial deposits derived from granite, schist, and gneiss

Typical profile

Ap - 0 to 10 inches: fine sandy loam
Bw1 - 10 to 22 inches: fine sandy loam
Bw2 - 22 to 26 inches: stratified gravel to gravelly loamy sand
2C - 26 to 65 inches: stratified gravel to very gravelly sand

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat excessively drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to very high (1.42 to 99.90 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 2 percent
Maximum salinity: Nonsaline (0.0 to 1.4 mmhos/cm)
Sodium adsorption ratio, maximum: 1.0
Available water supply, 0 to 60 inches: Low (about 4.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2s
Hydrologic Soil Group: A
Ecological site: F145XY008MA - Dry Outwash
Hydric soil rating: No

Minor Components

Sudbury

Percent of map unit: 5 percent
Landform: Deltas, terraces, outwash plains
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Tread, dip
Down-slope shape: Concave
Across-slope shape: Linear
Hydric soil rating: No

Hinckley

Percent of map unit: 5 percent
Landform: Deltas, kames, eskers, outwash plains
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Nose slope, side slope, crest, head slope, rise
Down-slope shape: Convex
Across-slope shape: Convex, linear
Hydric soil rating: No

Windsor

Percent of map unit: 3 percent
Landform: Outwash terraces, dunes, deltas, outwash plains
Landform position (two-dimensional): Shoulder
Landform position (three-dimensional): Tread, riser
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex

Hydric soil rating: No

Agawam

Percent of map unit: 2 percent
Landform: Outwash plains, outwash terraces, moraines, stream terraces, eskers, kames
Landform position (three-dimensional): Rise
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

267A—Copake fine sandy loam, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 98sr
Elevation: 570 to 1,340 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Copake and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Copake

Setting

Landform: Ridges
Landform position (two-dimensional): Summit
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over loose sandy glaciofluvial deposits derived from limestone and/or loose sandy and gravelly glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 4 inches: fine sandy loam
H2 - 4 to 26 inches: gravelly fine sandy loam
H3 - 26 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches

Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 1
Hydrologic Soil Group: A
Ecological site: F144AY044VT - Semi-Rich Well Drained Outwash
Hydric soil rating: No

Minor Components

Hero

Percent of map unit: 7 percent
Hydric soil rating: No

Groton

Percent of map unit: 5 percent
Hydric soil rating: No

Fredon

Percent of map unit: 3 percent
Landform: Terraces
Hydric soil rating: Yes

267B—Copake fine sandy loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 98ss
Elevation: 560 to 1,390 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Copake and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Copake

Setting

Landform: Ridges
Landform position (two-dimensional): Shoulder
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over loose sandy and gravelly glaciofluvial deposits derived from limestone and/or loose sandy glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 4 inches: fine sandy loam
H2 - 4 to 26 inches: gravelly fine sandy loam
H3 - 26 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: A
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Groton

Percent of map unit: 5 percent
Hydric soil rating: No

Hero

Percent of map unit: 3 percent
Hydric soil rating: No

Fredon

Percent of map unit: 2 percent
Landform: Terraces
Hydric soil rating: Yes

267C—Copake fine sandy loam, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: 98st
Elevation: 620 to 1,540 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Copake and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Copake

Setting

Landform: Ridges
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over loose sandy glaciofluvial deposits derived from limestone and/or loose sandy and gravelly glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 4 inches: fine sandy loam
H2 - 4 to 26 inches: gravelly fine sandy loam
H3 - 26 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: A
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Groton

Percent of map unit: 6 percent
Hydric soil rating: No

Hero

Percent of map unit: 4 percent
Hydric soil rating: No

267D—Copake fine sandy loam, 15 to 25 percent slopes

Map Unit Setting

National map unit symbol: 98sv
Elevation: 620 to 1,380 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Copake and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Copake

Setting

Landform: Ridges
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over loose sandy and gravelly glaciofluvial deposits derived from limestone and/or loose sandy glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 4 inches: fine sandy loam
H2 - 4 to 26 inches: gravelly fine sandy loam
H3 - 26 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 15 to 25 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: A
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Groton

Percent of map unit: 10 percent
Hydric soil rating: No

Hero

Percent of map unit: 5 percent
Hydric soil rating: No

269D—Groton gravelly sandy loam, 15 to 25 percent slopes

Map Unit Setting

National map unit symbol: 98t6
Elevation: 640 to 1,510 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Groton and similar soils: 95 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Groton

Setting

Landform: Terraces
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over loose sandy and gravelly glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 6 inches: gravelly sandy loam
H2 - 6 to 15 inches: gravelly sandy loam
H3 - 15 to 64 inches: very gravelly sand

Properties and qualities

Slope: 15 to 25 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): High to very high (2.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None

Available water supply, 0 to 60 inches: Low (about 4.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: A
Ecological site: F144BY601ME - Dry Sand
Hydric soil rating: No

Minor Components

Copake

Percent of map unit: 5 percent
Hydric soil rating: No

270A—Hero loam, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 98tb
Elevation: 560 to 1,790 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Hero and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hero

Setting

Landform: Terraces
Landform position (two-dimensional): Toeslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over friable sandy and gravelly glaciofluvial deposits derived from limestone and/or friable sandy glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 8 inches: loam
H2 - 8 to 32 inches: gravelly fine sandy loam
H3 - 32 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained

Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: About 18 to 30 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 5.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydrologic Soil Group: B
Ecological site: F144BY505ME - Loamy over Sandy, F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Copake

Percent of map unit: 6 percent
Hydric soil rating: No

Fredon

Percent of map unit: 4 percent
Landform: Terraces
Hydric soil rating: Yes

270B—Hero loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 98tc
Elevation: 620 to 1,620 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Hero and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hero

Setting

Landform: Terraces
Landform position (two-dimensional): Toeslope
Down-slope shape: Convex
Across-slope shape: Convex

Parent material: Friable coarse-loamy eolian deposits over friable sandy glaciofluvial deposits derived from limestone and/or friable sandy and gravelly glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 8 inches: loam
H2 - 8 to 32 inches: gravelly fine sandy loam
H3 - 32 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: About 18 to 30 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 5.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: B
Ecological site: F144BY505ME - Loamy over Sandy, F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Copake

Percent of map unit: 12 percent
Hydric soil rating: No

Fredon

Percent of map unit: 3 percent
Landform: Terraces
Hydric soil rating: Yes

298E—Groton and Hinckley soils, 25 to 35 percent slopes

Map Unit Setting

National map unit symbol: 2svls
Elevation: 640 to 1,270 feet
Mean annual precipitation: 36 to 71 inches
Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Groton and similar soils: 50 percent
Hinckley and similar soils: 40 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Groton

Setting

Landform: Kames, eskers, outwash terraces
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Crest, head slope, nose slope, side slope, riser
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Sandy and gravelly glaciofluvial deposits derived from limestone and dolomite and/or schist

Typical profile

Ap - 0 to 8 inches: gravelly sandy loam
Bw1 - 8 to 18 inches: very gravelly sandy loam
Bw2 - 18 to 24 inches: very gravelly loamy sand
Bw3 - 24 to 30 inches: very gravelly loamy sand
C1 - 30 to 52 inches: stratified extremely gravelly coarse sand to very gravelly loamy fine sand
C2 - 52 to 72 inches: stratified extremely gravelly coarse sand to gravelly loamy fine sand

Properties and qualities

Slope: 25 to 35 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 10 percent
Available water supply, 0 to 60 inches: Very low (about 2.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: F144BY601ME - Dry Sand
Hydric soil rating: No

Description of Hinckley

Setting

Landform: Outwash deltas, outwash terraces, moraines, eskers, kames, outwash plains, kame terraces
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Nose slope, side slope, crest, head slope, riser

Down-slope shape: Concave, convex, linear
Across-slope shape: Convex, linear, concave
Parent material: Sandy and gravelly glaciofluvial deposits derived from gneiss and/or granite and/or schist

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 8 inches: loamy sand
Bw1 - 8 to 11 inches: gravelly loamy sand
Bw2 - 11 to 16 inches: gravelly loamy sand
BC - 16 to 19 inches: very gravelly loamy sand
C - 19 to 65 inches: very gravelly sand

Properties and qualities

Slope: 25 to 35 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to very high (1.42 to 99.90 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 3.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: F144BY601ME - Dry Sand
Hydric soil rating: No

Minor Components

Merrimac

Percent of map unit: 5 percent
Landform: Outwash plains, kame terraces, outwash terraces, moraines, eskers, kames
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope, crest, head slope, nose slope, riser
Down-slope shape: Concave, convex, linear
Across-slope shape: Convex, linear, concave
Hydric soil rating: No

Copake

Percent of map unit: 5 percent
Landform: Kames, outwash terraces
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Crest, head slope, nose slope, side slope, riser
Down-slope shape: Linear
Across-slope shape: Convex
Hydric soil rating: No

500B—Amenia silt loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 98sc
Elevation: 590 to 1,670 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Amenia and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Amenia

Setting

Landform: Depressions
Landform position (two-dimensional): Shoulder
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Friable coarse-loamy eolian deposits over dense coarse-loamy lodgment till derived from limestone; friable coarse-loamy eolian deposits over dense coarse-loamy lodgment till derived from limestone

Typical profile

H1 - 0 to 8 inches: silt loam
H2 - 8 to 27 inches: silt loam
H3 - 27 to 64 inches: gravelly loam

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 18 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: C
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Stockbridge

Percent of map unit: 7 percent
Hydric soil rating: No

Kendaia

Percent of map unit: 5 percent
Landform: Depressions
Hydric soil rating: Yes

Lyons

Percent of map unit: 3 percent
Landform: Depressions
Hydric soil rating: Yes

506C—Nellis loam, 8 to 15 percent slopes, very stony

Map Unit Setting

National map unit symbol: 98v9
Elevation: 150 to 800 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Nellis and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Nellis

Setting

Landform: Drumlinoid ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over firm coarse-loamy lodgment till derived from limestone

Typical profile

H1 - 0 to 7 inches: loam
H2 - 7 to 32 inches: gravelly loam
H3 - 32 to 64 inches: gravelly loam

Properties and qualities

Slope: 8 to 15 percent
Surface area covered with cobbles, stones or boulders: 1.6 percent
Depth to restrictive feature: More than 80 inches

Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water supply, 0 to 60 inches: Moderate (about 7.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: B
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Amenia

Percent of map unit: 10 percent
Hydric soil rating: No

Farmington

Percent of map unit: 3 percent
Hydric soil rating: No

Kendaia

Percent of map unit: 2 percent
Landform: Depressions
Hydric soil rating: Yes

511C—Pittsfield loam, 8 to 15 percent slopes, very stony

Map Unit Setting

National map unit symbol: 98vv
Elevation: 0 to 1,000 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Pittsfield and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pittsfield

Setting

Landform: Drumlinoid ridges

Landform position (two-dimensional): Backslope, shoulder
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over friable, calcareous coarse-loamy basal till derived from limestone

Typical profile

H1 - 0 to 9 inches: loam
H2 - 9 to 32 inches: fine sandy loam
H3 - 32 to 64 inches: gravelly sandy loam

Properties and qualities

Slope: 8 to 15 percent
Surface area covered with cobbles, stones or boulders: 1.6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 8.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: A
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Amenia

Percent of map unit: 10 percent
Hydric soil rating: No

Farmington

Percent of map unit: 4 percent
Hydric soil rating: No

Kendaia

Percent of map unit: 1 percent
Landform: Depressions
Hydric soil rating: Yes

512D—Pittsfield loam, 15 to 25 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 98vz
Elevation: 0 to 1,000 feet

Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Pittsfield and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pittsfield

Setting

Landform: Drumlinoid ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over friable, calcareous coarse-loamy basal till derived from limestone

Typical profile

H1 - 0 to 9 inches: loam
H2 - 9 to 32 inches: fine sandy loam
H3 - 32 to 64 inches: gravelly sandy loam

Properties and qualities

Slope: 15 to 25 percent
Surface area covered with cobbles, stones or boulders: 9.0 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 8.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: A
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Farmington

Percent of map unit: 6 percent
Hydric soil rating: No

Amenia

Percent of map unit: 4 percent
Hydric soil rating: No

514E—Pittsfield and Nellis loams, 25 to 35 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 98w0
Elevation: 0 to 1,000 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Pittsfield and similar soils: 45 percent
Nellis and similar soils: 40 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pittsfield

Setting

Landform: Drumlinoid ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over friable, calcareous coarse-loamy basal till derived from limestone

Typical profile

H1 - 0 to 9 inches: loam
H2 - 9 to 32 inches: fine sandy loam
H3 - 32 to 64 inches: gravelly sandy loam

Properties and qualities

Slope: 25 to 35 percent
Surface area covered with cobbles, stones or boulders: 9.0 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 8.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: A

Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Description of Nellis

Setting

Landform: Drumlinoid ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over friable, calcareous coarse-loamy lodgment till derived from limestone

Typical profile

H1 - 0 to 7 inches: loam
H2 - 7 to 32 inches: gravelly loam
H3 - 32 to 60 inches: gravelly loam

Properties and qualities

Slope: 25 to 35 percent
Surface area covered with cobbles, stones or boulders: 9.0 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water supply, 0 to 60 inches: Moderate (about 7.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: B
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Farmington

Percent of map unit: 15 percent
Hydric soil rating: No

600—Pits, gravel

Map Unit Setting

National map unit symbol: 98vn

Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 120 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Pits, gravel: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pits, Gravel

Setting

Parent material: Loose sandy and gravelly glaciofluvial deposits derived from igneous and metamorphic rock

651—Udorthents, smoothed

Map Unit Setting

National map unit symbol: 98wc
Elevation: 640 to 1,620 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 120 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Udorthents, smoothed and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Udorthents, Smoothed

Setting

Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Excavated and filled land over loose glaciofluvial deposits derived from igneous and metamorphic rock and/or friable basal till derived from igneous and metamorphic rock

Properties and qualities

Depth to restrictive feature: More than 80 inches
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None

901E—Berkshire-Marlow association, 15 to 45 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 2wlnm
Elevation: 750 to 2,070 feet
Mean annual precipitation: 31 to 95 inches
Mean annual air temperature: 27 to 52 degrees F
Frost-free period: 90 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Berkshire, extremely stony, and similar soils: 55 percent
Marlow, extremely stony, and similar soils: 30 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Berkshire, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Backslope, summit, shoulder
Landform position (three-dimensional): Mountainflank, side slope, nose slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy supraglacial meltout till derived from phyllite and/or granite and gneiss and/or mica schist

Typical profile

Oi - 0 to 2 inches: slightly decomposed plant material
A - 2 to 4 inches: fine sandy loam
E - 4 to 5 inches: fine sandy loam
Bs1 - 5 to 7 inches: fine sandy loam
Bs2 - 7 to 13 inches: fine sandy loam
Bs3 - 13 to 21 inches: fine sandy loam
BC1 - 21 to 28 inches: fine sandy loam
BC2 - 28 to 33 inches: fine sandy loam
C - 33 to 65 inches: fine sandy loam

Properties and qualities

Slope: 15 to 45 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to high (0.14 to 14.17 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)

Available water supply, 0 to 60 inches: High (about 10.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: B
Ecological site: F144BY501ME - Loamy Slope (Northern Hardwoods)
Hydric soil rating: No

Description of Marlow, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Mountainflank, nose slope, side slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy lodgment till derived from mica schist and/or granite and/or phyllite

Typical profile

Oi - 0 to 2 inches: slightly decomposed plant material
A - 2 to 5 inches: fine sandy loam
E - 5 to 8 inches: fine sandy loam
Bs1 - 8 to 15 inches: fine sandy loam
Bs2 - 15 to 19 inches: fine sandy loam
BC - 19 to 33 inches: gravelly fine sandy loam
Cd - 33 to 65 inches: fine sandy loam

Properties and qualities

Slope: 15 to 45 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 20 to 41 inches to densic material
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.01 to 1.42 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 5.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: C
Ecological site: F144BY501ME - Loamy Slope (Northern Hardwoods)
Hydric soil rating: No

Minor Components

Lyman, extremely stony

Percent of map unit: 9 percent
Landform: Mountains, hills
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Mountainflank, side slope, crest
Down-slope shape: Convex

Across-slope shape: Convex
Hydric soil rating: No

Peru, extremely stony

Percent of map unit: 4 percent
Landform: Hills, mountains
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Mountainflank, nose slope, side slope
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Pillsbury, extremely stony

Percent of map unit: 1 percent
Landform: Hills, mountains
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Mountainflank, side slope, nose slope, interfluve
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Peacham, extremely stony

Percent of map unit: 1 percent
Landform: Mountains, hills
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainflank, interfluve, base slope
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

904E—Lyman-Tunbridge association, 15 to 60 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 2ty75
Elevation: 850 to 2,360 feet
Mean annual precipitation: 31 to 95 inches
Mean annual air temperature: 27 to 52 degrees F
Frost-free period: 60 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Lyman, extremely stony, and similar soils: 45 percent
Tunbridge, extremely stony, and similar soils: 40 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Lyman, Extremely Stony

Setting

Landform: Hills, mountains
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Mountainflank, mountaintop, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy supraglacial till derived from granite and gneiss and/or loamy supraglacial till derived from phyllite and/or loamy supraglacial till derived from mica schist

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 3 inches: loam
E - 3 to 5 inches: fine sandy loam
Bhs - 5 to 7 inches: loam
Bs1 - 7 to 11 inches: loam
Bs2 - 11 to 18 inches: channery loam
R - 18 to 28 inches: bedrock

Properties and qualities

Slope: 15 to 60 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 11 to 24 inches to lithic bedrock
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to high (0.00 to 14.03 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 3.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: D
Ecological site: F144BY702ME - Shallow and Moderately-deep Till
Hydric soil rating: No

Description of Tunbridge, Extremely Stony

Setting

Landform: Hills, mountains
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Mountainflank, mountaintop, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy supraglacial till derived from granite and gneiss and/or loamy supraglacial till derived from phyllite and/or loamy supraglacial till derived from mica schist

Typical profile

Oe - 0 to 3 inches: moderately decomposed plant material

Oa - 3 to 5 inches: highly decomposed plant material
E - 5 to 8 inches: fine sandy loam
Bhs - 8 to 11 inches: fine sandy loam
Bs - 11 to 26 inches: fine sandy loam
BC - 26 to 28 inches: fine sandy loam
R - 28 to 38 inches: bedrock

Properties and qualities

Slope: 15 to 60 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 20 to 40 inches to lithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to high (0.00 to 14.03 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 6.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: C
Ecological site: F144BY702ME - Shallow and Moderately-deep Till
Hydric soil rating: No

Minor Components

Berkshire, extremely stony

Percent of map unit: 9 percent
Landform: Mountains, hills
Landform position (two-dimensional): Backslope, summit, shoulder
Landform position (three-dimensional): Mountainflank, mountaintop, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Wonsqueak

Percent of map unit: 2 percent
Landform: Mountains, hills
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountaintop, mountainbase, side slope, crest
Microfeatures of landform position: Open depressions, open depressions
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Pillsbury, extremely stony

Percent of map unit: 2 percent
Landform: Hills, mountains
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Mountainflank, mountaintop, side slope, crest
Microfeatures of landform position: Open depressions, open depressions
Down-slope shape: Concave

Across-slope shape: Concave
Hydric soil rating: Yes

Peacham, extremely stony

Percent of map unit: 2 percent
Landform: Mountains, hills
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainflank, mountaintop, side slope, crest
Microfeatures of landform position: Open depressions, open depressions
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

905C—Peru-Marlow association, 3 to 15 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 2ty7p
Elevation: 790 to 2,100 feet
Mean annual precipitation: 31 to 95 inches
Mean annual air temperature: 27 to 52 degrees F
Frost-free period: 90 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Peru, extremely stony, and similar soils: 61 percent
Marlow, extremely stony, and similar soils: 20 percent
Minor components: 19 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Peru, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Mountainbase, mountainflank, side slope, nose slope, interfluve
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Loamy lodgment till derived from granite and/or loamy lodgment till derived from mica schist and/or loamy lodgment till derived from phyllite

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 5 inches: fine sandy loam
E - 5 to 6 inches: fine sandy loam
Bs1 - 6 to 7 inches: fine sandy loam
Bs2 - 7 to 13 inches: fine sandy loam
Bs3 - 13 to 18 inches: fine sandy loam

BC - 18 to 21 inches: fine sandy loam
Cd1 - 21 to 37 inches: fine sandy loam
Cd2 - 37 to 65 inches: fine sandy loam

Properties and qualities

Slope: 3 to 15 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 21 to 43 inches to densic material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.01 to 1.42 in/hr)
Depth to water table: About 17 to 34 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 3.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: C/D
Ecological site: F144BY501ME - Loamy Slope (Northern Hardwoods)
Hydric soil rating: No

Description of Marlow, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Mountainflank, mountainbase, side slope, nose slope, interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy lodgment till derived from granite and/or loamy lodgment till derived from mica schist and/or loamy lodgment till derived from phyllite

Typical profile

Oi - 0 to 2 inches: slightly decomposed plant material
A - 2 to 5 inches: fine sandy loam
E - 5 to 8 inches: fine sandy loam
Bs1 - 8 to 15 inches: fine sandy loam
Bs2 - 15 to 19 inches: fine sandy loam
BC - 19 to 33 inches: gravelly fine sandy loam
Cd - 33 to 65 inches: fine sandy loam

Properties and qualities

Slope: 3 to 15 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 20 to 41 inches to densic material
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.01 to 1.42 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 5.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: C
Ecological site: F144BY501ME - Loamy Slope (Northern Hardwoods)
Hydric soil rating: No

Minor Components

Lyman, extremely stony

Percent of map unit: 6 percent
Landform: Mountains, hills
Landform position (two-dimensional): Shoulder, summit, backslope
Landform position (three-dimensional): Mountainbase, mountainflank, nose slope, interfluve, side slope
Microfeatures of landform position: Rises, rises
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Berkshire, extremely stony

Percent of map unit: 5 percent
Landform: Hills, mountains
Landform position (two-dimensional): Backslope, summit, shoulder
Landform position (three-dimensional): Mountainbase, mountainflank, interfluve, side slope, nose slope
Microfeatures of landform position: Rises, rises
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Pillsbury, extremely stony

Percent of map unit: 5 percent
Landform: Hills, mountains
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Mountainbase, mountainflank, interfluve, side slope, nose slope
Microfeatures of landform position: Closed depressions, closed depressions, open depressions, open depressions
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Monadnock, extremely stony

Percent of map unit: 3 percent
Landform: Mountains, hills
Landform position (two-dimensional): Backslope, summit, shoulder
Landform position (three-dimensional): Mountainflank, mountainbase, side slope, nose slope, interfluve
Microfeatures of landform position: Rises, rises
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

909C—Tunbridge-Lyman association, 3 to 15 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 2trrm
Elevation: 1,080 to 2,390 feet
Mean annual precipitation: 31 to 95 inches
Mean annual air temperature: 27 to 52 degrees F
Frost-free period: 60 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Tunbridge, extremely stony, and similar soils: 50 percent
Lyman, extremely stony, and similar soils: 35 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Tunbridge, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Mountainbase, mountainflank, mountaintop, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy supraglacial till derived from granite and gneiss and/or loamy supraglacial till derived from phyllite and/or loamy supraglacial till derived from mica schist

Typical profile

Oe - 0 to 3 inches: moderately decomposed plant material
Oa - 3 to 5 inches: highly decomposed plant material
E - 5 to 8 inches: fine sandy loam
Bhs - 8 to 11 inches: fine sandy loam
Bs - 11 to 26 inches: fine sandy loam
BC - 26 to 28 inches: fine sandy loam
R - 28 to 38 inches: bedrock

Properties and qualities

Slope: 3 to 15 percent
Surface area covered with cobbles, stones or boulders: 7.1 percent
Depth to restrictive feature: 20 to 40 inches to lithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to high (0.00 to 14.03 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None

Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 6.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: C
Ecological site: F143XY702ME - Shallow And Moderately Deep Till, F143XY703ME - Shallow And Moderately Deep Humic Till
Hydric soil rating: No

Description of Lyman, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Mountainbase, mountainflank, mountaintop, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy supraglacial till derived from granite and gneiss and/or loamy supraglacial till derived from phyllite and/or loamy supraglacial till derived from mica schist

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 3 inches: loam
E - 3 to 5 inches: fine sandy loam
Bhs - 5 to 7 inches: loam
Bs1 - 7 to 11 inches: loam
Bs2 - 11 to 18 inches: channery loam
R - 18 to 28 inches: bedrock

Properties and qualities

Slope: 3 to 15 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 11 to 24 inches to lithic bedrock
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to high (0.00 to 14.03 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 3.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: D
Ecological site: F143XY702ME - Shallow And Moderately Deep Till
Hydric soil rating: No

Minor Components

Berkshire, extremely stony

Percent of map unit: 8 percent
Landform: Mountains, hills

Landform position (two-dimensional): Backslope, summit, shoulder
Landform position (three-dimensional): Mountainflank, mountainbase, side slope, interfluve, nose slope
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Peacham, extremely stony

Percent of map unit: 4 percent
Landform: Mountains, hills
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainbase, base slope, interfluve
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Pillsbury, extremely stony

Percent of map unit: 3 percent
Landform: Hills, mountains
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Mountainbase, mountainflank, side slope, nose slope, interfluve
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Soil Information for All Uses

Soil Properties and Qualities

The Soil Properties and Qualities section includes various soil properties and qualities displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each property or quality.

Soil Erosion Factors

Soil Erosion Factors are soil properties and interpretations used in evaluating the soil for potential erosion. Example soil erosion factors can include K factor for the whole soil or on a rock free basis, T factor, wind erodibility group and wind erodibility index.

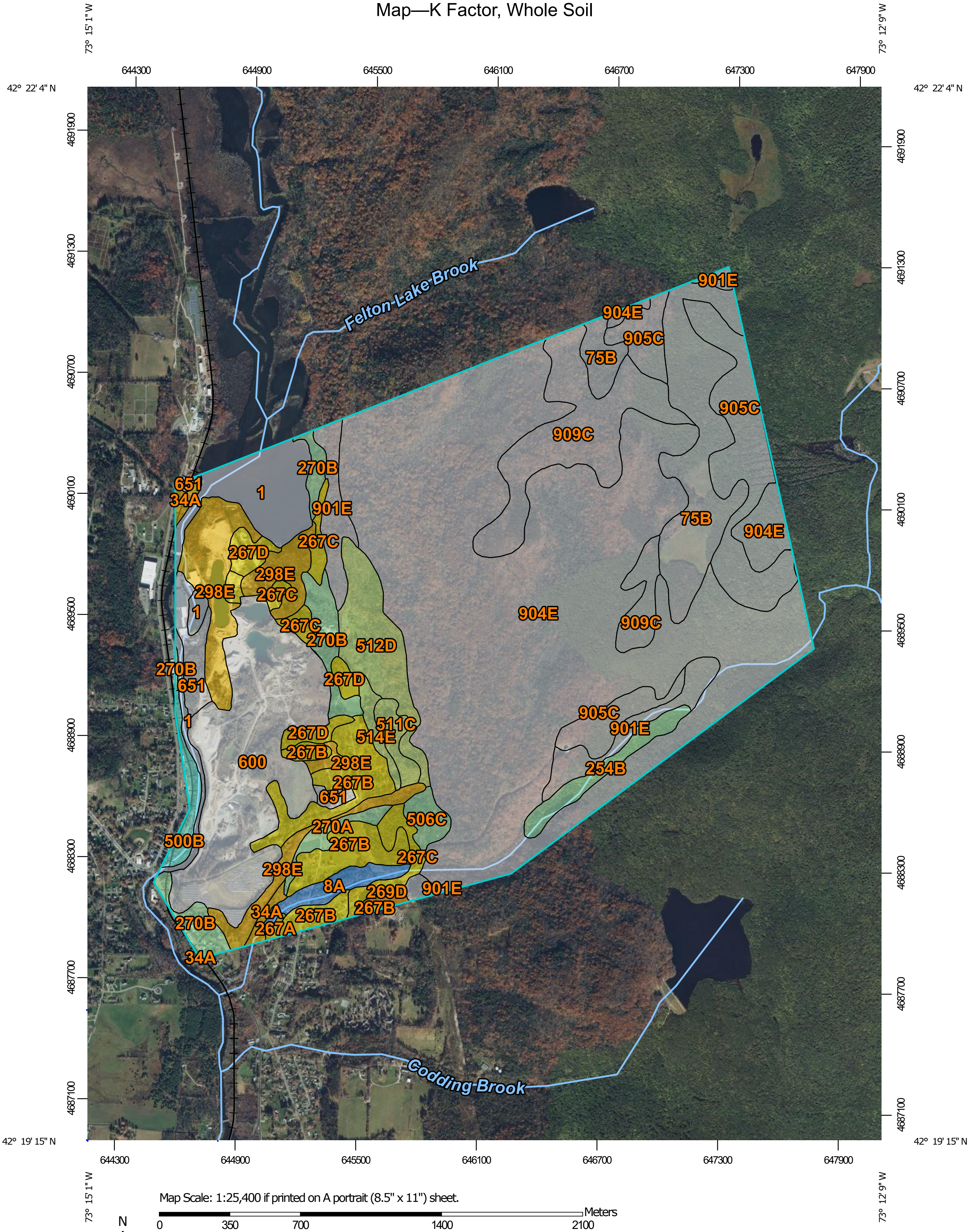
K Factor, Whole Soil

Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity (Ksat). Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

"Erosion factor Kw (whole soil)" indicates the erodibility of the whole soil. The estimates are modified by the presence of rock fragments.

Factor K does not apply to organic horizons and is not reported for those layers.

Map—K Factor, Whole Soil



Map Scale: 1:25,400 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 350, 700, 1400, 2100

Feet: 0, 1000, 2000, 4000, 6000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

.02
.05
.10
.15
.17
.20
.24
.28
.32
.37
.43
.49
.55
.64
Not rated or not available

Soil Rating Lines

.02
.05
.10
.15
.17
.20
.24
.28
.32
.37
.43
.49
.55
.64
Not rated or not available

Soil Rating Points

.02
.05
.10
.15
.17
.20
.24
.28
.32
.37
.43
.49
.55
.64
Not rated or not available

assumed K factor

Water Features

Streams and Canals

Transportation

Rails
Interstate Highways
US Routes
Major Roads
Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Berkshire County, Massachusetts
Survey Area Data: Version 17, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 15, 2021—Nov 8, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Table—K Factor, Whole Soil

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
1	Cwater		61.3	3.4%
8A	Limerick silt loam, 0 to 3 percent slopes, frequently flooded	.43	16.1	0.9%
34A	Fredon fine sandy loam, 0 to 3 percent slopes	.15	7.4	0.4%
75B	Pillsbury fine sandy loam, 0 to 8 percent slopes, very stony		107.9	6.1%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	.28	19.7	1.1%
267A	Copake fine sandy loam, 0 to 3 percent slopes	.17	1.4	0.1%
267B	Copake fine sandy loam, 3 to 8 percent slopes	.17	74.4	4.2%
267C	Copake fine sandy loam, 8 to 15 percent slopes	.17	30.8	1.7%
267D	Copake fine sandy loam, 15 to 25 percent slopes	.17	19.5	1.1%
269D	Groton gravelly sandy loam, 15 to 25 percent slopes	.10	3.5	0.2%
270A	Hero loam, 0 to 3 percent slopes	.28	9.4	0.5%
270B	Hero loam, 3 to 8 percent slopes	.28	38.6	2.2%
298E	Groton and Hinckley soils, 25 to 35 percent slopes	.15	85.4	4.8%
500B	Amenia silt loam, 3 to 8 percent slopes	.32	12.3	0.7%
506C	Nellis loam, 8 to 15 percent slopes, very stony	.28	10.9	0.6%
511C	Pittsfield loam, 8 to 15 percent slopes, very stony	.24	11.3	0.6%
512D	Pittsfield loam, 15 to 25 percent slopes, extremely stony	.24	49.2	2.8%
514E	Pittsfield and Nellis loams, 25 to 35 percent slopes, extremely stony	.24	7.7	0.4%
600	Pits, gravel		168.7	9.5%
651	Udorthents, smoothed		22.1	1.2%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
901E	Berkshire-Marlow association, 15 to 45 percent slopes, extremely stony		51.4	2.9%
904E	Lyman-Tunbridge association, 15 to 60 percent slopes, extremely stony		755.4	42.4%
905C	Peru-Marlow association, 3 to 15 percent slopes, extremely stony		112.7	6.3%
909C	Tunbridge-Lyman association, 3 to 15 percent slopes, extremely stony		106.2	6.0%
Totals for Area of Interest			**1,783.3**	**100.0%**

Rating Options—K Factor, Whole Soil

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Layer Options (Horizon Aggregation Method): Surface Layer (Not applicable)

Soil Qualities and Features

Soil qualities are behavior and performance attributes that are not directly measured, but are inferred from observations of dynamic conditions and from soil properties. Example soil qualities include natural drainage, and frost action. Soil features are attributes that are not directly part of the soil. Example soil features include slope and depth to restrictive layer. These features can greatly impact the use and management of the soil.

Hydrologic Soil Group

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

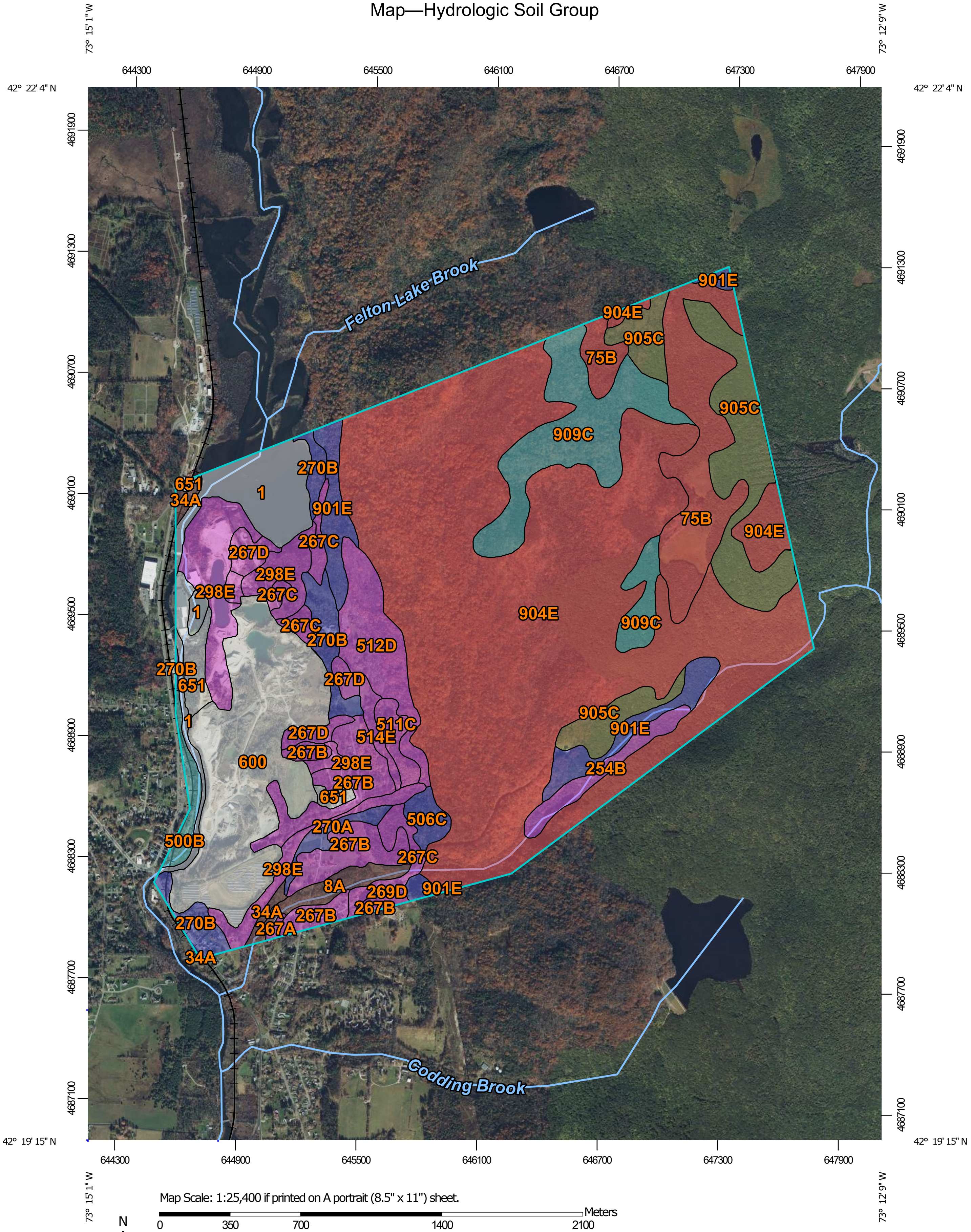
Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Map—Hydrologic Soil Group



Map Scale: 1:25,400 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 350, 700, 1400, 2100

Feet: 0, 1000, 2000, 4000, 6000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Berkshire County, Massachusetts
Survey Area Data: Version 17, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 15, 2021—Nov 8, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Table—Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
1	Cwater		61.3	3.4%
8A	Limerick silt loam, 0 to 3 percent slopes, frequently flooded	B/D	16.1	0.9%
34A	Fredon fine sandy loam, 0 to 3 percent slopes	B/D	7.4	0.4%
75B	Pillsbury fine sandy loam, 0 to 8 percent slopes, very stony	D	107.9	6.1%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	A	19.7	1.1%
267A	Copake fine sandy loam, 0 to 3 percent slopes	A	1.4	0.1%
267B	Copake fine sandy loam, 3 to 8 percent slopes	A	74.4	4.2%
267C	Copake fine sandy loam, 8 to 15 percent slopes	A	30.8	1.7%
267D	Copake fine sandy loam, 15 to 25 percent slopes	A	19.5	1.1%
269D	Groton gravelly sandy loam, 15 to 25 percent slopes	A	3.5	0.2%
270A	Hero loam, 0 to 3 percent slopes	B	9.4	0.5%
270B	Hero loam, 3 to 8 percent slopes	B	38.6	2.2%
298E	Groton and Hinckley soils, 25 to 35 percent slopes	A	85.4	4.8%
500B	Amenia silt loam, 3 to 8 percent slopes	C	12.3	0.7%
506C	Nellis loam, 8 to 15 percent slopes, very stony	B	10.9	0.6%
511C	Pittsfield loam, 8 to 15 percent slopes, very stony	A	11.3	0.6%
512D	Pittsfield loam, 15 to 25 percent slopes, extremely stony	A	49.2	2.8%
514E	Pittsfield and Nellis loams, 25 to 35 percent slopes, extremely stony	A	7.7	0.4%
600	Pits, gravel		168.7	9.5%
651	Udorthents, smoothed		22.1	1.2%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
901E	Berkshire-Marlow association, 15 to 45 percent slopes, extremely stony	B	51.4	2.9%
904E	Lyman-Tunbridge association, 15 to 60 percent slopes, extremely stony	D	755.4	42.4%
905C	Peru-Marlow association, 3 to 15 percent slopes, extremely stony	C/D	112.7	6.3%
909C	Tunbridge-Lyman association, 3 to 15 percent slopes, extremely stony	C	106.2	6.0%
Totals for Area of Interest			**1,783.3**	**100.0%**

Rating Options—Hydrologic Soil Group

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

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Attachment 5

SW-867

United States
Environmental Protection
Agency

Office of Water and
Waste Management
Washington DC 20460

SW-867
September 1980
C. 2

EPA

Evaluating Cover Systems for Solid and Hazardous Waste

EVALUATING COVER SYSTEMS FOR SOLID AND HAZARDOUS WASTE

by

R. J. Lutton

U. S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi 39180

Interagency Agreement No. EPA-IAG-D7-01097

Project Officer

Robert E. Landreth
Solid and Hazardous Waste Research Division
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MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

DISCLAIMER

Permit Writers Guidance Manual/Technical Resource Document

Preface

The land disposal of hazardous waste is subject to the requirements of Subtitle C of the Resource Conservation and Recovery Act of 1976. This Act requires that the treatment, storage, or disposal of hazardous wastes after November 19, 1980, be carried out in accordance with a permit. The one exception to this rule is that facilities in existence as of November 19, 1980 may continue operations until final administrative dispostion is made of the permit application (providing that the facility complies with the Interim Status Standards for disposers of hazardous waste in 40 CFR Part 265). Owners or operators of new facilities must apply for and receive a permit before beginning operation of such a facility.

The Interim Status Standards (40 CFR Part 265) and some of the administrative portions of the Permit Standards (40 CFR Part 264) were published by EPA in the Federal Register on May 19, 1980. EPA will soon publish technical permit standards in Part 264 for hazardous waste disposal facilities. These regulations will ensure the protection of human health and the environment by requiring evaluations of hazardous waste management facilities in terms of both site-specific factors and the nature of the waste that the facility will manage.

The permit official must review and evaluate permit applications to determine whether the proposed objectives, design, and operation of a land disposal facility will be in compliance with all applicable provisions of the regulations (40 CFR 264).

EPA is preparing two types of documents for permit officials responsible for hazardous waste landfills, surface impoundments, and land treatment facilities: Permit Writers Guidance Manuals and Technical Resource Documents. The Permit Writers Guidance Manuals provide guidance for conducting the review and evaluation of a permit application for site-specific control objectives and designs. The Technical Resource Documents support the Permit Writers Guidance Manuals in certain areas (i.e. liners, leachate management, closure, covers, water balance) by describing current technologies and methods for evaluating the performance of the applicant's design. The information and guidance presented in these manuals constitute a suggested approach for review and evaluation based on best engineering judgments. There may be alternative and equivalent methods for conducting the review and evaluation. However, if the results of these methods differ from those of the EPA method, their validity may have to be validated by the applicant.

In reviewing and evaluating the permit application, the permit official must make all decisions in a well defined and well documented manner. Once an initial decision is made to issue or deny the permit, the Subtitle C regulations (40 CFR 124.6, 124.7 and 124.8) require preparation of either a statement of basis or a fact sheet that discusses the reasons behind the decision. The statement of basis or fact sheet then becomes part of the permit review process specified in 40 CRF 124.6-124.20.

These manuals are intended to assist the permit official in arriving at a logical, well-defined, and well-documented decision. Checklists and logic flow diagrams are provided throughout the manuals to ensure that necessary factors are considered in the decision process. Technical data are presented to enable the permit official to identify proposed designs that may require more detailed analysis because of a deviation from suggested practices. The technical data are not meant to provide rigid guidelines for arriving at a decision. References are cited throughout the manuals to provide further guidance for the permit official when necessary.

FOREWORD

The Environmental Protection Agency was created because of increasing public and governmental concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of the environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is the first necessary step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and the solid and hazardous waste pollutant discharges from municipal and community sources; to preserve and treat public drinking water supplies; and to minimize the adverse economic, social, health and aesthetic effects of pollution. This publication is one of the products of that research--a vital communications link between the researcher and the user community.

This report is to be used as a tool for evaluating various landfill cover systems. This data information can be used in determining cover design requirements for compliance with the current regulations.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

A critical part of the sequence of designing, constructing, and maintaining an effective cover over solid and hazardous waste is the evaluation of engineering plans. Such evaluation is an important function of regulating agencies, and accompanying documentation can form one basis for issuing or denying a permit to the owner/operator of the waste disposal facility. This manual describes 36 steps in evaluation of plans submitted for approval. Generally, the evaluator considers available soils, site conditions, details of cover design, and post-closure maintenance and contingencies.

This report was submitted in fulfillment of Phase III of Interagency Agreement No. EPA-IAG-D7-01097 between the U. S. Environmental Protection Agency and the U. S. Army Engineer Waterways Experiment Station (WES). Work for this manual was conducted during the period December 1979 to July 1980, and work was completed in July 1980. Dr. R. J. Lutton, Geotechnical Laboratory, WES, was principal investigator and author. Director of WES during the work period was COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

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METRIC CONVERSION TABLE

Multiply	By	To Obtain
acres	4046.856	square meters
cubic feet per second	0.02831685	cubic meters per second
degrees (angle)	0.01745329	radians
feet	0.3048	meters
gallons (U. S. liquid)	0.003785412	cubic meters
inches	0.0254	meters
pounds (mass)	0.4535924	kilograms
pounds (mass) per acre	0.1120851	grams per square meter
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
square feet	0.09290304	square meters
tons (short, mass)	907.1847	kilograms
tons (mass) per acre	0.2241702	kilograms per square meter

SECTION 1

INTRODUCTION

Growing concern for the preservation of a healthful environment, now and in the future, was the major impetus to the enactment of Public Law 94-580, "Resource Conservation and Recovery Act of 1976" (21 October 1976). An important part of solid and hazardous waste management is the regulatory control exercised by the Environmental Protection Agency (EPA) regional offices and corresponding agencies in state governments. In turn, a major facet of this regulatory function is the evaluation of the adequacy of closure covers over the wastes.

PURPOSE AND SCOPE

This manual presents a procedure for evaluating closure covers proposed for solid and hazardous wastes. The manual is written principally for staff members in the Regional EPA offices and/or state offices charged with evaluating applications from owners/operators of solid and hazardous waste disposal areas. All aspects of cover are addressed in sufficient detail to allow for a complete evaluation of the entire cover system. For more details on the subjects covered in this manual, the reader is referred to a recent report emphasizing design and construction of covers which serves as the backup document.[1]

PROCEDURES OF EVALUATION

The evaluation of cover characteristics and design should be kept in conformance to applicable regulations. The sequence of procedures is outlined as follows:

1. Examine soil test data

2. Examine topography

3. Examine climate data

4. Evaluate composition

5. Evaluate thickness

6. Evaluate placement

7. Evaluate configuration

8. Evaluate drainage

9. Evaluate vegetation

10. Evaluate post-closure maintenance

11. Evaluate contingencies plan

The first three procedures in the evaluation process (presented in SECTION 2) constitute a careful review of materials and conditions at the proposed or existing site under consideration. Procedures 4-9 outline evaluations of the characteristics of the cover system within the constraints offered by review procedures 1-3. Procedures 10 and 11 evaluate the adequacy of the cover system and post-closure plan for future conditions, both expected and unexpected.

Opportunity will be provided in the evaluation scheme in Section 2 for consideration of departures from more or less conventional designs. Such an option is specifically intended for instances where the owner/operator, for one reason or another, proposes a design based on a special engineering study or calculations. In evaluating such departures in design, the permitting authority will find useful the additional technical guidance in Reference 1 or may enlist an experienced consulting firm or other source of technical assistance to conduct the evaluation.

SECTION 2

EXAMINATION OF DATA

TEST DATA REVIEW PROCEDURE

Sampling and testing are intended to characterize and delineate all important soil types, and therefore should be under the direction of an experienced engineer or geologist having competence in the field of soil mechanics. Field sampling data and laboratory test results should be thorough and according to widely accepted procedures. Table 1 summarizes the tests that may be necessary.

Review Field Sampling of Soils — Step 1

The objective of Step 1* is to establish that the applicant has satisfactorily documented the physical characteristics, volume, and spatial distribution of each of the major, distinguishable soil types to be used as cover. These data, obtained from test pits or borings in the borrow area, must be accurate since the adequacy of the cover system and the feasibility of the covering operation are directly affected.

The evaluation is accomplished by examining a map of soil sampling locations along with some graphical or tabular presentation of the depths and nature of the soils at each location. Soil types collected at each location should be classified as described under Step 2. Soil type should be identified at regular depth intervals even where the soil is obviously uniform to the depth of interest. Changes in soil types should be located. Much of the delineation of soil types is accomplished on the basis of characteristics observed and used in the field, e.g. color and feel when rubbed between fingers. Such field characteristics should be explained and related to the traditional U. S. Department of Agriculture (USDA) soil classes based on grain size (Figures 1 and 2) where reasonable. Characterization in terms of the Unified Soil Classification System (USCS) (Figure 3) is confirmed subsequently in laboratory testing (Step 2).

The owner/operator application should include a brief description of the field sampling methods besides the observations. The traditional manner of exploring soil to depths of more than a few feet is by soil boring but trenching below ground surface or cleaning an existing bluff face or pit wall

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*Step 1 may be unnecessary where the plan is to contract for the required volumes of certain soil types delivered to the waste disposal site.

TABLE 1. LABORATORY TEST METHODS FOR SOIL

Name of Test	Standard or Preferred Method*	Properties or Parameters Determined	Remarks/Special Equipment Requirements
		Index and Classification Tests	
Gradation Analysis	ASTM D421 D422 D2217	Particle size distribution	
Percent Fines	ASTM D1140	Percent of weight of material finer than No. 200 sieve	
Atterberg Limits	ASTM D423 D424 D427	Plastic limit, liquid limit, plasticity index, shrinkage factors	
Specific Gravity	ASTM D854	Specific gravity or apparent specific gravity of soil solids	Boiling should not be used for de-airing
Soil Description	ASTM D2488	Description of soil from visual-manual examination	
Soil Classification	ASTM D2487	Unified soil classification	
		Moisture-Density Relations	
Bulk Unit Weight	Reference 3	Bulk unit weight (bulk density)	
Water Content	ASTM D2216 D2974	Water content as percent of dry weight	
Relative Density	Reference 3	Maximum and minimum density of cohesionless soils	Modified test may be substituted for test with vibratory table
Compaction	ASTM D698 (or 5- to 15-blow modification)	Optimum water and maximum density	Method for earth and rock mixtures is given in Reference 3

(Continued)

TABLE 1. (continued)

Name of Test	Standard or Preferred Method*	Properties or Parameters Determined	Remarks/Special Equipment Requirements
		Consolidation and Permeability	
Consolidation	ASTM D2435	One-dimensional compressibility, permeability of cohesive soil	
Permeability	ASTM D2434	Permeability	
		Physical and Chemical Properties	
Mineralogy	Reference 4	Identification of minerals	Requires X-ray diffraction apparatus. Differential thermal analysis apparatus may also be used
Organic Content	Reference 5 ASTM D2974	Organic and inorganic carbon content as percent of dry weight	Where organic matter content is critical, D2974 results should be verified by wet combustion tests (Reference 5)
Soluble salts	Reference 6	Concentration of soluble salts in soil pore water	
Pinhole Test	Reference 7	Dispersion tendency in cohesive soils	Significant in evaluation of potential erosion or piping
		Shear Strength and Deformability	
Unconfined Compression	ASTM D2166	Strength of cohesive soil in uniaxial compression	

(Continued)

TABLE 1. (continued)

Name of Test	Standard or Preferred Method*	Properties or Parameters Determined	Remarks/Special Equipment Requirements
Direct Shear, Consolidated-Drained	ASTM D3080	Cohesion and angle of internal friction under drained conditions	
Triaxial Compression, Unconsolidated-Undrained	ASTM D2850	Shear strength parameters; cohesion and angle of internal friction for soils of low permeability	
Triaxial Compression, Consolidated-Undrained	Reference 3	Shear strength parameters; cohesion and angle of internal friction for consolidated soil	Circumferential drains, if used, should be slit to avoid stiffening test specimen
Triaxial Compression, Consolidated-Drained	Reference 3	Shear strength parameters; cohesion and angle of internal friction, for long-term loading conditions	Circumferential drains, if used, should be slit to avoid stiffening test specimen

* ASTM standard methods are given in Reference 2.

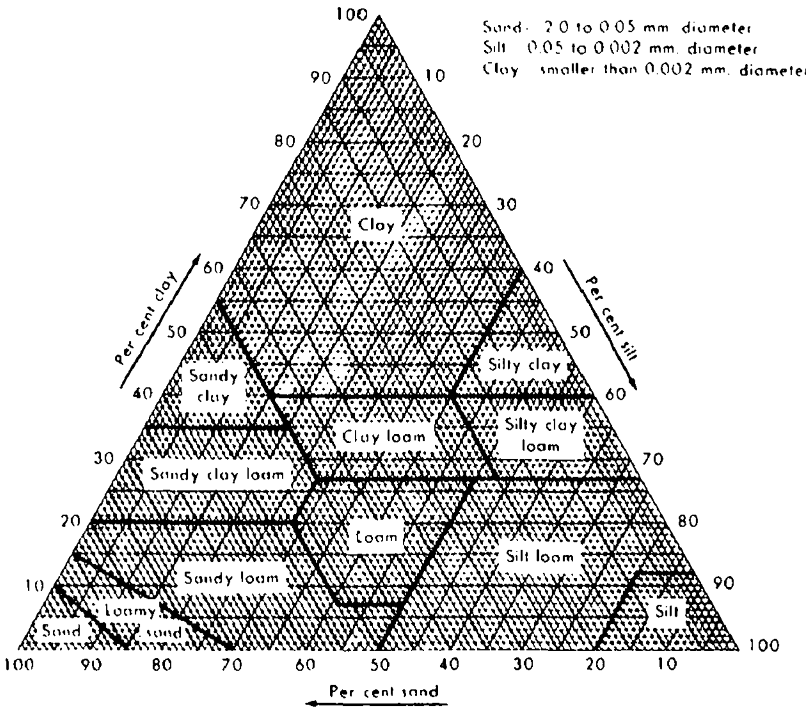


Figure 1. USDA textural classification chart.

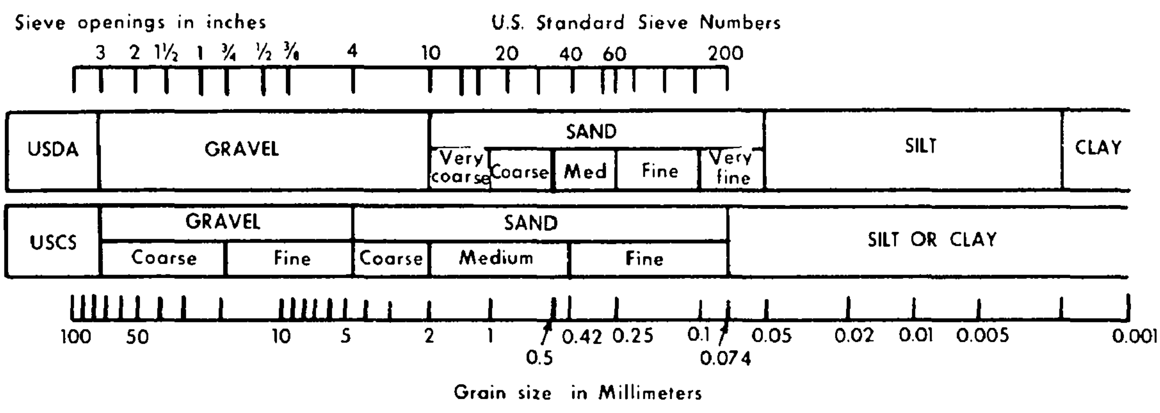


Figure 2. Comparison of USCS and USDA particle-size scales.

Major Divisions			Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)		
1	2		3	4	5		
Coarse-grained Soils More than half of material is **larger** than No. 200 sieve size.	Gravels More than half of coarse fraction is larger than No. 4 sieve size.	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.		
			GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.		
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixture.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).		
			GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below).		
	Sands More than half of coarse fraction is smaller than No. 4 sieve size.	Clean Sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.		
			SP	Poorly graded sands or gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.		
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).		
	(For visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)		SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).		
The No. 200 sieve size is about the **smallest** particle visible to the **naked** eye.					Identification Procedures on Fraction Smaller than No. 40 Sieve Size		
					Dry Strength (Crushing characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency near PL)
Fine-grained Soils More than half of material is **smaller** than No. 200 sieve size	Silts and Clays Liquid limit is less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight	Quick to slow	None
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium
			OL	Organic silts and organic silty clays of low plasticity.	Slight to medium	Slow	Slight
	Silts and Clays Liquid limit is greater than 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium	Slow to none	Slight to medium
			CH	Inorganic clays of high plasticity, fat clays.	High to very high	None	High
			OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium
Highly Organic Soils			Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.		

(1) Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well-graded gravel-sand mixture with clay binder. (2) All sieve sizes on this chart are U. S. standard.

FIELD IDENTIFICATION PROCEDURES FOR FINE-GRAINED SOILS OR FRACTIONS (MINUS NO. 40 SIEVE)

Screening is not intended; simply remove by hand the coarse particles that interfere with tests.

Dilatancy (reaction to shaking). After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

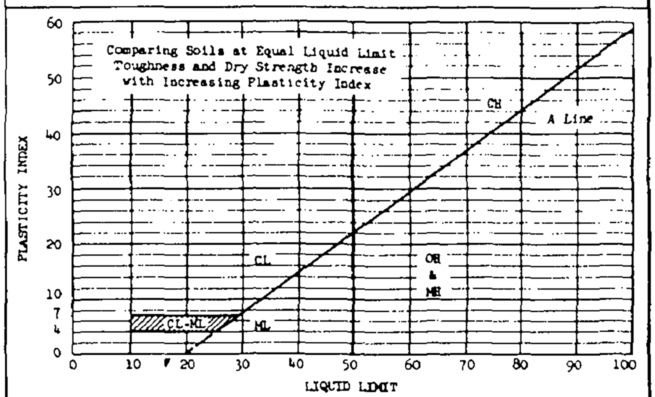
Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (crushing characteristics). After removing particles larger than No. 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air-drying, and then test its

Figure 3. Summary of the USC system.

(continued)

Information Required for Describing Soils	Laboratory Classification Criteria		
6	7		
For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions, and drainage characteristics.	Use grain-size curve in identifying the fractions as given under field identification.	Determine percentages of gravel and sand from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows: Less than 5% = GW, GP, SW, SP. More than 12% = GM, GC, SM, SC. 5% to 12% = Borderline cases requiring use of dual symbols.	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Not meeting all gradation requirements for GW
Give typical name; indicate approximate percentages of sand and gravel, maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.			Atterberg limits below "A" line or PI less than 4 Atterberg limits above "A" line with PI greater than 7 Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Not meeting all gradation requirements for SW
Example: Silty sand, gravelly; about 20% hard, angular gravel particles 1/2-in. maximum size; rounded and subangular sand grains, coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).			Atterberg limits below "A" line or PI less than 4 Atterberg limits above "A" line with PI greater than 7 Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. Give typical name; indicate degree and character of plasticity; amount and maximum size of coarse grains; color in wet condition; odor, if any; local or geologic name and other pertinent descriptive information; and symbol in parentheses. Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML).			

PLASTICITY CHART

For laboratory classification of fine-grained soils

strength by breaking and crumbling between the fingers. This strength is a measure of the character and quality of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic of clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (consistency near plastic limit). After particles larger than the No. 40 sieve size are removed, a specimen of soil about one-half inch cube in size is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be limped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

Figure 3. (continued)

may be as effective and less costly where on-site equipment is sufficient. Whatever the method, it should be documented in the application.

The evaluator must decide whether the arrangement and spacing of samples have been adequate to delineate the vertical and lateral extent of the major soil types. Where the evaluation indicates that sampling intervals are too large, it may be necessary to require additional samples at intermediate positions. One effective technique is to sample at fairly close spacing along a single line across the borrow area. Elsewhere in the area there may be a need for only a few additional borings to confirm that the stratification (including thicknesses) along the cross section apply elsewhere also. A grid pattern may also be definitive. The following example helps to clarify Step 1.

> Example: Suppose an application presents as an inclosure the plan map in Figure 4. The sampling methods at the three locations have been reviewed and found to be satisfactory; a geological technician made depth measurements and identified and sampled the soil types. The evaluator observes that one of the three sampling locations is distinct from the other two. The evaluator therefore recommends that new sample locations be added to delineate the extent of the CL soil more confidently since this soil type is important in design of the particular cover.

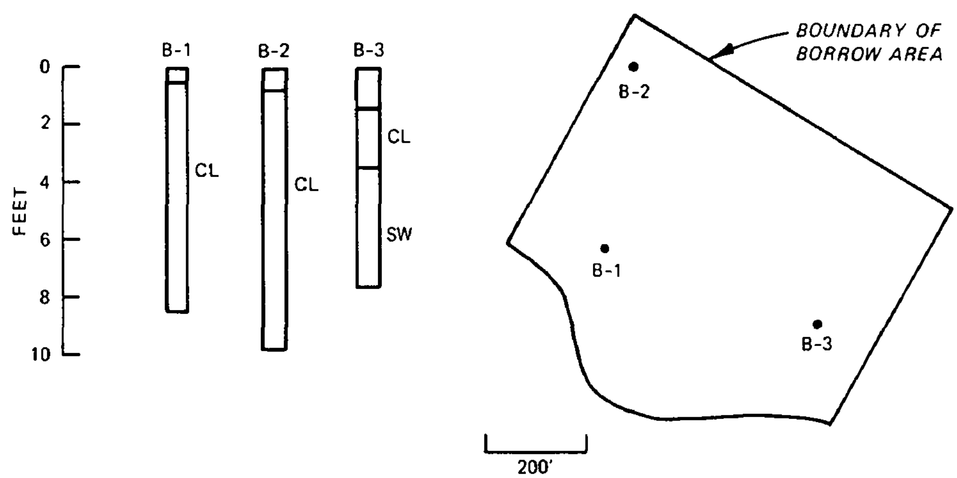


Figure 4. Hypothetical cover soil source.

<u>Check Adequacy of Soil Testing Program</u> <u>Step 2</u>

Two major aspects of the testing program that need to be evaluated are the selection of tests and the adequacy of testing facilities and personnel.

Tests that might be expected or perhaps even specified as minimum requirements for all diagnostic samples are as follows:

Grain-Size Distribution (Figure 5)

Percent Fines

Atterberg Limits

Soil Classification

Water Content

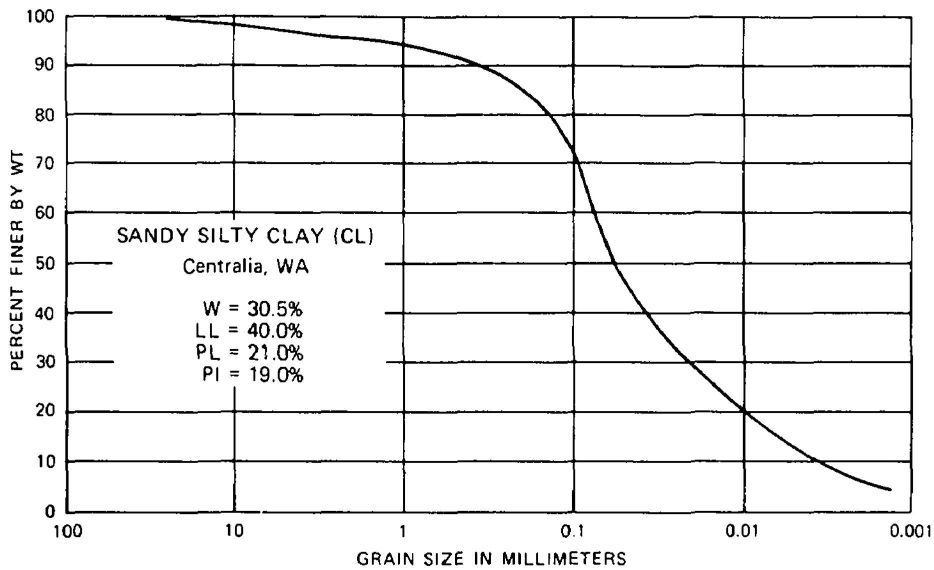


Figure 5. Gradation of a landfill cover soil.

The tests may be required in duplicate (or more) for better representation and checking. These tests are basically indexing tests but also useful for establishing the uniformity or variability within individual soil types. Other important tests are compaction (Figure 6) and permeability. Even one of these additional tests or test series may be adequate to establish characteristics of the unit as a whole provided that unit is relatively uniform in its index properties.

The remaining soil tests (Table 1) are assigned only where special problems of slope stability, consolidation, etc. are anticipated. The need for these tests may not become apparent until after most of the routine index testing has been accomplished, sometimes not until the critical review by the evaluator. Nevertheless, the lack of information from special tests may occasionally constitute a basis for delaying a permit application.

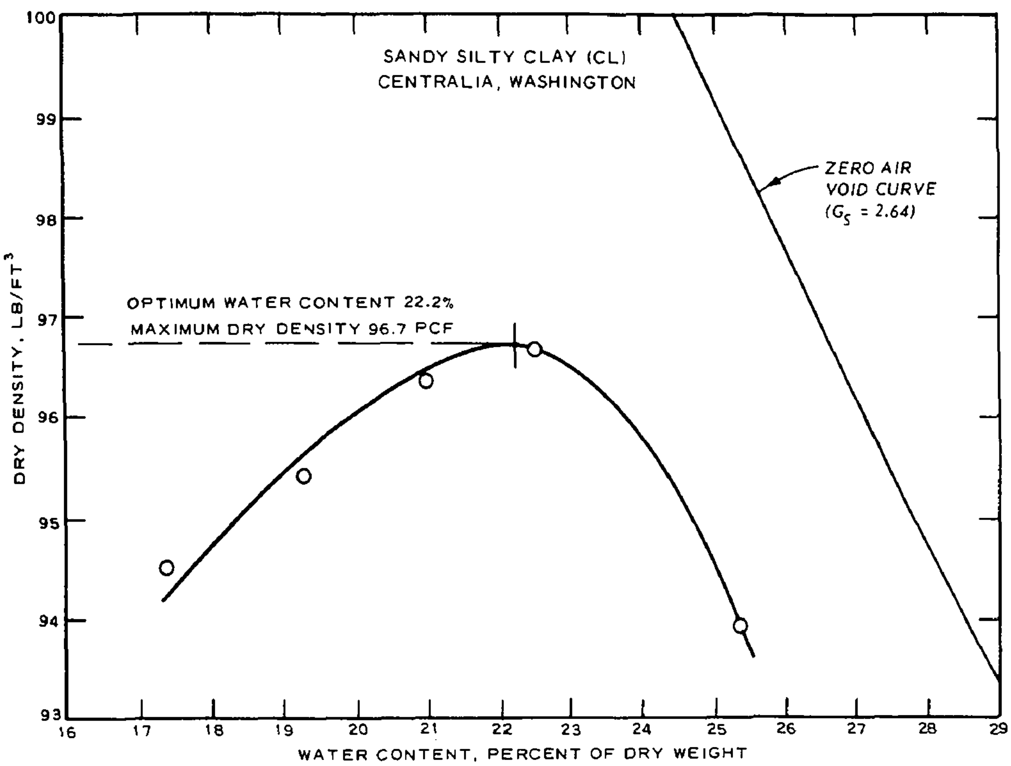


Figure 6. Standard compaction test results with landfill cover soil.[1]

Example: In reviewing a permit application an evaluator finds that a county soil survey report has been used as the basis for characterizing the soil at the proposed borrow area. The applicant has used Atterberg limits, classification, and grain-size distribution data from the report for type Grenada 6 soil which has been mapped over 36 percent of the county and specifically is shown as underlying the borrow area. After careful consideration, the evaluator requests that several deep soil boring samples from the borrow area be tested at a qualified testing laboratory to verify or reject the suitability of the data from the general county report for cover design. These samples will also serve to show how well the county survey of surficial agricultural soils represents the soils at depths below a few feet which, of necessity, will contribute to total cover soil volume.

<u>Check Soil Volumes Available</u> — <u>Step 3</u>

At some stage, not necessarily when the site or borrow area is sampled and tested, the sufficiency of cover soil volume should be evaluated.

Accurate volume calculations depend upon accurate measurements of soil thicknesses and areas. Accordingly, the evaluator may recommend additional sampling locations, not only for a better fix on soil indices and properties but to allow a better calculation of the volumes. Where the data in the application have shown a uniformity of soil type, it may only be necessary to check thicknesses rather than to sample and test also. The following example illustrates the situation, but also see the example under Step 1.

> Example: An applicant has submitted the information shown in Figure 7 as a basis for his estimates of volumes of soil types available for use as cover. The evaluator reasons that there is a possibility of a sizable overestimation of suitable soils available to complete the closure since variations of layer thicknesses between the existing sample locations are a distinct possibility (shown by dashed line in the figure). In this hypothetical case, the evaluator chooses to accept the estimated volumes on the basis of observations he has made in a field inspection and after consultation with a staff geologist.

An important factor in checking volumes available can be the bulking factor. Some natural soils, particularly those at depth, have a relatively high unit weight in situ. After excavation, working, and placement as cover over solid waste, these soils will have experienced a reduction in unit weight, i.e., a bulking effect, and available volumes tend to be underestimated. In contrast, other soils, particularly those near the surface, have a relatively low unit weight in situ so that available volumes are easily overestimated. The evaluator should carefully check the basis for any bulking factor where soil is in short supply.

TOPOGRAPHICAL DATA REVIEW PROCEDURE

Examine Configuration and Topography — Step 4

Next the surface configuration of the cover is examined to assure that evaluations can be made in regard to slope stability, water erosion, and wind erosion. Most engineered fills for highways, foundations, and so forth are designed on the basis of accurate topography or multiple cross sections, and the evaluator may reasonably expect some such basic data to accompany the closure plan. Otherwise, the justification for omitting such basic data should be convincingly presented in the application or be self evident.

One basic form of data presentation is with cross sections through the cover extending across the site (see Step 1). Cross sections should show thickness of the closure cover and solid waste and the limits of natural soil previously excavated for use as cover. Besides being useful for engineering design and for evaluation of the design, cross sections are potentially useful for monitoring changes in configuration that may take place as a result of settlement in the long term. Preparation of cross sections is well within the capability of most organizations engaged in construction and can reasonably be expected as a part of an application.

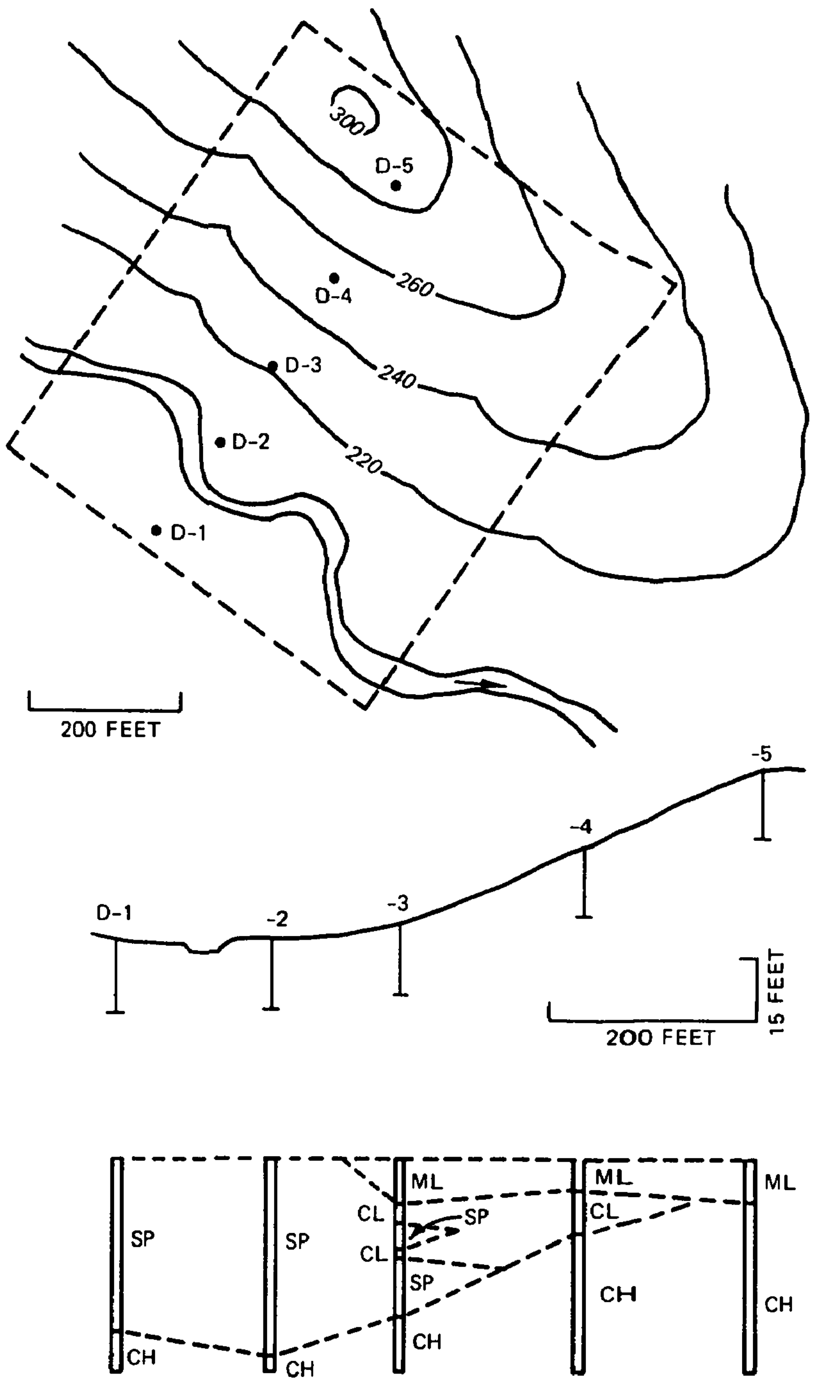


Figure 7. Hypothetical cover soil volume data.

A set of cross sections, often parallel to one another, can be highly useful. Ordinarily the line of section (the surface trace of the cross section) should trend downslope. Since many solid waste landfills will be completed with a somewhat irregular surface configuration approaching natural hills and swales, it may be necessary for the cross sections to be oblique to one another rather than parallel. About the only criterion for evaluating sufficiency in the number of cross sections is whether they present the important aspects of the surface form, closure cover, and underlying solid waste.

> Example: Suppose that the configuration of a solid waste landfill is as shown in Figure 8. The owner/operator of the landfill is seeking permission to place final cover and move his current operations to an adjacent site. He has supplied the sketch of the site and the surveyed cross section as the only graphical information of the actual layout at the site. In his evaluation, the staff member of the permitting authority feels there is insufficient data on the existing configuration, i.e. the base on which cover will be placed, and he requires the applicant to provide another cross section based on field measurements across the west side. The evaluator has reasoned that the west edge of the landfill near the drainageway is steeper and otherwise distinct from the large open side on the south and therefore should be represented accurately and separately in cross section for special examination.

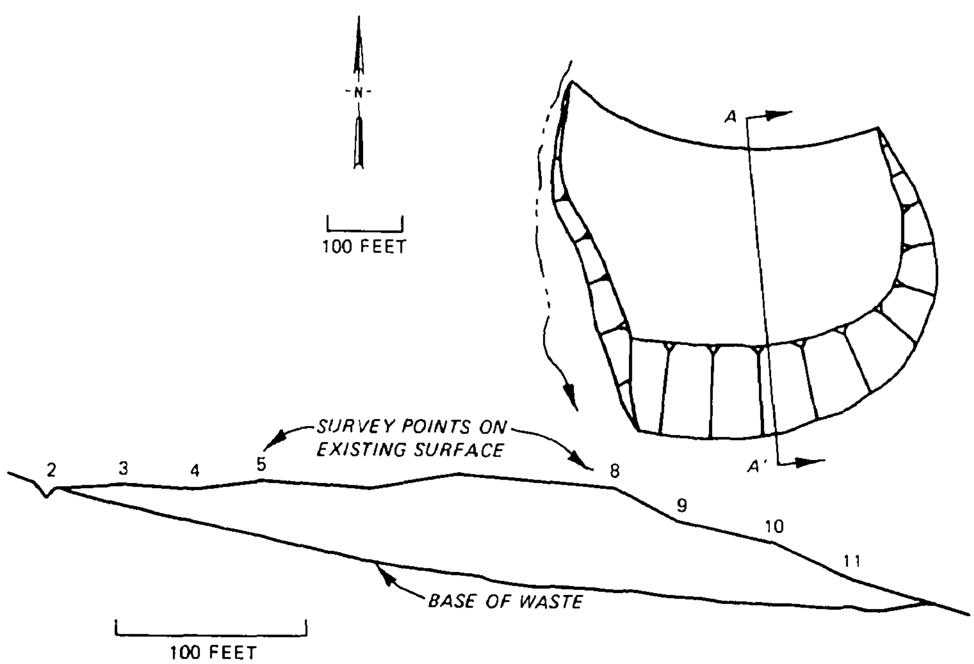


Figure 8. Hypothetical landfill configuration.

Examine Precipitation Records — Step 5

The application should include data on the precipitation to be expected at the site. A useful record typically gives average amounts for a period of at least several years in the past, e.g. the average monthly precipitations from the last 20 years or thereabout. Average data can be supplemented with typical records of rainfall on a daily or even hourly basis for a better picture of rainfall distribution in detail. The source of all climatological data should be given also so that verifications can be made. Figure 9 is a map of average annual precipitation that the evaluator can use to check roughly the expected annual precipitation provided by the applicant. Similar information is available for Alaska and Hawaii. In some mountainous or coastal regions the average rainfall can vary over short distances, and special care must be exercised in evaluation as illustrated by the following example.

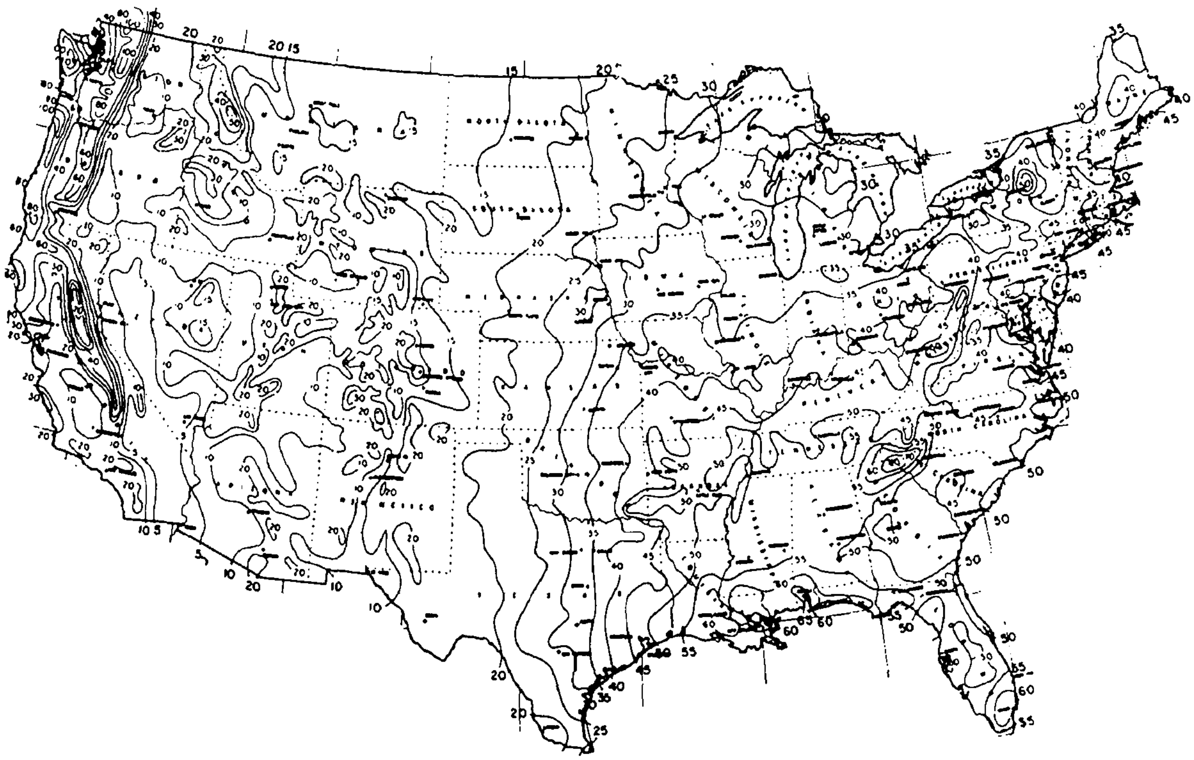


Figure 9. Average annual precipitation in inches (US Dept of Agriculture)

Example: Precipitation records provided in the permit application concerning a landfill for a city in the Pacific Northwest are those compiled from the downtown weather station. The evaluator recognizes that there is a difference in the weather at the downtown location (near sea level) and the weather at the landfill which is located in foothills at the far end of the same county. Therefore, he requests more representative data or conclusive evidence that any departures will be on the conservative side.

Examine Evapotranspiration Estimates Step 6

Since evapotranspiration operates in an important manner to remove moisture from the cover, it must be regarded as a major factor in cover design. Therefore, an applicant should include in documentation an accurate estimate of monthly evapotranspiration as evidence that this factor has been included in the design. The source of information should be included also. Where the evapotranspiration data have been derived through calculations from other parameters, the calculations should be included and explained, and references should be made to original sources. Figure 10 is a map of average annual lake evaporation over the contiguous United States which the evaluator can use to check roughly the expected annual evapotranspiration. Evapotranspiration approximately equals lake evaporation which is about 0.7 x pan evaporation.

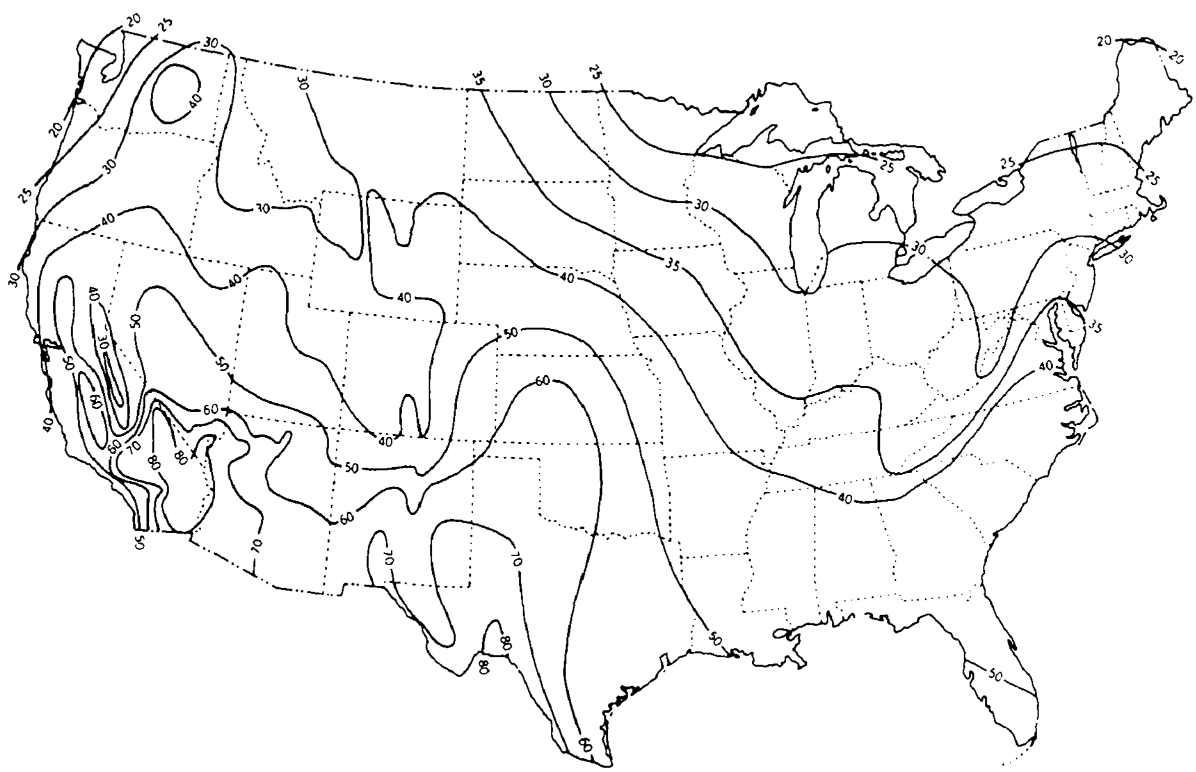


Figure 10. Average annual lake evaporation in inches, according to the National Weather Service.

Closure covers should be designed not only for average precipitation but also for high rates over short durations. Such information is readily available in the form of design storms for any locality and it is reasonable to expect that the documentation accompanying an application recognize several extreme rainfalls for recurrence intervals of possible interest. For an average size landfill a 1-hour storm and storms of longer duration are of typical interest. The recurrence interval would likely be 10 or 20 years but the applicant should present reasons for choosing specific intervals and storm durations. Figure 11 is an example of summary information available to the evaluator for checking design storm amounts supplied in an application.

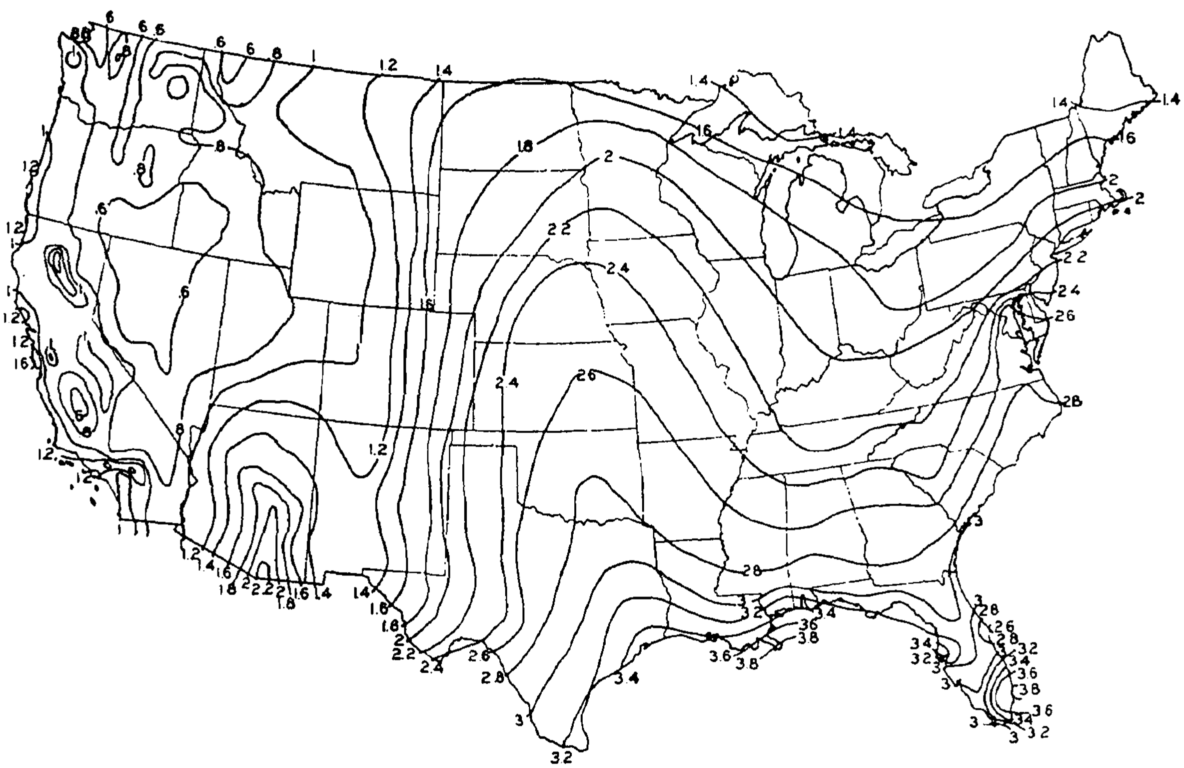


Figure 11. Ten-year 1-hour rainfall in inches (US Weather Bureau)

A sequel to the presentation of design storm data is the calculation of flood discharges for ditches and other elements of the drainage system. The calculation in simplest form utilizes the rational equation:

$$Q = C_{RO} \ i \ A$$

where Q = peak discharge, cubic feet/second
C_{RO} = runoff coefficient
i = rainfall intensity, inches//hour
A = area of basin, acres

The formula above incorporates the approximation that 1 inch/hour/acre = 1 cubic foot/second. Roughly approximated, the C_{RO} for vegetated clayey soils on flats and slopes are about 0.5 and 0.7 respectively and for vegetated sandy soils on flats and slopes are about 0.2 and 0.4.

SECTION 3

STEPS IN EVALUATION

Steps in this section differ from those in Section 2 by involving actual evaluation of the designs and judgments submitted by the applicant rather than just the examination and ordering of basic data.

COVER COMPOSITION EVALUATION PROCEDURE

The basis for evaluating the composition of the cover is the collection of data on quantities and descriptions supplied with the application.

Evaluate Composition Step 8

Referring to Table 2,[1] the evaluator should check the soil composition for suitability as cover by establishing the soil's strengths and deficiencies in a general way. Where a soil is rated IV or higher, look for special design features to compensate for deficiencies (e.g., multilayering to supplement a vulnerable soil with other types). Higher rating numbers tend to indicate greater need for special features. There is need, of course, to exercise good judgment when applying a somewhat subjective ranking as that in the table.

In the particularly important function of minimizing infiltration, it may be necessary to reject a simple cover design of one layer and require inclusion of a clay soil layer or other barrier. This necessity may arise where the dominant soil proposed as cover is:

a. Designated GW, GP, or SP by testing (see Figure 3)

b. Dispersive and therefore possibly subject to internal erosion (see Reference 1)

c. Insufficient in volume for cover design

Other options may be to import a more suitable soil type or in some way to improve characteristics by additional treatments.

> Example: According to the testing results accompanying the permit application, cover at a solid waste disposal site will consist of gravelly sand classified SW according to the USCS. The permitting authority has previously assigned a high priority to impeding water percolation into the solid waste. The evaluator, therefore, notifies

TABLE 2. RANKING OF USCS SOIL TYPES ACCORDING TO PERFORMANCE OF COVER FUNCTIONS

USCS Symbol	Typical Soils	Trafficability: Go-No Go (RCI Value)*	Trafficability: Stickiness (Clay, %)	Trafficability: Slipperiness (Sand-Gravel, %)	Water Percolation: Impede (k, cm/s)*	Water Percolation: Assist (k, cm/s)*	Gas Migration: Impede (H_c, cm)*	Gas Migration: Assist (H_c, cm)*
GW	Well-graded gravels, gravel-sand mixtures, little or no fines	I (>200)	I (0-5)	I (95-100)	X (10^{-2})	III	X (6)	I
GP	Poorly graded gravels, gravel-sand mixtures, little or no fines	I (>200)	I (0-5)	I (95-100)	XII (10^{-1})	I	IX ---	II
GM	Silty gravels, gravel-sand-silt mixtures	III (177)	III (0-20)	III (60-95)	VII (5×10^{-4})	VI	VII (68)	IV
GC	Clayey gravels, gravel-sand-clay mixtures	V (150)	VI (10-50)	V (50-90)	V (10^{-4})	VIII	IV ---	VII
SW	Well-graded sands, gravelly sands, little or no fines	I (>200)	II (0-10)	II (95-100)	IX (10^{-3})	IV	VIII (60)	III
SP	Poorly graded sands, gravelly sands, little or no fines	I (>200)	II (0-10)	II (95-100)	XI (5×10^{-2})	II	VII ---	IV
SM	Silty sands, sand-silt mixtures	II (179)	IV (0-20)	IV (60-95)	VIII (10^{-3})	V	VI (112)	V
SC	Clayey sands, sand-clay mixtures	IV (157)	VII (10-50)	VI (50-90)	VI (2×10^{-4})	VII	V ---	VI
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity	IX (104)	V (0-20)	VII (0-60)	IV (10^{-5})	IX	III (180)	VIII
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	VII (111)	VIII (10-50)	VIII (0-55)	II (3×10^{-8})	XI	II (160)	IX
OL	Organic silts and organic silty clays of low plasticity	X (64)	V (0-20)	VII (0-60)	---	---	---	---
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	VIII (107)	IX (50-100)	IX (0-50)	III (10^{-7})	X	---	---
CH	Inorganic clays of high plasticity, fat clays	VI (145)	X (50-100)	X (0-50)	I (10^{-9})	XII	I (200-400+)	X
OH	Organic clays of medium to high plasticity, organic silts	XI (62)	---	---	---	---	---	---
Pt	Peat and other highly organic soils	XII (46)	---	---	---	---	---	---

Water Percolation, Assist: Same k values as for Impede Water Percolation.

Gas Migration, Assist: Same H_c values as for Impede Gas Migration.

(continued)

TABLE 2. (continued)

USCS Symbol	Fire Resistance	Erosion Control: Water (K-Factor)*	Erosion Control: Wind (Sand-Gravel, %)	Dust Control	Reduce Freeze Action: Fast Freeze (H_c, cm)*	Reduce Freeze Action: Saturation (Heave, mm/day)	Crack Resistance (Expansion, %)
GW	Same as Impede Gas Migration	I (< .05)	I (95-100)	Same ranking and values as for Wind Erosion Control	X	I (0.1-3)	I (0)
GP		I ---	I (95-100)		IX	I (0.1-3)	I (0)
GM		IV ---	III (60-95)		VII	IV (0.4-4)	III ---
GC		III ---	V (50-90)		IV	VII (1-8)	V ---
SW		II (.05)	II (95-100)		VIII	II (0.2-2)	I (0)
SP		II ---	II (95-100)		VII	II (0.2-2)	I (0)
SM		VI (.12-.27)	IV (60-95)		VI	V (0.2-7)	II ---
SC		VII (.14-.27)	VI (50-90)		V	VI (1-7)	IV ---
ML		XIII (.60)	VII (0-60)		III	X (2-27)	VI ---
CL		XII (.28-.48)	VIII (0-55)		II	VIII (1-6)	VIII (1-10)
OL		XI (.21-.29)	VII (0-60)		---	VIII ---	VII ---
MH		X (.25)	IX (0-50)		---	IX ---	IX ---
CH		IX (.13-.29)	X (0-50)		I	III (0.8)	X (>10)
OH		VIII ---	---		---	---	IX ---
Pt		V (.13)	---		---	---	---

(continued)

TABLE 2. (continued)

USCS Symbol	Side Slope: Stability	Side Slope: Seepage	Side Slope: Drainage	Discourage Burrowing	Impede Vector Emergence	Discourage Birds	Support Vegetation	Future Use: Natural	Future Use: Foundation
GW	Determine on basis of laboratory testing	Same ranking and values as for Impede Water Percolation	Same ranking and values as for Assist Water Percolation	Same ranking and values as for Slipperiness Trafficability	X	All soils are suitable	X	Same ranking as for Support Vegetation	Same ranking and values as for Go-No Go Trafficability
GP					X		X		
GM					VIII		VI		
GC					V		V		
SW					IX		IX		
SP					IX		IX		
SM					VII		II		
SC					IV		I		
ML					VI		III		
CL					III		VII		
OL					VI		IV		
MH					II		IV		
CH					I		VIII		
OH					---		VIII		
Pt					---		III		

* RCI is rating cone index, k is coefficient of permeability, H_c is capillary head, and K-Factor is the soil erodibility factor. The ratings I to XIII are for best through poorest in performing the specified cover function.

the applicant that the SW soil (well graded sand) is unacceptable (ranked IX in Table 2) in a single-layer configuration and that it will be rejected unless a layered system with a barrier layer is incorporated.

Example: The applicant at a site has proposed to use a clayey silt for closure cover. The applicant had previously been asked to obtain at his own expense a series of tests on the soil to determine its tendency towards dispersion. The area has a high rainfall, and its low topography can conceivably cause a detention of runoff with increased opportunity for infiltration. Internal erosion that can affect dispersive soils would conceivably lead to a deterioration of the cover by migration of soil particles into the solid waste below. The laboratory test report in the second submittal of the application confirms that the silty soil has a modest tendency for dispersion. The evaluator concludes that inclusion of a clay barrier is advisable. However, the evaluator goes on to explain that other solutions to the potential problem may be investigated also since the applicant has indicated an interest in treating the dispersive soils with lime in order to flocculate clay particles and reduce their tendency towards dispersion.

The susceptibility of particular soil types to erosion can also be evaluated according to a useful erosion loss equation (see Step 18).

THICKNESS EVALUATION PROCEDURE

The evaluation of closure cover thickness is often of primary importance and the evaluator should devote considerable attention to it. Thickness in excess of a certain established minimum* may be governed by one or more of the following factors:

a. Coverage

b. Infiltration

c. Gas migration

d. Trafficability and support requirements

e. Freeze/thaw or dry/soak effects

This list may be extended by addition of other factors of possible concern such as:

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*Minimum cover thickness requirements vary from state to state according to experience.

f. Cracking (factors f,g,h,i are discussed in reference 1)

g. Differential settlement and offset

h. Membrane protection

i. Vegetative requirements

Evaluate coverage — Step 9

The closure cover functions basically to cover solid waste completely, and therefore, some guidance is in order to evaluate for factor a above. A reasonable criterion of adequacy for coverage over irregular solid waste can be offered as follows:

$$T \geq 2R$$

where T is cover thickness and R is relief. The relief is defined for this criterion as the vertical distance from high point to low point of irregularities on the top surface of the solid waste. The size of the area over which this vertical distance should be measured corresponds roughly to the size of the equipment used for placing closure cover. Where intermediate size dozers are to be used, the area within which the relief is measured would be on the order of 20 by 20 feet. In large covering operations where pans or other large pieces of equipment are to be used, the area size could be on the order of 50 feet across.

The applicant may choose to circumvent the requirement of increasing thickness above the established minimum to compensate for relief by smoothing the upper surface of solid waste. Where sand fill is abundantly available, it can be mixed with heterogenous solid waste in roughly equal proportions for a more workable material to achieve a smoother top surface. The sand-waste mixture thus forms a buffer[1] that can improve the performance and longevity of the cover placed above.

Evaluate Thickness for Infiltration — Step 10

Logically, the next criterion to be examined in the evaluation concerns infiltration, b above. Adequacy against infiltration can be evaluated by use of a water balance technique in which input of water on a monthly or daily basis is compared with expected losses from surface runoff and evapotranspiration. Excesses beyond storage capacity of the cover soil are considered to pass through the cover as percolation. The evaluator is referred to another manual[8] in which the details of a recommended computerized procedure are outlined step by step.

For purposes of evaluating the thickness of the cover, a somewhat abbreviated water balance technique may be useful also. This method has been suggested for predicting percolation by EPA,[9] and its utility in evaluating or designing cover has been reviewed.[1] The water balance technique serves to check the effect of increased thickness for providing increased water storage in the cover soil and consequent decrease in percolation. The example below illustrates the technique and its use.

> Example: Using a 30-year climate record, the evaluator analyzes the effectiveness of a 2-foot silty sand cover with grass at Chippewa Falls, Wisconsin. Table 3 shows the water balance tabulation. The average annual percolation is calculated to be 3.88 inches. The evaluator next expands this analysis to explore the effects of a much thicker cover on percolation. The result is shown in Table 4. A storage capacity of 8 inches (representing greatly increased thickness) is substituted for the storage of 1.05 inches used in Table 3. The overall effect on cumulative percolation is small, with a reduction by only about 20 percent to an annual percolation of 3.13 inches. His analysis indicates to the evaluator that increasing cover thickness is not an efficient way of reducing percolation in this area.

Evaluate Thickness for Gas Migration Step 11

Thickening the cover may be a direct and effective procedure for reducing gas migration through the cover, especially to the extent that increased thickness enhances maintenance of a high moisture content. The technique is especially attractive for remedial work where problems are localized. Increasing thickness of coarse-grained soils affects gas discharge inversely. In fine-grained soils the open pore space necessary for migration is at least intermittently blocked by the included pore water, and the evaluator must consider this complication critically in arriving at his recommendations.

> Example: The cover proposed for a solid waste disposal site in a high-rainfall area consists of a fine-grained soil that basically functions to exclude most percolation. Anticipating eventual problems with gas migration through this cover, the evaluator considers recommending thickening of the cover design. However, after careful consideration, the evaluator concludes that adjustments of the thickness will not have a dramatic effect because the soil usually retains considerable moisture (depending on the complications of rainfall history and evapotranspiration[1]) and is already blocking most of the gas movement. The evaluator learns that the applicant believes that thickening the cover to reduce the remaining intermittent, uncontrolled gas discharge will also not be cost-effective and, therefore, thickening is not favored by the applicant. He then concentrates his immediate attention on considering other options such as gas vents though it may be necessary to return later to the thickening technique despite its low cost-effectiveness.

TABLE 3. MONTHLY WATER BALANCE ANALYSIS IN INCHES FOR CHIPPEWA FALLS, WISCONSIN[1]

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Average Precipitation (P)	0.89†	0.71†	0.77‡ 0.77‡	2.55	3.73	4.19	3.65	3.56	3.37	2.04	0.67‡ 0.67‡	1.00†	4.04 24.53
Runoff (RO)			0.05	0.17	0.24	0.27	0.24	0.23	0.22	0.13	0.04		1.59
Moisture available for infiltration (I)	0.00	0.00	0.72	2.38	3.49	3.92	3.41	3.33	3.15	1.91	0.63	0.00	22.94
Potential evapotranspiration (PET)	0.00	0.00	0.00	1.10	2.50	3.90	4.60	4.00	2.70	1.20	0.00	0.00	20.00
(I - PET)	0.00	0.00	0.72	1.28	0.99	0.02	-1.19	-0.67	0.45	0.71	0.63	0.00	
(Σ neg (I - PET))						(0)	-1.19	-1.86					
Soil moisture storage (ST)	1.05	1.05	1.05§	1.05	1.05	1.05	0.27	0.13	0.58	1.05	1.05	0.05	
(ΔST)	0.00	0.00	0.00	0.00	0.00	0.00	-0.78	-0.14	+0.45	+0.47	0.00	0.00	
Actual evapotranspiration (AET)	0.00	0.00	0.00	1.10	2.50	3.90	4.19	3.47	2.70	1.20	0.00	0.00	19.06
Percolation (PRC)	0.00	0.00	0.72	1.28	0.99	0.02	0.00	0.00	0.00	0.24	0.63	0.00	3.88

† Precipitation between November 16 and March 15 is listed as snow but is changed to runoff at spring thaw.

‡ Precipitation in November and March is divided into half rain, half snow.

§ Water-holding capacity is assumed to be at maximum in March when snow melts.

TABLE 4. MONTHLY WATER BALANCE ANALYSIS IN INCHES WITH THICK COVER*

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Average Precipitation (P)	0.89†	0.71†	0.77‡ 0.77‡	2.55	3.73	4.19	3.65	3.56	3.37	2.04	0.67‡ 0.67‡	1.00†	4.04 24.53
Runoff (RO)			0.05	0.17	0.24	0.27	0.24	0.23	0.22	0.13	0.04		1.59
Moisture available for infiltration (I)	0.00	0.00	0.72	2.38	3.49	3.92	3.41	3.33	3.15	1.91	0.63	0.00	22.94
Potential evapotranspiration (PET)	0.00	0.00	0.00	1.10	2.50	3.90	4.60	4.00	2.70	1.20	0.00	0.00	20.00
(I - PET)	0.00	0.00	0.72	1.28	0.99	0.02	-1.19	-0.67	0.45	0.71	0.63	0.00	
(Σ neg (I - PET))						(0)	-1.19	-1.86					
Soil moisture storage (ST)	8.00	8.00	8.00§	8.00	8.00	8.00	6.89	6.33	6.78	7.49	8.00	8.00	
(ΔST)	0.00	0.00	0.00	0.00	0.00	0.00	-1.11	-0.56	+0.45	+0.71	+0.51	0.00	
Actual evapotranspiration (AET)	0.00	0.00	0.00	1.10	2.50	3.90	4.52	3.89	2.70	1.20	0.00	0.00	19.81
Percolation (PRC)	0.00	0.00	0.72	1.28	0.99	0.02	0.00	0.00	0.00	0.00	0.12	0.00	3.13

* Compare with Table 3.

† Precipitation between November 16 and March 15 is listed as snow but is changed to runoff at spring thaw.

‡ Precipitation in November and March is divided into half rain, half snow.

§ Water-holding capacity is assumed to be at maximum in March when snow melts.

Evaluate Support Requirements — Step 12

The low bearing capacity of some solid waste landfills can be circumvented by increasing soil thickness above waste. In this way the relatively strong soil resists punching and rotational shear. The thickness of soil should be at least 1.5 x the width of footings. However, any proposal to superimpose buildings on the cover should receive particularly critical reviews and would ordinarily be rejected for a hazardous waste site. Past experience with buildings on landfills is replete with cases of structural damage from differential settlement and unnecessary hazard from accumulation of methane and other gases.

Consider Freeze/Thaw and Dry/Soak Effects — Step 13

In cold regions of the country, special attention may need to be directed to disturbing effects of freezing. Similarly in semiarid areas subject to periods of sustained drying conditions, equal concern may be warranted in regard to excessive drying and cracking. The reasons for concern have been summarized elsewhere.[1]

The evaluator may check for adequacy of the cover thickness by use of Figure 12 or similar summary. In case of a need for greater detail or in locations of mountainous terrain where the depth of freezing can vary over short distances, the evaluator should seek information on depth of freezing from a local agricultural agency. The depth of drying to be expected over extended droughty periods can similarly be estimated on the basis of experience in the region.

> Example: An applicant has proposed to use 3 feet of soil in the northern Great Plains where the average annual maximum depth of freezing is 3 feet. To avoid disturbance of the cover to its full thickness the evaluator recommends that cover thickness be increased to 4 feet.

Before requiring substantial modification by thickening the cover, the evaluator would ordinarily obtain a consensus among selected local engineers that the disturbance of the cover could be significant.

PLACEMENT EVALUATION PROCEDURE

After selection of the material and appropriate thickness for cover, efforts should be directed to the most effective placement and treatment. Cover can be improved in several ways as it is constructed. Materials may be added for better gradation, hauling and spreading equipment can be operated beneficially, and certain layering can be introduced.[1]

Evaluate Cover Compaction — Step 14

Some compaction is almost always accomplished during the spreading of cover soil; and this densification is highly effective in producing benefits,

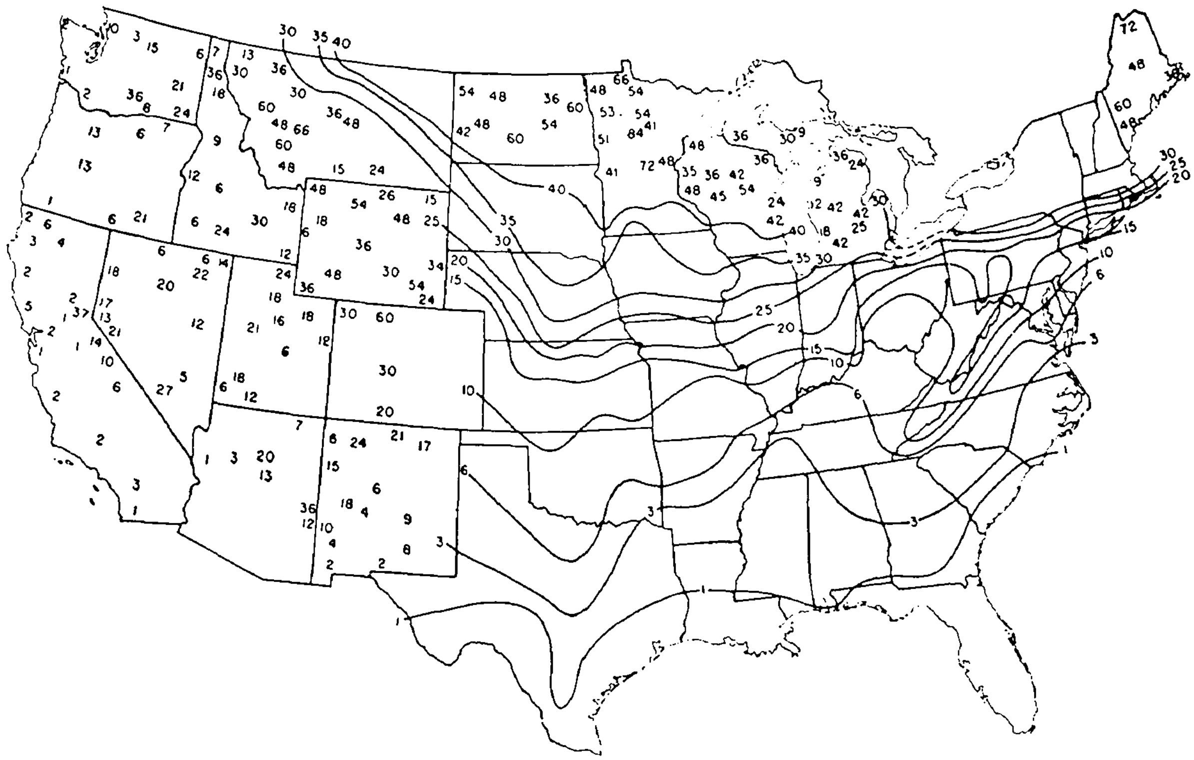

Figure 12. Regional depth of frost penetration in inches.[11]

principally increasing strength and reducing permeability. Figures 13 and 14 illustrate these effects and provide the evaluator some guidance on what can be achieved. The laboratory compaction test provides a useful data base on which the evaluator can judge the effects of compaction of the cover under consideration. It has been found[1] that soil compacted routinely over soft waste (municipal wastes) falls below standard compaction curves such as obtained in ASTM D698 (Table 1). The differences in field compaction results over spongy solid waste versus those over a hard base can be compensated approximately by using laboratory test procedures with fewer than the "standard" 25 blows of the compacting hammer. Keep in mind that the objective of the laboratory tests is to model actual field compaction of cover soil with dozers and other compacting equipment.

Approximate general guidance (Figure 15) has been derived regarding the field compaction effort necessary in 6 to 12 inches of soil cover on municipal solid waste. Field dry density of the cover can be predicted from measured placement water contents by using laboratory compaction curves at appropriately light compaction effort. For example, where a dozer makes four passes on the average, a 5-blow compaction curve should be determined

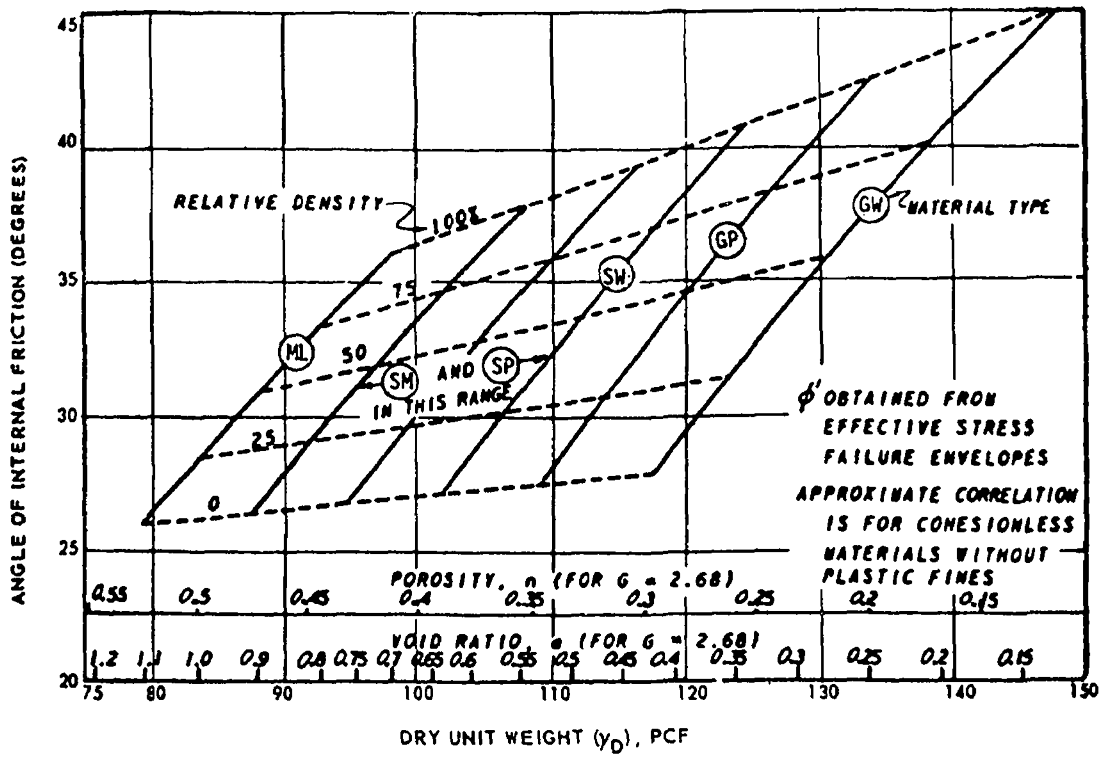

Figure 13. Relation of effective angle of internal friction to dry unit weight (US Navy).

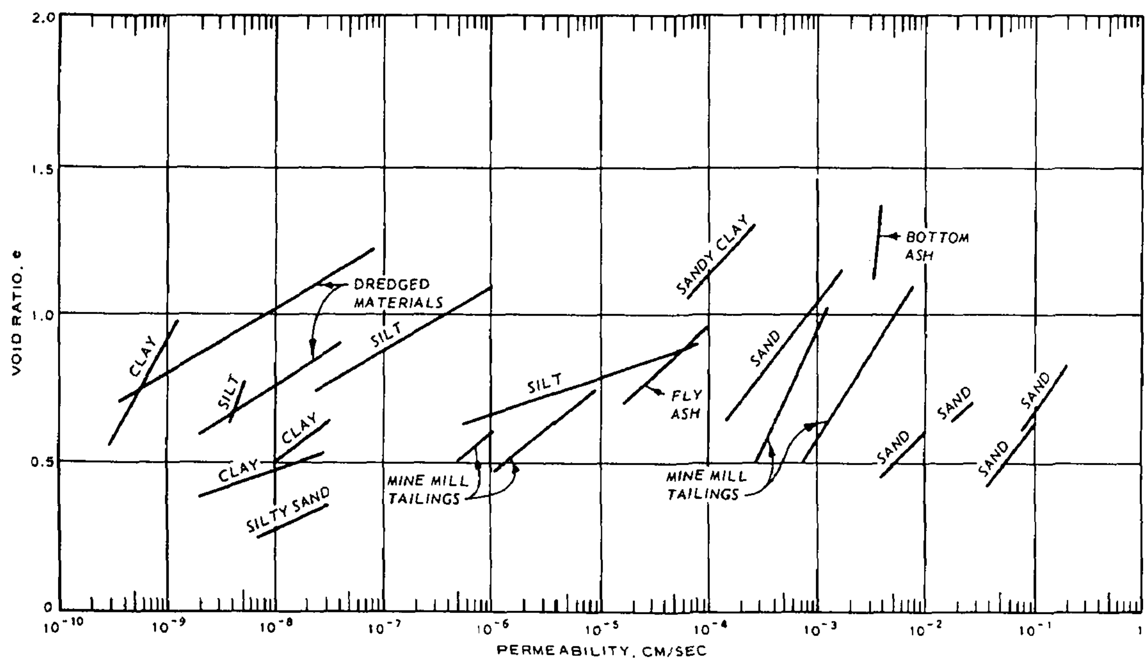

Figure 14. Coefficient of permeability of materials as affected by degree of compaction.

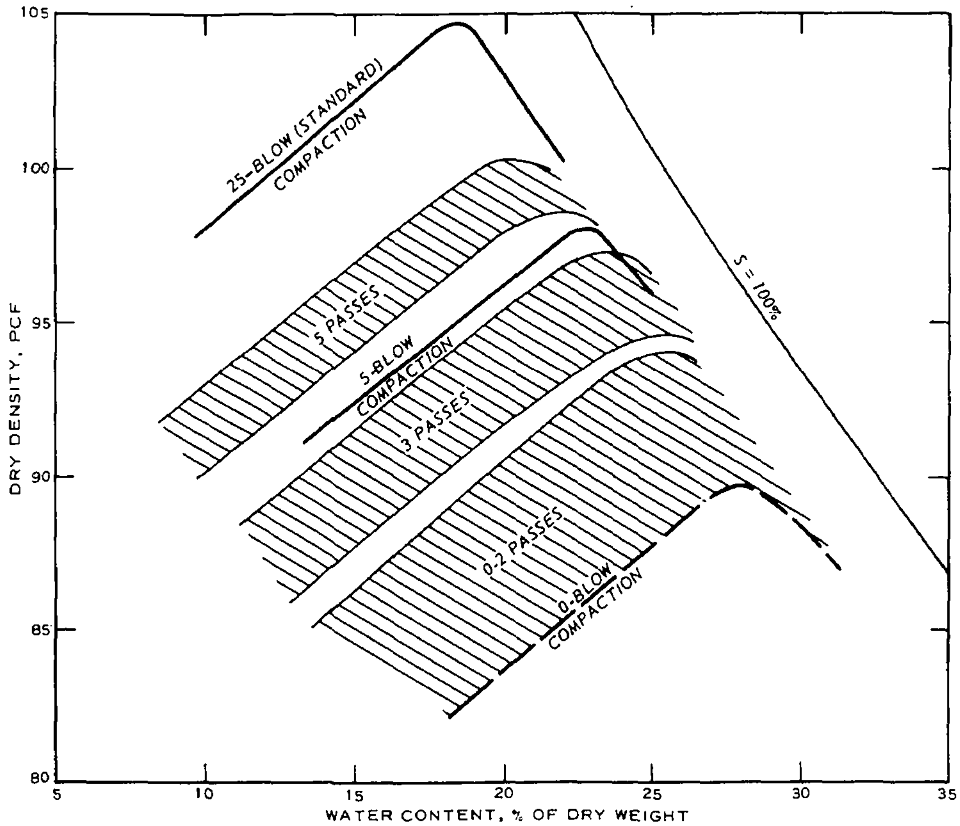

Figure 15. Schematic guidance for predicting cover compaction results with intermediate-size dozers on municipal solid waste using laboratory test results.

by laboratory testing and be used for predictions. The curves shown in Figure 15 appear generally valid, but relations between field compaction and laboratory curves should be determined site-specifically if cover density data are deemed necessary;[1] the evaluator may need to make this judgment under Step 2. A reasonable goal for which one might strive, particularly in the compaction of barrier layers, is 90 percent of maximum dry density according to 5- or 15-blow compaction tests. On the other hand, when compacting on a solid base, e.g., on a granular soil-like solid waste, one might strive for 90 percent of maximum dry density by standard 25-blow tests.

Example: In his second submission of an application, an owner/operator has included results of 15-blow compaction tests conducted on the cover soil by a certified testing laboratory (Figure 16). It is claimed later that approximately 90 percent of maximum dry density will be achieved with six passes of the compacting equipment. The natural water content is approximately 10 percent. The evaluator notes that the cover soil is to be excavated and hauled and placed directly. He therefore asks the applicant to expand on his intentions as far as manipulating the water content of the soil closer to optimum in order to reasonably expect 90 percent of maximum dry density.

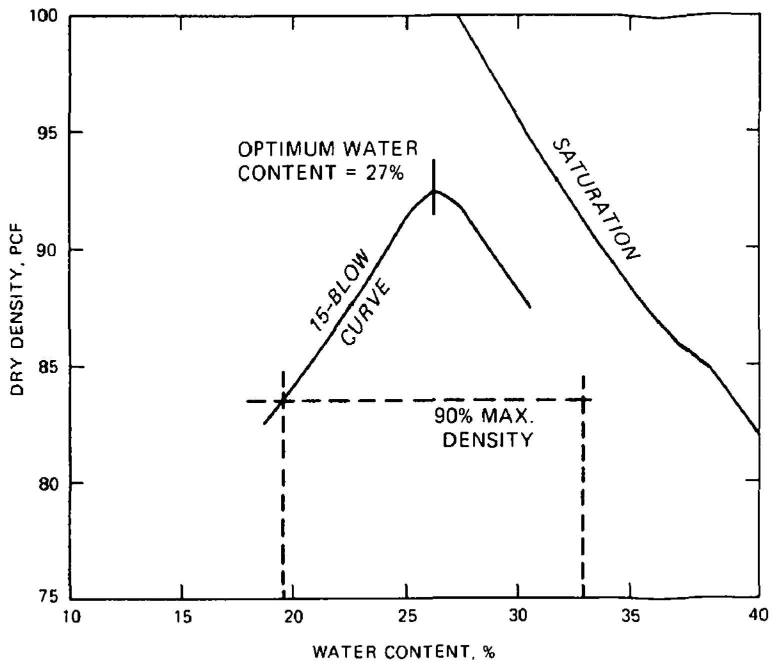

Figure 16. Hypothetical cover soil compaction.

Evaluate Internal Layering — Step 15

Layering is a promising technique for final solid waste cover. By combining two or three distinct materials in layers (Figure 17) the designer may mobilize favorable characteristics of each together at little extra expense. The following descriptions[1] should help to guide the evaluation of layered cover designs.

The primary feature in layered systems is usually the barrier. This layer functions to restrict passage of water or gas. Barrier layers are almost always composed of clayey soil that has inherently low permeability; USCS types CH, CL, and SC (Figure 3) are recommended. Soil barriers are susceptible to deterioration by cracking when exposed at the surface, so that a buffer layer above is recommended to protect the clayey soil from excessive drying.

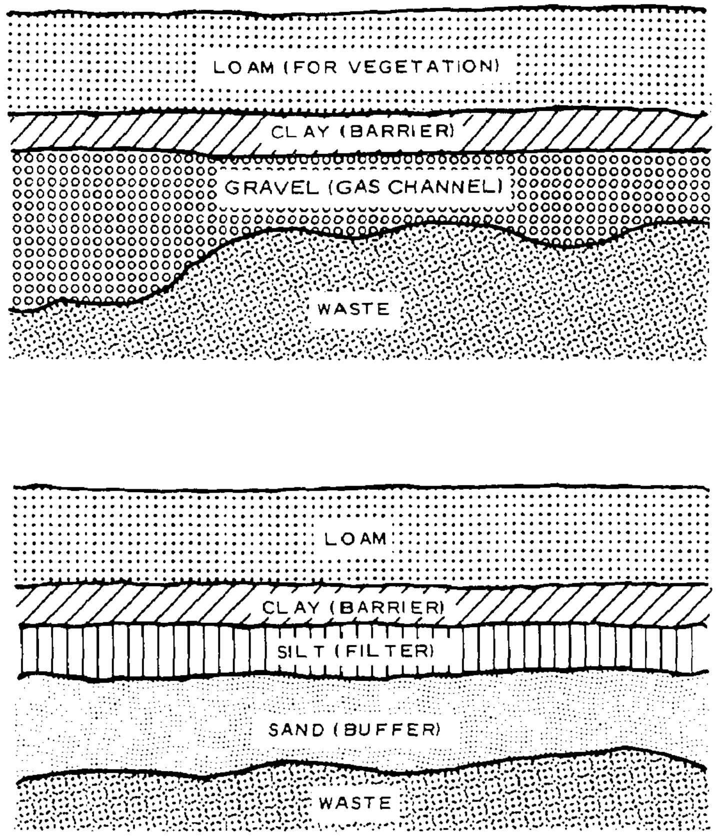

Figure 17. Typical layered cover systems.

Synthetic membranes of butyl or neoprene rubber, hypalon, polyolefin, polyvinyl chloride, etc. may be considered in place of soil barriers.[1] Usually a sheet thickness of at least 20 mils is required. Some membranes should be spread carefully over a smooth base to lie in a relaxed state or a 5-percent slack may be necessary; usually the manufacturers provide directions. Soils immediately above and below a membrane can constitute critical components of the layered cover since irregularities and hard pieces impinging on the membrane can cause damage, particularly during subsequent compaction. Therefore, the application should address thoroughly the question of preserving the integrity of the impermeable membrane during construction. Manufacturer's recommendations for splicing the membrane in the field should be followed and should be detailed in the application. Provide a trench at least 8 inches deep or other anchorage at the top of any slope. The evaluation of synthetic membranes in layered cover systems may benefit from related guidance on basal liner systems presented in another manual;[10] particularly in regard to reactivity between waste and membrane.

Barrier layers may also be constructed by adding certain additives or cements to the available soil. Addition of bentonite clay is a proven means of reducing permeability, but homogenizing the mixture can present difficulties and may need to be confirmed by laboratory tests, post-placement examination, or other means identified in the permit application. Other additions to soil, such as lime, portland cement, and bituminous cement, may require an even more conservative stance on the part of the evaluator since experiences with these materials in layered covers are quite limited.

Layered cover systems should include buffer soil layers[1] where a buffer layer may be described as a random layer having a subordinate covering function. Buffers serve to protect the barrier layer or membrane sheet from tears, cracks, offsets, punctures, and other deterioration. Below a barrier or the main cover soil a buffer also provides a smooth, regular base. Any soil type will serve as a buffer ordinarily, but it should be free of clods. A properly placed buffer filling voids around barrels of waste serves to minimize settlement and disruption of the final capping cover.

Where layers with grossly discordant grain sizes are joined, there may be a tendency for fine particles to penetrate the coarser layer. As a result, the effectiveness of coarse layers that may be used for water drainage can be reduced by clogging of the pores. Removals from the fine layer may promote additional bad effects, such as internal erosion and settlement. Similar problems can develop around pipe drains buried in the cover system. Such problems are confronted in construction and agriculture, and procedures have been established for choosing grain size for a filter. A widely used criterion is written

$$\frac{D_{15}\text{(filter soil)}}{D_{85\text{(protected soil)}}} < 4 \text{ to } 5$$

where D_{15} and D_{85} refer to the grain sizes for which 15 and 85 percent by weight of the soils are finer, respectively. Common filter soils are SP, SM, ML, and MH (Figure 3); filter fabric or cloth may be considered in place of a soil filter layer.

> Example: Suppose that grain-size distribution curves have been submitted with the application to represent soils to be used in a layered system. The evaluator locates the D_{15} and D_{85} grain sizes at the points shown in Figure 18. Since the ratio of these sizes does not meet the criterion, the application is returned for modification of design.

A water drainage layer, blanket, or channel may be designed into cover in numerous ways to provide a path for water to exit rapidly. Well sorted (poorly graded) sand and gravel are recommended as effective drainage materials, i.e. soils classified GP and SP. Drainage channels and layers may be associated with a system of buried pipe drains but the expense of this combined system ordinarily limits its applicability to high-priority disposal areas.

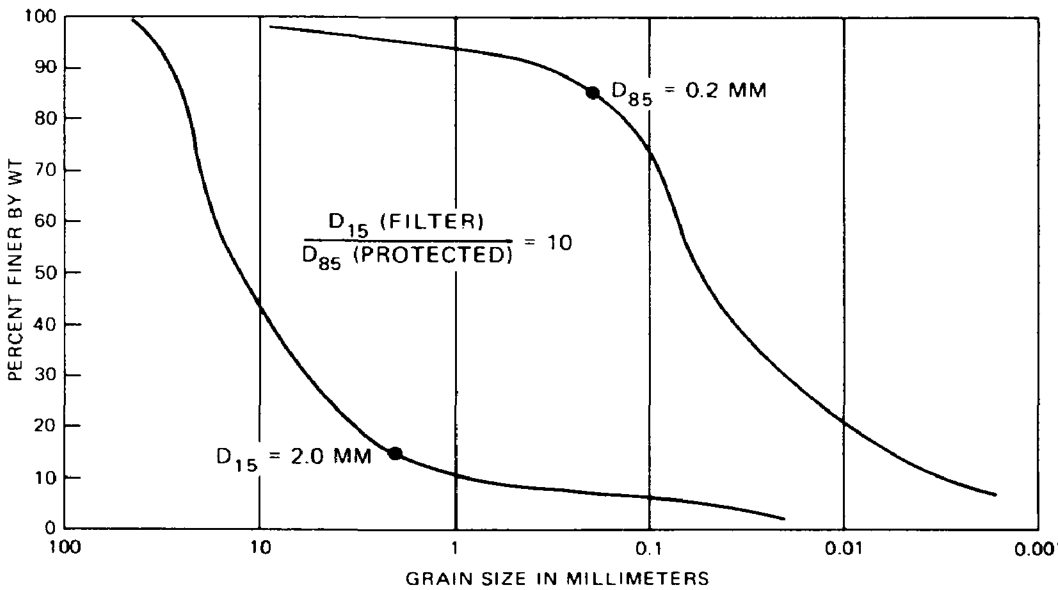

Figure 18. Hypothetical size gradation of ineffective filter soil.

Gas drainage layer and vents may have granular consistency and interconnections and general configuration similar to those of the water drainage layer or channel. Both layer types function to transmit preferentially. The position in the cover system is a main distinction. The gas drainage layer is placed on the lower side to intercept gases rising from waste cells whereas the drain for water is positioned on the upper side to intercept water percolating from the surface. Figure 19 illustrates a passive gas

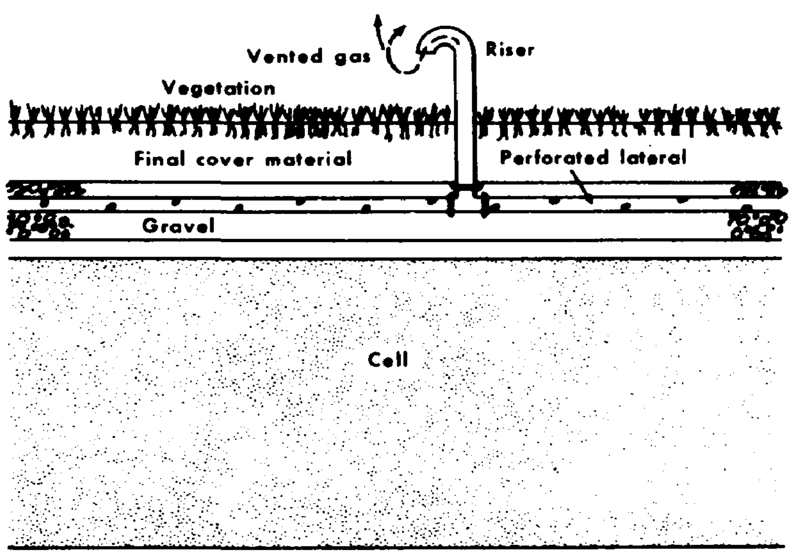

Figure 19. Passive collecting and venting system of laterals in gravel trenches above waste cell.

vent design concept, but the pressure-induced draft systems are preferred to passive vents in most cases. Details of the systems should be included in the permit application.

Evaluate Top Soil — Step 16

A top soil or a subsoil made amenable to supporting vegetation frequently forms the top of a layered cover system. Untreated subsoils are seldom suitable directly, so it has been necessary frequently to supplement subsoil with fertilizers, conditioners, etc., as explained elsewhere (Steps 24-26) to obtain the desired result. Loams or USCS types GM, GC, SM, SC, ML, and CL (Figure 3) are recommended but agronomic considerations usually prevail. The upper lift should be placed in a loose condition and not compacted.

Review Proposed Construction Techniques — Step 17

The application should be carefully reviewed for conformance to the following general recommendations[1] for layering (from the bottom up):

a. Make buffer layer below barrier thick and dense enough to provide smooth, stable base for compacting in c. below.

b. Compact all layers except topsoil and top lift of upper buffer.

c. In barrier layer, consider striving for 90 percent of maximum dry density according to 5- or 15-blow compaction test where solid waste is soft or according to standard 25-blow compaction test where solid waste is granular and soil-like.

d. Cover barrier layer soon enough to prevent excessive drying and cracking.

e. Provide sufficient design thickness to assure performance of layer function; specifying a 6- to 12-inch minimum should prevent excessively thin spots resulting from poor spreading techniques.

f. Construct in plots small enough to allow rapid completion.

g. Consider seeding topsoil at time of spreading.

CONFIGURATION EVALUATION PROCEDURE

The concern for the configuration of the cover surface is driven mostly by a concern to avoid excessive erosion or excessive infiltration. Not only is erosion objectionable in itself but erosion can degrade the cover and seriously reduce its effectiveness.

The USDA universal soil loss equation (USLE) is a convenient tool for use in evaluating erosion potential. The USLE predicts average annual soil loss as the product of six quantifiable factors. The equation is:

$$A = R\ K\ L\ S\ C\ P$$

where A = average annual soil loss, in tons/acre
R = rainfall and runoff erosivity index
K = soil erodibility factor, tons/acre
L = slope-length factor
S = slope-steepness factor
C = cover/management factor
P = practice factor

The data necessary as input to this equation are available to the evaluator in a figure and tables included below. Note that the evaluations in Step 8 on soil composition and Steps 23-29 on vegetation all impact on the evaluation of erosion also.

Factor R in the USLE can be calculated empirically from climatological data. For average annual soil loss determinations, however, R can be obtained directly from Figure 20. Factor K, the average soil loss for a given soil in

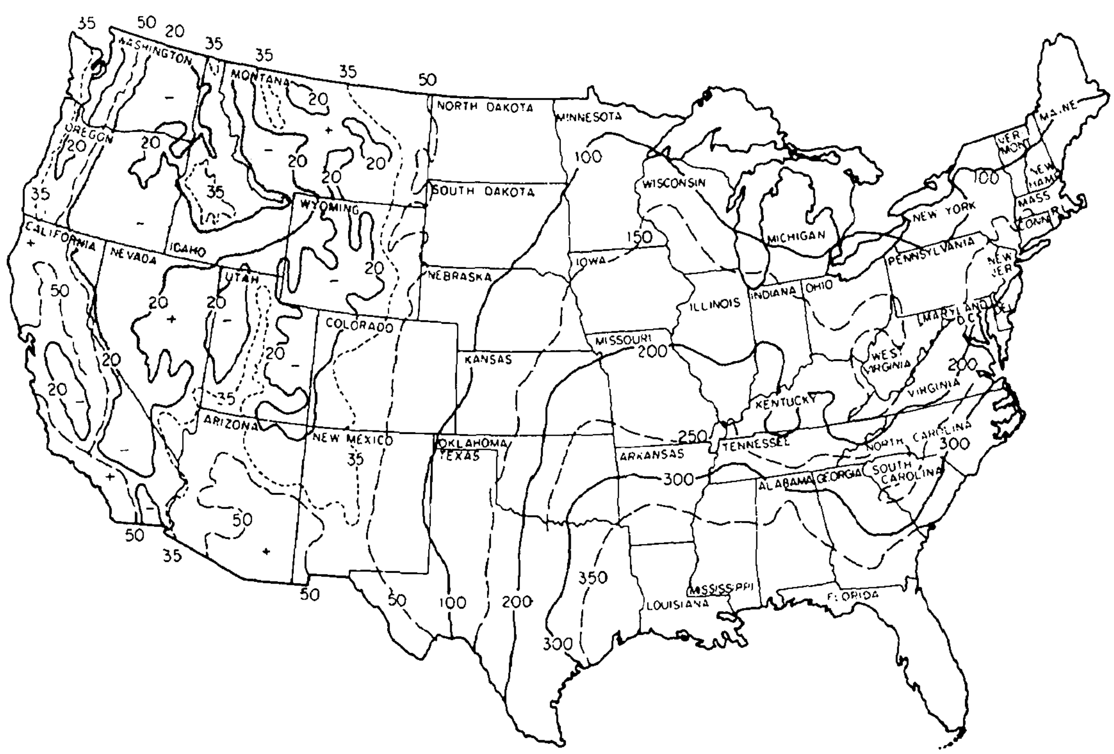

Figure 20. Average annual values of rainfall-erosivity factor R .[11]

a unit plot, pinpoints differences in erosion according to differences in soil type. Long-term plot studies under natural rainfall have produced K values generalized in Table 5 for the USDA soil types.

TABLE 5. APPROXIMATE VALUES OF FACTOR K FOR USDA TEXTURAL CLASSES[11]

Texture class	Organic matter content <0.5% K	2% K	4% K
Sand	0.05	0.03	0.02
Fine sand	.16	.14	.10
Very fine sand	.42	.36	.28
Loamy sand	.12	.10	.08
Loamy fine sand	.24	.20	.16
Loamy very fine sand	.44	.38	.30
Sandy loam	.27	.24	.19
Fine sandy loam	.35	.30	.24
Very fine sandy loam	.47	.41	.33
Loam	.38	.34	.29
Silt loam	.48	.42	.33
Silt	.60	.52	.42
Sandy clay loam	.27	.25	.21
Clay loam	.28	.25	.21
Silty clay loam	.37	.32	.26
Sandy clay	.14	.13	.12
Silty clay	.25	.23	.19
Clay		0.13-0.29	

The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values.

The evaluator must next consider the shape of the slope in terms of length and inclination. The appropriate LS factor is obtained from Table 6. A nonlinear slope may have to be evaluated as a series of segments, each with uniform gradient. Two or three segments should be sufficient for most engineered landfills, provided the segments are selected so that they are also of equal length (Table 6 can be used, with certain adjustments). Enter Table 6 with the total slope length and read LS values corresponding to the percent slope of each segment. For three segments, multiply the chart LS values for the upper, middle, and lower segments by 0.58, 1.06, and 1.37,

TABLE 6. VALUES OF THE FACTOR LS FOR SPECIFIC COMBINATIONS OF SLOPE LENGTH AND STEEPNESS[11]

% Slope	Slope length (feet)											
	25	50	75	100	150	200	300	400	500	600	800	1000
0.5	0.07	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.17	0.19	0.20
1	0.09	0.10	0.12	0.13	0.15	0.16	0.18	0.20	0.21	0.22	0.24	0.26
2	0.13	0.16	0.19	0.20	0.23	0.25	0.28	0.31	0.33	0.34	0.38	0.40
3	0.19	0.23	0.26	0.29	0.33	0.35	0.40	0.44	0.47	0.49	0.54	0.57
4	0.23	0.30	0.36	0.40	0.47	0.53	0.62	0.70	0.76	0.82	0.92	1.0
5	0.27	0.38	0.46	0.54	0.66	0.76	0.93	1.1	1.2	1.3	1.5	1.7
6	0.34	0.48	0.58	0.67	0.82	0.95	1.2	1.4	1.5	1.7	1.9	2.1
8	0.50	0.70	0.86	0.99	1.2	1.4	1.7	2.0	2.2	2.4	2.8	3.1
10	0.69	0.97	1.2	1.4	1.7	1.9	2.4	2.7	3.1	3.4	3.9	4.3
12	0.90	1.3	1.6	1.8	2.2	2.6	3.1	3.6	4.0	4.4	5.1	5.7
14	1.2	1.6	2.0	2.3	2.8	3.3	4.0	4.6	5.1	5.6	6.5	7.3
16	1.4	2.0	2.5	2.8	3.5	4.0	4.9	5.7	6.4	7.0	8.0	9.0
18	1.7	2.4	3.0	3.4	4.2	4.9	6.0	6.9	7.7	8.4	9.7	11.0
20	2.0	2.9	3.5	4.1	5.0	5.8	7.1	8.2	9.1	10.0	12.0	13.0
25	3.0	4.2	5.1	5.9	7.2	8.3	10.0	12.0	13.0	14.0	17.0	19.0
30	4.0	5.6	6.9	8.0	9.7	11.0	14.0	16.0	18.0	20.0	23.0	25.0
40	6.3	9.0	11.0	13.0	16.0	18.0	22.0	25.0	28.0	31.0	--	--
50	8.9	13.0	15.0	18.0	22.0	25.0	31.0	--	--	--	--	--
60	12.0	16.0	20.0	23.0	28.0	--	--	--	--	--	--	--

Values given for slopes longer than 300 feet or steeper than 18% are extrapolations beyond the range of the research data and, therefore, less certain than the others.

respectively. The average of the three products is a good estimate of the overall effective LS value. If two segments are sufficient, multiply by 0.71 and 1.29.

Factor C in the USLE is the ratio of soil loss from land cropped under specified conditions to that from clean-tilled, continuous fallow. Therefore, C combines effects of vegetation, crop sequence, management, and agricultural (as opposed to engineering) erosion-control practices. On landfills, freshly covered and without vegetation or special erosion-reducing procedures of cover placement, C will usually be about unity. Where there is vegetative cover or significant amounts of gravel, roots, or plant residues or where cultural practices increase infiltration and reduce runoff velocity, C is much less than unity. Estimate C by reference to Table 7 for cover management conditions anticipated in the application, and consider changes that may take place in time. See Reference 1 for additional guidance.

Factor P in the USLE is similar to C except that it accounts for additional erosion-reducing effects of land management practices that are superimposed on the cultural practices, e.g., contouring, terracing, and

TABLE 7. GENERALIZED VALUES OF FACTOR C FOR STATES EAST OF THE ROCKY MOUNTAINS[11]

Crop, rotation, and management	Productivity level	
	High	Mod.
	C value	
Base value: continuous fallow, tilled up and down slope	1.00	1.00
CORN		
C, RdR, fall TP, conv	0.54	0.62
C, RdR, spring TP, conv	.50	.59
C, RdL, fall TP, conv	.42	.52
C, RdR, wc seeding, spring TP, conv	.40	.49
C, RdL, standing, spring TP, conv	.38	.48
C-W-M-M, RdL, TP for C, disk for W	.039	.074
C-W-M-M-M, RdL, TP for C, disk for W	.032	.061
C, no-till pl in c-k sod, 95-80% rc	.017	.053
COTTON		
Cot, conv (Western Plains)	0.42	0.49
Cot, conv (South)	.34	.40
MEADOW		
Grass & Legume mix	0.004	0.01
Alfalfa, lespedeza or Sericia	.020	
Sweet clover	.025	
SORGHUM, GRAIN (Western Plains)		
RdL, spring TP, conv	0.43	0.53
No-till pl in shredded 70-50% rc	.11	.18
SOYBEANS		
B, RdL, spring TP, conv	0.48	0.54
C-B, TP annually, conv	.43	.51
B, no-till pl	.22	.28
C-B, no-till pl, fall shred C stalks	.18	.22
WHEAT		
W-F, fall TP after W	0.38	
W-F, stubble mulch, 500 lbs rc	.32	
W-F, stubble mulch, 1000 lbs rc	.21	

Abbreviations defined:

B - soybeans
C - corn
c-k - chemically killed
conv - conventional
cot - cotton
F - fallow
M - grass & legume hay
pl - plant
W - wheat
wc - winter cover

lbs rc - pounds of crop residue per acre remaining on surface after new crop seeding
% rc - percentage of soil surface covered by residue mulch after new crop seeding
70-50% rc - 70% cover for C values in first column; 50% for second column
RdR - residues (corn stover, straw, etc.) removed or burned
RdL - all residues left on field (on surface or incorporated)
TP - turn plowed (upper 5 or more inches of soil inverted, covering residues)

contour strip-cropping. Approximate values of P, related only to slope steepness, are listed in Table 8. These values are based on rather limited field data, but P has a narrower range of possible values than the other five factors.

TABLE 8. VALUES OF FACTOR P[11]

Practice	Land slope (percent)				
	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
	(Factor P)				
Contouring (P_c)	0.60	0.50	0.60	0.80	0.90
Contour strip cropping (P_{sc})					
R-R-M-M[1]	0.30	0.25	0.30	0.40	0.45
R-W-M-M	0.30	0.25	0.30	0.40	0.45
R-R-W-M	0.45	0.38	0.45	0.60	0.68
R-W	0.52	0.44	0.52	0.70	0.90
R-O	0.60	0.50	0.60	0.80	0.90
Contour listing or ridge planting (P_{cl})	0.30	0.25	0.30	0.40	0.45
Contour terracing (P_t)[2]	[3] $0.6/\sqrt{n}$	$0.5/\sqrt{n}$	$0.6/\sqrt{n}$	$0.8/\sqrt{n}$	$0.9/\sqrt{n}$
No support practice	1.0	1.0	1.0	1.0	1.0

[1] R = rowcrop, W = fall-seeded grain, O = spring-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that rowcrop strips are always separated by a meadow or winter-grain strip.

[2] These P_t values estimate the amount of soil eroded to the terrace channels and are used for conservation planning. For prediction of off-field sediment, the P_t values are multiplied by 0.2.

[3] n = number of approximately equal-length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

Example: An owner/operator proposes to close one section of his small landfill with a sandy clay subsoil cover having the surface configuration shown in Figure 21. The factor R has been established as 200 for this locality. The evaluator questions anticipated erosion along the steep side and assigns the following values to the other factors in the USLE after inspecting Tables 5 through 8:

$$K = 0.14 \quad LS = 8.3 \quad C = 1.00 \quad P = 0.90$$

The rate of erosion for the steep slope of the landfill is calculated as follows:

$$A = 200\ (0.14\ \text{tons/acre})\ (8.3)\ (1.00)\ (0.90) = 209\ \text{tons/acre}$$

This erosion not only exceeds a limit recommended by the permitting authority but also indicates a potential exposure of solid waste in that side of the landfill. The evaluator therefore recommends that the owner/operator review his plan of closure to reduce the potential erosion. One way that the operator might accomplish this reduction in erosion is by placing additional solid waste along the steep slope in an overlapping wedge as indicated in the figure. Although the new cover would have a greater slope length, the overall effect is to reduce the factor LS and the amount of erosion.

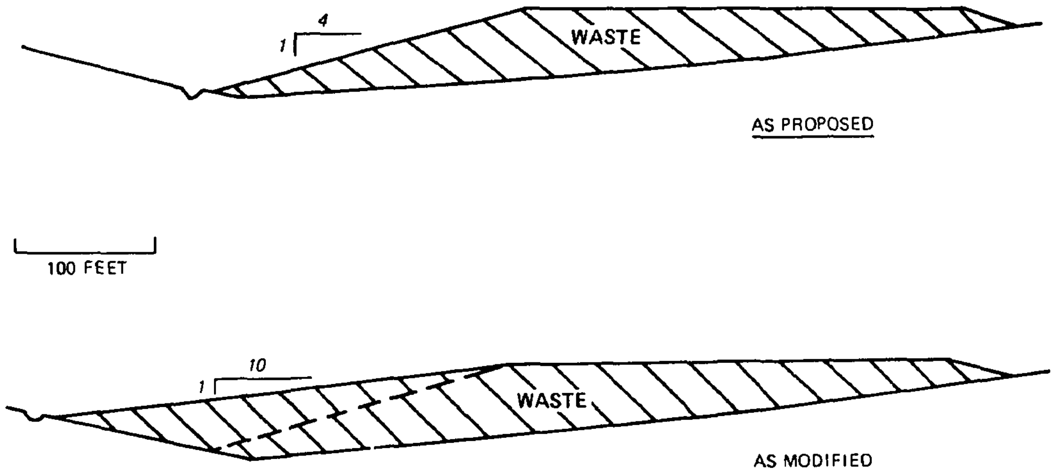

Figure 21. Hypothetical landfill configuration and modification.

Evaluate Surface Slope Inclination — Step 19

Rainfall runoff is increased by increases in inclination of the surface, and accordingly, infiltration decreases. Since erosion also increases with increasing inclination (Step 18), the balance between these opposing considerations often must be carefully evaluated. On slopes of less than 3 percent, the irregularities of the surface and vegetation commonly act as traps for detention of runoff. The value 5 percent has been suggested and used in grounds maintenance[12] as an approximation of an inclination sufficient to facilitate runoff without risking excessive erosion. A quantitative evaluation of the erosional effect of inclination is outlined for factor LS under Step 18.

Slope inclination becomes more critical as inclination is increased. Not only is erosion more serious, but slope mass stability can become a factor on relatively steep side slopes of landfills and surface impoundments. Usually the evaluator will do well to seek assistance from technical agencies experienced in analyzing slope stability since varied strength properties and seepage conditions can greatly complicate the mass stability. As a rough guide, however, the evaluator can usually count on the rule of thumb that not exceeding 1V (vertical) on 4H (horizontal) or other inclination shown by experience or analysis to be relatively stable would assure satisfactory slope performance in most cases.

The vulnerability of knoll-like configurations to wind erosion can be evaluated by the use of Figure 22. An adjustment factor is obtained as an erosion loss percentage of 100 or more in comparison with erosion loss from a similar flat surface. This factor should be used to estimate the effects of sides of landfills that may present a knoll-like configuration toward the prevailing winds.

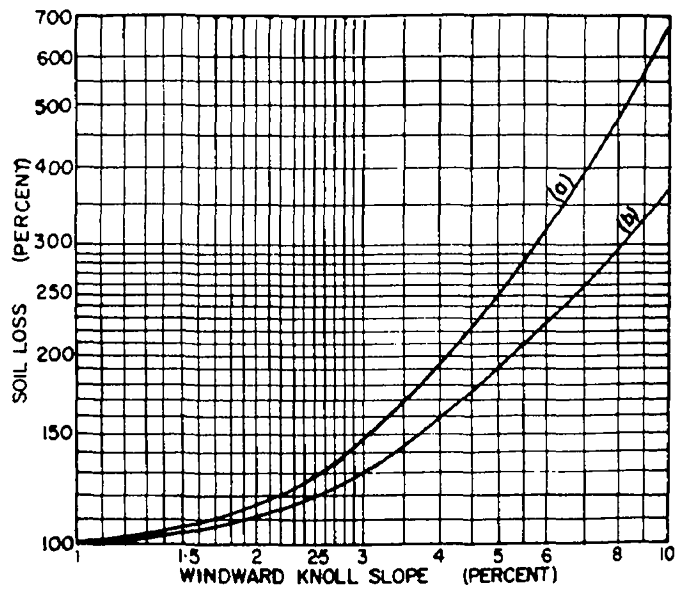

Figure 22. Knoll adjustment (a) from top of knoll and (b) from upper third of slope.[13] (Reproduced by permission of Soil Science Society of America.)

Finally, another general rule of thumb[14] provides that 1V on 2H is the maximum slope on which vegetation can be established and maintained, assuming ideal soil with low erodibility and adequate moisture-holding capacity. In soils less than ideal, maximum vegetative stability cannot be attained on slopes steeper than about 1V on 3H. Optimum vegetative stability generally requires slopes of 1V on 4H or flatter.

DRAINAGE EVALUATION PROCEDURE

Check Overall Drainage System — Step 20

Examine the documentation to establish that drainage of surface runoff from the covered area and surroundings has been thoroughly addressed. Maps presenting topography or other descriptions of surface configuration should be carefully reviewed to see that rainfall or snow melt on any part of the site is free to move downslope without encountering obstacles that might lead to ponding or excessive erosion. At the same time, a check should be made to see that the slope is not anywhere in excess of the slopes for flat surfaces and for ditches provided in the regulations. In those places such as the edge of the landfill where slopes may of necessity be relatively steep, a check for adverse effects in the form of excessive erosion should be made as explained elsewhere (Step 18).

Evaluate Ditch Design — Step 21

To confirm the adequacy of drainage ditches, the evaluator should formally check the hydraulic calculations on which design for ditch cross sections are based. This step can be important but for many landfills may only be necessary where diversion ditches convey runoff from beyond the site around its edge. Calculation should not usually be necessary on the landfill cover itself unless an overflow situation would have serious consequences.

Design (and evaluation) of a ditch is routinely accomplished using the Rational equation (Step 7) and Manning's equation. It was explained in Section 2 that calculations of discharge Q for design storm or storms should be included with the documentation supplied with the application for closure. Q in cubic feet/second is used to calculate ditch cross sections in Manning's equation:

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

where n = coefficient of roughness
A = area, square feet
R = hydraulic radius, feet
S = energy gradient, feet/foot

The Manning n value is usually obtained from a table and that authoritative reference should be cited in the application to facilitate checking. For a rough check, use $n = 0.02$. The S in the equation is simply the longitudinal inclination of the ditch.

The design amounts to a manipulation of the remaining unknowns A and R within certain constraints. Numerous tables have been developed and are available for assistance in design; again these references should be identified when used. The cross sectional area A of the waterfilled ditch is affected by the choice of shape, e.g., between triangular and trapezoidal. The hydraulic radius R is also affected since it is by definition the area divided by the wetted perimeter formed by the ditch. A final constraint is the requirement that erosion in the ditch be limited by limiting discharge velocity Q/A to an appropriate maximum from among those determined as critical for the range of soil types (Table 9).

Evaluate Culvert Design — Step 22

Evaluations of culverts and other closed structures that may occasionally be used as a part of the drainage system are approached in approximately

TABLE 9. THRESHOLD VELOCITY FOR EROSION IN DITCHES

Soil	V_{max}, feet/second
GP	7-8
GW, GC	5-7
GM	2-5
SC	3-4
SM	2-3
SW, SP	1-2
CL, CH	2-3
ML, MH	3-5

the same way as Step 21. An added complication is the capacity of the structure to transmit the water. Where the capacity is too small, water will back up and form a pond, at least temporarily.

VEGETATION EVALUATION PROCEDURE

Rapid establishment and maintenance of vegetation can be accomplished on soil covering solid waste only by carefully addressing soil type, nutrient and pH levels, climate, species selection, mulching, and seeding time.[1] Fertile soils, if available at all for landfill cover, are usually cost-prohibitive, so that nonproductive soils or subsoils often have to be used. County agricultural agents may be able to provide guidance.

Evaluate Soil Suitability for Vegetation — Step 23

Soil composed of a mixture of clay, silt, and sand such that none of the components dominates is called a loam. The stickiness of the clay and the floury nature of the silt are balanced by the nonsticky and mealy or gritty characteristics contributed by the sand. A loam is rated overall best for supporting vegetation as it is easily kept in good physical condition and is conducive to good seed germination and easy penetration by roots.

Clay-rich soils may be productive when in good physical condition, but they require special management methods to prevent puddling or breaking down of the clay granules. Silt-rich soils lack the cohesive properties of clay and the grittiness of sand, are water retentive, and usually are easily kept in good condition. Soils made up largely of sand can be productive if sufficient organic matter is present internally or as a surface mulch to hold nutrients and moisture; sandy soils tend to dry out very rapidly and lose nutrients by leaching.

Remember that worthwhile steps in establishing vegetation may be to stockpile and then to reuse the original topsoil. The less fertile underlying soil will be available as daily or intermediate cover. As the operation nears completion, the stockpiled topsoil can be used in the final cover to facilitate rapid growth of grasses and/or shrubbery. The original topsoil must be significantly more fertile than underlying soil strata; otherwise, stockpiling is not practical or economical.

Evaluate pH Level — Step 24

Tests should be made to determine pH and buffering capacity (usually stated as tons/acre of lime necessary to adjust the soil pH to around 6.5). The amount of lime necessary to neutralize a given soil depends upon soil pore-water pH and "reserve acidity." The reserve acidity is a single factor which incorporates several variables; soils with high levels of organic matter and/or clay require higher amounts of lime for pH adjustment. The pH of subsoil (where appreciable in the cover) also influences lime requirements; acidic subsoils require higher levels and repetitive applications of lime. Some buried landfill wastes act much like acid subsoils making higher lime application levels or more frequent liming intervals necessary for adequate pH control.

Evaluate Nitrogen and Organic Matter — Step 25

Nitrogen is of special importance in establishing vegetation because it is needed in relatively large amounts during vigorous growth but is easily lost from the soil. Nitrogen fertilizer requirements depend upon the amount of organic matter present (higher organic matter levels requiring higher application rates), the soil texture (more is required on sandy soils), and the seed mixture chosen (more is required for grasses than legumes). Generally 50 to 85 lb/acre of nitrogen are recommended. Fertilizers are rated by the amount of nitrogen they contain per weight of fertilizer (e.g. 6 percent nitrogen). To calculate the amount of fertilizer necessary to furnish the recommended amount of nitrogen, simply divide the recommended application by the fractional amount of nitrogen the fertilizer to be used contains. For example, to apply 50 lb/acre nitrogen using fertilizer which is 6 percent nitrogen, divide 50 by 0.06 to get 833 lb/acre fertilizer required. Table 10 indicates typical ranges of organic matter in different soil types and a rough range of nitrogen levels present in a typical loam with moderate levels of organic matter.

Evaluate Other Nutrients — Step 26

Necessary levels of phosphorus in soil are shown in Table 10. Unlike nitrogen, phosphorus is not mobile in the soil and thus is lost very slowly to leaching. It is possible to give enough phosphorus in one application to last several growing seasons. Generally at least 15 lb/acre of phosphorus*

*In calculating on the basis of P_2O_5, remember that percent P_2O_5 is 2.3 times an equivalent percent phosphorus.

TABLE 10. RELATIVE LEVELS OF ORGANIC MATTER AND MAJOR NUTRIENTS IN SOILS[15]

	Organic Matter, percent					
Relative Level*	Sand, Loamy Sand	Sandy Loam, Loam, Silt Loam	Clay Loam, Sandy Clay, Clay	Nitrogen lb/acre	Phosphorus lb/acre	Potassium lb/acre
Very low	<0.6	<1.6	<2.6	<20	<6	<60
Low	0.6-1.5	1.6-3.0	2.6-4.5	20-50	6-10	60-90
Medium	1.6-2.5	3.1-4.5	4.6-6.5	50-85	11-20	91-220
High	2.6-3.5	4.6-5.5	6.6-7.5	85-125	21-30	221-260
Very high	>3.5	>5.5	>7.5	>125	>30	>260

* Medium level is typical of agricultural loam soil. Low levels need supplemental fertilization; high levels need no fertilization under normal circumstances.

is recommended as a starter. The availability of phosphorus to the plant is quite dependent on pH. At optimum pH values (6.2-6.8) amounts of 50 lb/acre are usually adequate; at pH values below 6.2 or between 6.9 and 7.5, about 80 lb/acre is needed for optimum growth. Under very alkaline conditions (pH greater than 7.5), phosphorus levels of 110 lb/acre are required. These recommendations are for raw subsoils, or for sandy or high clay soils of low organic material content.

Potassium is much less important in grass establishment than in legume establishment and maintenance; thus the rate of application depends upon both test results and species to be seeded. A minimum application of 26 lb/acre potassium (32 lb/acre K_2O) as a starter is recommended under any circumstances. Applications can run as high as 230 lb/acre potassium (277 lb/acre K_2O) on impoverished soils where legumes are to be seeded. Potassium is moderately mobile in the soil and is slowly leached out, but one heavy application should be adequate for several growing seasons.

Evaluate Species Selection — Step 27

Each species of grass, legume, shrub, or tree has its own environmental and biological strengths and limitations. Moisture, light, temperature, elevation, aspect, balance and level of nutrients, and competitive cohabitants are all parameters which favor or restrict plant species. The selection of the best plant species for a particular site depends upon knowledge of adapted plants that have the desired characteristics. Table 11 gives the major parameters usually important to species selection and examples of grasses and legumes exhibiting the parameters. Characteristics which almost universally should be given precedence are: low growing and spreading from rhizomes or stolons; rapid germination and development; and resistance to fire, insects, and disease. Plants which are poisonous or are likely to escape the site and become noxious should be avoided.

TABLE 11. IMPORTANT CHARACTERISTICS OF GRASSES AND LEGUMES

Characteristic	Degree *	Common Examples
Texture	Fine	Kentucky bluegrass, bentgrass, red fescue
	Coarse	Smooth bromegrass, reed canarygrass, timothy
Growth height	Short	Kentucky bluegrass, buffalograss, red fescue
	Medium	Redtop, perennial ryegrass
	Tall	Smooth bromegrass, timothy, switchgrass
Growth habit	Bunch	Timothy, big bluestem, sand dropseed, perennial ryegrass
	Sod former	Quackgrass, smooth bromegrass, Kentucky bluegrass, switch grass
Reproduction	Seed	Red and alsike clover, sand dropseed, rye, perennial ryegrass, field bromegrass
	Vegetative	Prairie cordgrass, some bentgrasses
	Seed and vegetative	White clover, crownvetch, quackgrass, Kentucky bluegrass, smooth bromegrass
Annual	Summer	Rabbit clover, oats, soybeans, corn, sorghum
	Winter	Rye, hairy vetch, field bromegrass
Perennials	Short-lived	Timothy, perennial ryegrass, red and white clover
	Long-lived	Birdsfoot trefoil, crownvetch, Kentucky bluegrass, smooth bromegrass
Maintenance	Difficult	Tall fescue, reed canarygrass, timothy, alfalfa
	Moderate	Kentucky bluegrass, smooth bromegrass
	Easy	Crownvetch, white clover, birdsfoot trefoil, big bluestem
Shallow rooted	Weak	Sand dropseed, crabgrass, foxtail, white clover
	Strong	Timothy, Kentucky bluegrass
Deep rooted	Weak	Many weeds
	Strong	Big bluestem, switchgrass, alfalfa, reed canarygrass
Moisture	Dry	Sheep fescue, sand dropseed, smooth bromegrass
	Moderate	Crested wheatgrass, red clover
	Wet	Reed canarygrass, bentgrass
Temperature	Hot	Lehman lovegrass, fourwing saltbush, ryegrass
	Moderate	Orchard grass, Kentucky bluegrass, white clover
	Cold	Alfalfa, hairy vetch, smooth bromegrass, slender wheatgrass

*Variety, specific characteristic, subcharacteristic, or favored condition.

A very large number of species of grasses and legumes are available for reclamation use. Species that find wide and frequent application are described in Tables 12 and 13. A local agronomist should be consulted for recommendation of locally adapted plant varieties.

Evaluate Time of Seeding Step 28

Probably the most critical of all decisions in the successful establishment of vegetative cover on poor soils is the time of seeding. The optimum time of seeding depends on the species selected and the local climate. Best seeding time under normal circumstances is presented in Tables 12 and 13 for the recommended grasses and legumes. A local county agent or seed house should be consulted for more specific local information.

Most perennials require a period of cool, moist weather to become established to the extent that they can withstand a cold winter freeze or hot summer drought. Early fall (late August in the north through October in the south) usually allows enough time for the plants to develop to the stage that they can withstand a hard winter. Plants then have a good start for early spring growth and can reach full development before any summer drought. Spring planting is usually second choice for all but a few of the more rapidly developing perennials. Germination and early development are

*TABLE 12. GRASSES COMMONLY USED FOR REVEGETATION**

Variety	Best Seeding Time	Seed Density† seeds/ft^2	Important Characteristics	Areas/Conditions of Adaptation
Redtop bentgrass	Fall	14	Strong, rhizomatous roots, perennial	Wet, acid soils, warm season
Smooth bromegrass	Spring	2.9	Long-lived perennial	Damp, cool summers, drought resistant
Field bromegrass	Spring	6.4	Annual, fibrous roots, winter rapid growth	Cornbelt eastward
Kentucky bluegrass	Fall	50	Alkaline soils, rapid grower, perennial	North, humid, U.S. south to Tennessee
Tall fescue	Fall	5.5	Slow to establish, long-lived perennial, good seeder	Widely adapted, damp soils
Meadow fescue	Fall	5.3	Smaller than tall, susceptible to leaf rust	Cool to warm regions, widely adapted
Orchard grass	Spring	12	More heat tolerant but less cold resistant than smooth bromegrass or Kentucky bluegrass	Temperate U.S.
Annual ryegrass	Fall	5.6	Not winter hardy, poor dry land grass	Moist southern U.S.
Timothy	Fall	30	Shallow roots, bunch grass	Northern U.S., cool, humid areas
Reed canarygrass	Late summer	13	Tall coarse, sod former, perennial, resists flooding and drought	Northern U.S., wet, cool areas

* Taken from many sources, but especially 15 and 16.

† Number of seeds per square foot when applied at 1 lb/acre.

TABLE 13. LEGUMES COMMONLY USED FOR REVEGETATION

Variety	Best Seeding Time	Seed Density† seeds/ft^2	Important Characteristics	Areas/Conditions of Adaptation
Alfalfa (many varieties)	Late summer	5.2	Good on alkaline loam, requires good management	Widely adapted
Birdsfoot trefoil	Spring	9.6	Good on infertile soils, tolerant to acid soils	Moist, temperate U.S.
Sweet clover	Spring	6.0	Good pioneer on non-acid soils	Widely adapted
Red clover	Early spring	6.3	Not drought resistant, tolerant to acid soils	Cool, moist areas
Alsike clover	Early spring	16	Similar to red clover	Cool, moist areas
Korean lespedeza	Early spring	5.2	Annual, widely adapted	Southern, U.S.
Sericea lespedeza	Early spring	8.0	Perennial, tall erect plant, widely adapted	Southern, U.S.
Hairy vetch	Fall	0.5	Winter annual, survives below 0°F, widely adapted	All of U.S.
White clover	Early fall	18	World-wide, many varieties, does well on moist, acid soils	All of U.S.
Crownvetch	Early fall	2.7	Perennial, creeping stems and rhizomes, acid tolerant	Northern U.S.

* Taken from many sources but mainly 15 and 16.

† Number of seeds per square foot when applied at 1 lb/acre.

slowed due to the cool early spring weather. Late frosts often severely damage the young plants. Late spring planting does not allow enough time for most perennials to mature before summer and annuals will usually outcompete the preferred perennials.

Annuals generally are best planted in spring and early summer. Growth is completed quickly before the summer heat and the soil moisture is used up. During this period annuals easily out-compete the perennials. Annuals can, however, be planted any time the soil is damp and warm when a quick plant cover is desired and often will provide an acceptable mulch for fall seeded perennials.

Evaluate Seed and Surface Protection — Step 29

Bare soil as a seeding medium suffers from large temperature and moisture fluctuations and from rapid degeneration due to wind and water erosion. Mulches provide temporary protection against these influences and therefore the use of mulch should be expected in the plan for closure cover.

Almost any material spread, formed or simply left on the soil surface will act as a mulch, e.g., straw and other crop residues, sawdust, wood chips, wood fiber, bark, manure, brush, jute or burlap, gravel, stones, peat, paper, leaves, plastic film, and various organic and inorganic liquids. For straw used where erosion is not anticipated, an application of 1.5 tons/acre is

MAX EROSION RATE

recommended. On slopes or elsewhere where erosion threatens, 2 tons/acre produces better results. Application rates over 2.5 tons/acre often result in reduced germination and emergence and such high rates should be avoided.

Rapid growing, summer cover crops can be used to advantage as living mulches if final grade work is finished in late spring or early summer when chances of successful perennial grass-legume seedings are low. Coarse grasses such as Sudan grass or a local equivalent are good choices as they are widely adaptable and the tall, stiff stalks are most effective as a mulch.

Petroleum-based products such as asphalt and resins are often suitable and are frequently used as mulching materials. Specially formulated emulsions of asphalt under various trade names have been used throughout the world to prevent erosion, reduce evaporation, promote seed germination, and warm the soil to advance the seeding date. The film clings to but does not deeply penetrate the soil; it is not readily destroyed by wind and rain and remains effective from 4 to 10 weeks. Application rates of 1000-1200 gallons/acre are usually required to control erosion. Asphalt mulches cost about twice the applied cost of a straw mulch.

SECTION 4

POST-CLOSURE PLAN

Provisions for maintenance and for contingencies after site closure should follow a logical plan.

MAINTENANCE EVALUATION PROCEDURE

Some cover deterioration like erosion can be tolerated where the post-closure plan has provisions for frequent, regular maintenance. Elsewhere regular maintenance of the cover may be planned on a less frequent interval, in which case a more conservative cover design is necessary at the start.

Evaluate Design/Maintenance Balance — Step 30

Check to see that the plan for closure covering generally achieves a reasonable balance between initial design and plans for monitoring, maintenance, and repair. So many specific factors (climate, waste type, soil, vegetation, etc.) are involved in evaluating this balance that little detailed guidance can be offered; nevertheless the assessment is important and should be performed with care and diligence. The following example helps clarify the general nature of the problem and the recommended philosophy.

> Example: In a late modification, the applicant formally proposes to reduce the frequency of post-closure monitoring inspection visits to a remote hazardous waste site by overdesigning the closure cover at the start. A certain period between inspection visits has become more or less standard in the region on the basis of experience, but the applicant now proposes to double this period. The overdesign amounts to prescribing a thicker cover than might ordinarily be considered sufficient. In this case the evaluator rejects the proposed modification of less frequent inspections. He reasons that emergency conditions such as from wind or water erosion or from cover cracking can compound and intensify the problem in a short period in this region and therefore frequent inspections are imperative and necessary.

Evaluate Maintenance of Vegetation — Step 31

After vegetation is established on a landfill, maintenance is necessary to keep less desirable, native species from taking over and weak areas in the cover from developing. In most areas judicious, twice-yearly mowing will keep down weed and brush species. Annual fertilization (and liming if necessary) will generally allow desirable species to out-compete the weedy species of lower quality. Occasional use of selective herbicides usually controls noxious invaders, but care must be taken to avoid injuring or weakening the desirable species, lest more harm than benefit results in the long run. In rare circumstances, large insect populations may threaten the stand of vegetation so that insecticide application becomes desirable. The evaluator should review the intermediate and long-range plans for maintaining vegetation with cognizance of plant needs in establishment (and reestablishment) as outlined in Steps 24-29.

Landfill cover soils are usually shallow and of low quality for growing high-quality vegetation. This problem is greatly compounded if an impervious clay or plastic barrier is incorporated in the cover. Such a barrier makes the plant-root zone susceptible to swamping after moderate rains since vertical drainage is impeded. Upon saturation, the soil becomes anaerobic and roots in the system are threatened. Short periods of swamping will weaken the vegetation; longer periods may cause a complete loss. Swamping tolerant species (such as Reed canary grass) and surface drainage will lessen these problems.

On the other extreme, the thin soil dries excessively during dry periods. No deep soil moisture is available to tide the plants over even moderate droughts. Plants which have been weakened by prior waterlogging or that are not drought-tolerant are especially vulnerable. Irrigation may be necessary during prolonged dry spells to preclude complete loss of plant cover.

Landfills may continue to produce gases and soluble organic decomposition products for years after closure, and vegetation can be damaged. An impervious cover over the landfill may shield the plant roots from these products and also keeps the landfill dry so that gas production is low or nonexistent. Deep-rooted shrubs or trees are usually not recommended on landfills since roots will tend to penetrate into the waste zone.

Evaluate Provisions for Condition Surveys — Step 32

Applications for closures should include plans for monitoring the site in the future. An annual site visit by a technical person qualified to evaluate the condition of the cover may be considered sufficient by the permitting authority for some sites. Elsewhere, however, it may be judged that more frequent inspections are necessary. Provisions should be made in the application for collecting documentation during the site visit. The documentation and inspection reports should be kept on site by the owner/ operator or at some other location where it can be examined conveniently. Copies of the reports including all significant observations or conclusions should be kept in the applicant's file for review on request by the overseeing agency.

Example: The evaluator has reviewed an application for closing a site and found that there is sufficient planning to monitor site conditions over an extended period. He notes, however, that the site visits are to be made by a representative of the owner/operator with no provision for a state or EPA representative to accompany the inspector. Among changes he requires in this application, therefore, is the stipulation in the post-closure plan that the state agency (or EPA) will be notified five days before the site visit so that they may send a representative.

CONTINGENCY PLAN EVALUATION PROCEDURE

Evaluate Plan for Erosion Damage Repair — Step 33

Long-term maintenance helps to avoid erosion problems. However, unusual climate conditions and shortcomings in the design occasionally cause excessive erosion by wind or water even on well-maintained covers.

Factors that need to be considered in the plan include the future source of supply of fill soil for repair and the ability of someone to undertake the repair work. The extent of repair work should be detailed in words to the effect that repair work will bring lines and grades at least to their original configuration. It is also appropriate to expect that the remedial work will involve redesign where excessive erosion indicates that the original design was deficient. Some of the many options that might be mentioned for consideration in the case of a necessity for repair would include construction of berms, protection of slopes and channels by riprap, and the use of other special energy dissipators such as check dams.

In anticipation of major problems of sheet erosion across entire surfaces such methods as terracing might be identified, provided their effect on infiltration is not excessively adverse.

In those regions where wind erosion can present a serious problem, the post-closure plan should include specific statements on correcting wind erosion problems. The following example is illustrative of the recommended attitude.

Example: Consider a site in the southern Great Plains. An applicant proposes to dispose of waste in a trench operation in which soil excavated from the trench will be used as final cover. Since a considerable mound will have been formed upon closure, the evaluator foresees the possibility of eventual wind erosion. No provision with specifics for timely repair addresses this possible erosion problem, so the evaluator recommends that the applicant develop contingencies accordingly. The evaluator offers for consideration the use of snow fences as one quick response technique.

Evaluate Plan for Vegetation Repair — Step 34

Waste disposal areas have long-lived potential for negative impact and permanent vegetative cover should be maintained. Once a cover of vegetation is started and stabilized, extensive root systems develop and decomposition processes form a layer of humus capable of perpetuating the cover of vegetation. However, erosion forces, burrowing animals, etc., may damage parts of this cover of soil, humus, and vegetation. Provisions should be made for repairing such damage, specifically for transplanting grass sod, planting the new seeds or shrubs, and replacing eroded soil during the inactive life of the area.

The principal part of the application documents that the evaluator should carefully review is that part dealing with measures to return damaged vegetation to a state such as originally planned (see VEGETATION EVALUATION PROCEDURES, SECTION 2). One additional facet of the plan for maintenance of vegetation is the fact that deterioration of the vegetative cover is often widespread; swampiness or droughtiness, nutrient starvation, or methane migration in the cover quickly affects the entire vegetation system. Exceptions are problems induced by erosion, and repair in this case should be of less concern. Because of this potential widespread impact the applicant's plans for maintaining or for repairing the vegetation should be closely tied to the monitoring plan and should be adequate to respond quickly to the early stages of a major problem.

Evaluate Plan for Drainage Renovation — Step 35

The principal part of the applicant's plan for drainage renovation should include sufficient details to assure that the drainage system for the site as designed will be restored quickly to its original condition. In addition to this, the plan for repair should provide for such additional work as becomes necessary after a period of operations. Such additional work might include placement of riprap along a slope subjected to more erosive action than anticipated in the original drainage design. Except for such unexpected problems, the maintenance of drainage should amount to fairly straightforward cleaning of ditches and cutting of brush.

Evaluate Provisions for Other Cover Deterioration — Step 36

Contingency planning should include making provisions for all forms of cover deterioration other than erosion and distress of the vegetation, covered elsewhere. Such deterioration might result from excessive root penetration, cracking, disturbance by cold weather, seepage, and slope instability. The evaluator should consider the likely effectiveness of post-closure plans to addressing such problems in a timely manner. His evaluation should, of course, be made in the context of policies established by state agencies and/or EPA. Such policies need not necessarily assign responsibility for correcting such unanticipated problems to the owner/operator.

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Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **F-2** **Subject:** **Final Cover Drainage Layer Design**

Prepared By: **MA** **Date:** **February 2024**

Reviewed By: **BMS** **Date:** **February 2024**

Objective

Determine minimum required transmissivity for the geocomposite drainage layer in the final cover of the Upland Disposal Facility. Estimate the maximum applied loading on geocomposite layer under installed conditions.

References

1. Arcadis U.S. Inc., Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 8: Final Grading Plan.* February 2024.
2. "Hydraulic Design of Geosynthetic and granular Liquid Collection Layers," Giroud, J.P., Zornberg, J.G., and A. Zhao., technical paper presented in Geosynthetics International – Special Issue on Liquid Collection Systems, 2000.
3. "Geosynthetic Landfill Cover Design Methodology and Construction Experience in the Pacific Northwest", Theil, R.S. and Stewart, M.G., proceedings for Geosynthetics '93 held in Vancouver, V. C., 1993.

Assumptions

1. The minimum required geocomposite transmissivity for the final cover subsurface drainage layer is determined by evaluating the longest undrained slope of each slope gradient on the geocomposite drainage layer surface. The final cover subgrade includes 5% (plateau area) and 33% (side slope areas) slope gradients. Based on the grading depicted in Reference 1, transmissivity values are calculated for the following maximum undrained slopes:

   i) 435 feet at 5% (Plateau)

   ii) 120 feet at 33% (Sideslopes)

   The location of subsurface collection pipes defines the limits of the undrained slope lengths.
2. The minimum required transmissivity is calculated using Giroud's equation (Reference 2).
3. The impingement rate (rate of water supply to the geocomposite) is calculated based on the unit gradient method (presented in Reference 3), which assumes the impingement rate equals the final soil permeability. This unit gradient method assumes enough water is available to completely saturate the cover soil, causing the water to approach the geocomposite at rate equivalent to the soil's

permeability. The topsoil overlying the geocomposite is assumed to have an effective permeability of $5.5x10^{-5}$ cm/s, therefore the impingement rate is $5.5x10^{-5.}$

4. Giroud's equation includes reduction factors that account for reduction in geocomposite transmissivity over time (Reference 2). These factors include geotextile intrusion, creep reduction in genet core thickness, chemical clogging, and biological clogging. These factors in addition to the factors of safety are used to calculate the minimum required geocomposite transmissivity for the plateau area and sideslopes.

   Each reduction factor has a recommended range per Reference 3 for cover soil infiltration scenarios. Since there is less likelihood for slope instability on the plateau of the UDF rather than the sideslopes, the lower end of the range of values is used. For the sideslopes' reduction factors and factors of safety, the mid-range factors are chosen to represent the greater likelihood of slope instability. The selected reduction factors are as follows:

   <u>Plateau Reduction Factors:</u>

   - RF_{in} = 1.0 (Reduction factor accounting for geotextile intrusion; see Reference 2 for range)
   - RF_{cr} = 1.1 (Reduction factor accounting for creep reduction in geonet core thickness; see Reference 2 for range)
   - RF_{cc} = 1.0 (Reduction factor accounting for chemical clogging; see Reference 2 for range)
   - RF_{bc}= 1.2 (reduction factor accounting for biological clogging; see Reference 2 for range)

   <u>Sideslope Reduction Factors:</u>

   - RF_{in} = 1.1 (Reduction factor accounting for geotextile intrusion; see Reference 2 for range)
   - RF_{cr} = 1.2 (Reduction factor accounting for creep reduction in geonet core thickness; see Reference 2 for range)
   - RF_{cc} = 1.1 (Reduction factor accounting for chemical clogging; see Reference 2 for range)
   - RF_{bc}= 1.3 (reduction factor accounting for biological clogging; see Reference 2 for range)

5. Giroud's equation includes a factor of safety (FS) for hydraulic characteristics (i.e., hydraulic conductivity and transmissivity). Per Reference 2, a factor of safety for hydraulic characteristics between 2.00-3.00 is acceptable. The selected factor of safety for the plateau area is 2.00, while the factor of safety for the sideslopes is 2.5.
6. For conservatism, a factor of 2.0 is used for calculation of the maximum applied loading on the geocomposite in final conditions.
7. The assumed unit weight of the cover soils is 120 pcf.
8. The assumed weight of low ground pressure construction equipment is 5 psi (720 psf)

Calculations

1. Minimum required Geocomposite Transmissivity

The transmissivity for the geocomposite is calculated using Giroud's equation for a single uniform slope (Reference 4).

$$\theta = \frac{TSF q_h L}{sin\beta + \frac{\frac{t_{LCL}}{L}}{TSF} cos^2\beta} \quad (Equation\ 1)$$

Where,

Θ = ultimate transmissivity for the slope

TSF = total serviceability factor (combination of reduction and overall design safety factors) = RF_{in} * RF_{cr} * RF_{cc} * RF_{bc} * FS (See assumptions 4 and 5 for values).

q_h = impingement rate (rate at which water infiltrates through the cover soils into the geocomposite) = of $5.5x10^{-5}$ (Assumption 3)

L = maximum drainage length

t_{LCL}= thickness of geonet core in geocomposite

β = slope angle of drainage layer

TSF = 2.64 (plateau) and 4.72 (sideslopes)

q_h = $5.5x10^{-5}$

L = 435 feet = 133 meters (plateau), 120 feet = 37 meters (sideslopes)

t_{LCL} = thickness of geonet core in geocomposite = 0.5 cm

β = 2.86° (5%), 18.43° (33%)

∴ θ = 3.87x 10^{-3} m^2/s = 38.7 cm^2/s = minimum required geocomposite transmissivity for plateau areas.

∴ θ = 3.1 x 10^{-4} m^2/s = 3.1 cm^2/s = minimum required geocomposite transmissivity for sideslope areas.

2. Maximum Applied Load on the Geocomposite

Because the in-place transmissivity of the geocomposite is partly a function of the cover soil thickness and associated loading, it is necessary to estimate the maximum load that will be applied to the geocomposite for the plateau area and the sideslope area. The proposed cover system includes 1.5 ft of general fill and 0.5 ft of topsoil. Therefore, the final cover geocomposite will experience a maximum soil load of approximately 240 psf (2 ft x 120 pcf = 240 psf). The operation of low ground pressure construction equipment over the geocomposite during final cover construction is expected to result in another 720 psf (Assumption 8). Combining the low ground pressure weight and the maximum soil cover thickness and multiplying by a safety factor of 2 (Assumption 6) yields a design loading of 1,920 psf for the geocomposite atop the plateau area.

Summary

The geocomposite drainage layer in the final cover system must provide the following minimum transmissivities:

- 5% Plateau Slope: $\theta = 3.87\text{x } 10^{-3}$ m^2/s = 38.7 cm^2/s with a hydraulic gradient of 0.1 and an applied loading of 1,920 psf

- 33% Sideslope: $\theta = 3.1 \text{ x } 10^{-4}$ m^2/s = 3.1 cm^2/s with a hydraulic gradient of 0.33 and an applied loading of 1,920 psf

A hydraulic gradient of 0.1 is representative of the plateau slope of 5% and is more easily attained and controlled in a laboratory. Because geocomposite transmissivity decreases with increasing hydraulic gradient, utilizing the 0.1 value rather than 0.05 will yield a conservative measurement for the geocomposite transmissivity.

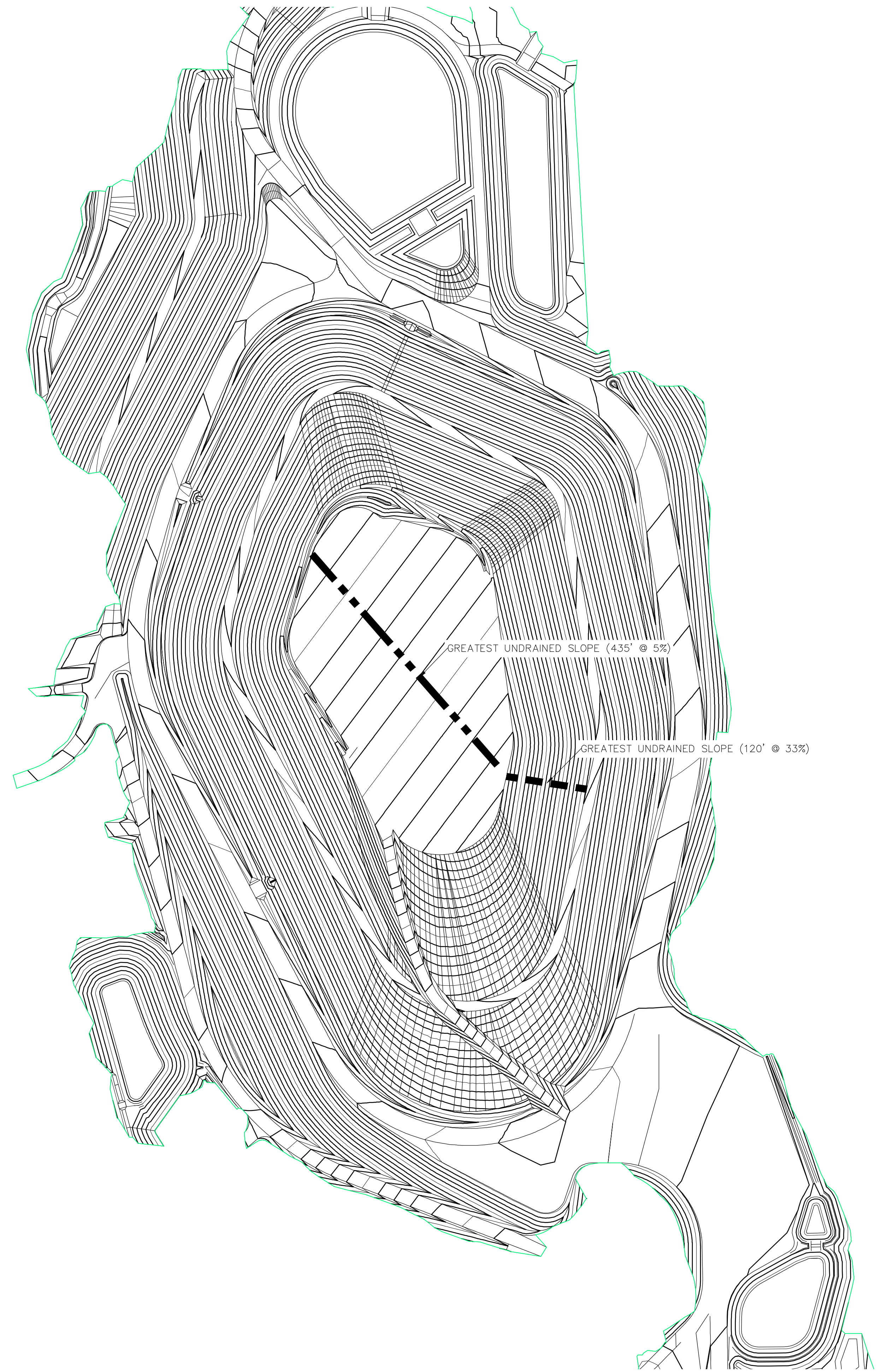
Attachments

1. Longest Undrained Paths

2. Geocomposite Transmissivity Calculations

Attachment 1

Longest Undrained Paths



0 100' 200'
GRAPHIC SCALE

UPLAND DISPOSAL FACILITY

GEOCOMPOSITE UNDRAINED PATHS

ARCADIS

FIGURE
1

C:\Users\MAugenstein\ARCADIS\GE Upland Disposal Facility - Documents\UDF Design\Final Design Plan\Final Design Plan Report\Appendices\Appendix F - Final Cover Design Calculations\D-2_Final Cover Drainage Layer Design\Slope Path Exhibit.dwg LAYOUT: LAYOUT2 SAVED: 2/9/2024 9:55 AM ACADVER:
24.2S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 2/9/2024 9:56 AM BY: AUGENSTEIN, MARY
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EG
Final Surface

Attachment 2

Geocomposite Transmissivity Calculations

Upland Disposal Facility Design
Lee, MA

Giroud's Equation for Minimum Required Transmissivity
Final Cover Drainage Layer Design - Plateau

Input

Drainage Length [m]:	133
Drainage Layer Thickness [cm]:	0.5
Slope of Drainage Layer [ft/ft]:	0.05
Impingement Rate, q_h, [cm/s][1]:	5.50E-05

Factor of Safety		Typical Range for Factor of Safety: Surface Water	Leachate Collection	Leachate Detection
Intrusion Reduction Factor, RF_{in}	1.0	1.0-1.2	1.0-1.2	1.0-1.2
Creep Reduction Factor, RF_{cr}:	1.1	1.1-1.4	1.4-2.0	1.4-2.0
Chemical Clogging Reduction Factor, RF_{cc}:	1.0	1.0-1.2	1.5-2.0	1.5-2.0
Biological Clogging Reduction Factor, RF_{bc}:	1.2	1.2-1.5	1.5-2.0	1.5-2.0
Overall FS for Drainage, FS:	2.0	2.0-3.0	2.0-3.0	2.0-3.0

Output

Total Serviceability Factor[2]	2.64
Required Transmissivity [cm^2/s]:	**38.7**

Note:
1. Impingement rate is based on use of Unit Gradient Method, which assumes the cover soil is saturated and impingement rate equals the permeability of overlying material, which is conservatively assumed to be $5x10^{-5}$ cm/s.
2. Given the conservative nature of the Unit Gradient Method and the reduced risk of slope instability on plateau areas, the total serviceability factor is based on low end of the range of typical factors of safety for final cover system applications.

Upland Disposal Facility
Lee, MA

Giroud's Equation for Minimum Required Transmissivity
Final Cover Drainage Layer Design - Sideslopes

Input

Drainage Length [m]:	37
Drainage Layer Thickness [cm]:	0.5
Slope of Drainage Layer [ft/ft]:	0.33
Impingement Rate, q_h, [cm/s][1]:	5.50E-05

Factor of Safety

		Typical Range for Factor of Safety		
		Surface Water	Leachate Collection	Leachate Detection
Intrusion Reduction Factor, RF_{in}	1.1	1.0-1.2	1.0-1.2	1.0-1.2
Creep Reduction Factor, RF_{cr}:	1.2	1.1-1.4	1.4-2.0	1.4-2.0
Chemical Clogging Reduction Factor, RF_{cc}	1.1	1.0-1.2	1.5-2.0	1.5-2.0
Biological Clogging Reduction Factor, RF_{bc}	1.3	1.2-1.5	1.5-2.0	1.5-2.0
Overall FS for Drainage, FS:	2.5	2.0-3.0	2.0-3.0	2.0-3.0

Output

Total Serviceability Factor[2]	4.72
Required Transmissivity [cm^2/s]:	**3.1**

Note:
1. Impingement rate is based on use of Unit Gradient Method, which assumes the cover soil is saturated and impingement rate equals the permeability of overlying material, which is conservatively assumed to be $5x10^{-5}$ cm/s.
2. Total serviceability factor is based on the average value of typical factors of safety for final cover system applications.

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **F-3** **Subject:** **Final Cover Drainage Collection Pipe Design**

Prepared By: **MA** **Date:** **February 2024**

Reviewed By: **BMS** **Date:** **February 2024**

Objective

Determine the maximum allowable lengths for collection pipes in the subsurface drainage layer of the proposed final cover system for plateau and sideslope area.

References

1. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 7: Consolidation Grading Plan.* February 2024.
2. Arcadis U.S., Inc. *Calculation Brief F-2:* Final Cover Drainage Layer Design," Arcadis, February 2024.

Assumptions

1. The maximum allowable pipe lengths are based on the unit-width hydraulic capacity of the geocomposite draining to the pipes (i.e., the flow that reaches each linear foot of pipe) and the hydraulic capacity of the pipes.
2. For calculating the hydraulic capacity of the subsurface pipes, pipe-full conditions are assumed.
3. The hydraulic capacity of the subsurface collection pipes uses the Manning Equation and is a function of pipe diameter (6" or 8"), pipe roughness, and longitudinal slope of the pipe. The longitudinal slope of the pipe is approximately the slope of the surface water drainage feature. Final cover slopes above subsurface collection pipes can be seen on Reference 1.
4. The collection pipes are modeled as corrugated, smooth-bore HDPE with a Manning "n" value of 0.012.
5. Minimum slope for the plateau surface water drainage features is ~3%, and ~2% for the sideslopes surface water drainage features. The capacity of the collection pipes is based on these minimum slopes.
6. Collection pipes drain into downchute pipes that run down the UDF sideslopes. Downchute pipe earthwork is depicted in Reference 1. Collection pipes and downchute pipes are coincident.

   The hydraulic capacity of the downchute pipes is not a governing condition due to steeper slope providing more capacity for downchute pipes. The capacity of the downchute pipes is therefore not evaluated in this calculation

Calculations

1. **Unit-Width Hydraulic Capacity of Geocomposite Drainage to Collection Pipes**

The design transmissivity for the geocomposite is based on maximum anticipated flows in the drainage layer, with respective reductions and safety factors. Darcy's law is used to determine the unit-width hydraulic capacity of the geocomposite. The design transmissivity value from Reference 2 is used in this calculation.

Unit-Width Discharge for Collection Pipes on the Plateau

$Q_G = kiA$

$k = \frac{\theta}{t}$

$A = Lt$

$\therefore\ Q_G = L\theta i$ (t cancels out)

Where,

L = Length of collection pipe = 1' (Assumption 1)

Θ = geocomposite design transmissivity = 38.7 cm^2/s = 0.042 ft^2/s (Reference 2)

Plateau Q_G = 1*0.042*0.05 = 0.0021 cfs/ft

Unit-Width Discharge for Collection Pipes on the Sideslopes

$Q_G = kiA$

$k = \frac{\theta}{t}$

$A = Lt$

$\therefore\ Q_G = L\theta i$ (t cancels out)

Where,

L = Length of collection pipe = 1' (Assumption 1)

Θ = geocomposite design transmissivity = 3.1 cm^2/s = 0.0033 ft^2/s (Reference 2)

Sideslopes Q_G = 1*0.0033*0.33 = 0.0011 cfs/ft

2. **Pipe-Full Capacity**

Per Assumption 2, pipe-full conditions are assumed. The Manning equation is used to evaluate the capacity of collection pipes (6" and 8") as follows:

Plateau

$$Q_P = \frac{1.49}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

Where,

Q_P = pipe-full flow rates (cfs)

A = cross-section area of pipe flowing full = $\pi D^2/4$ (Diameter is 6" (0.5') or 8" (0.67'))

n = 0.012 (Assumption 4)

R = Hydraulic radius = A/P

P = wetted perimeter of pipe flowing full = πD

S = Slope of collector pipes = 0.02 (Assumption 5)

Q_P = 0.86 cfs (6" Pipe)

Q_P = 1.88 cfs (8" Pipe)

Sideslopes

$$Q_P = \frac{1.49}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

Where,

Q_P = pipe-full flow rates (cfs)

A = cross-section area of pipe flowing full = $\pi D^2/4$ (Diameter is 6" (0.5') or 8" (0.67'))

n = 0.012 (Assumption 4)

R = Hydraulic radius = A/P

P = wetted perimeter of pipe flowing full = πD

S = Slope of collector pipes = 0.02 (Assumption 5)

Q_P = 0.86 cfs (6" Pipe)

Q_P = 1.88 cfs (8" Pipe)

3. **Maximum Undrained Collection Pipe Lengths**

The hydraulic capacity of the pipes and the unit-width discharge to the pipes from the geocomposite are used to determine the maximum undrained length of each pipe size as follows:

$$L_{max} = \frac{Q_P}{Q_G}$$

Where,

L_{max} = Maximum allowable pipe length

Q_P = Hydraulic capacity of pipe (varies depending on pipe size and slope, see above for values)

Q_G = Design flow from geocomposite transmissivity = 0.0021 cfs/ft (plateau), 0.0011 cfs/ft (sideslopes)

The calculated maximum allowable pipe lengths are summarized in the table below:

Table 1: Summary of Maximum Pipe Lengths

Area	Geocomposite Capacity (cfs/ft)	Pipe Diameter (in)	Pipe-Full Capacity (cfs)	Maximum Length (ft)
Plateau	0.0021	6	0.86	410
Plateau		8	1.88	896
Sideslope	0.0011	6	0.86	782
Sideslope		8	1.88	1,709

Summary

The maximum pipe lengths for 6-in and 8-in-diameter collection pipes on the plateau and sideslope areas is determined herein to aid in final design. Based on the proposed lengths of collection piping in the final cover, 6-in-diameter collection piping may be utilized if two adjacent 6-inch pipes are used where the maximum allowable pipe length for a 6-in-diameter pipe is exceeded. The following table summarizes the required pipe sizes for final cover collection piping.

Table 2: Summary of Required Final Cover Collection Pipe Sizing

Location	Pipe Diameter (in)	Number of Pipes
Plateau (East)	6	1
Plateau (West)	6	2
Diversion Berm (East)	6	2
Diversion Berm (West)	6	2
Perimeter Ditch (East)	6	1 [1]
Perimeter Ditch (West)	6	1 [1]

Notes:

1) Maximum allowable pipe length between outlets is 792 ft (as stated in Table 1). The suggested spacing between outlets of the collection piping at the perimeter ditch is 600 feet.

Attachments

1. Subsurface Collection Piping Capacity Calculations

Attachment 1

Subsurface Collection piping Capacity Calculations

Plateau Area, 6" Dia. Pipe

Design Flow to Each LF of Collection Pipe from Geocomposite				
Item	***Value***	***Unit***	***Description***	***Assumption***
L	1	ft	Length of collection pipe draining geocomposite	Assumed 1' to determine maximum undrained pipe length
i	0.05	ft/ft	Slope of geocomposite transmitting flow to collection pipe	Geocomposite is laid directly on subgrade slope. Slope from Drawing C-3 "Subgrade Grading Plan"
Φ	0.042	ft^2/s	Design transmissivity	Value for 4% slope areas from calculation sheet entitled "Geocomposite Drainage Layer Calculations," converted to customary units
Flow Multiplier	1	-	Factor to account for inflow from primary inflow side and lesser inflow from opposite side	Lesser inflow side assumed to be no more than 25% of the flow entering on primary side
Q_G	**0.00210**	**cfs**	**Design flow from 1' of geocomposite draining to pipe from both sides**	**Calculated using Darcy's Law and defintion of transmissivity**

Pipe-Full Flow Capacity of 6" Dia. Pipe				
Item	***Value***	***Unit***	***Description***	***Assumption***
D	0.5	ft	Pipe diameter	-
A	0.20	ft^2	Cross sectional area of pipe	Circular flow area, pipe flowing full
n	0.012	-	Manning's n	Smooth-bore, corrugated HDPE pipe, value from Manufacturer literature
P	1.57	ft	Wetted perimeter	Circular flow area, pipe flowing full
S	0.03	ft/ft	Slope of pipe	Based on longitudinal slope of collection pipe trenches. Slope from Drawing C-3 "Subgrade Grading Plan"
R	0.13	ft	Hydraulic radius	R=A/P
Q_P	**1.06**	**cfs**	**Flow capacity of pipe**	**Pipe-full capacity based on Manning's Equation**

Maximum Undrained Length for 6" Dia. Pipe				
Item	***Value***	***Unit***	***Description***	***Assumption***
Q_P	1.06	cfs	Pipe-full capacity of pipe	-
Q_G	0.00210	cfs	Design flow to each LF of collection pipe from geocomposite	-
L_{max}	**505**	**ft**	**Maximum undrained pipe length**	**-**

Plateau Area, 8" Dia. Pipe

Design Flow to Each LF of Collection Pipe from Geocomposite				
Item	***Value***	***Unit***	***Description***	***Assumption***
L	1	ft	Length of collection pipe draining geocomposite	Assumed 1' to determine maximum undrained pipe length
i	0.05	ft/ft	Slope of geocomposite transmitting flow to collection pipe	Geocomposite is laid directly on subgrade slope. Slope from Drawing C-3 "Subgrade Grading Plan"
Φ	0.042	ft^2/s	Design transmissivity	Value for 4% slope areas from calculation sheet entitled "Geocomposite Drainage Layer Calculations," converted to customary units
Flow Multiplier	1	-	Factor to account for inflow from primary inflow side and lesser inflow from opposite side	Lesser inflow side assumed to be no more than 25% of the flow entering on primary side
Q_G	**0.00210**	**cfs**	**Design flow from 1' of geocomposite draining to pipe from both sides**	**Calculated using Darcy's Law and defintion of transmissivity**

Pipe-Full Flow Capacity of 8" Dia. Pipe				
Item	***Value***	***Unit***	***Description***	***Assumption***
D	0.67	ft	Pipe diameter	-
A	0.35	ft^2	Cross sectional area of pipe	Circular flow area, pipe flowing full
n	0.012	-	Manning's n	Smooth-bore, corrugated HDPE pipe, value from Manufacturer literature
P	2.10	ft	Wetted perimeter	Circular flow area, pipe flowing full
S	0.03	ft/ft	Slope of pipe	Based on longitudinal slope of collection pipe trenches. Slope from Drawing C-3 "Subgrade Grading Plan"
R	0.17	ft	Hydraulic radius	R=A/P
Q_P	**2.30**	**cfs**	**Flow capacity of pipe**	**Pipe-full capacity based on Manning's Equation**

Maximum Undrained Length for 8" Dia. Pipe				
Item	***Value***	***Unit***	***Description***	***Assumption***
Q_P	2.30	cfs	Pipe-full capacity of pipe	-
Q_G	0.00210	cfs	Design flow to each LF of collection pipe from geocomposite	-
L_{max}	**1095**	**ft**	**Maximum undrained pipe length**	**-**

Sideslope Area, 6" Dia. Pipe

Design Flow to Each LF of Collection Pipe from Geocomposite				
Item	***Value***	***Unit***	***Description***	***Assumption***
L	1	ft	Length of collection pipe draining geocomposite	Assumed 1' to determine maximum undrained pipe length
i	0.33	ft/ft	Slope of geocomposite transmitting flow to collection pipe	Geocomposite is laid directly on subgrade slope. Slope from Drawing C-3 "Subgrade Grading Plan"
Φ	0.0033	ft^2/s	Design transmissivity	Value for 33% sideslope areas from calculation sheet entitled "Geocomposite Drainage Layer Calculations," converted to customary units
Flow Multiplier	1	-	Factor to account for inflow from primary inflow side and lesser inflow from opposite side	Lesser inflow side assumed to be no more than 25% of the flow entering on primary side
Q_G	**0.0011**	**cfs**	**Design flow from 1' of geocomposite draining to pipe from both sides**	**Calculated using Darcy's Law and defintion of transmissivity**

Pipe-Full Flow Capacity of 6" Dia. Pipe				
Item	***Value***	***Unit***	***Description***	***Assumption***
D	0.5	ft	Pipe diameter	-
A	0.20	ft^2	Cross sectional area of pipe	Circular flow area, pipe flowing full
n	0.012	-	Manning's n	Smooth-bore, corrugated HDPE pipe, value from Manufacturer literature
P	1.57	ft	Wetted perimeter	Circular flow area, pipe flowing full
S	0.02	ft/ft	Slope of pipe	Based on longitudinal slope of collection pipe trenches. Slope from Drawing C-3 "Subgrade Grading Plan"
R	0.13	ft	Hydraulic radius	R=A/P
Q_P	**0.86**	**cfs**	**Flow capacity of pipe**	**Pipe-full capacity based on Manning's Equation**

Maximum Undrained Length for 6" Dia. Pipe				
Item	***Value***	***Unit***	***Description***	***Assumption***
Q_P	0.86	cfs	Pipe-full capacity of pipe	-
Q_G	0.0011	cfs	Design flow to each LF of collection pipe from geocomposite	-
L_{max}	**782**	**ft**	**Maximum undrained pipe length**	**-**

Sideslope Area, 8" Dia. Pipe

Design Flow to Each LF of Collection Pipe from Geocomposite				
Item	***Value***	***Unit***	***Description***	***Assumption***
L	1	ft	Length of collection pipe draining geocomposite	Assumed 1' to determine maximum undrained pipe length
i	0.33	ft/ft	Slope of geocomposite transmitting flow to collection pipe	Geocomposite is laid directly on subgrade slope. Slope from Drawing C-3 "Subgrade Grading Plan"
Φ	0.0033	ft^2/s	Design transmissivity	Value for 33% sideslope areas from calculation sheet entitled "Geocomposite Drainage Layer Calculations," converted to customary units
Flow Multiplier	1	-	Factor to account for inflow from primary inflow side and lesser inflow from opposite side	Lesser inflow side assumed to be no more than 25% of the flow entering on primary side
Q_G	**0.0011**	**cfs**	**Design flow from 1' of geocomposite draining to pipe from both sides**	**Calculated using Darcy's Law and defintion of transmissivity**

Pipe-Full Flow Capacity of 8" Dia. Pipe				
Item	***Value***	***Unit***	***Description***	***Assumption***
D	0.67	ft	Pipe diameter	-
A	0.35	ft^2	Cross sectional area of pipe	Circular flow area, pipe flowing full
n	0.012	-	Manning's n	Smooth-bore, corrugated HDPE pipe, value from Manufacturer literature
P	2.10	ft	Wetted perimeter	Circular flow area, pipe flowing full
S	0.02	ft/ft	Slope of pipe	Based on longitudinal slope of collection pipe trenches. Slope from Drawing C-3 "Subgrade Grading Plan"
R	0.17	ft	Hydraulic radius	R=A/P
Q_P	**1.88**	**cfs**	**Flow capacity of pipe**	**Pipe-full capacity based on Manning's Equation**

Maximum Undrained Length for 8" Dia. Pipe				
Item	***Value***	***Unit***	***Description***	***Assumption***
Q_P	1.88	cfs	Pipe-full capacity of pipe	-
Q_G	0.00110	cfs	Design flow to each LF of collection pipe from geocomposite	-
L_{max}	**1709**	**ft**	**Maximum undrained pipe length**	**-**

Appendix G

Stormwater Management System calculations

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **G-1** **Subject:** **Design Storm**

Prepared By: **MA** **Date:** **February 2024**

Reviewed By: **BMS/SES** **Date:** **February 2024**

Objective

Determine the Design Precipitation Event (i.e., rainfall amount and temporal distribution) for use in designing drainage features for the Upload Disposal Facility (UDF) in Lee, Massachusetts factoring in resiliency to anticipated climate change.

References

1. Northeast Regional Climate Center (NRCC). *Intensity Duration Frequency Curves for New York State Future Projections for a Changing Climate*. Town of West Otis, MA. Accessed August 2023. https://ny-idf-projections.nrcc.cornell.edu/.
2. US Environmental Protection Agency (USEPA). *Climate Change Indicators: Heavy Precipitation*. Accessed September 2023. https://www.epa.gov/climate-indicators/climate-change-indicators-heavy-precipitation.
3. NRCC. *Extreme Precipitation in New York & New England*. Accessed September 2023. http://precip.eas.cornell.edu/#/data_and_products.

Assumptions

1. The revised final permit set forth by the USEPA requires that the UDF be designed and constructed to be resilient to potential changes due to climate change. Available data indicates that climate change will increase the variability of precipitation, with more rainfall occurring in higher intensity events (Reference 2).
2. Present day design rainfall intensities and depths (i.e., without the impact of climate change considered) are presented in Reference 3.
3. The impact of climate change on design rainfall is presented in Reference 1 and varies according to the recurrence interval of the storm event and the number of years into the future that the impact is intended to represent. The anticipated impact of climate change on rainfall intensity and depth is presented in Reference 1 and is dependent on several parameters, including the following:
   - Time period over which climate change impact is projected: years 2070 to 2099 based on the long-term existence of the UDF and its drainage features.
   - Dataset: West Otis station (nearest station in Reference 1 to the UDF).

- Emission scenario: high representative concentration pathway 8.5, which is the highest concentration of four greenhouse emission concentration trajectories.
- Data utilized: mean values.

4. The following return intervals and storm durations are selected for use in the design of the following permanent UDF drainage features:
   - 2-year, 24-hour: infiltration basin design and pre- and post-development comparison.
   - 10-year, 24-hour: infiltration basin design and pre- and post-development comparison.
   - 25-year, 24-hour: open channel and culvert design.
   - 100-year, 24-hour: infiltration basin design, pre- and post-development comparison, and the design of the UDF perimeter ditch and associated culverts.

Calculations

1. Present Day Rainfall Depths

The current (i.e., without adjustments for climate change) rainfall depths for the design events to be used for the UDF are presented in Reference 3).

Table 1: Present Day Design Rainfall Depths, Lee, MA (Reference 3)

Storm Event	24-Hour Event Depth
2-Year	2.85
10-Year	4.21
25-Year	5.27
100-Year	7.63

2. Estimated Future Rainfall Depths with Adjustment for Climate Change

While it may be appropriate to utilize present day rainfall depths for near-term temporary drainage features, the permanent UDF drainage features are anticipated to be in service for the foreseeable future. Consequently, the impact of climate change is incorporated into the design of these features.

Reference 1 provides the estimated changes in rainfall associated with climate change and are summarized in the table below. The values from Reference 1 are summarized in the table below, along with the percentage increase for the respective storm events under present day conditions.

Table 2: Projected Increased Rainfall Intensities and Depths, West Otis, MA

Storm Event	Ave. Intensity, in/hr (Reference 1)	24-Hour Event Depth, in *	Increase from Present Day Values
2-Year	0.16	3.84	35%
10-Year	0.22	5.28	25%
25-Year	0.27	6.48	23%
100-Year	0.38	9.12	19%

*Storm event depth is the product of the average intensity and the storm duration.

In comparing the datasets from the NRCC, the future time period was chosen as a worst-case scenario to best model rainfall events post-closure. The incorporation of the adjusted values during a future time period provides a robust and conservative approach to designing permanent drainage features.

Summary

The design of permanent drainage features for the UDF are based on a conservative (i.e., worst-case) estimate of future rainfall depths, inclusive of climate change. Specifically, the projected future rainfall data are based on the most distant time period and the largest greenhouse gas emissions scenario. Compared to present day rainfall depths, the values adjusted for climate change are between 19% and 35% greater.

Attachments

1. Present Day Rainfall Data (Reference 3)
2. NRCC Projected Rainfall Data (Reference 1)

Attachment 1

Present Day Rainfall Data

Extreme Precipitation Tables

Northeast Regional Climate Center

Data represents point estimates calculated from partial duration series. All precipitation amounts are displayed in inches.

Metadata for Point

Smoothing	Yes
State	
Location	
Latitude	42.304 degrees North
Longitude	73.234 degrees West
Elevation	280 feet
Date/Time	Mon Sep 25 2023 13:54:21 GMT-0400 (Eastern Daylight Time)

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.31	0.47	0.59	0.77	0.96	1.19	**1yr**	0.83	1.08	1.36	1.66	2.02	2.45	2.73	**1yr**	2.16	2.63	3.08	3.68	4.20	**1yr**
2yr	0.36	0.55	0.69	0.91	1.14	1.42	**2yr**	0.99	1.28	1.62	1.97	2.38	2.85	3.22	**2yr**	2.53	3.09	3.60	4.28	4.90	**2yr**
5yr	0.43	0.67	0.84	1.13	1.44	1.80	**5yr**	1.24	1.59	2.06	2.50	2.99	3.56	4.04	**5yr**	3.15	3.89	4.52	5.25	6.04	**5yr**
10yr	0.49	0.77	0.97	1.32	1.71	2.16	**10yr**	1.48	1.87	2.47	2.99	3.57	4.21	4.81	**10yr**	3.73	4.62	5.37	6.13	7.08	**10yr**
25yr	0.58	0.92	1.17	1.62	2.16	2.74	**25yr**	1.86	2.32	3.14	3.80	4.51	5.27	6.05	**25yr**	4.66	5.82	6.76	7.53	8.73	**25yr**
50yr	0.66	1.07	1.37	1.92	2.58	3.29	**50yr**	2.23	2.74	3.78	4.55	5.37	6.24	7.21	**50yr**	5.52	6.93	8.05	8.81	10.24	**50yr**
100yr	0.77	1.24	1.60	2.27	3.09	3.95	**100yr**	2.67	3.23	4.54	5.45	6.40	7.39	8.59	**100yr**	6.54	8.26	9.58	10.30	12.01	**100yr**
200yr	0.88	1.44	1.86	2.67	3.70	4.74	**200yr**	3.19	3.82	5.45	6.53	7.63	8.76	10.23	**200yr**	7.76	9.84	11.42	12.06	14.10	**200yr**
500yr	1.08	1.78	2.31	3.36	4.70	6.05	**500yr**	4.06	4.77	6.94	8.29	9.63	10.98	12.92	**500yr**	9.72	12.42	14.41	14.87	17.44	**500yr**

Lower Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.25	0.38	0.47	0.63	0.78	0.95	**1yr**	0.67	0.93	1.04	1.26	1.51	2.19	2.40	**1yr**	1.94	2.30	2.69	3.18	3.45	**1yr**
2yr	0.35	0.54	0.66	0.89	1.10	1.26	**2yr**	0.95	1.23	1.42	1.81	2.30	2.77	3.11	**2yr**	2.45	2.99	3.50	4.18	4.74	**2yr**
5yr	0.39	0.61	0.75	1.03	1.31	1.50	**5yr**	1.13	1.47	1.68	2.13	2.68	3.31	3.74	**5yr**	2.93	3.60	4.18	4.87	5.61	**5yr**
10yr	0.41	0.63	0.78	1.10	1.42	1.71	**10yr**	1.22	1.67	1.77	2.39	2.99	3.73	4.22	**10yr**	3.30	4.06	4.74	5.44	6.19	**10yr**
25yr	0.45	0.68	0.85	1.21	1.59	2.03	**25yr**	1.38	1.99	1.99	2.78	3.42	4.37	4.95	**25yr**	3.86	4.76	5.56	6.30	7.30	**25yr**
50yr	0.47	0.72	0.89	1.28	1.73	2.32	**50yr**	1.49	2.27	2.17	3.12	3.77	4.92	5.60	**50yr**	4.35	5.38	6.25	7.02	8.19	**50yr**
100yr	0.49	0.74	0.93	1.35	1.85	2.65	**100yr**	1.59	2.59	2.35	3.50	4.16	5.54	6.32	**100yr**	4.90	6.08	7.02	7.81	8.21	**100yr**
200yr	0.72	1.09	1.38	1.99	2.78	3.05	**200yr**	2.40	2.98	2.53	3.97	4.57	6.21	7.13	**200yr**	5.50	6.86	7.89	8.69	8.79	**200yr**
500yr	0.53	0.79	1.02	1.48	2.10	3.68	**500yr**	1.81	3.60	2.76	4.69	5.20	7.24	8.38	**500yr**	6.41	8.06	9.16	9.97	9.55	**500yr**

Upper Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.36	0.55	0.67	0.90	1.11	1.26	**1yr**	0.96	1.23	1.41	1.65	2.23	2.63	2.97	**1yr**	2.33	2.85	3.32	3.93	4.53	**1yr**
2yr	0.38	0.59	0.72	0.98	1.20	1.40	**2yr**	1.04	1.36	1.56	2.00	2.55	2.97	3.37	**2yr**	2.63	3.24	3.76	4.42	5.13	**2yr**
5yr	0.47	0.73	0.90	1.24	1.58	1.74	**5yr**	1.36	1.70	1.96	2.52	3.10	3.86	4.37	**5yr**	3.41	4.21	4.90	5.68	6.46	**5yr**
10yr	0.57	0.88	1.09	1.52	1.96	2.09	**10yr**	1.69	2.05	2.45	3.02	3.68	4.74	5.39	**10yr**	4.20	5.19	6.07	6.88	7.82	**10yr**
25yr	0.73	1.12	1.39	1.98	2.61	2.68	**25yr**	2.25	2.62	3.22	3.95	4.69	6.25	7.12	**25yr**	5.53	6.84	8.07	8.92	10.21	**25yr**
50yr	0.89	1.35	1.68	2.42	3.25	3.25	**50yr**	2.81	3.17	3.97	4.80	5.63	7.70	8.81	**50yr**	6.82	8.47	10.04	10.85	12.37	**50yr**
100yr	1.08	1.64	2.05	2.96	4.06	3.90	**100yr**	3.50	3.81	4.91	5.84	6.75	9.51	10.92	**100yr**	8.41	10.50	12.52	13.25	14.80	**100yr**
200yr	1.23	1.85	2.34	3.39	4.73	4.71	**200yr**	4.08	4.60	6.08	7.10	8.08	11.74	13.54	**200yr**	10.39	13.02	15.59	16.19	17.99	**200yr**
500yr	1.73	2.58	3.32	4.82	6.85	6.02	**500yr**	5.91	5.88	8.12	9.19	10.29	15.56	18.02	**500yr**	13.77	17.32	20.91	21.14	23.41	**500yr**

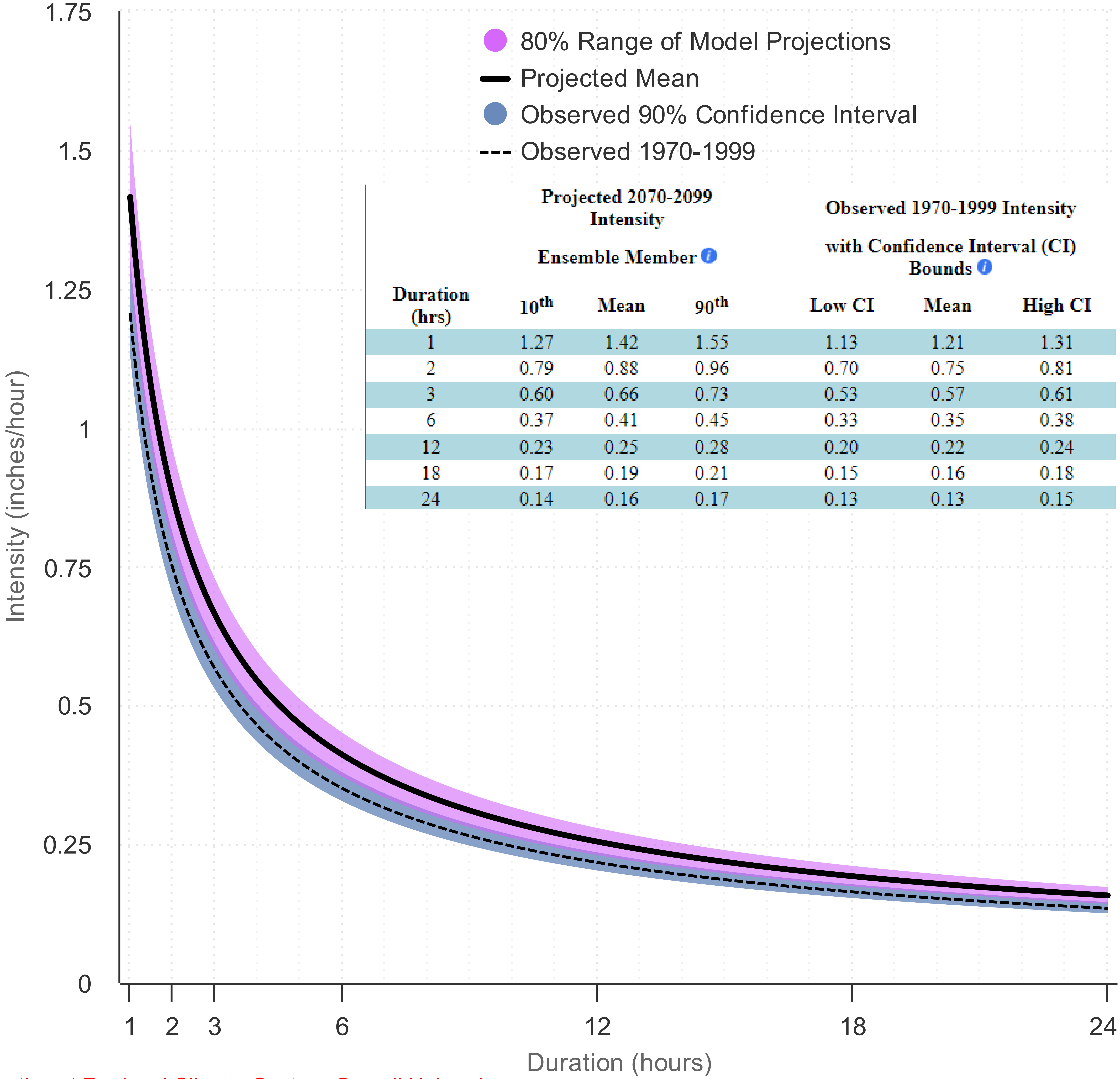
Attachment 2

NRCC Projected Rainfall Data

Intensity Duration Frequency Curves: 2-yr Return Period
RCP 8.5 Projection 2070-2099 vs. Observed (1970-1999)

PROJECTED - 2 YEAR

WEST OTIS



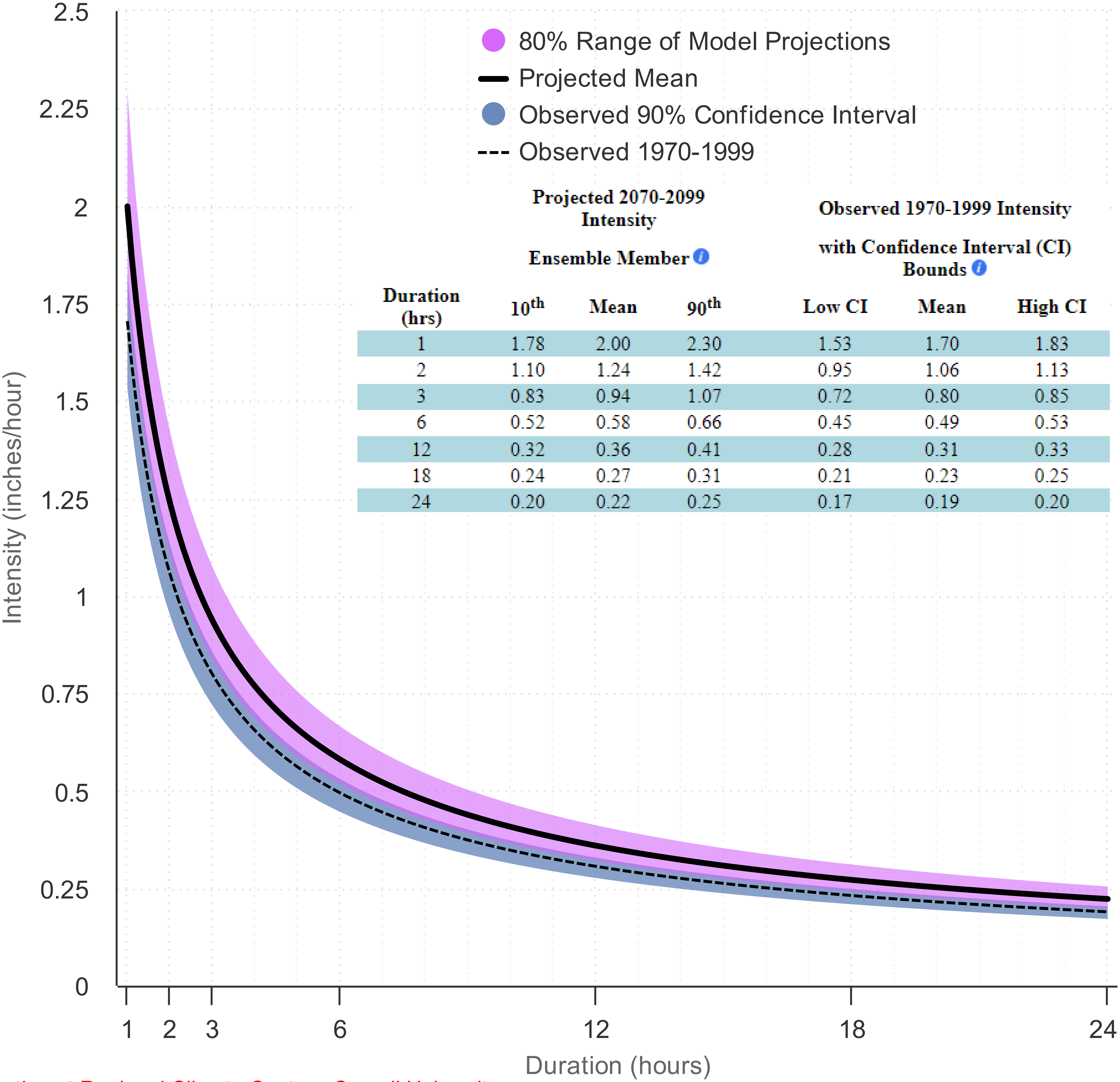
Duration (hrs)	Projected 2070-2099 Intensity Ensemble Member 10th	Mean	90th	Observed 1970-1999 Intensity with Confidence Interval (CI) Bounds Low CI	Mean	High CI
1	1.27	1.42	1.55	1.13	1.21	1.31
2	0.79	0.88	0.96	0.70	0.75	0.81
3	0.60	0.66	0.73	0.53	0.57	0.61
6	0.37	0.41	0.45	0.33	0.35	0.38
12	0.23	0.25	0.28	0.20	0.22	0.24
18	0.17	0.19	0.21	0.15	0.16	0.18
24	0.14	0.16	0.17	0.13	0.13	0.15

Northeast Regional Climate Center - Cornell University

Intensity Duration Frequency Curves: 10-yr Return Period
RCP 8.5 Projection 2070-2099 vs. Observed (1970-1999)

PROJECTED - 10 YEAR

WEST OTIS



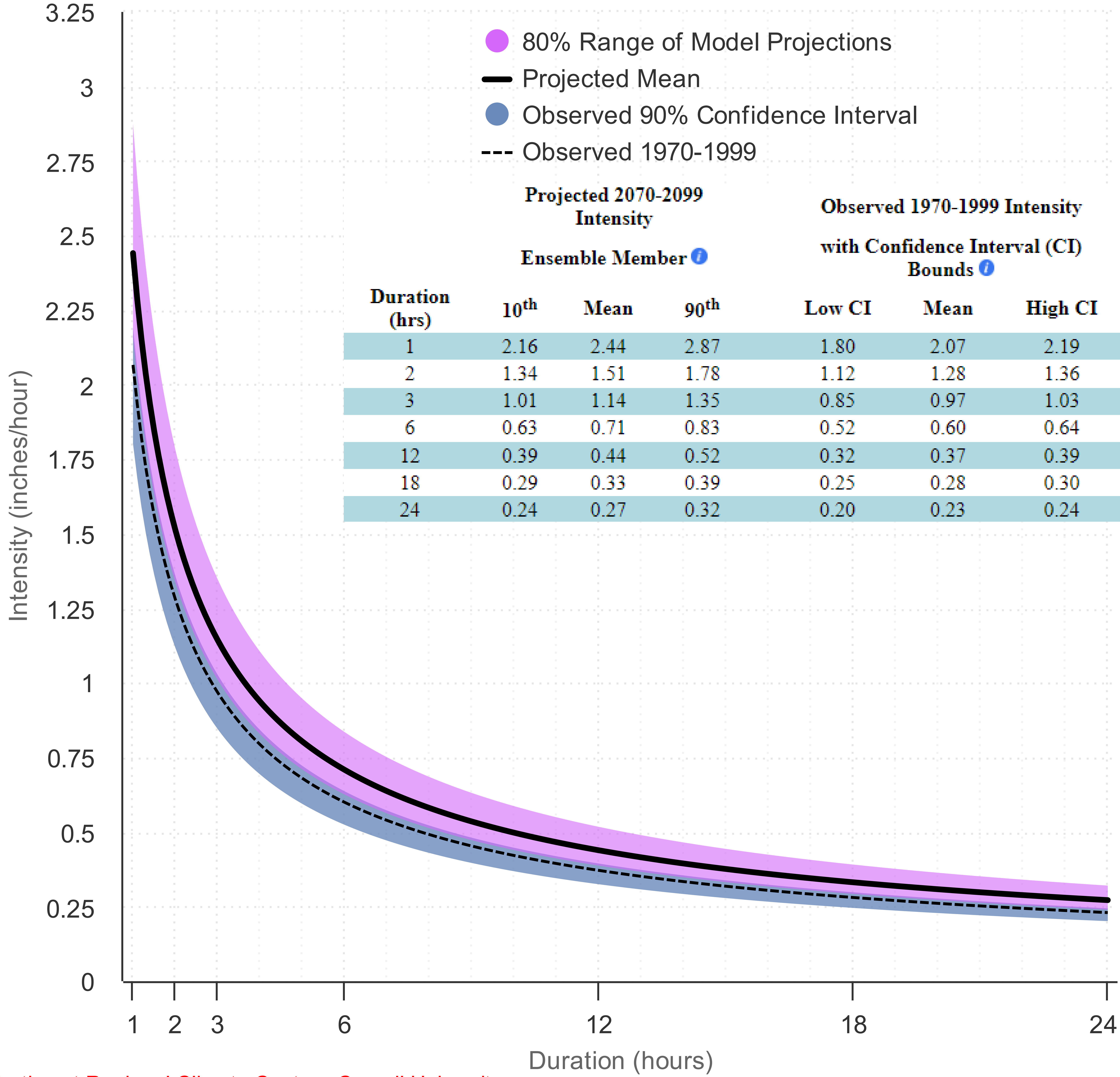
Duration (hrs)	Projected 2070-2099 Intensity Ensemble Member			Observed 1970-1999 Intensity with Confidence Interval (CI) Bounds		
	10th	Mean	90th	Low CI	Mean	High CI
1	1.78	2.00	2.30	1.53	1.70	1.83
2	1.10	1.24	1.42	0.95	1.06	1.13
3	0.83	0.94	1.07	0.72	0.80	0.85
6	0.52	0.58	0.66	0.45	0.49	0.53
12	0.32	0.36	0.41	0.28	0.31	0.33
18	0.24	0.27	0.31	0.21	0.23	0.25
24	0.20	0.22	0.25	0.17	0.19	0.20

Northeast Regional Climate Center - Cornell University

Intensity Duration Frequency Curves: 25-yr Return Period
RCP 8.5 Projection 2070-2099 vs. Observed (1970-1999)

PROJECTED - 25 YEAR

WEST OTIS



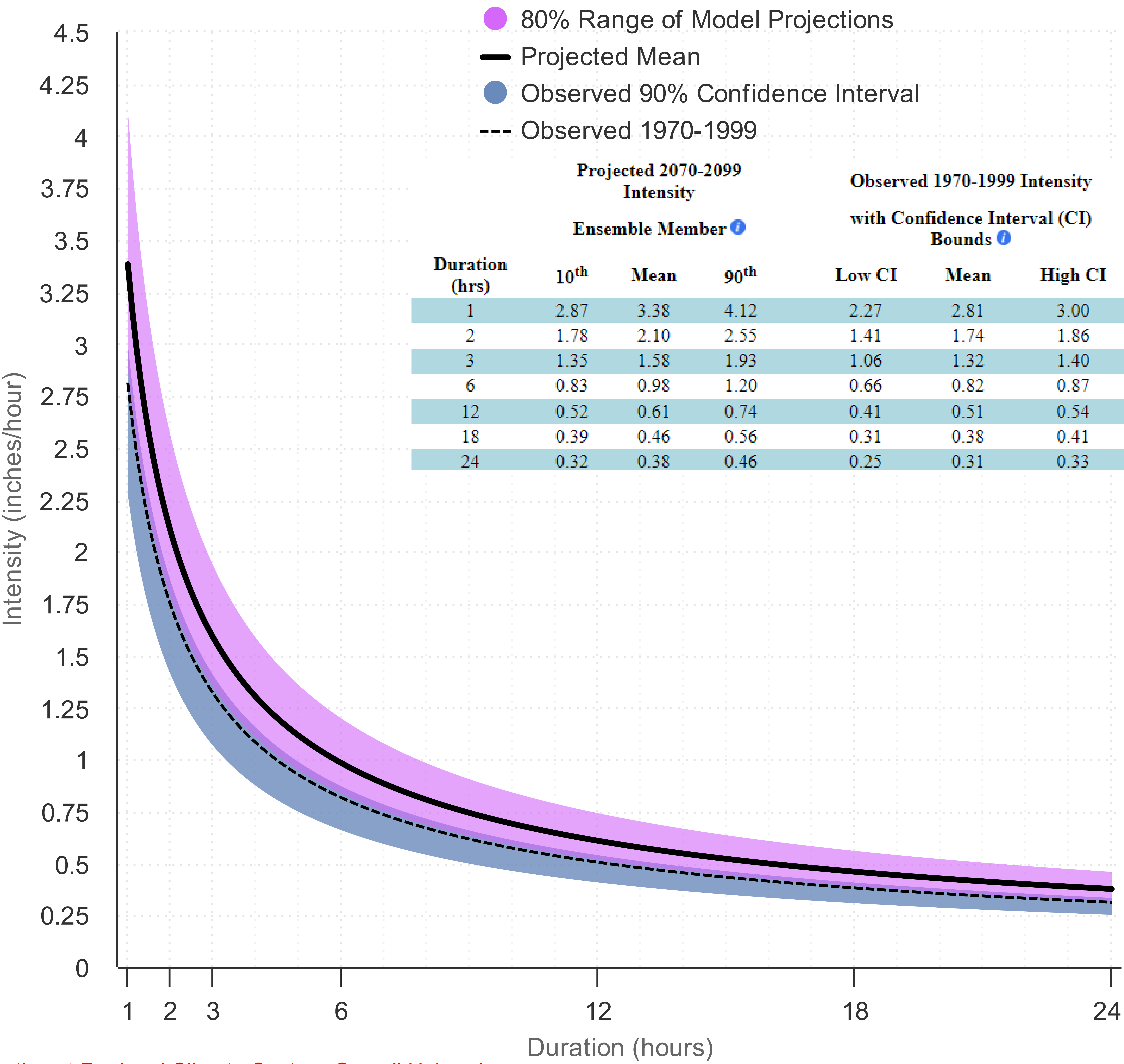
	Projected 2070-2099 Intensity Ensemble Member			Observed 1970-1999 Intensity with Confidence Interval (CI) Bounds		
Duration (hrs)	10^{th}	Mean	90^{th}	Low CI	Mean	High CI
1	2.16	2.44	2.87	1.80	2.07	2.19
2	1.34	1.51	1.78	1.12	1.28	1.36
3	1.01	1.14	1.35	0.85	0.97	1.03
6	0.63	0.71	0.83	0.52	0.60	0.64
12	0.39	0.44	0.52	0.32	0.37	0.39
18	0.29	0.33	0.39	0.25	0.28	0.30
24	0.24	0.27	0.32	0.20	0.23	0.24

Northeast Regional Climate Center - Cornell University

Intensity Duration Frequency Curves: 100-yr Return Period
RCP 8.5 Projection 2070-2099 vs. Observed (1970-1999)

PROJECTED - 100 YEAR

WEST OTIS



Duration (hrs)	Projected 2070-2099 Intensity Ensemble Member 10th	Mean	90th	Observed 1970-1999 Intensity with Confidence Interval (CI) Bounds Low CI	Mean	High CI
1	2.87	3.38	4.12	2.27	2.81	3.00
2	1.78	2.10	2.55	1.41	1.74	1.86
3	1.35	1.58	1.93	1.06	1.32	1.40
6	0.83	0.98	1.20	0.66	0.82	0.87
12	0.52	0.61	0.74	0.41	0.51	0.54
18	0.39	0.46	0.56	0.31	0.38	0.41
24	0.32	0.38	0.46	0.25	0.31	0.33

Northeast Regional Climate Center - Cornell University

ARCADIS

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **G-2** **Subject:** **Existing Stormwater Conditions**

Prepared By: **SES/CSH/MTA** **Date:** **February 2024**

Reviewed By: **SES/BMS** **Date:** **February 2024**

Objective

Assess existing stormwater conditions to identified design points surrounding the Upland Disposal Facility (UDF). These existing stormwater conditions are used to compare against proposed stormwater conditions following UDF construction and closure, which are evaluated in a separate calculation.

References

1. Arcadis U.S., Inc. *Upland Disposal Facility Final Design Plan*, Appendix G-1: Design Storm. February 2024.
2. Autodesk, Inc. *Civil3D*. Computer Software. 2023.
3. Massachusetts Department of Environmental Protection (MassDEP). *Massachusetts Stormwater Handbook and Stormwater Standards*, Volume 3, Chapter 1. 2008.
4. National Resources Conservation Service - United States Department of Agriculture (NRCS-USDA). *Web Soil Survey.* http://websoilsurvey.sc.egov.usda.gov/. Accessed April, 2023 (select pages attached).
5. HydroCAD Software Solutions, LLC. *HydroCAD Version 10.2*. Computer Software, 2022.
6. Natural Resource Conservation Service. *Urban Hydrology for Small Watersheds.* Technical Release 55 (TR-55). June 1986 (portions attached)
7. MassDEP Division of Watershed Management. *Hydrology Handbook for Conservation Commissioners.* March 2002.
8. National Resources Conservation Service – United Stated Department of Agriculture (NRCS-USDA). *National Engineering Handbook*. Chapter 7- Hydrologic Soil Groups. pp. 7-2. May 2007.
9. San Francisco Stormwater Management Requirements and Design Guidelines. *Appendix C: Criteria for Infiltration-Based BMPs.* May 2016.
10. Arcadis U.S. Inc *Pre-Design Investigation Summary Report for Upland Disposal Facility Area.* February 2024.

Assumptions

1. Modeled precipitation amounts are as follows (Reference 1).

   - 2-year, 24-hour: 3.84 inches
   - 10-year, 24-hour: 5.28 inches
   - 100-year, 24-hour: 9.12 inches

   The modeled precipitation amounts are adjusted for climate change predictions based on assumptions made in Reference 1.

2. Design points represent locations at which all of the following conditions apply:

   - Stormwater can or has the potential to drain offsite under existing conditions.
   - Stormwater can or has the potential to drain offsite under proposed conditions following construction and closure of the UDF.
   - The rate and/or volume of stormwater runoff draining to the design points may be increased by the construction and closure of the UDF.

   Portions of the site that do not drain offsite under existing conditions and/or are not affected by the construction and closure of the UDF (based on their drainage areas laying entirely outside of the proposed limits of grading for the UDF) are not analyzed herein.

3. Stormwater runoff conditions from the drainage areas to the design points are analyzed based on conditions that exist at the present time and prior to UDF construction.

4. Stormwater conditions to each design point are determined using Reference 5, which utilizes the NRCS curve number (CN) method to convert rainfall to runoff. CNs are selected from Reference 6 based on hydrologic soil groups (HSGs) and ground cover types present under existing conditions, as summarized below.

   - Soil Types: For portions of drainage areas outside of the limits of work, Reference 4 is used to determine HSG. Off-site portions of drainage areas include HSG A, B, C, and D. For portions of drainage areas within the GE parcel, the HSG is based on data collected during test pitting performed to support the UDF design. The characteristics of surface and near surface soils determine the HSG. Relevant test pit data from Reference 10 is summarized in Attachment 5, and based on this data, HSG B is deemed representative of existing conditions.

   - Cover Types: An aerial image of the GE parcel and the surrounding area is used to determine existing ground cover (e.g., vegetation type and density). Numerous site visits and investigations provided further opportunity to refine the assessment of cover type present on the GE parcel.

- Considering existing soils and cover types, CN values are as follows (Reference 6):

Cover Type	**CN for Indicated HSG**			
	A	**B**	**C**	**D**
Woods, Good Condition	30	55	70	77
Pasture, Grassland, or Range, Poor Condition (<50% Coverage)	68	79		
Pasture, Grassland, or Range, Fair Condition (50% to 75% Coverage)	49	69		
Brush, Good Condition	30	48		
Fallow, Bare Soil	77	86		
Gravel	96	96		
Paved Roads w/ Open Ditches, 50% Impervious	83	89		
Open Water		98		
Roofs	98	98		

- A weighted curve number for each drainage area is calculated as shown in Attachment 1.

5. Drainage area acreages and time of concentration (Tc) paths are delineated using Autodesk Civil3D software (Reference 2) based on survey information and publicly available GIS data.

6. The maximum distance for an assumed sheet flow segment of a Tc path is 50 feet before transitioning to shallow concentrated flow (References 3 and 7).

7. For the purposes of calculating Tc values, all existing channels used for estimation of channel flow segments are assumed to have trapezoidal geometry with a bottom width of 1 foot, side slopes of 3 Horizontal: 1 Vertical, and a flow depth of 1 foot. Manning's n values for channels are assumed to be 0.025 based on a typical earthen channel that is clean and winding (Reference 5).

8. The following input values were used for hydrograph modeling purposes (Reference 6):

   - Storm Type: Type III, 24-hour Rainfall Distribution (Attachment 4)
   - Antecedent moisture condition (AMC): 2
   - Initial Abstraction (Ia/S) Ratio: 0.20

9. In some instances, stormwater runoff reaching a design point passes through one or more existing depressions that allow temporary storage of stormwater and infiltration into the subsurface, thereby reducing the stormwater runoff rate and volume reaching the design point. The degree to which this occurs can be determined using hydrologic routing, which accounts for the stormwater runoff hydrograph into the infiltration area, the storage volume of the depression, and the rate of infiltration expected based on site soil permeability testing (Reference 10).

10. Hydrologic routing through existing infiltration areas is only performed when the proposed UDF development is anticipated to increase the rate and volume of stormwater runoff into a stormwater management area and/or affects the configuration of the infiltration area. Existing infiltration areas that are proposed to be modified in configuration or to receive increases in stormwater runoff rates and/or volumes are included in the UDF design as Stormwater Management Areas (SMAs). The post-construction stormwater conditions associated with these SMAs is evaluated in a separate calculation and are compared to the existing conditions determined herein.

Calculations

1. Design Points and Contributing Drainage Areas

Based on existing topography and the proposed footprint of the UDF, a total of nine design points are identified. The design points and the contributing drainage area ID(s) are summarized in Table 1.

Table 1: Design Points

Design Point	Design Point Description	Contributing Drainage Areas	Hydrologic Routing Performed for Flow to Design Point (Y/N)?
1	Point of discharge to jointly owned quarry pond on western property line	1A E, 1B E, 2A E, 2B E, 3 E	Y
2	Point of overflow to on-site area to the north and potentially to abutter along eastern property line (depression forms future SMA-1)	3E	Y
3	Point of overflow to Woodland Road along eastern property line	4 E	N
4	Point of overflow to Woodland Road along eastern property line	5 E	N
5	Point of overflow to Woodland Road along eastern property line (depression forms future SMA-2)	6 E	Y
6	Point of overflow to abutter along western property line (depression forms future SMA-3A and SMA-3B)	8 E	Y
7	Point of overflow to abutter along southern property line (future location of SMA-4)	7 E	Y
8	Point of overflow to abutter along western property line	9 E	N
9	Quarry pond within property limits that overflows to jointly owned quarry pond on western property line (future location of SMA-5)	10 E	Y

The design point locations and drainage area boundaries are shown in the attached Existing Drainage Area Map (Figure 1). It is noted that all design points are downstream of existing depressions that provide attenuation of offsite peak flowrates (Assumption 9). However, the rate and volume of stormwater runoff reaching Design Points 3, 4, and 8 will be reduced as a result of UDF construction and closure; therefore, the effect of their associated infiltration areas is not analyzed herein (Assumption 10). The degree of attenuation provided by upstream infiltration areas to the flow to Design Points 1 ,2, 5, 6, 7, and 9 is evaluated later in this calculation.

2. Existing Drainage Area Hydrologic Conditions

The drainage areas presented above in Table 1 are modeled using HydroCAD (Reference 5) to generate stormwater runoff hydrographs. Table 2 summarizes the hydrologic input parameters and calculated peak flow rates from each drainage area under existing conditions.

Table 2: Existing Hydrologic Conditions

Drainage Area	Area (acres)	Composite CN	Tc (min)	2-yr, 24-hr		10-yr, 24-hr		100-yr, 2-hr	
				Volume (ac-ft)	Rate (cfs)	Volume (ac-ft)	Rate (cfs)	Volume (ac-ft)	Rate (cfs)
1A E	38.00	62	34.2	2.475	15.29	5.111	35.71	14.072	104.84
1B-E	2.99	42	15.1	0.019	0.03	0.097	0.41	0.499	4.41
2A E	48.62	62	34.0	3.167	19.61	6.540	45.85	18.005	134.37
2B E	5.76	40	6.8	0.021	0.03	0.144	0.54	0.851	9.24
3 E	24.91	58	32.8	1.233	6.84	2.752	18.64	8.192	61.56
4 E	1.59	44	6.6	0.016	0.03	0.064	0.35	0.297	3.59
5 E	1.83	56	6.7	0.078	0.63	0.181	2.12	0.564	7.60
6 E	4.33	53	17.6	0.141	0.74	0.359	2.78	1.201	11.55
7 E	10.99	43	11.8	0.090	0.14	0.398	1.94	1.943	19.26
8 E	1.06	62	6.0	0.069	0.79	0.143	1.88	0.393	5.51
9 E	0.97	73	6.0	0.114	1.56	0.202	2.83	0.470	6.58
10 E	15.30	66	8.3	1.264	14.62	2.449	30.72	6.302	81.86

The individual acreages for each CN value and the composite CN for each drainage area are provided in Attachment 1. The HydroCAD model schematic, modeling inputs, and results are provided in Attachment 2.

3. Hydrologic Routing Through Existing Infiltration Areas Upstream of Design Points

The rate of stormwater reaching six design points are affected by upstream infiltration areas that will be altered under proposed conditions. These areas are identified on the UDF construction plans as Stormwater Management Areas (SMAs) 1, 2, 3, 4, 5, and 6. Tables 3, 4, and 5 summarize the hydrologic routing through these six existing infiltration areas for the respective storm events.

Table 3: Hydrologic Routing for Existing Infiltration Areas – 2-yr 24-hr Storm

Design Point	Corresponding SMA #	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Water Surface El. (ft)
2	1	6.84	0.00	995.12
5	2	0.74	0.00	1026.53
6	3	0.79	0.02	1025.36
7	4	0.14	0.11	989.14
9	5	14.62	3.89	949.90
1	6	24.76	0.00	984.09

Table 4: Hydrologic Routing for Existing Infiltration Areas – 10-yr 24-hr Storm

Design Point	Corresponding SMA #	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Water Surface El. (ft)
2	1	18.64	0.00	997.57
5	2	2.78	0.43	1026.77
6	3	1.88	0.33	1025.44
7	4	1.94	1.48	989.56
9	5	30.72	9.28	950.03
1	6	120.280	11.07	985.11

Table 5: Hydrologic Routing for Existing Infiltration Areas – 100-yr 24-hr Storm

Design Point	Corresponding SMA #	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Water Surface El. (ft)
2	1	61.56	7.86	1001.83
5	2	11.55	9.25	1027.45
6	3	5.51	5.43	1026.06
7	4	19.26	18.26	990.68
9	5	81.86	17.43	951.13
1	6	245.69	159.64	987.91

*Time to drain to SMA-5 is not applicable as SMA-5 is an existing water-filled quarry pond.

4. Design Point Analysis

Table 6 below summarizes the peak flows at the nine design points. The naming of the design points below is consistent with the HydroCAD model (Attachment 2).

Table 6: Design Point Results

Design Point	Peak Flow Rate (cfs)		
	2-yr, 24-hr	10-yr, 24-hr	100-yr, 24-hr
1	0.00	11.07	159.64
2	0.00	0.00	7.86
3	0.03	0.35	3.59
4	0.63	2.12	7.60
5	0.00	0.43	9.25
6	0.02	0.33	5.43
7	0.11	1.48	18.26
8	1.56	2.83	6.58
9	5.51	14.88	17.43

The complete routing diagram for existing conditions can be seen in Attachment 2.

Figures

1. Existing Drainage Area Map
2. Existing Hydrologic Conditions

Attachments

1. Existing Conditions Curve Number Calculations
2. HydroCAD Existing Condition Modelling Input and Results
3. Custom Soil Resource Report for Berkshire County, Massachusetts (September 27, 2023)
4. SDS Rainfall Distribution Map
5. Infiltration Testing and Boring Spreadsheet

Figure 1

Existing Drainage Area Map

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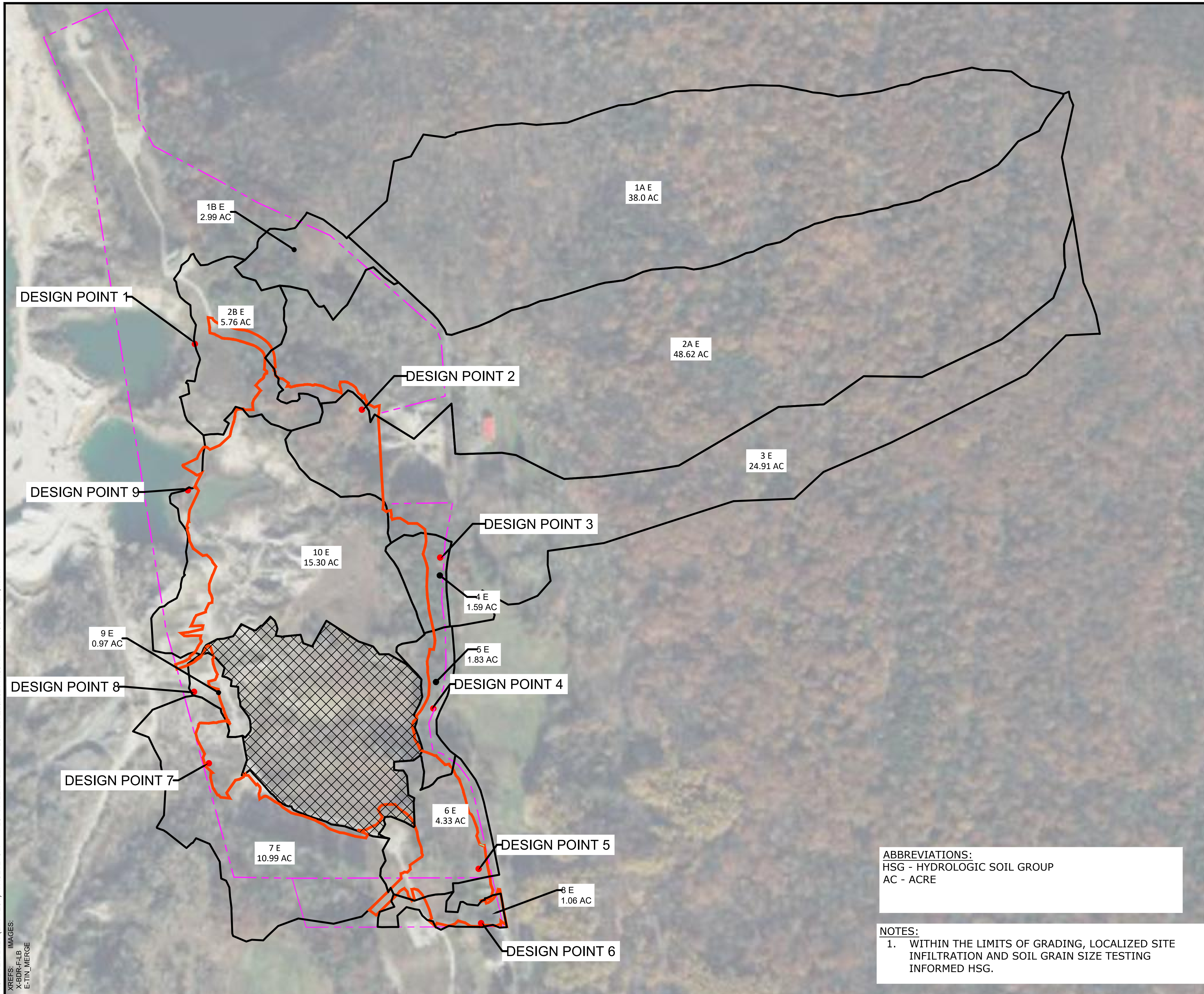

LEGEND

- SUBCATCHMENT BOUNDARY
- DESIGN POINT
- PROPERTY LINE
- HSG BOUNDARY/LIMITS OF GRADING[1]
- DRAINAGE AREA TO ON-SITE DEPRESSION (NO-OFFSITE DISCHARGE)

ABBREVIATIONS:
HSG - HYDROLOGIC SOIL GROUP
AC - ACRE

NOTES:
1. WITHIN THE LIMITS OF GRADING, LOCALIZED SITE INFILTRATION AND SOIL GRAIN SIZE TESTING INFORMED HSG.

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EXISTING DRAINAGE AREA MAP

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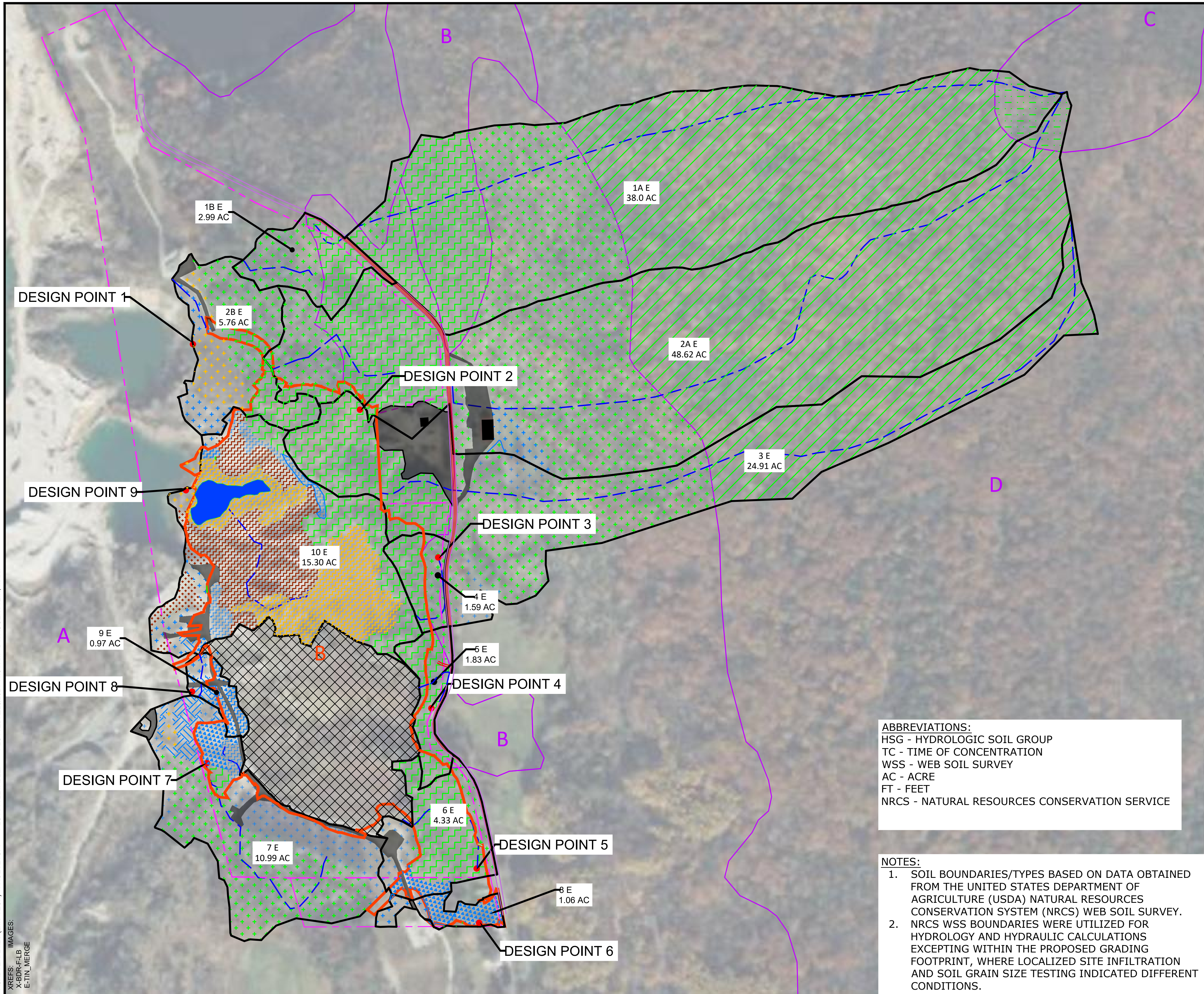
FIGURE
1

Figure 2

Existing Hydrologic Conditions



LEGEND

- WOODS, HSG A (GOOD CONDITION)
- WOODS, HSG B (GOOD CONDITION)
- WOODS, HSG C (GOOD CONDITION)
- WOODS, HSG D (GOOD CONDITION)
- PASTURE, HSG A (FAIR CONDITION)
- PASTURE, HSG A (POOR CONDITION)
- PASTURE, HSG B (POOR CONDITION)
- PASTURE, HSG B (FAIR CONDITION)
- BRUSH, HSG A (GOOD CONDITION)
- BRUSH, HSG B (GOOD CONDITION)
- PAVED ROAD WITH DITCHES
- GRAVEL
- ROOFS
- OPEN WATER
- BARE SOIL, HSG A
- BARE SOIL, HSG B
- 1600 — INDEX ELEVATION CONTOUR (100-FT INT.)
- INTERMEDIATE ELEVATION CONTOUR (10-FT INT.)
- DESIGN POINT
- PROPERTY LINE
- SUBCATCHMENT BOUNDARY
- A — NRCS WSS HSG BOUNDARY/LABEL[1]
- A — HSG BOUNDARY BASED ON SITE TESTS[2]
- A, B, C, D — HSG LABEL
- TC PATH
- ROAD(S)
- DRAINAGE AREA TO ON-SITE DEPRESSION (NO OFF-SITE DISCHARGE)

ABBREVIATIONS:
HSG - HYDROLOGIC SOIL GROUP
TC - TIME OF CONCENTRATION
WSS - WEB SOIL SURVEY
AC - ACRE
FT - FEET
NRCS - NATURAL RESOURCES CONSERVATION SERVICE

NOTES:
1. SOIL BOUNDARIES/TYPES BASED ON DATA OBTAINED FROM THE UNITED STATES DEPARTMENT OF AGRICULTURE (USDA) NATURAL RESOURCES CONSERVATION SYSTEM (NRCS) WEB SOIL SURVEY.
2. NRCS WSS BOUNDARIES WERE UTILIZED FOR HYDROLOGY AND HYDRAULIC CALCULATIONS EXCEPTING WITHIN THE PROPOSED GRADING FOOTPRINT, WHERE LOCALIZED SITE INFILTRATION AND SOIL GRAIN SIZE TESTING INDICATED DIFFERENT CONDITIONS.

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EXISTING HYDROLOGIC CONDITIONS

ARCADIS

FIGURE
2

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Attachment 1

Existing Conditions Curve Number Calculations

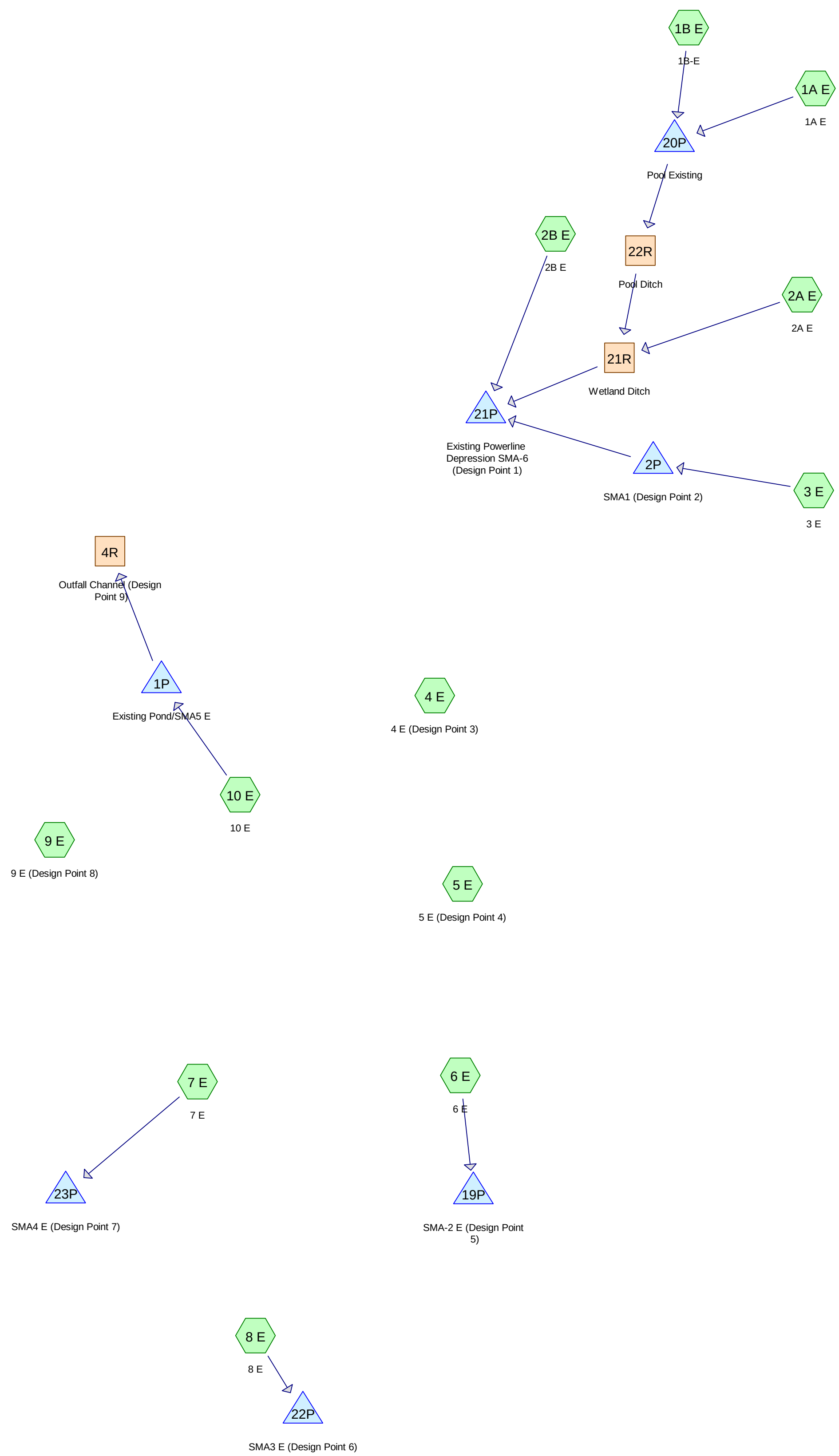
Drainage Area	Area (sf)	Soil Type	Cover Type	Curve Number	Weighted CN	Total Area (ac)
1A E	47371.12	C	Woods - Good Condition	70		
	952077.33	D	Woods - Good Condition	77		
	384265.73	A	Woods - Good Condition	30		
	272645.19	B	Woods - Good Condition	55	62	38.0
1B E	43.28	A	Streets and roads: Paved; open ditches (including right-of-way)	83		
	6141.05	B	Streets and roads: Paved; open ditches (including right-of-way)	89		
	74049.08	A	Woods - Good Condition	30		
	49966.84	B	Woods - Good Condition	55	42	2.99
2A E	23498.80	C	Woods - Good Condition	70		
	1195601.52	D	Woods - Good Condition	77		
	473690.97	A	Woods - Good Condition	30		
	4663.27	B	Woods - Good Condition	55		
	10950.60	B	Streets and roads: Paved; open ditches (including right-of-way)	89		
	32828.48	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	3654.64	A	Impervious areas: Paved parking lots, roofs, driveways (excluding right-of-way)	98		
	27384.34	A	Gravel (w/o right-of-way)	96		
	25695.99	A	Woods - Good Condition	30		
	578.26	B	Streets and roads: Paved; open ditches (including right-of-way)	89		
	21236.57	B	Gravel (w/o right-of-way)	96		
	991.83	B	Impervious areas: Paved parking lots, roofs, driveways (excluding right-of-way)	98		
	193213.81	B	Woods - Good Condition	55		
	21479.00	B	Woods - Good Condition	55		
	82307.50	A	Woods - Good Condition	30	62	48.62
2B E	97573.58	A	Woods - Good Condition	30		
	48957.50	B	Woods - Good Condition	55		
	56311.01	A	Brush - Brush-weed-grass mixture with brush the major element - Good Condition	30		
	1975.27	B	Brush - Brush-weed-grass mixture with brush the major element - Good Condition	48		
	862.62	B	Gravel (w/o right-of-way)	96		
	483.19	B	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	69		
	7574.27	A	Gravel (w/o right-of-way)	96		
	36956.18	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49	40	5.76
3 E	417571.92	D	Woods - Good Condition	77		
	360928.16	A	Woods - Good Condition	30		
	6524.56	A	Gravel (w/o right-of-way)	96		
	42287.06	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	10461.00	A	Streets and roads: Paved; open ditches (including right-of-way)	83		
	3588.89	B	Streets and roads: Paved; open ditches (including right-of-way)	89		
	54669.17	B	Gravel (w/o right-of-way)	96		
	58.99	B	Impervious areas: Paved parking lots, roofs, driveways (excluding right-of-way)	98		
	188844.41	B	Woods - Good Condition	55	58	24.91

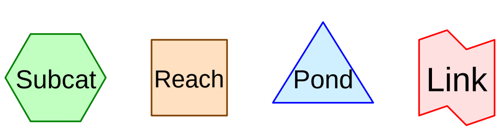
4 E	31464.06	A	Woods - Good Condition	30			
	37822.26	B	Woods - Good Condition	55	44	1.59	
5 E	1545.42	A	Streets and roads: Paved; open ditches (including right-of-way)	83			
	4754.01	A	Woods - Good Condition	30			
	69830.63	B	Woods - Good Condition	55			
	3739.49	B	Streets and roads: Paved; open ditches (including right-of-way)	89	56	1.83	
6 E	107260.13	B	Woods - Good Condition	55			
	6160.17	B	Woods - Good Condition	55			
	1421.58	B	Woods - Good Condition	55			
	21969.16	A	Woods - Good Condition	30			
	3668.40	A	Streets and roads: Paved; open ditches (including right-of-way)	83			
	12851.73	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49			
	9583.22	A	Gravel (w/o right-of-way)	96			
	21313.01	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49			
	1056.37	A	Woods - Good Condition	30			
	2974.51	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49			
	436.30	B	Streets and roads: Paved; open ditches (including right-of-way)	89	53	4.33	
7 E	9194.56	A	Gravel (w/o right-of-way)	96			
	9294.87	B	Gravel (w/o right-of-way)	96			
	108831.42	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49			
	264310.55	A	Woods - Good Condition	30			
	7758.52	A	Brush - Brush-weed-grass mixture with brush the major element - Good Condition	30			
	33117.45	A	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	68			
	5209.66	A	Gravel (w/o right-of-way)	96			
	8299.33	B	Woods - Good Condition	55			
	16153.48	B	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	79			
	1176.88	B	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	69			
	1518.18	B	Gravel (w/o right-of-way)	96			
	3046.51	B	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	69			
	5662.72	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49			
	310.62	B	Woods - Good Condition	55			
	4706.90	A	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	68	43	10.99	
8 E	13344.67	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49			
	1676.09	A	Woods - Good Condition	30			
	30540.00	B	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	69			
	765.56	A	Gravel (w/o right-of-way)	96	62	1.06	
9 E	11904.62	B	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	69			
	5717.52	B	Gravel (w/o right-of-way)	96			
	8019.54	B	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	79			
	6682.52	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49			
	7600.70	A	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	68			

	2511.06	A	Gravel (w/o right-of-way)	96	73	0.97
10 E	3306.29	A	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	68		
	24180.74	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	30547.96	A	Fallow: Bare Soil	77		
	8880.83	A	Gravel (w/o right-of-way)	96		
	11397.65	B	Gravel (w/o right-of-way)	96		
	2005.99	B	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	69		
	911.77	B	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	69		
	31326.18	B	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	69		
	197894.57	B	Fallow: Bare Soil	86		
	206545.90	B	Brush - Brush-weed-grass mixture with brush the major element - Good Condition	48		
	106757.57	B	Woods - Good Condition	55		
	7569.60	A	Brush - Brush-weed-grass mixture with brush the major element - Good Condition	30		
	27258.10	A	Open Water: Ponds and lakes: classified as impervious	98		
	1876.51	B	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	79		
	5896.22	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49	66	15.30

Attachment 2

HydroCAD Existing Conditions Modelling Input and Results





Routing Diagram for Existing Conditions_R1
Prepared by ARCADIS U S Inc, Printed 2/27/2024
HydroCAD® 10.20-3c s/n 02786 © 2023 HydroCAD Software Solutions LLC

Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	2-YR	Type III 24-hr		Default	24.00	1	3.84	2
2	10-YR	Type III 24-hr		Default	24.00	1	5.28	2
3	100-YR	Type III 24-hr		Default	24.00	1	9.12	2

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
39.060	62	(1A E, 8 E)
5.760	40	(2B E)
24.910	58	(3 E)
1.590	44	(4 E)
1.830	56	(5 E)
4.330	53	(6 E)
10.990	43	(7 E)
0.970	73	(9 E)
15.300	66	(10 E)
2.990	42	From CN Spreadsheet (1B E)
48.620	62	From CN Spreadsheet (2A E)
156.350	**59**	**TOTAL AREA**

Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1A E: 1A E Runoff Area=38.000 ac 0.00% Impervious Runoff Depth=0.78"
Flow Length=3,236' Tc=34.2 min CN=62 Runoff=15.29 cfs 2.475 af

Subcatchment 1B E: 1B-E Runoff Area=2.990 ac 0.00% Impervious Runoff Depth=0.08"
Flow Length=329' Tc=15.1 min CN=42 Runoff=0.03 cfs 0.019 af

Subcatchment 2A E: 2A E Runoff Area=48.620 ac 0.00% Impervious Runoff Depth=0.78"
Flow Length=4,073' Tc=34.0 min CN=62 Runoff=19.61 cfs 3.167 af

Subcatchment 2B E: 2B E Runoff Area=5.760 ac 0.00% Impervious Runoff Depth=0.04"
Flow Length=248' Tc=6.8 min CN=40 Runoff=0.03 cfs 0.021 af

Subcatchment 3 E: 3 E Runoff Area=24.910 ac 0.00% Impervious Runoff Depth=0.59"
Flow Length=3,460' Tc=32.8 min CN=58 Runoff=6.84 cfs 1.233 af

Subcatchment 4 E: 4 E (Design Point 3) Runoff Area=1.590 ac 0.00% Impervious Runoff Depth=0.12"
Flow Length=362' Tc=6.6 min CN=44 Runoff=0.03 cfs 0.016 af

Subcatchment 5 E: 5 E (Design Point 4) Runoff Area=1.830 ac 0.00% Impervious Runoff Depth=0.51"
Flow Length=270' Tc=6.7 min CN=56 Runoff=0.63 cfs 0.078 af

Subcatchment 6 E: 6 E Runoff Area=4.330 ac 0.00% Impervious Runoff Depth=0.39"
Flow Length=474' Tc=17.6 min CN=53 Runoff=0.74 cfs 0.141 af

Subcatchment 7 E: 7 E Runoff Area=10.990 ac 0.00% Impervious Runoff Depth=0.10"
Flow Length=1,023' Tc=11.8 min CN=43 Runoff=0.14 cfs 0.090 af

Subcatchment 8 E: 8 E Runoff Area=1.060 ac 0.00% Impervious Runoff Depth=0.78"
Tc=6.0 min CN=62 Runoff=0.79 cfs 0.069 af

Subcatchment 9 E: 9 E (Design Point 8) Runoff Area=0.970 ac 0.00% Impervious Runoff Depth=1.41"
Tc=6.0 min CN=73 Runoff=1.56 cfs 0.114 af

Subcatchment 10 E: 10 E Runoff Area=15.300 ac 0.00% Impervious Runoff Depth=0.99"
Flow Length=885' Tc=8.3 min CN=66 Runoff=14.62 cfs 1.264 af

Reach 4R: Outfall Channel (Design Avg. Flow Depth=0.19' Max Vel=4.36 fps Inflow=3.89 cfs 0.494 af
n=0.022 L=5.0' S=0.0480 '/' Capacity=17.43 cfs Outflow=3.01 cfs 0.483 af

Reach 21R: Wetland Ditch Avg. Flow Depth=0.73' Max Vel=5.76 fps Inflow=24.77 cfs 5.177 af
n=0.035 L=49.0' S=0.0494 '/' Capacity=48.15 cfs Outflow=24.76 cfs 5.177 af

Reach 22R: Pool Ditch Avg. Flow Depth=0.21' Max Vel=2.25 fps Inflow=11.00 cfs 2.010 af
n=0.035 L=202.1' S=0.0247 '/' Capacity=166.36 cfs Outflow=10.96 cfs 2.010 af

Pond 1P: Existing Pond/SMA5 E Peak Elev=949.90' Storage=6.042 af Inflow=14.62 cfs 1.264 af
Discarded=0.58 cfs 6.814 af Primary=3.89 cfs 0.494 af Outflow=4.47 cfs 7.308 af

Pond 2P: SMA1 (Design Point 2) Peak Elev=995.12' Storage=1.064 af Inflow=6.84 cfs 1.233 af
Discarded=0.18 cfs 1.233 af Primary=0.00 cfs 0.000 af Outflow=0.18 cfs 1.233 af

Pond 19P: SMA-2 E (Design Point 5) Peak Elev=1,026.53' Storage=0.081 af Inflow=0.74 cfs 0.141 af
Discarded=0.07 cfs 0.141 af Primary=0.00 cfs 0.000 af Outflow=0.07 cfs 0.141 af

Pond 20P: Pool Existing Peak Elev=992.65' Storage=0.753 af Inflow=15.29 cfs 2.495 af
Outflow=11.00 cfs 2.010 af

Pond 21P: Existing Powerline Depression Peak Elev=984.09' Storage=4.528 af Inflow=24.76 cfs 5.198 af
Discarded=0.72 cfs 5.198 af Primary=0.00 cfs 0.000 af Outflow=0.72 cfs 5.198 af

Pond 22P: SMA3 E (Design Point 6) Peak Elev=1,025.36' Storage=0.035 af Inflow=0.79 cfs 0.069 af
Discarded=0.03 cfs 0.059 af Primary=0.02 cfs 0.003 af Outflow=0.04 cfs 0.062 af

Pond 23P: SMA4 E (Design Point 7) Peak Elev=989.14' Storage=0.021 af Inflow=0.14 cfs 0.090 af
Discarded=0.02 cfs 0.032 af Primary=0.11 cfs 0.058 af Outflow=0.13 cfs 0.090 af

Total Runoff Area = 156.350 ac Runoff Volume = 8.687 af Average Runoff Depth = 0.67"
100.00% Pervious = 156.350 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 1A E: 1A E

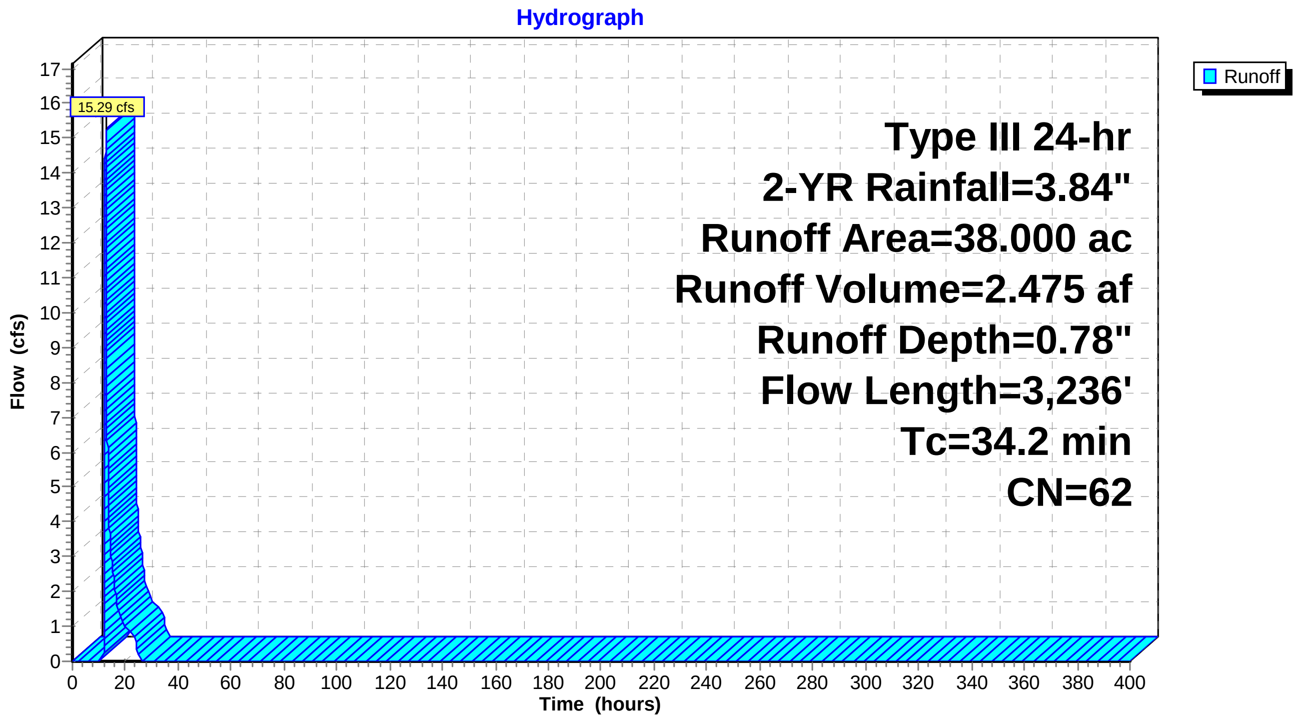
Runoff = 15.29 cfs @ 12.57 hrs, Volume= 2.475 af, Depth= 0.78"
Routed to Pond 20P : Pool Existing

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	38.000	62	
	38.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	50	0.0400	0.06		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.7	228	0.0790	1.41		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
7.9	1,488	0.3970	3.15		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
8.1	1,050	0.1850	2.15		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.6	420	0.0570	10.83	64.98	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
34.2	3,236	Total			

Subcatchment 1A E: 1A E



Summary for Subcatchment 1B E: 1B-E

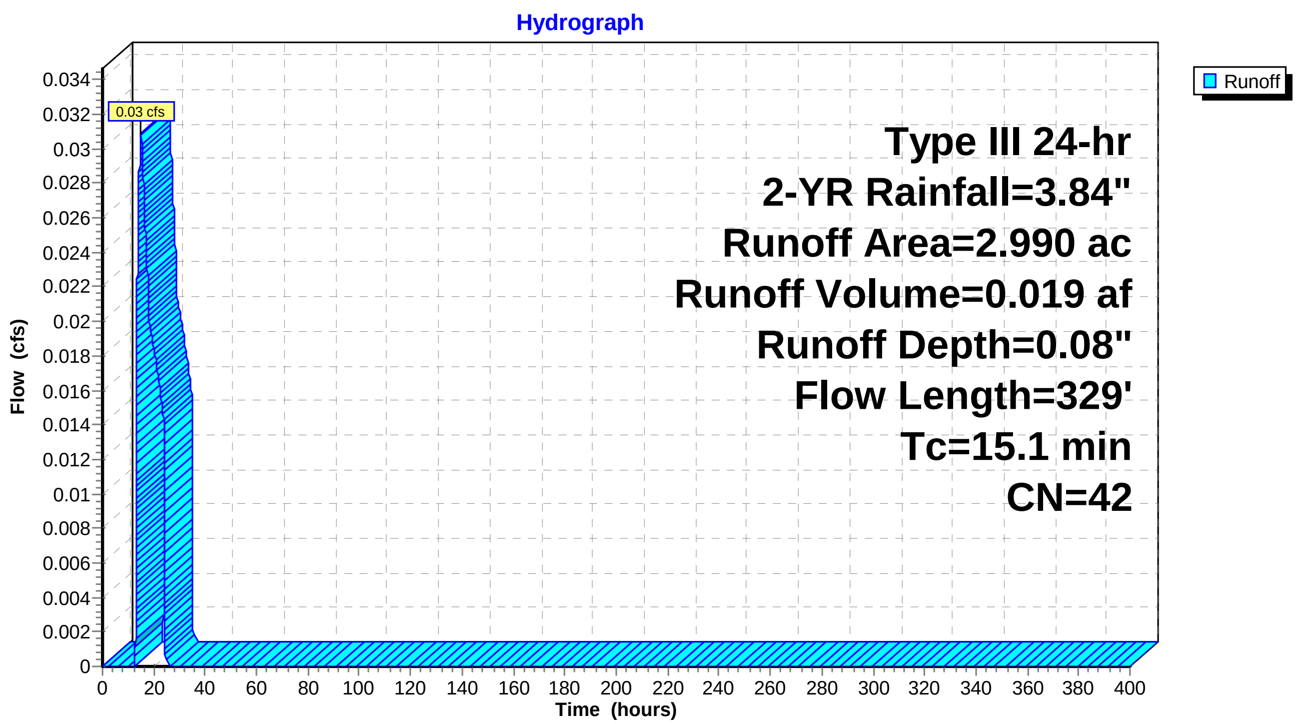
Runoff = 0.03 cfs @ 15.05 hrs, Volume= 0.019 af, Depth= 0.08"
Routed to Pond 20P : Pool Existing

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	2.990	42	From CN Spreadsheet
	2.990		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.6	50	0.0750	0.07		**Sheet Flow, Sheet** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.9	159	0.0330	0.91		**Shallow Concentrated Flow, SCF-1** Woodland Kv= 5.0 fps
0.1	58	0.1720	18.81	112.88	**Channel Flow, CF-1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.5	62	0.1510	1.94		**Shallow Concentrated Flow, SCF-2** Woodland Kv= 5.0 fps
15.1	329	Total			

Subcatchment 1B E: 1B-E



Summary for Subcatchment 2A E: 2A E

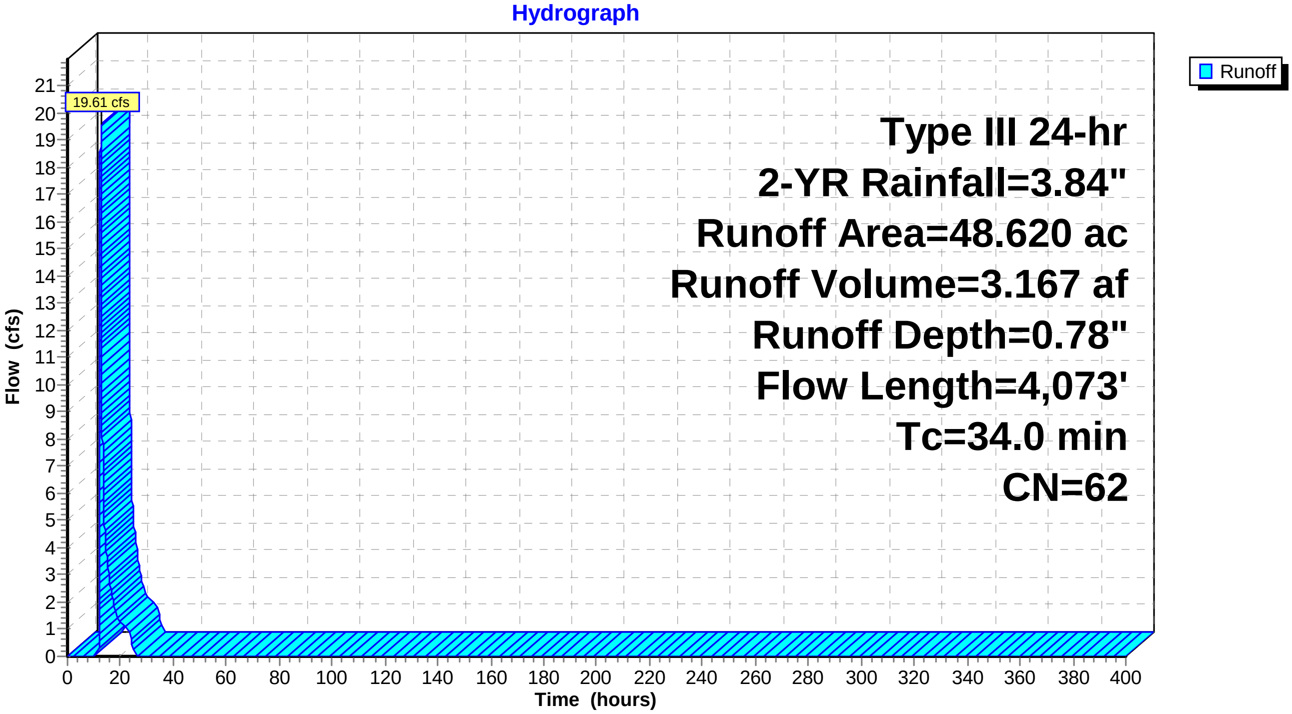
Runoff = 19.61 cfs @ 12.58 hrs, Volume= 3.167 af, Depth= 0.78"
Routed to Reach 21R : Wetland Ditch

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	48.620	62	From CN Spreadsheet
	48.620		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	50	0.0400	0.06		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.3	207	0.0870	1.47		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
2.4	337	0.2140	2.31		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
2.2	464	0.4830	3.47		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.4	592	0.2570	23.00	137.98	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
1.1	1,448	0.2280	21.66	129.96	**Channel Flow, CF 2** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.3	152	0.0480	9.94	59.63	**Channel Flow, CF-5** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.2	138	0.0480	9.94	59.63	**Channel Flow, CF-3** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.2	148	0.0480	9.94	59.63	**Channel Flow, CF-4** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
10.0	537	0.0320	0.89		**Shallow Concentrated Flow, SCF-4** Woodland Kv= 5.0 fps
34.0	4,073	Total			

Subcatchment 2A E: 2A E



Summary for Subcatchment 2B E: 2B E

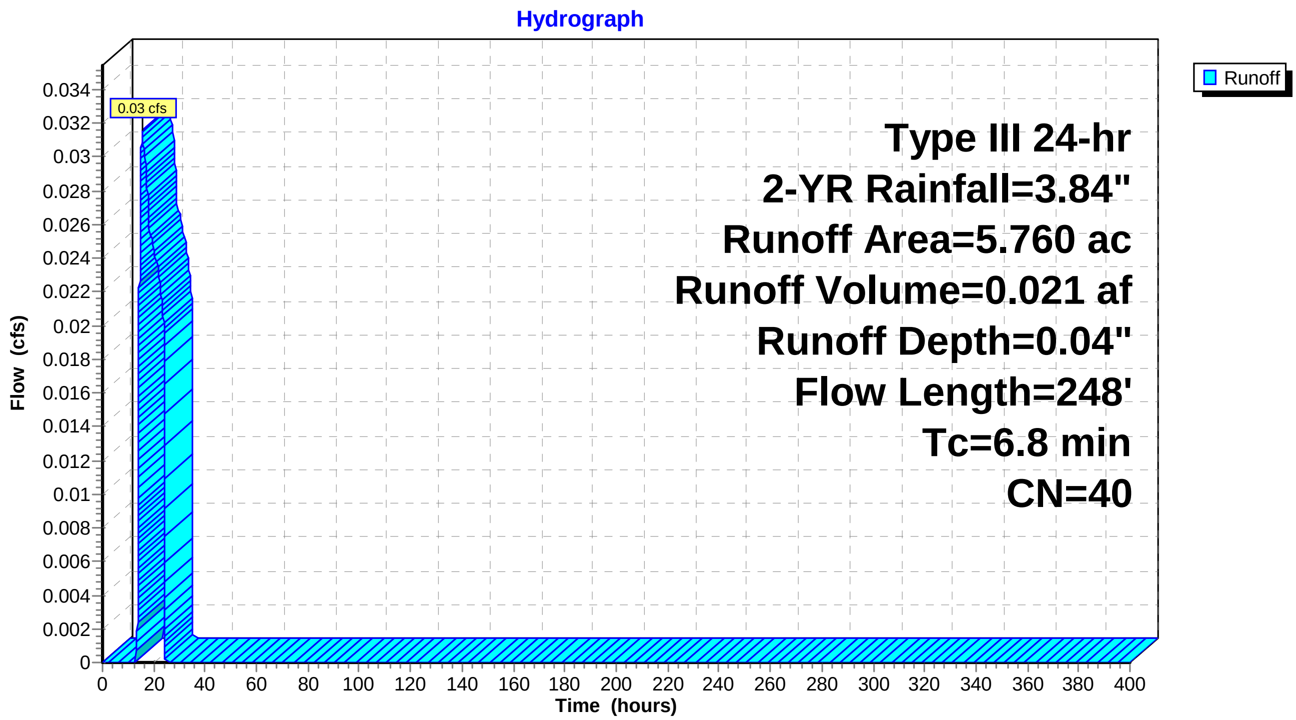
Runoff = 0.03 cfs @ 15.54 hrs, Volume= 0.021 af, Depth= 0.04"
Routed to Pond 21P : Existing Powerline Depression SMA-6 (Design Point 1)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	5.760	40	
	5.760		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	50	0.1410	0.16		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.84"
1.6	198	0.1720	2.07		**Shallow Concentrated Flow, SCF-1** Woodland Kv= 5.0 fps
6.8	248	Total			

Subcatchment 2B E: 2B E



Summary for Subcatchment 3 E: 3 E

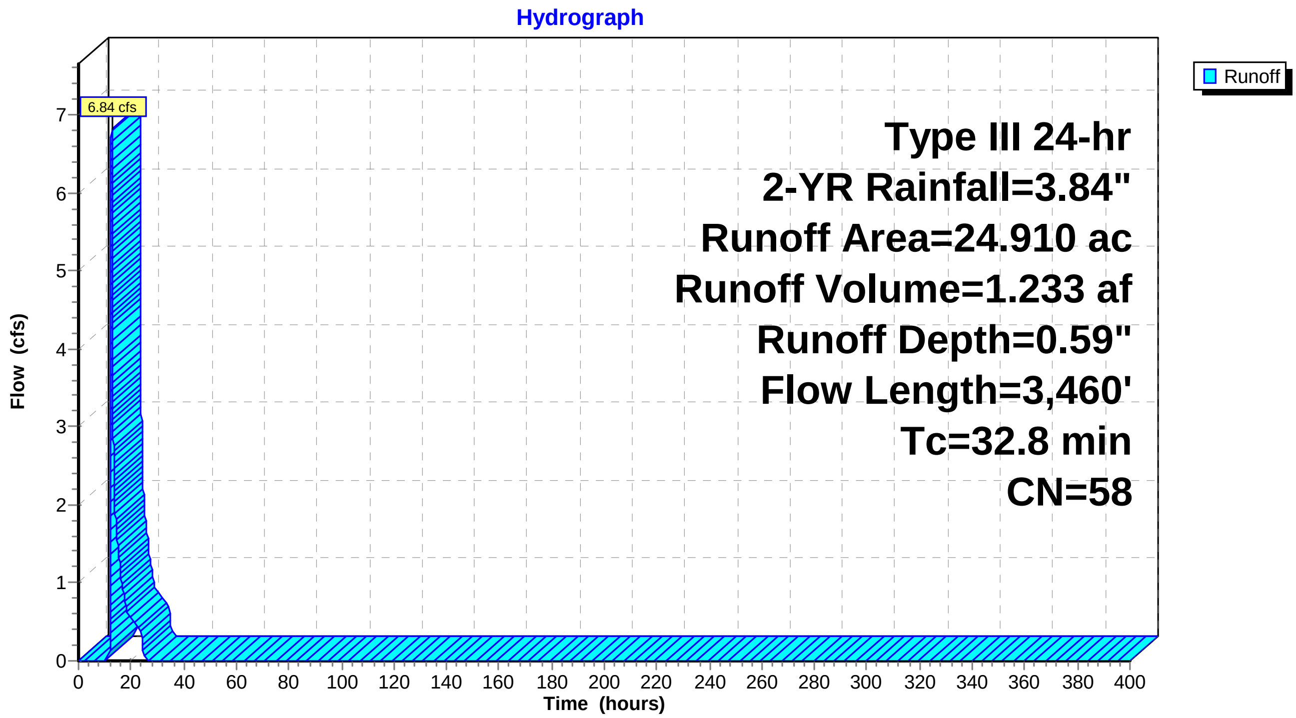
Runoff = 6.84 cfs @ 12.58 hrs, Volume= 1.233 af, Depth= 0.59"
Routed to Pond 2P : SMA1 (Design Point 2)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	24.910	58	
	24.910		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.6	50	0.1200	0.09		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
5.9	657	0.1390	1.86		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
6.7	1,207	0.3630	3.01		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
10.1	1,240	0.1690	2.06		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.5	306	0.0590	11.02	66.11	**Channel Flow, CF** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
32.8	3,460	Total			

Subcatchment 3 E: 3 E



Summary for Subcatchment 4 E: 4 E (Design Point 3)

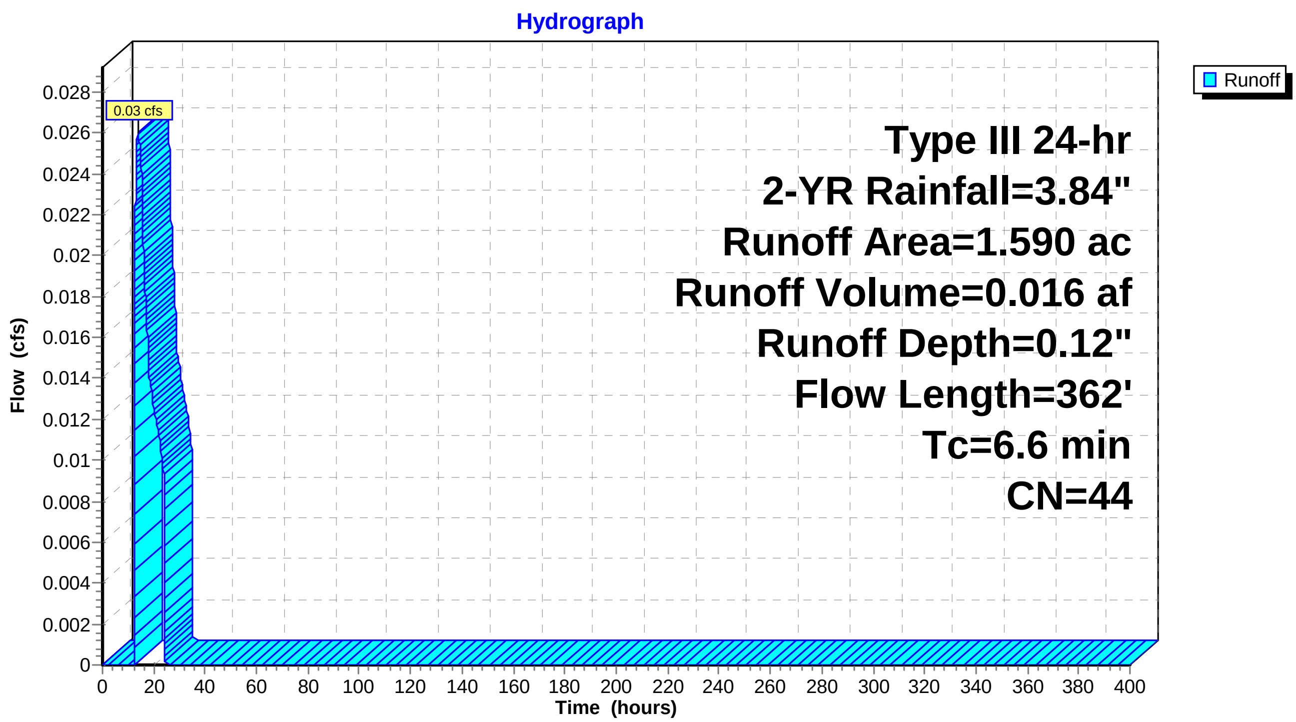
Runoff = 0.03 cfs @ 13.75 hrs, Volume= 0.016 af, Depth= 0.12"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	1.590	44	
	1.590		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.9	50	0.1600	0.17		**Sheet Flow, SF** Woods: Light underbrush n= 0.400 P2= 3.84"
1.3	126	0.1110	1.67		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
0.4	186	0.0320	8.11	48.69	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
6.6	362	Total			

Subcatchment 4 E: 4 E (Design Point 3)



Summary for Subcatchment 5 E: 5 E (Design Point 4)

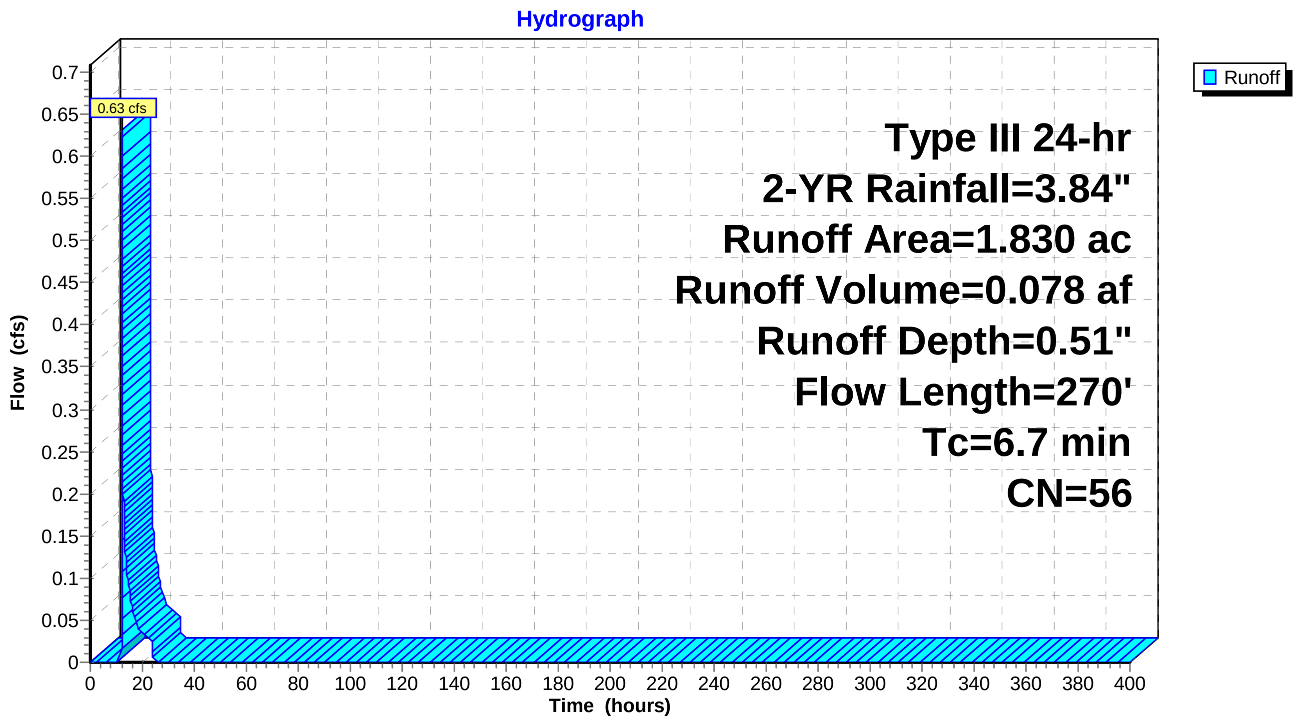
Runoff = 0.63 cfs @ 12.14 hrs, Volume= 0.078 af, Depth= 0.51"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	1.830	56	
	1.830		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	50	0.1200	0.15		**Sheet Flow, SF** Woods: Light underbrush n= 0.400 P2= 3.84"
0.8	95	0.1550	1.97		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
0.4	125	0.0120	4.97	29.81	**Channel Flow,** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
6.7	270	Total			

Subcatchment 5 E: 5 E (Design Point 4)



Summary for Subcatchment 6 E: 6 E

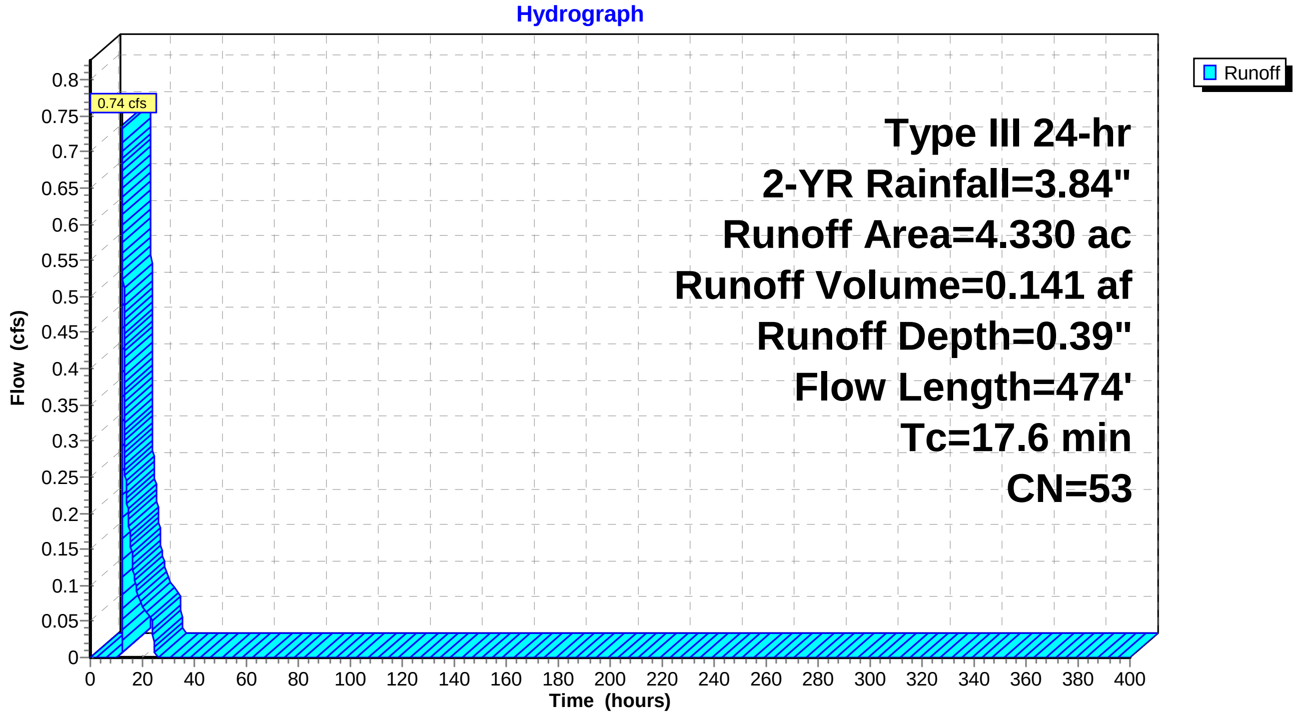
Runoff = 0.74 cfs @ 12.46 hrs, Volume= 0.141 af, Depth= 0.39"
Routed to Pond 19P : SMA-2 E (Design Point 5)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	4.330	53	
	4.330		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.3	50	0.0200	0.07		**Sheet Flow, SF** Woods: Light underbrush n= 0.400 P2= 3.84"
6.3	424	0.0500	1.12		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
17.6	474	Total			

Subcatchment 6 E: 6 E



Summary for Subcatchment 7 E: 7 E

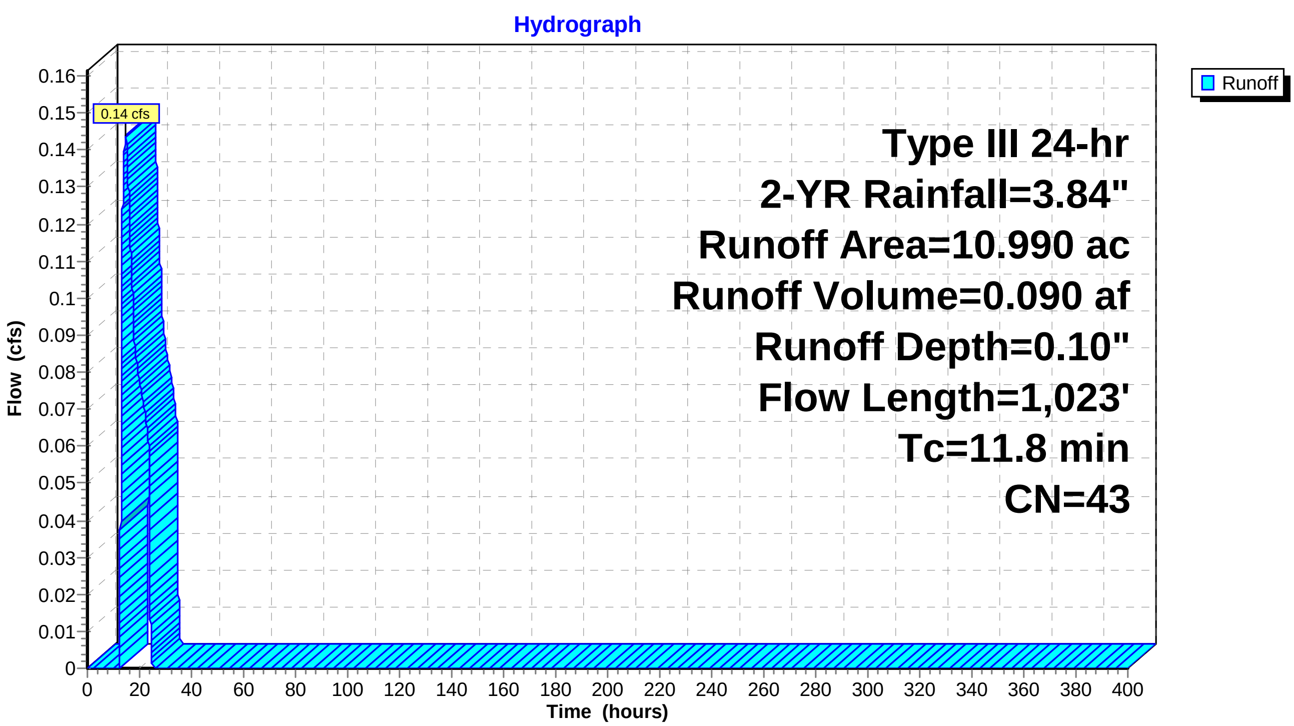
Runoff = 0.14 cfs @ 14.75 hrs, Volume= 0.090 af, Depth= 0.10"
Routed to Pond 23P : SMA4 E (Design Point 7)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	10.990	43	
	10.990		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.5	50	0.0200	0.11		**Sheet Flow, SF** Grass: Dense n= 0.240 P2= 3.84"
3.4	320	0.0500	1.57		**Shallow Concentrated Flow, SCF 1** Short Grass Pasture Kv= 7.0 fps
0.9	653	0.0640	11.48	68.85	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
11.8	1,023	Total			

Subcatchment 7 E: 7 E



Summary for Subcatchment 8 E: 8 E

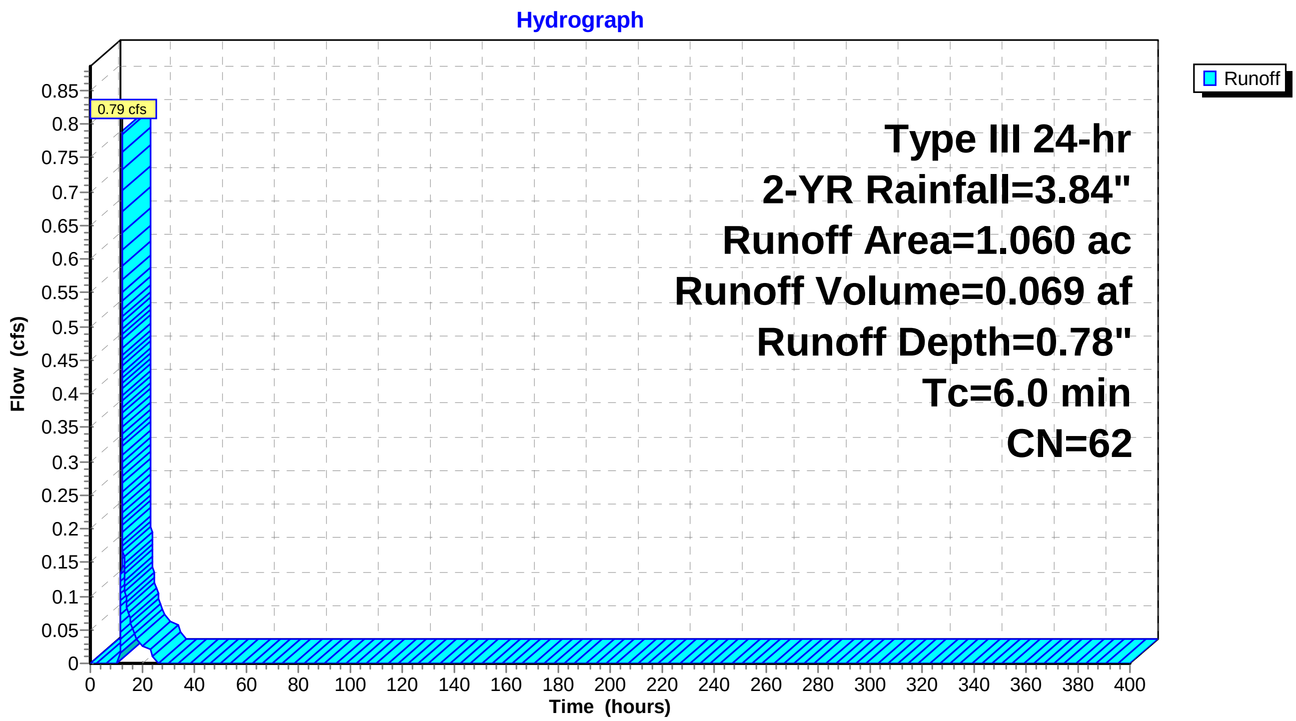
Runoff = 0.79 cfs @ 12.11 hrs, Volume= 0.069 af, Depth= 0.78"
Routed to Pond 22P : SMA3 E (Design Point 6)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	1.060	62	
	1.060		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment 8 E: 8 E



Summary for Subcatchment 9 E: 9 E (Design Point 8)

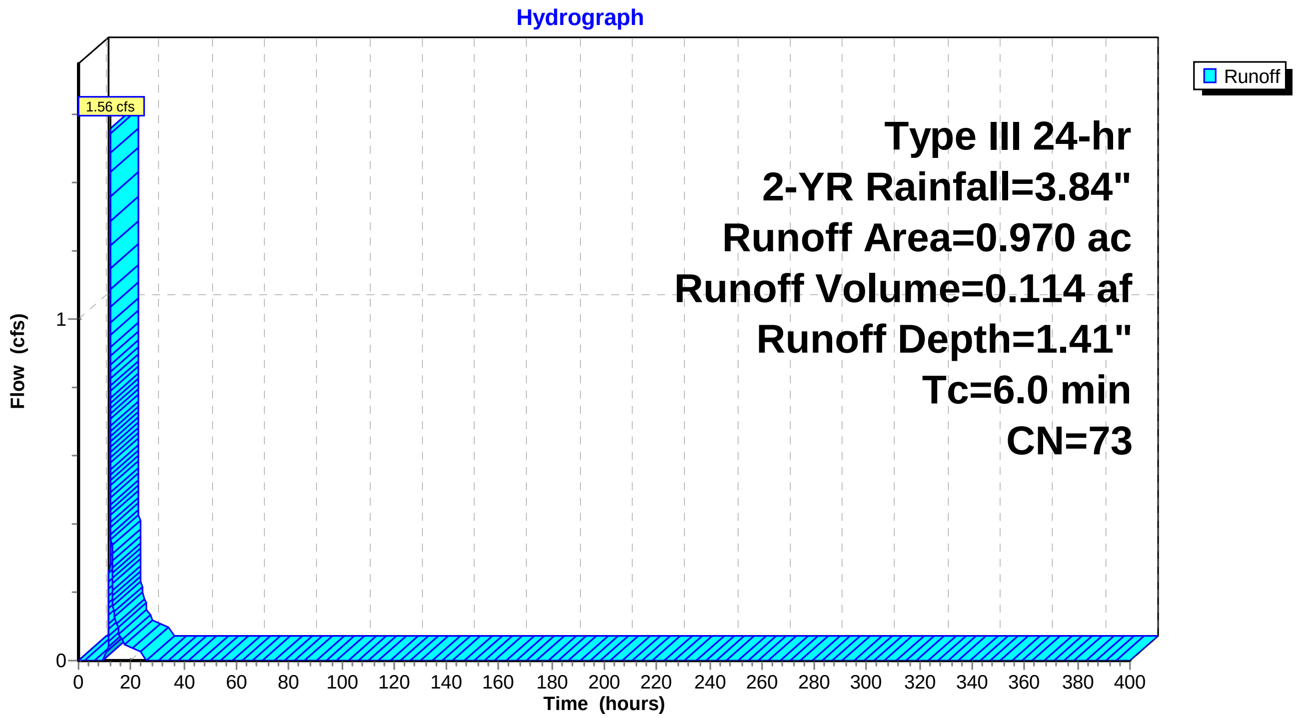
Runoff = 1.56 cfs @ 12.09 hrs, Volume= 0.114 af, Depth= 1.41"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	0.970	73	
	0.970		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, TR55 Min (calculation TC less than 6 minutes)**

Subcatchment 9 E: 9 E (Design Point 8)



Summary for Subcatchment 10 E: 10 E

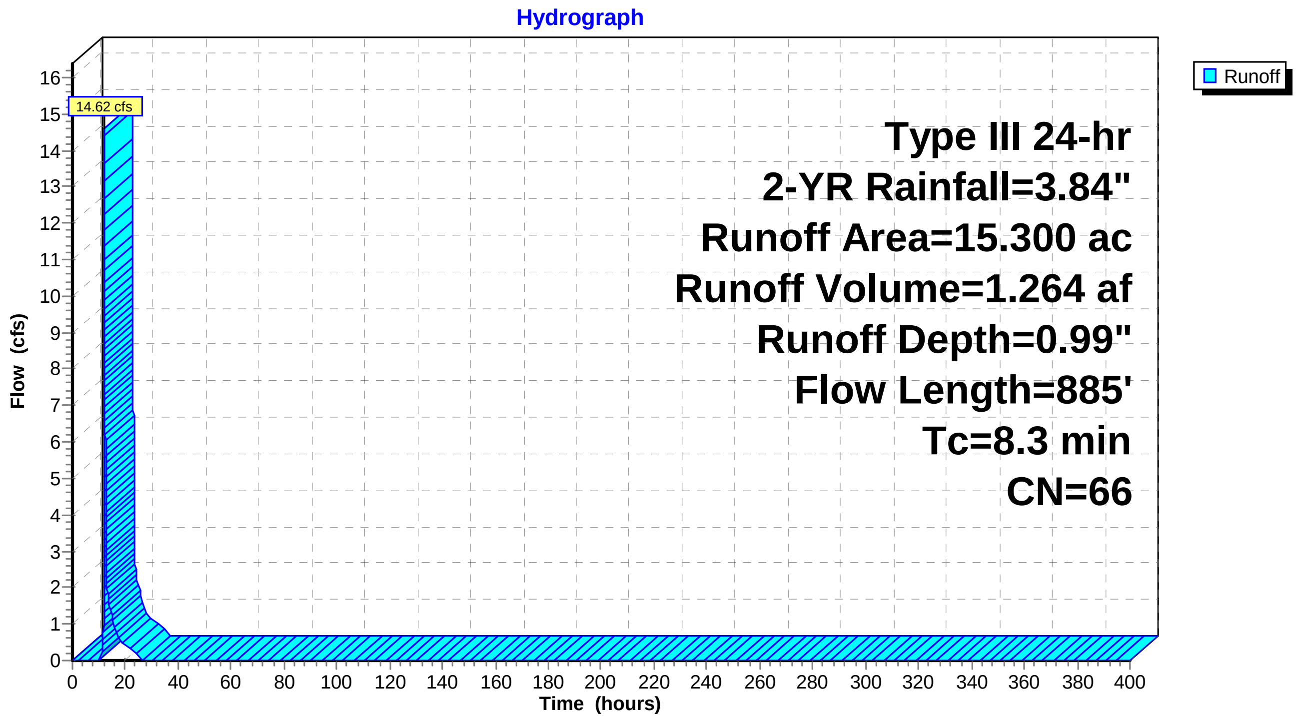
Runoff = 14.62 cfs @ 12.13 hrs, Volume= 1.264 af, Depth= 0.99"
Routed to Pond 1P : Existing Pond/SMA5 E

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	15.300	66	
	15.300		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	50	0.0440	0.15		**Sheet Flow, SF** Grass: Dense n= 0.240 P2= 3.84"
1.3	302	0.0590	3.91		**Shallow Concentrated Flow, SCF 1** Unpaved Kv= 16.1 fps
0.1	180	0.2860	24.26	145.55	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
1.4	353	0.0640	4.07		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
8.3	885	Total			

Subcatchment 10 E: 10 E



Summary for Reach 4R: Outfall Channel (Design Point 9)

[85] Warning: Oscillations may require smaller dt or Finer Routing (severity=1)

Inflow Area = 15.300 ac, 0.00% Impervious, Inflow Depth = 0.39" for 2-YR event
Inflow = 3.89 cfs @ 0.00 hrs, Volume= 0.494 af
Outflow = 3.01 cfs @ 0.09 hrs, Volume= 0.483 af, Atten= 23%, Lag= 5.3 min

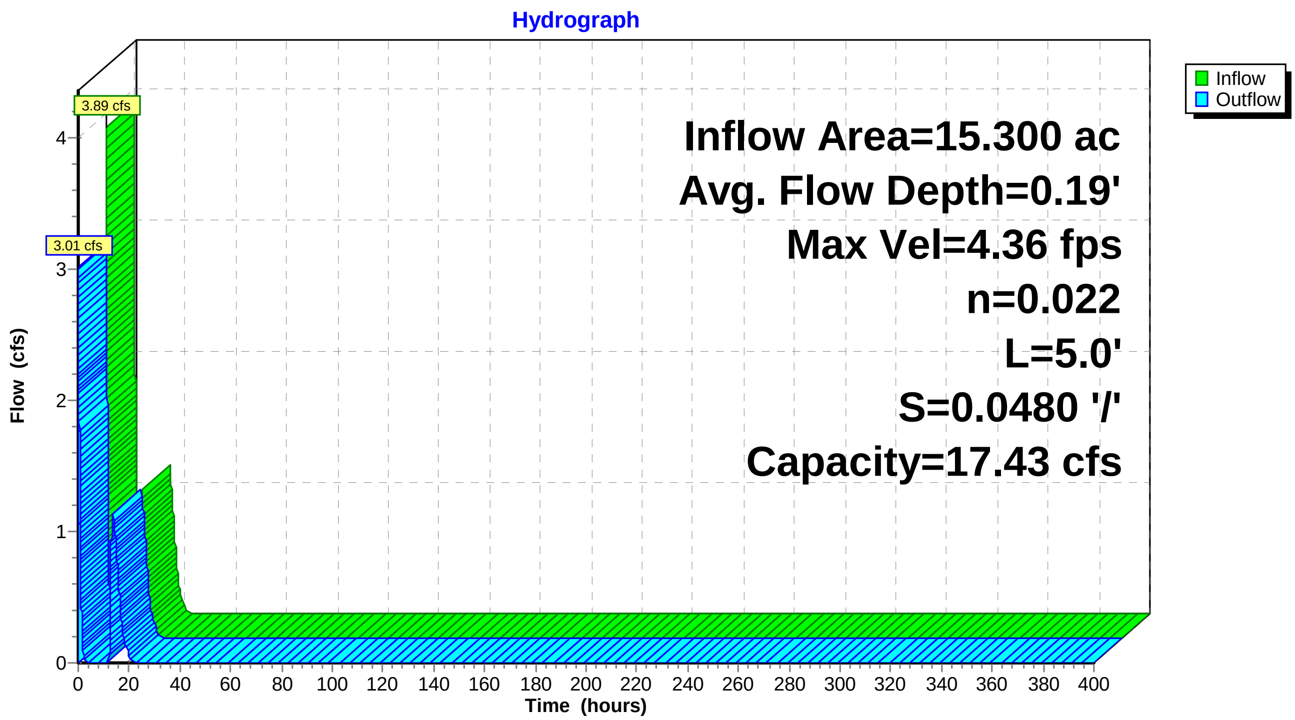
Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 2
Max. Velocity= 4.36 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 2.10 fps, Avg. Travel Time= 0.0 min

Peak Storage= 3 cf @ 0.09 hrs
Average Depth at Peak Storage= 0.19' , Surface Width= 4.26'
Bank-Full Depth= 0.50' Flow Area= 2.3 sf, Capacity= 17.43 cfs

3.00' x 0.50' deep channel, n= 0.022 Earth, clean & straight
Side Slope Z-value= 3.3 '/' Top Width= 6.30'
Length= 5.0' Slope= 0.0480 '/'
Inlet Invert= 949.68', Outlet Invert= 949.44'

‡

Reach 4R: Outfall Channel (Design Point 9)



Summary for Reach 21R: Wetland Ditch

Inflow Area = 89.610 ac, 0.00% Impervious, Inflow Depth = 0.69" for 2-YR event
Inflow = 24.77 cfs @ 12.85 hrs, Volume= 5.177 af
Outflow = 24.76 cfs @ 12.85 hrs, Volume= 5.177 af, Atten= 0%, Lag= 0.3 min
Routed to Pond 21P : Existing Powerline Depression SMA-6 (Design Point 1)

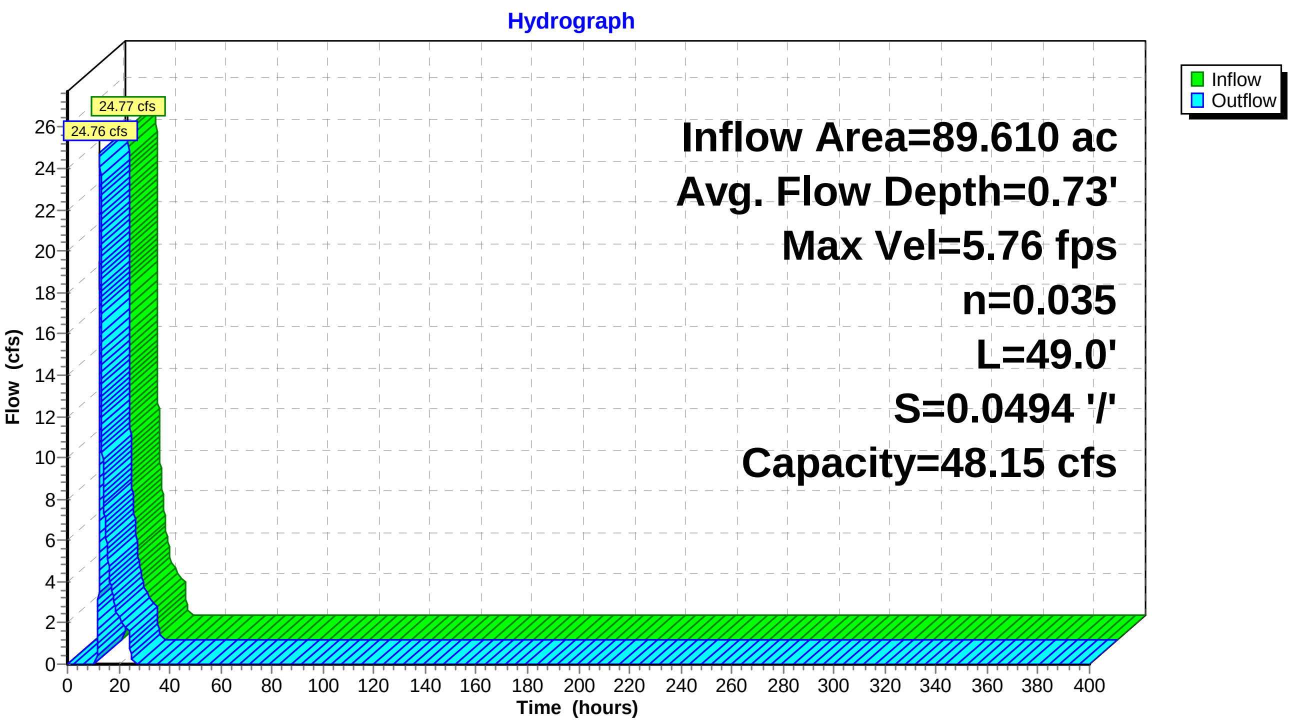
Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Max. Velocity= 5.76 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 2.39 fps, Avg. Travel Time= 0.3 min

Peak Storage= 211 cf @ 12.85 hrs
Average Depth at Peak Storage= 0.73' , Surface Width= 8.82'
Bank-Full Depth= 1.00' Flow Area= 7.0 sf, Capacity= 48.15 cfs

3.00' x 1.00' deep channel, n= 0.035 Earth, dense weeds
Side Slope Z-value= 4.0 '/' Top Width= 11.00'
Length= 49.0' Slope= 0.0494 '/'
Inlet Invert= 984.59', Outlet Invert= 982.17'

‡

Reach 21R: Wetland Ditch



Summary for Reach 22R: Pool Ditch

Inflow Area = 40.990 ac, 0.00% Impervious, Inflow Depth = 0.59" for 2-YR event
Inflow = 11.00 cfs @ 12.86 hrs, Volume= 2.010 af
Outflow = 10.96 cfs @ 12.91 hrs, Volume= 2.010 af, Atten= 0%, Lag= 2.6 min
Routed to Reach 21R : Wetland Ditch

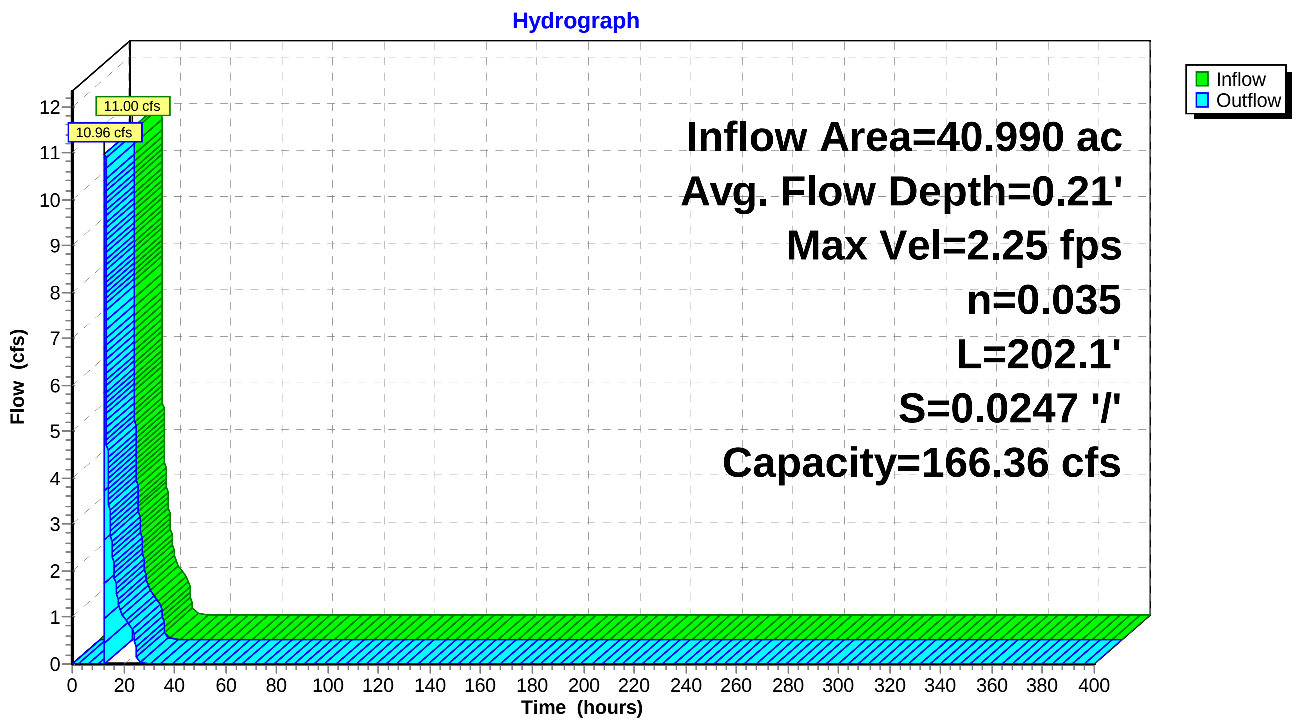
Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.25 fps, Min. Travel Time= 1.5 min
Avg. Velocity = 0.82 fps, Avg. Travel Time= 4.1 min

Peak Storage= 985 cf @ 12.88 hrs
Average Depth at Peak Storage= 0.21' , Surface Width= 24.83'
Bank-Full Depth= 1.00' Flow Area= 28.8 sf, Capacity= 166.36 cfs

22.00' x 1.00' deep channel, n= 0.035
Side Slope Z-value= 6.8 '/' Top Width= 35.60'
Length= 202.1' Slope= 0.0247 '/'
Inlet Invert= 992.44', Outlet Invert= 987.45'

‡

Reach 22R: Pool Ditch



Summary for Pond 1P: Existing Pond/SMA5 E

Inflow Area = 15.300 ac, 0.00% Impervious, Inflow Depth = 0.99" for 2-YR event
Inflow = 14.62 cfs @ 12.13 hrs, Volume= 1.264 af
Outflow = 4.47 cfs @ 0.00 hrs, Volume= 7.308 af, Atten= 69%, Lag= 0.0 min
Discarded = 0.58 cfs @ 0.00 hrs, Volume= 6.814 af
Primary = 3.89 cfs @ 0.00 hrs, Volume= 0.494 af
Routed to Reach 4R : Outfall Channel (Design Point 9)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Starting Elev= 949.90' Surf.Area= 1.245 ac Storage= 6.042 af
Peak Elev= 949.90' @ 0.00 hrs Surf.Area= 1.245 ac Storage= 6.042 af

Plug-Flow detention time= 10,962.9 min calculated for 1.264 af (100% of inflow)
Center-of-Mass det. time= 4,461.1 min (5,339.1 - 878.0)

Volume	Invert	Avail.Storage	Storage Description
#1	940.00'	9.105 af	**Custom Stage Data (Conic)** Listed below (Recalc)

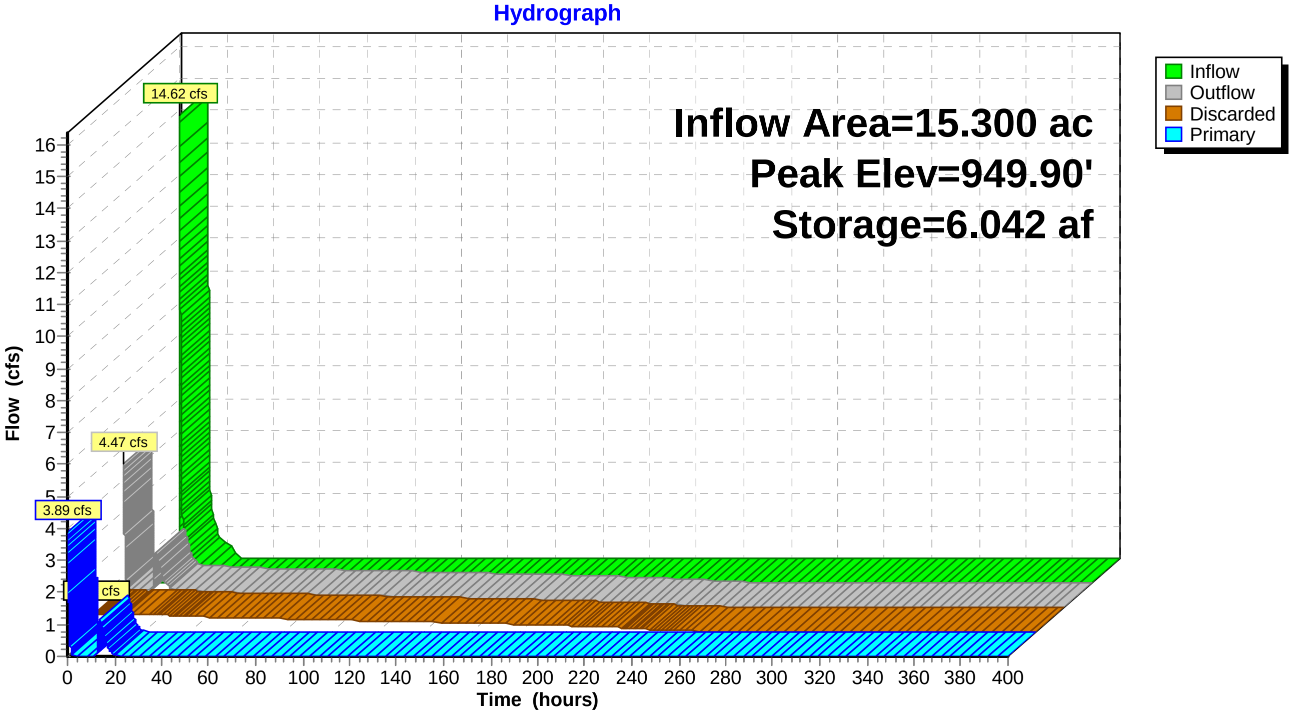
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
940.00	0.005	0.000	0.000	0.005
941.00	0.085	0.037	0.037	0.085
942.00	0.297	0.180	0.217	0.297
943.00	0.453	0.372	0.589	0.454
944.00	0.553	0.502	1.092	0.554
945.00	0.645	0.598	1.690	0.647
946.00	0.737	0.690	2.381	0.740
947.00	0.832	0.784	3.165	0.836
948.00	0.928	0.880	4.044	0.934
949.00	1.027	0.977	5.021	1.034
950.00	1.270	1.146	6.168	1.278
952.00	1.677	2.938	9.105	1.687

Device	Routing	Invert	Outlet Devices
#1	Discarded	940.00'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	949.68'	**Channel/Reach** using Reach 4R: Outfall Channel (Design Point 9)

Discarded OutFlow Max=0.58 cfs @ 0.00 hrs HW=949.90' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.58 cfs)

Primary OutFlow Max=3.89 cfs @ 0.00 hrs HW=949.90' (Free Discharge)
↑—**2=Channel/Reach** (Channel Controls 3.89 cfs @ 4.74 fps)

Pond 1P: Existing Pond/SMA5 E



Summary for Pond 2P: SMA1 (Design Point 2)

Inflow Area = 24.910 ac, 0.00% Impervious, Inflow Depth = 0.59" for 2-YR event
Inflow = 6.84 cfs @ 12.58 hrs, Volume= 1.233 af
Outflow = 0.18 cfs @ 24.46 hrs, Volume= 1.233 af, Atten= 97%, Lag= 713.2 min
Discarded = 0.18 cfs @ 24.46 hrs, Volume= 1.233 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 21P : Existing Powerline Depression SMA-6 (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 6
Peak Elev= 995.12' @ 24.46 hrs Surf.Area= 0.477 ac Storage= 1.064 af

Plug-Flow detention time= 2,719.4 min calculated for 1.233 af (100% of inflow)
Center-of-Mass det. time= 2,719.5 min (3,652.0 - 932.5)

Volume	Invert	Avail.Storage	Storage Description
#1	992.00'	6.087 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

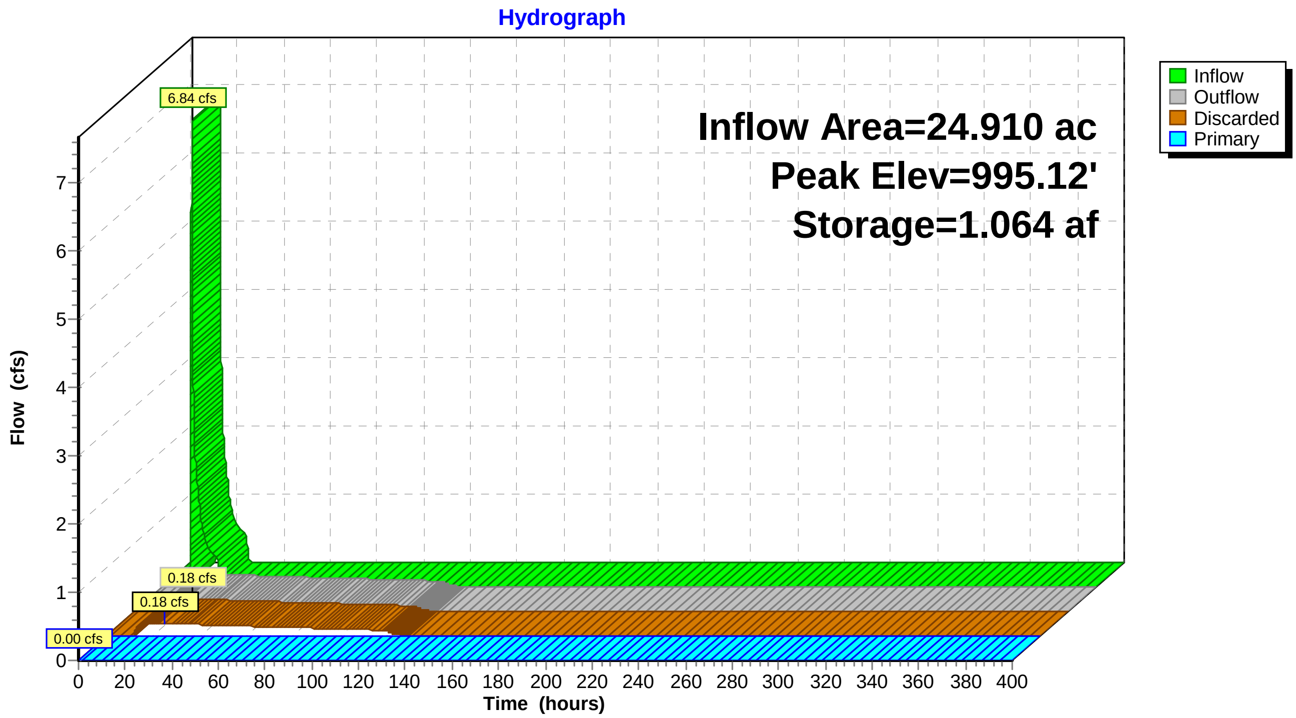
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
992.00	0.210	0.000	0.000
994.00	0.377	0.587	0.587
996.00	0.557	0.934	1.521
998.00	0.731	1.288	2.809
1,000.00	0.946	1.677	4.486
1,001.53	1.147	1.601	6.087

Device	Routing	Invert	Outlet Devices
#1	Discarded	992.00'	**0.380 in/hr Exfiltration over Surface area**
#2	Primary	1,001.52'	**16.0' long + 3.0 '/' SideZ x 36.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.18 cfs @ 24.46 hrs HW=995.12' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.18 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=992.00' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 2P: SMA1 (Design Point 2)



Summary for Pond 19P: SMA-2 E (Design Point 5)

Inflow Area = 4.330 ac, 0.00% Impervious, Inflow Depth = 0.39" for 2-YR event
Inflow = 0.74 cfs @ 12.46 hrs, Volume= 0.141 af
Outflow = 0.07 cfs @ 20.68 hrs, Volume= 0.141 af, Atten= 91%, Lag= 493.6 min
Discarded = 0.07 cfs @ 20.68 hrs, Volume= 0.141 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 6
Peak Elev= 1,026.53' @ 20.68 hrs Surf.Area= 0.173 ac Storage= 0.081 af

Plug-Flow detention time= 674.9 min calculated for 0.141 af (100% of inflow)
Center-of-Mass det. time= 674.9 min (1,621.8 - 946.9)

Volume	Invert	Avail.Storage	Storage Description
#1	1,025.60'	0.086 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

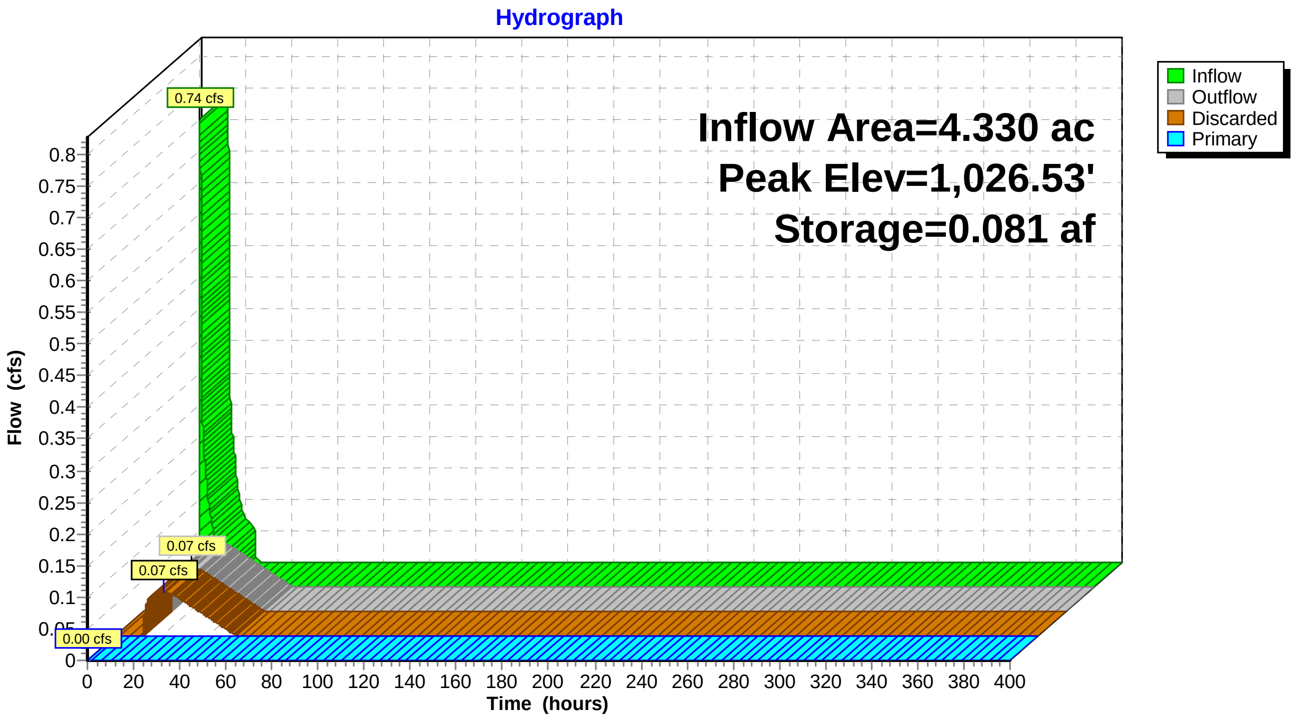
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,025.60	0.002	0.000	0.000
1,026.55	0.178	0.086	0.086

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,025.60'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	1,026.54'	**1.0' long + 3.0 '/' SideZ x 0.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32

Discarded OutFlow Max=0.07 cfs @ 20.68 hrs HW=1,026.53' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.07 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,025.60' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 19P: SMA-2 E (Design Point 5)



Summary for Pond 20P: Pool Existing

Inflow Area = 40.990 ac, 0.00% Impervious, Inflow Depth = 0.73" for 2-YR event
Inflow = 15.29 cfs @ 12.57 hrs, Volume= 2.495 af
Outflow = 11.00 cfs @ 12.86 hrs, Volume= 2.010 af, Atten= 28%, Lag= 17.4 min
Primary = 11.00 cfs @ 12.86 hrs, Volume= 2.010 af
Routed to Reach 22R : Pool Ditch

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Starting Elev= 991.00' Surf.Area= 0.198 ac Storage= 0.165 af
Peak Elev= 992.65' @ 12.86 hrs Surf.Area= 0.515 ac Storage= 0.753 af (0.588 af above start)

Plug-Flow detention time= 172.5 min calculated for 1.845 af (74% of inflow)
Center-of-Mass det. time= 53.5 min (971.2 - 917.7)

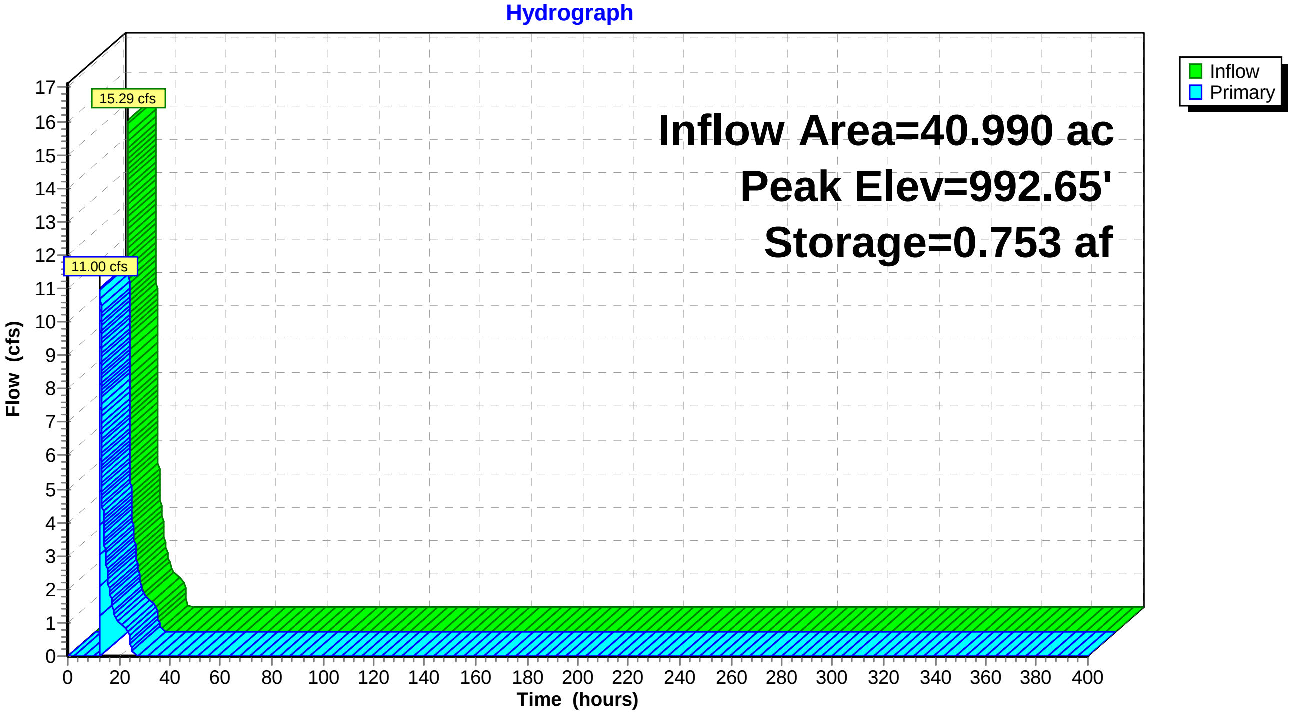
Volume	Invert	Avail.Storage	Storage Description
#1	988.50'	0.945 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
988.50	0.001	0.000	0.000
989.00	0.009	0.003	0.003
989.50	0.026	0.009	0.011
990.00	0.057	0.021	0.032
990.50	0.138	0.049	0.081
991.00	0.198	0.084	0.165
991.50	0.280	0.119	0.284
992.00	0.404	0.171	0.455
993.00	0.575	0.490	0.945

Device	Routing	Invert	Outlet Devices
#1	Primary	992.44'	**Channel/Reach** using Reach 22R: Pool Ditch

Primary OutFlow Max=10.99 cfs @ 12.86 hrs HW=992.65' (Free Discharge)
└─**1=Channel/Reach** (Channel Controls 10.99 cfs @ 2.25 fps)

Pond 20P: Pool Existing



Summary for Pond 21P: Existing Powerline Depression SMA-6 (Design Point 1)

[62] Hint: Exceeded Reach 21R OUTLET depth by 1.88' @ 25.33 hrs
[64] Warning: Exceeded Reach 21R outlet bank by 0.92' @ 24.62 hrs

Inflow Area = 120.280 ac, 0.00% Impervious, Inflow Depth = 0.52" for 2-YR event
Inflow = 24.76 cfs @ 12.85 hrs, Volume= 5.198 af
Outflow = 0.72 cfs @ 24.62 hrs, Volume= 5.198 af, Atten= 97%, Lag= 705.9 min
Discarded = 0.72 cfs @ 24.62 hrs, Volume= 5.198 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 2
Peak Elev= 984.09' @ 24.62 hrs Surf.Area= 1.548 ac Storage= 4.528 af

Plug-Flow detention time= 3,092.1 min calculated for 5.198 af (100% of inflow)
Center-of-Mass det. time= 3,092.0 min (4,032.3 - 940.3)

Volume	Invert	Avail.Storage	Storage Description
#1	978.00'	7.820 af	**Custom Stage Data (Conic)** Listed below

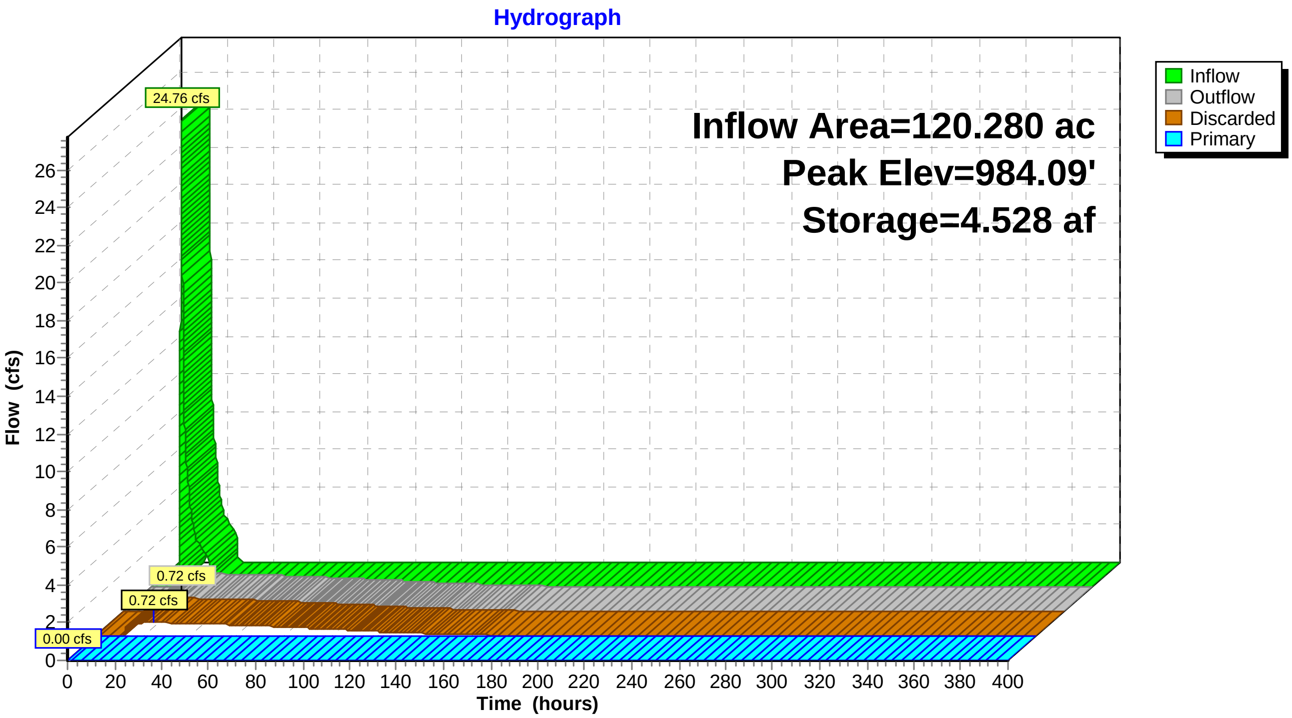
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
978.00	0.028	0.000	0.000	0.028
979.00	0.163	0.086	0.086	0.163
980.00	0.378	0.263	0.349	0.378
981.00	0.712	0.536	0.886	0.712
982.00	1.050	0.876	1.761	1.051
983.00	1.330	1.187	2.948	1.331
984.00	1.530	1.429	4.377	1.533
985.00	1.720	1.624	6.001	1.724
986.00	1.920	1.819	7.820	1.925

Device	Routing	Invert	Outlet Devices
#1	Primary	984.30'	**165.0 deg x 1.70' rise Sharp-Crested Vee/Trap Weir** Cv= 2.47 (C= 3.09)
#2	Discarded	978.00'	**0.460 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.72 cfs @ 24.62 hrs HW=984.09' (Free Discharge)
└─**2=Exfiltration** (Exfiltration Controls 0.72 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=978.00' (Free Discharge)
└─**1=Sharp-Crested Vee/Trap Weir** (Controls 0.00 cfs)

Pond 21P: Existing Powerline Depression SMA-6 (Design Point 1)



Summary for Pond 22P: SMA3 E (Design Point 6)

[93] Warning: Storage range exceeded by 0.01'

Inflow Area = 1.060 ac, 0.00% Impervious, Inflow Depth = 0.78" for 2-YR event
Inflow = 0.79 cfs @ 12.11 hrs, Volume= 0.069 af
Outflow = 0.04 cfs @ 14.06 hrs, Volume= 0.062 af, Atten= 95%, Lag= 117.5 min
Discarded = 0.03 cfs @ 14.06 hrs, Volume= 0.059 af
Primary = 0.02 cfs @ 14.06 hrs, Volume= 0.003 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 1,025.36' @ 14.06 hrs Surf.Area= 0.056 ac Storage= 0.035 af

Plug-Flow detention time= 739.0 min calculated for 0.062 af (89% of inflow)
Center-of-Mass det. time= 688.1 min (1,578.4 - 890.3)

Volume	Invert	Avail.Storage	Storage Description
#1	1,024.50'	0.035 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

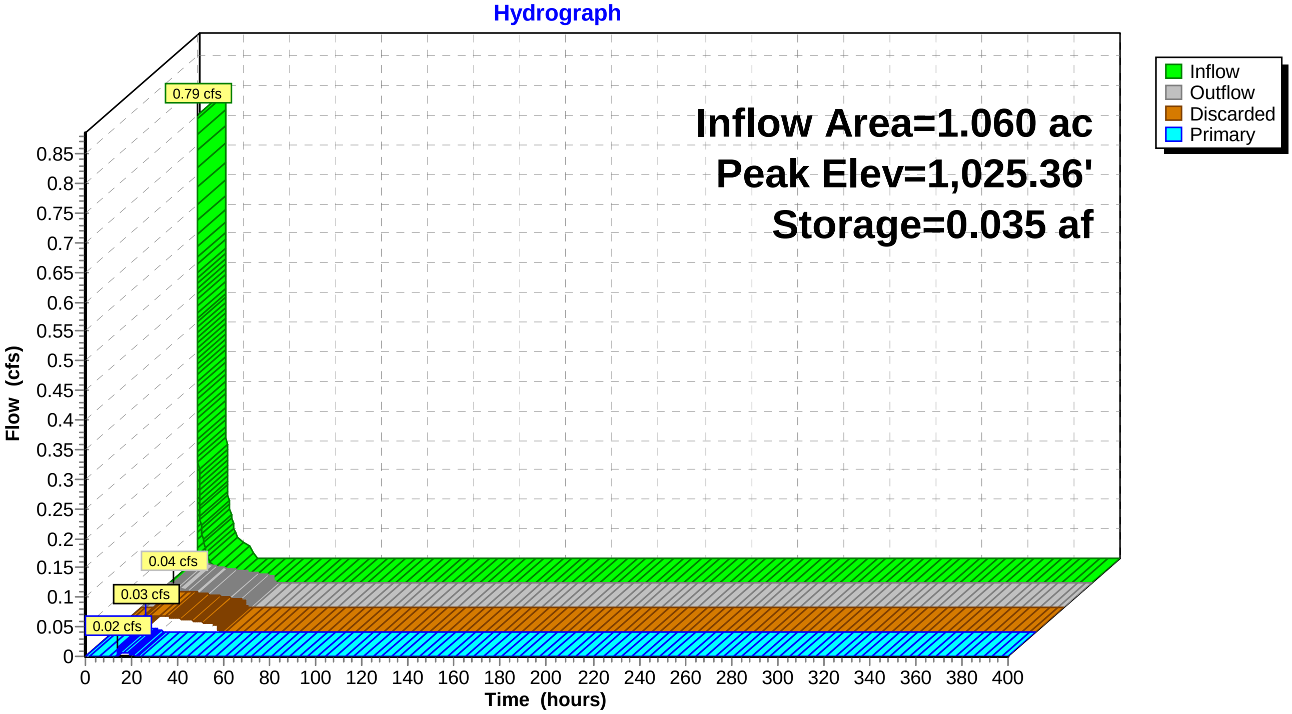
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,024.50	0.026	0.000	0.000
1,025.35	0.056	0.035	0.035

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,024.50'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,025.33'	**177.0 deg x 0.20' rise Sharp-Crested Vee/Trap Weir** Cv= 2.46 (C= 3.08)

Discarded OutFlow Max=0.03 cfs @ 14.06 hrs HW=1,025.36' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.03 cfs)

Primary OutFlow Max=0.01 cfs @ 14.06 hrs HW=1,025.36' (Free Discharge)
└─**2=Sharp-Crested Vee/Trap Weir** (Weir Controls 0.01 cfs @ 0.42 fps)

Pond 22P: SMA3 E (Design Point 6)



Summary for Pond 23P: SMA4 E (Design Point 7)

Inflow Area = 10.990 ac, 0.00% Impervious, Inflow Depth = 0.10" for 2-YR event
Inflow = 0.14 cfs @ 14.75 hrs, Volume= 0.090 af
Outflow = 0.13 cfs @ 15.81 hrs, Volume= 0.090 af, Atten= 11%, Lag= 63.6 min
Discarded = 0.02 cfs @ 15.81 hrs, Volume= 0.032 af
Primary = 0.11 cfs @ 15.81 hrs, Volume= 0.058 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 989.14' @ 15.81 hrs Surf.Area= 0.037 ac Storage= 0.021 af

Plug-Flow detention time= 231.6 min calculated for 0.090 af (100% of inflow)
Center-of-Mass det. time= 231.6 min (1,287.5 - 1,055.9)

Volume	Invert	Avail.Storage	Storage Description
#1	988.20'	0.247 af	**Custom Stage Data (Conic)** Listed below (Recalc)

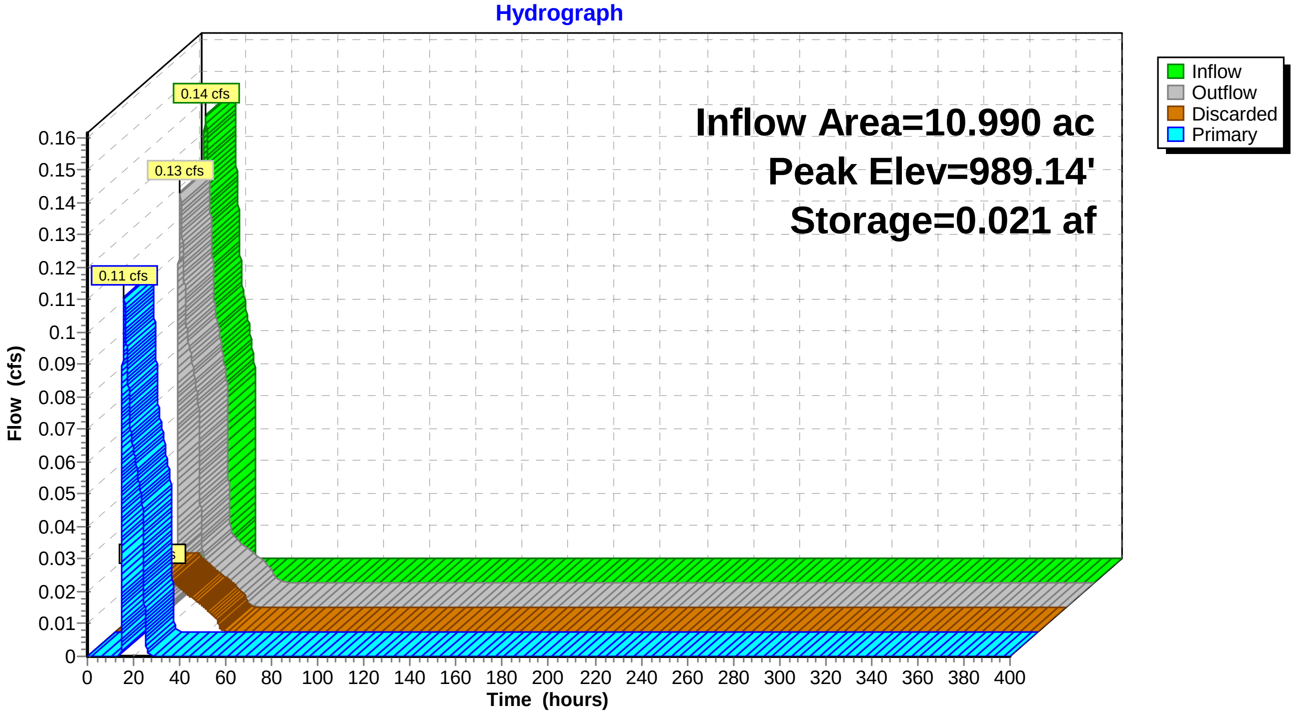
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
988.20	0.007	0.000	0.000	0.007
988.50	0.018	0.004	0.004	0.018
989.00	0.034	0.013	0.016	0.034
992.00	0.130	0.230	0.247	0.131

Device	Routing	Invert	Outlet Devices
#0	Primary	992.00'	**Automatic Storage Overflow** (Discharged without head)
#1	Discarded	988.20'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	988.91'	**121.0 deg x 4.00' rise Sharp-Crested Vee/Trap Weir** Cv= 2.48 (C= 3.10)

Discarded OutFlow Max=0.02 cfs @ 15.81 hrs HW=989.14' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=0.11 cfs @ 15.81 hrs HW=989.14' (Free Discharge)
↑—**2=Sharp-Crested Vee/Trap Weir** (Weir Controls 0.11 cfs @ 1.19 fps)

Pond 23P: SMA4 E (Design Point 7)



Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1A E: 1A E Runoff Area=38.000 ac 0.00% Impervious Runoff Depth=1.61"
Flow Length=3,236' Tc=34.2 min CN=62 Runoff=35.71 cfs 5.111 af

Subcatchment 1B E: 1B-E Runoff Area=2.990 ac 0.00% Impervious Runoff Depth=0.39"
Flow Length=329' Tc=15.1 min CN=42 Runoff=0.41 cfs 0.097 af

Subcatchment 2A E: 2A E Runoff Area=48.620 ac 0.00% Impervious Runoff Depth=1.61"
Flow Length=4,073' Tc=34.0 min CN=62 Runoff=45.85 cfs 6.540 af

Subcatchment 2B E: 2B E Runoff Area=5.760 ac 0.00% Impervious Runoff Depth=0.30"
Flow Length=248' Tc=6.8 min CN=40 Runoff=0.54 cfs 0.144 af

Subcatchment 3 E: 3 E Runoff Area=24.910 ac 0.00% Impervious Runoff Depth=1.33"
Flow Length=3,460' Tc=32.8 min CN=58 Runoff=18.64 cfs 2.752 af

Subcatchment 4 E: 4 E (Design Point 3) Runoff Area=1.590 ac 0.00% Impervious Runoff Depth=0.48"
Flow Length=362' Tc=6.6 min CN=44 Runoff=0.35 cfs 0.064 af

Subcatchment 5 E: 5 E (Design Point 4) Runoff Area=1.830 ac 0.00% Impervious Runoff Depth=1.19"
Flow Length=270' Tc=6.7 min CN=56 Runoff=2.12 cfs 0.181 af

Subcatchment 6 E: 6 E Runoff Area=4.330 ac 0.00% Impervious Runoff Depth=0.99"
Flow Length=474' Tc=17.6 min CN=53 Runoff=2.78 cfs 0.359 af

Subcatchment 7 E: 7 E Runoff Area=10.990 ac 0.00% Impervious Runoff Depth=0.44"
Flow Length=1,023' Tc=11.8 min CN=43 Runoff=1.94 cfs 0.398 af

Subcatchment 8 E: 8 E Runoff Area=1.060 ac 0.00% Impervious Runoff Depth=1.61"
Tc=6.0 min CN=62 Runoff=1.88 cfs 0.143 af

Subcatchment 9 E: 9 E (Design Point 8) Runoff Area=0.970 ac 0.00% Impervious Runoff Depth=2.50"
Tc=6.0 min CN=73 Runoff=2.83 cfs 0.202 af

Subcatchment 10 E: 10 E Runoff Area=15.300 ac 0.00% Impervious Runoff Depth=1.92"
Flow Length=885' Tc=8.3 min CN=66 Runoff=30.72 cfs 2.449 af

Reach 4R: Outfall Channel (Design Avg. Flow Depth=0.36' Max Vel=6.23 fps Inflow=9.28 cfs 1.601 af
n=0.022 L=5.0' S=0.0480 '/' Capacity=17.43 cfs Outflow=9.28 cfs 1.590 af

Reach 21R: Wetland Ditch Avg. Flow Depth=1.31' Max Vel=7.67 fps Inflow=79.97 cfs 11.263 af
n=0.035 L=49.0' S=0.0494 '/' Capacity=48.15 cfs Outflow=79.95 cfs 11.263 af

Reach 22R: Pool Ditch Avg. Flow Depth=0.41' Max Vel=3.44 fps Inflow=35.35 cfs 4.723 af
n=0.035 L=202.1' S=0.0247 '/' Capacity=166.36 cfs Outflow=35.31 cfs 4.723 af

Pond 1P: Existing Pond/SMA5 E Peak Elev=950.03' Storage=6.212 af Inflow=30.72 cfs 2.449 af
Discarded=0.60 cfs 6.892 af Primary=9.28 cfs 1.601 af Outflow=9.87 cfs 8.493 af

Pond 2P: SMA1 (Design Point 2) Peak Elev=997.57' Storage=2.503 af Inflow=18.64 cfs 2.752 af
Discarded=0.27 cfs 2.752 af Primary=0.00 cfs 0.000 af Outflow=0.27 cfs 2.752 af

Pond 19P: SMA-2 E (Design Point 5) Peak Elev=1,026.77' Storage=0.086 af Inflow=2.78 cfs 0.359 af
Discarded=0.07 cfs 0.156 af Primary=0.43 cfs 0.004 af Outflow=0.50 cfs 0.160 af

Pond 20P: Pool Existing Peak Elev=992.85' Storage=0.862 af Inflow=36.12 cfs 5.208 af
Outflow=35.35 cfs 4.723 af

Pond 21P: Existing Powerline Depression Peak Elev=985.11' Storage=6.199 af Inflow=80.33 cfs 11.407 af
Discarded=0.81 cfs 6.112 af Primary=11.07 cfs 5.295 af Outflow=11.87 cfs 11.407 af

Pond 22P: SMA3 E (Design Point 6) Peak Elev=1,025.44' Storage=0.035 af Inflow=1.88 cfs 0.143 af
Discarded=0.03 cfs 0.062 af Primary=0.33 cfs 0.006 af Outflow=0.35 cfs 0.068 af

Pond 23P: SMA4 E (Design Point 7) Peak Elev=989.56' Storage=0.039 af Inflow=1.94 cfs 0.398 af
Discarded=0.02 cfs 0.036 af Primary=1.48 cfs 0.363 af Outflow=1.50 cfs 0.398 af

Total Runoff Area = 156.350 ac Runoff Volume = 18.441 af Average Runoff Depth = 1.42"
100.00% Pervious = 156.350 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 1A E: 1A E

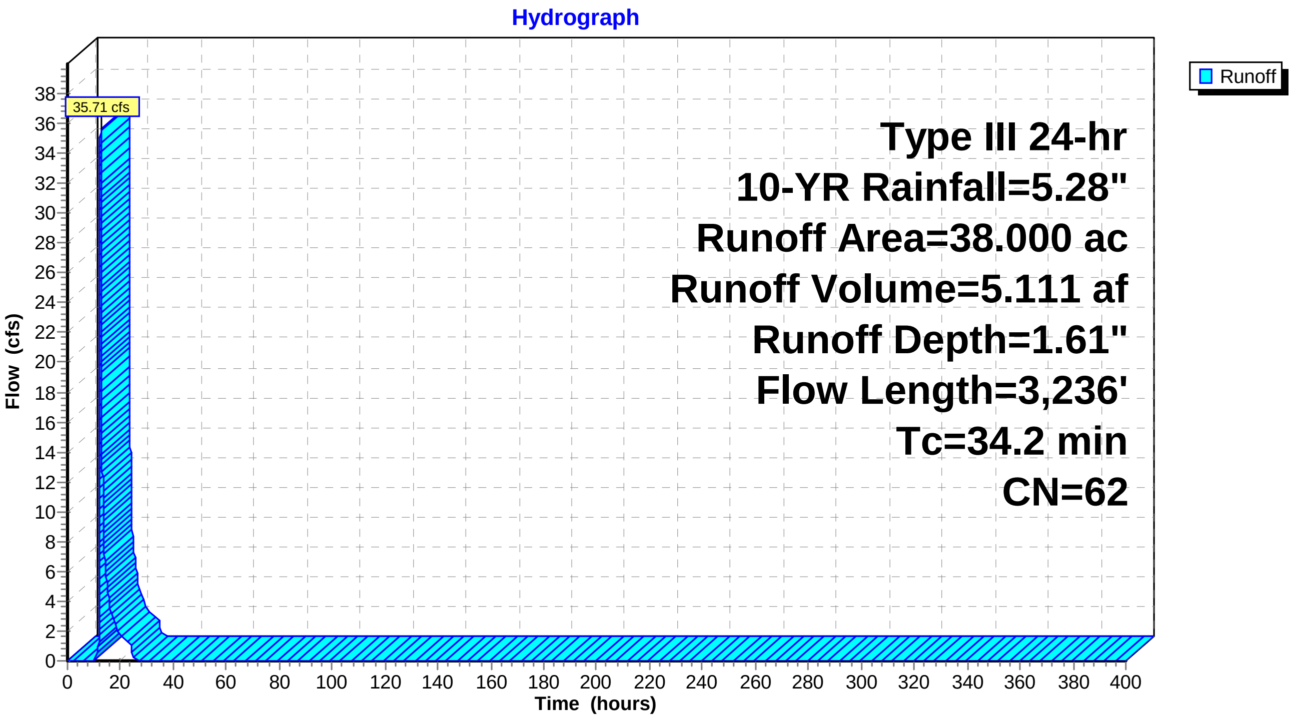
Runoff = 35.71 cfs @ 12.51 hrs, Volume= 5.111 af, Depth= 1.61"
Routed to Pond 20P : Pool Existing

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	38.000	62	
	38.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	50	0.0400	0.06		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.7	228	0.0790	1.41		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
7.9	1,488	0.3970	3.15		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
8.1	1,050	0.1850	2.15		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.6	420	0.0570	10.83	64.98	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
34.2	3,236	Total			

Subcatchment 1A E: 1A E



Summary for Subcatchment 1B E: 1B-E

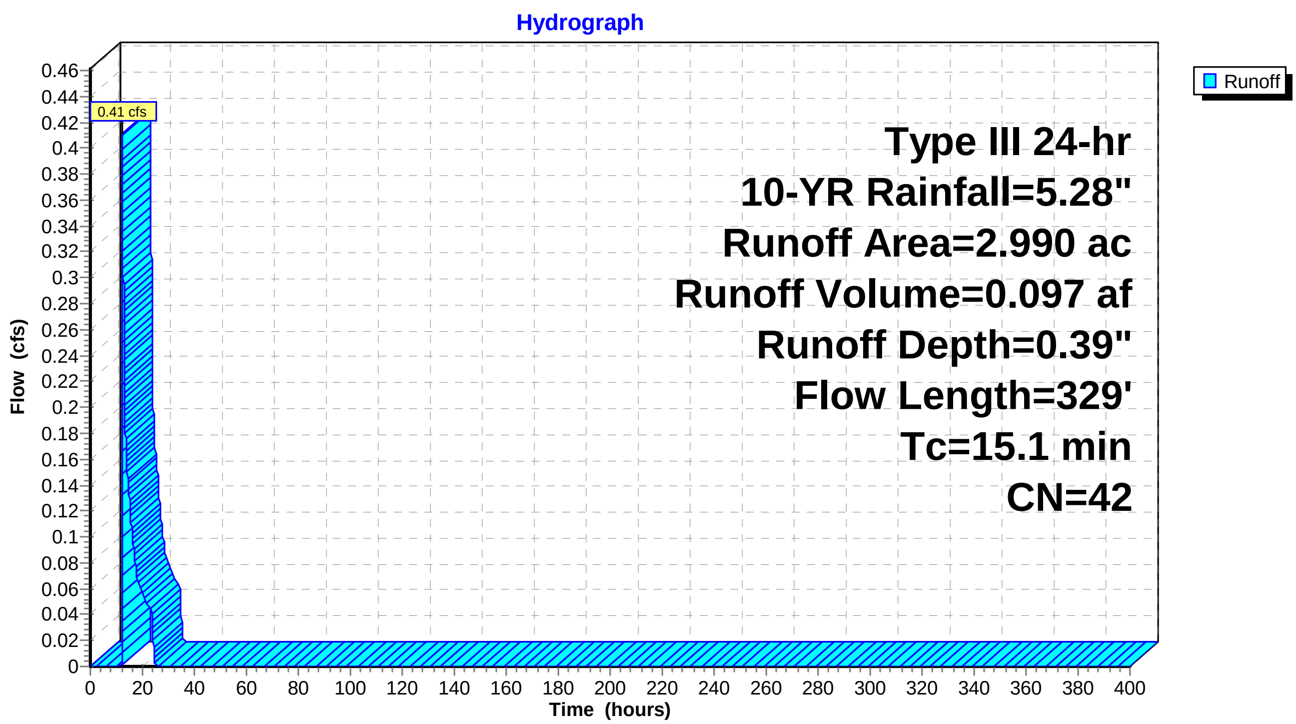
Runoff = 0.41 cfs @ 12.49 hrs, Volume= 0.097 af, Depth= 0.39"
Routed to Pond 20P : Pool Existing

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	2.990	42	From CN Spreadsheet
	2.990		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.6	50	0.0750	0.07		**Sheet Flow, Sheet** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.9	159	0.0330	0.91		**Shallow Concentrated Flow, SCF-1** Woodland Kv= 5.0 fps
0.1	58	0.1720	18.81	112.88	**Channel Flow, CF-1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.5	62	0.1510	1.94		**Shallow Concentrated Flow, SCF-2** Woodland Kv= 5.0 fps
15.1	329	Total			

Subcatchment 1B E: 1B-E



Summary for Subcatchment 2A E: 2A E

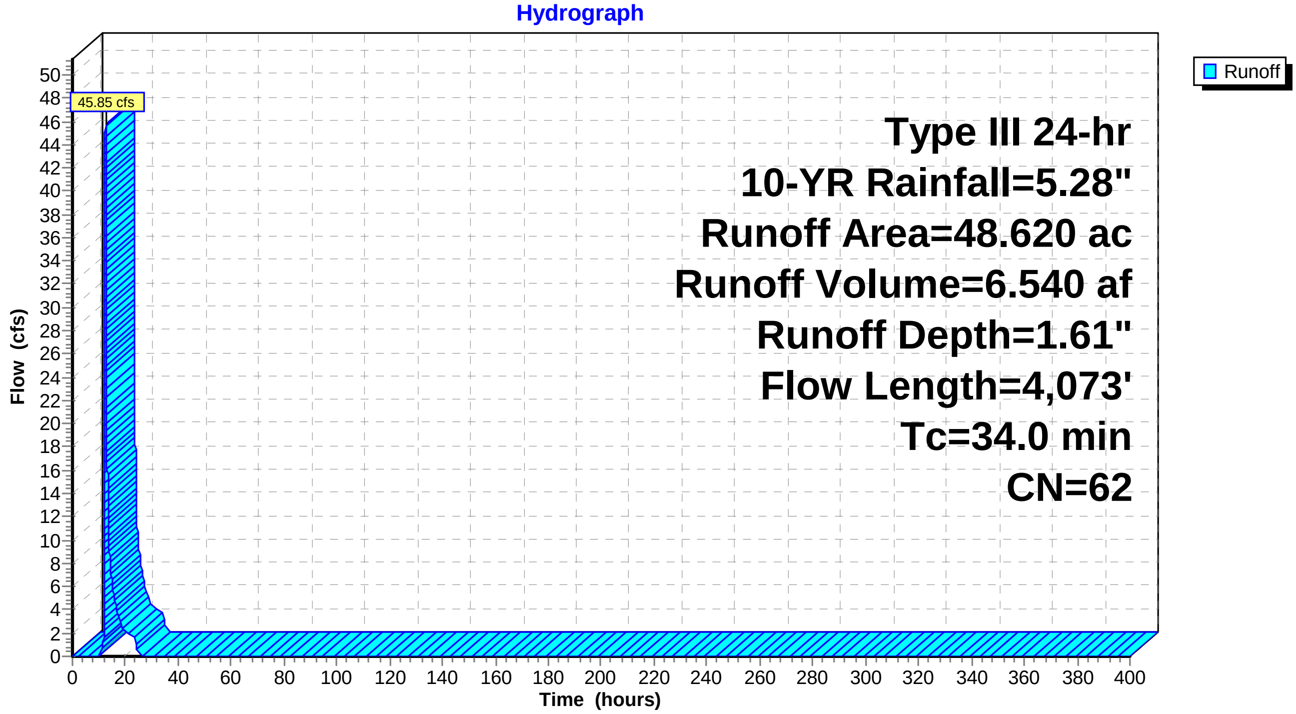
Runoff = 45.85 cfs @ 12.51 hrs, Volume= 6.540 af, Depth= 1.61"
Routed to Reach 21R : Wetland Ditch

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	48.620	62	From CN Spreadsheet
	48.620		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	50	0.0400	0.06		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.3	207	0.0870	1.47		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
2.4	337	0.2140	2.31		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
2.2	464	0.4830	3.47		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.4	592	0.2570	23.00	137.98	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
1.1	1,448	0.2280	21.66	129.96	**Channel Flow, CF 2** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.3	152	0.0480	9.94	59.63	**Channel Flow, CF-5** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.2	138	0.0480	9.94	59.63	**Channel Flow, CF-3** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.2	148	0.0480	9.94	59.63	**Channel Flow, CF-4** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
10.0	537	0.0320	0.89		**Shallow Concentrated Flow, SCF-4** Woodland Kv= 5.0 fps
34.0	4,073	Total			

Subcatchment 2A E: 2A E



Summary for Subcatchment 2B E: 2B E

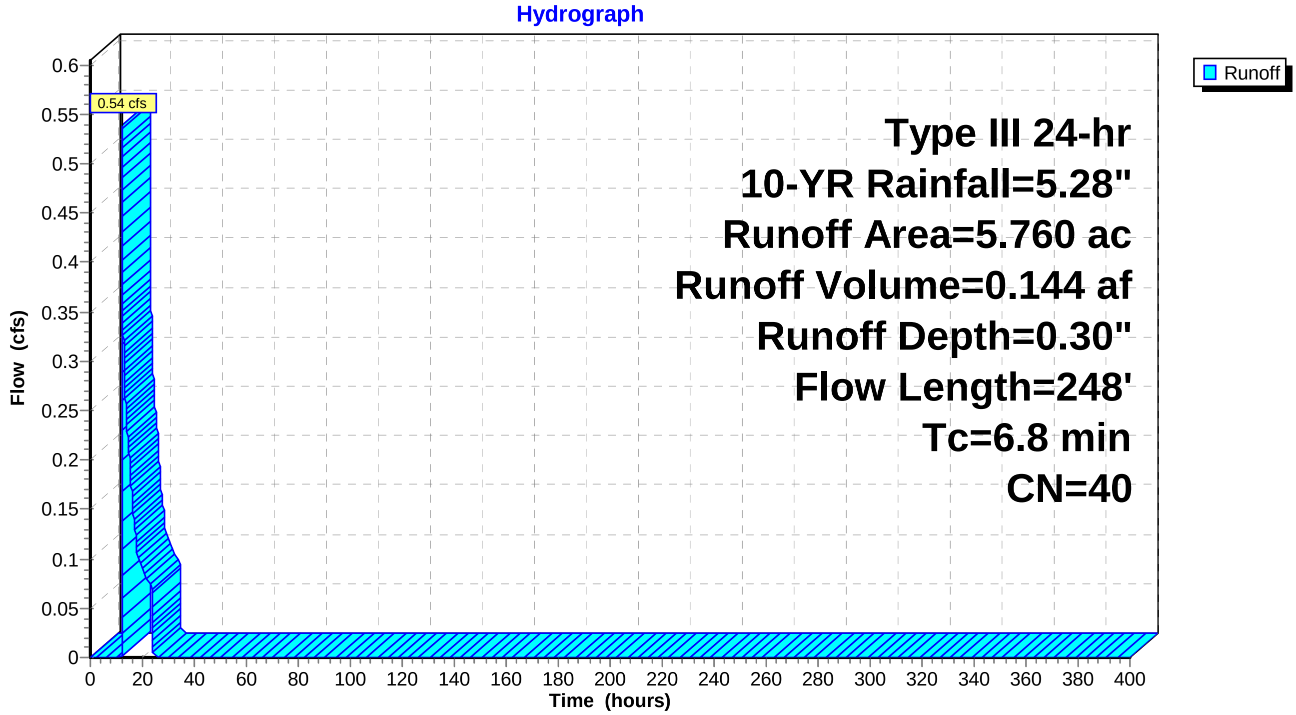
Runoff = 0.54 cfs @ 12.41 hrs, Volume= 0.144 af, Depth= 0.30"
Routed to Pond 21P : Existing Powerline Depression SMA-6 (Design Point 1)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	5.760	40	
	5.760		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	50	0.1410	0.16		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.84"
1.6	198	0.1720	2.07		**Shallow Concentrated Flow, SCF-1** Woodland Kv= 5.0 fps
6.8	248	Total			

Subcatchment 2B E: 2B E



Summary for Subcatchment 3 E: 3 E

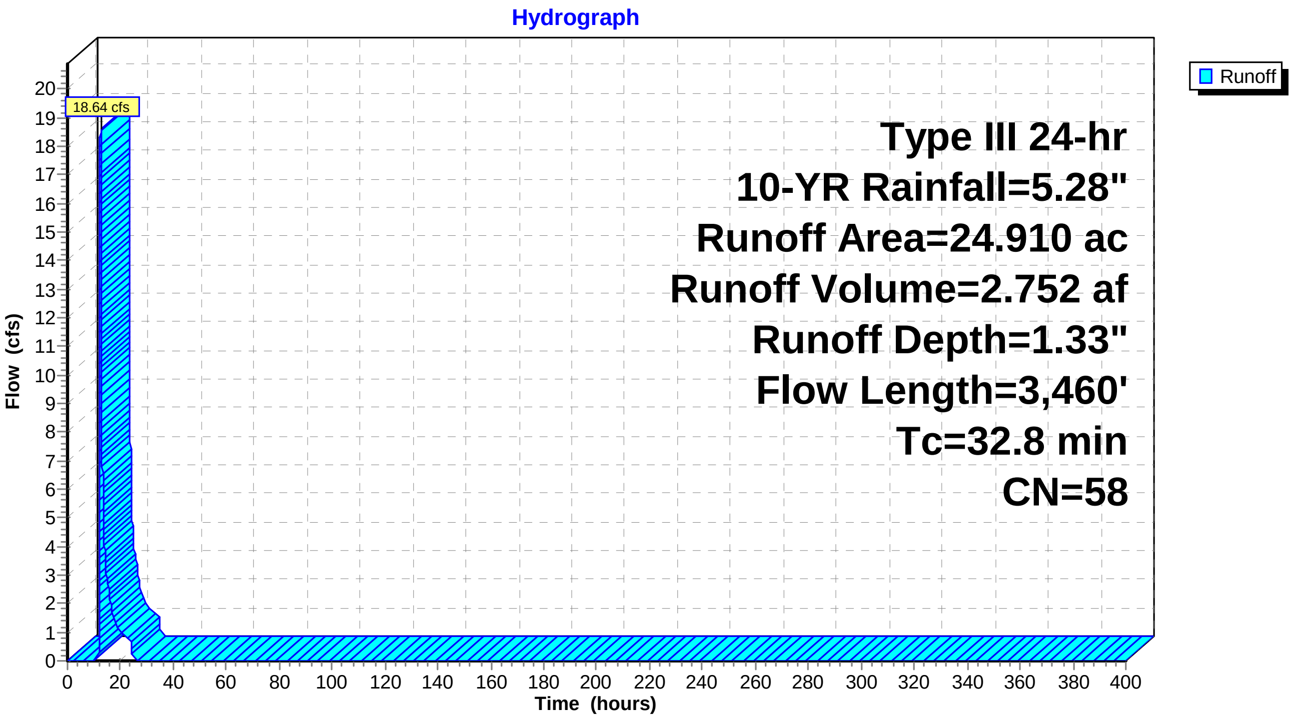
Runoff = 18.64 cfs @ 12.51 hrs, Volume= 2.752 af, Depth= 1.33"
Routed to Pond 2P : SMA1 (Design Point 2)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	24.910	58	
	24.910		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.6	50	0.1200	0.09		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
5.9	657	0.1390	1.86		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
6.7	1,207	0.3630	3.01		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
10.1	1,240	0.1690	2.06		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.5	306	0.0590	11.02	66.11	**Channel Flow, CF** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
32.8	3,460	Total			

Subcatchment 3 E: 3 E



Summary for Subcatchment 4 E: 4 E (Design Point 3)

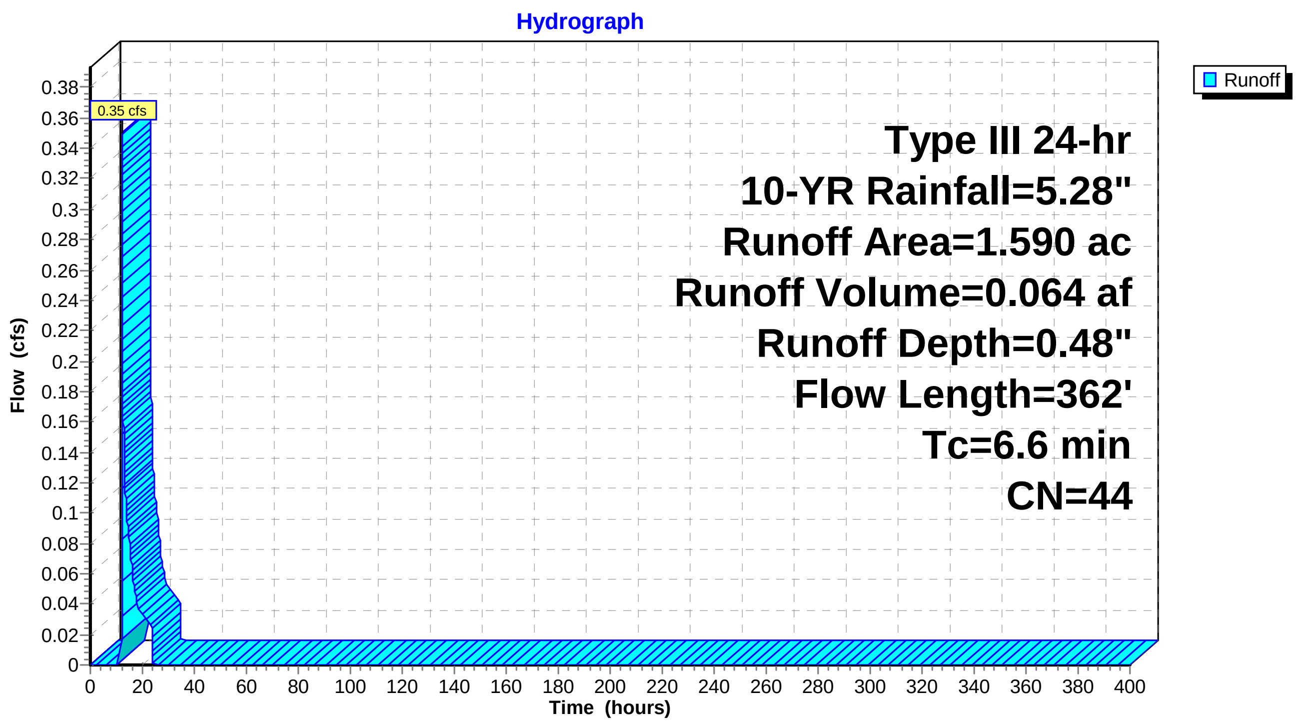
Runoff = 0.35 cfs @ 12.30 hrs, Volume= 0.064 af, Depth= 0.48"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	1.590	44	
	1.590		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.9	50	0.1600	0.17		**Sheet Flow, SF** Woods: Light underbrush n= 0.400 P2= 3.84"
1.3	126	0.1110	1.67		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
0.4	186	0.0320	8.11	48.69	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
6.6	362	Total			

Subcatchment 4 E: 4 E (Design Point 3)



Summary for Subcatchment 5 E: 5 E (Design Point 4)

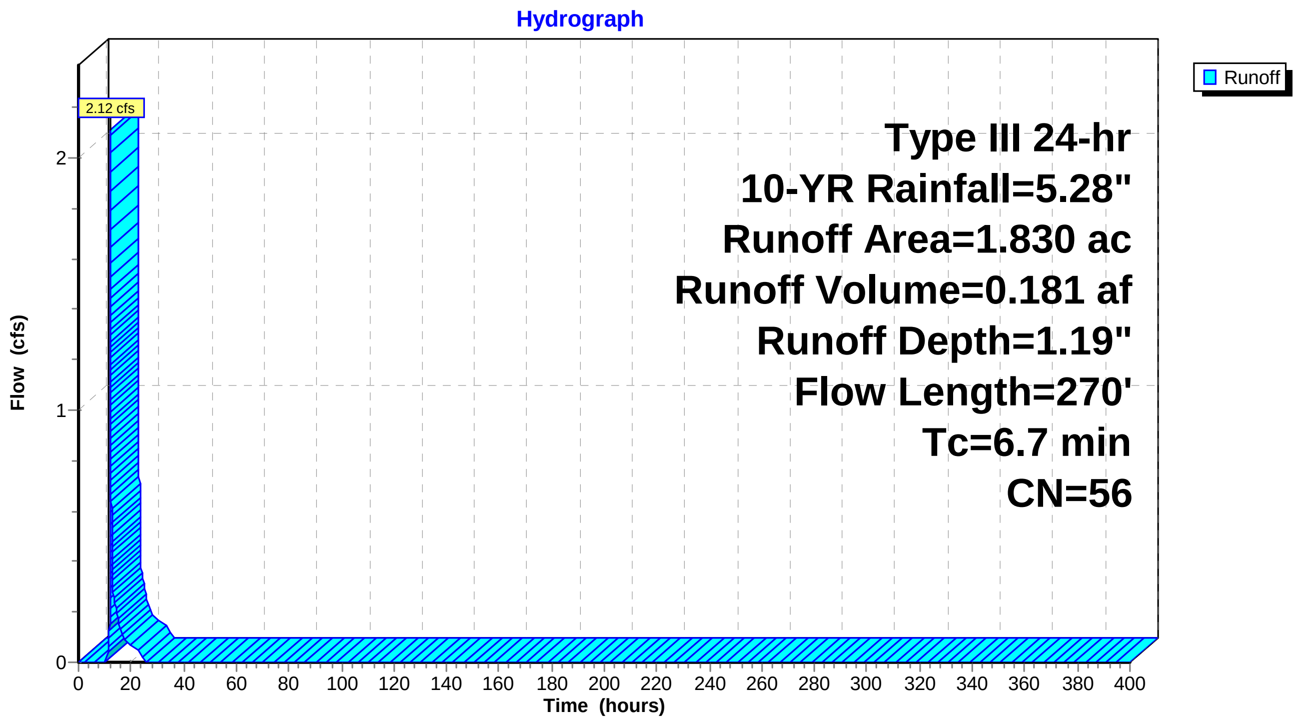
Runoff = 2.12 cfs @ 12.11 hrs, Volume= 0.181 af, Depth= 1.19"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	1.830	56	
	1.830		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	50	0.1200	0.15		**Sheet Flow, SF** Woods: Light underbrush n= 0.400 P2= 3.84"
0.8	95	0.1550	1.97		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
0.4	125	0.0120	4.97	29.81	**Channel Flow,** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
6.7	270	Total			

Subcatchment 5 E: 5 E (Design Point 4)



Summary for Subcatchment 6 E: 6 E

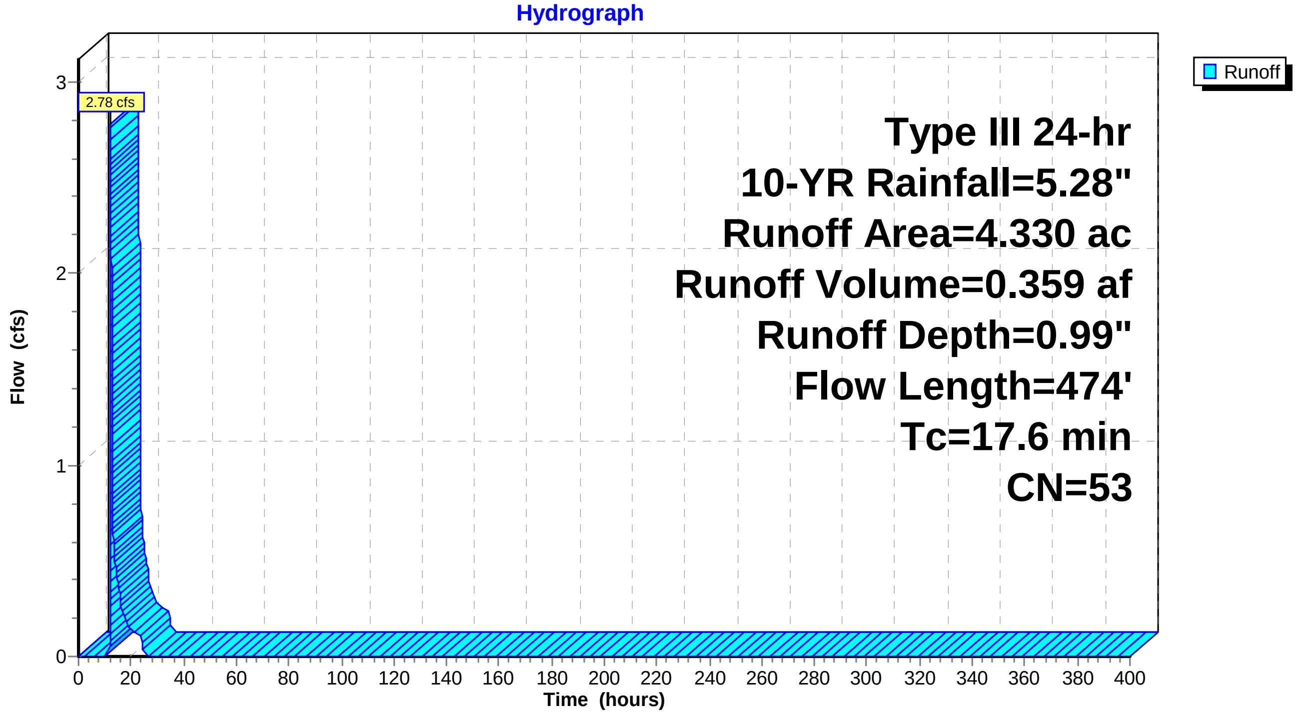
Runoff = 2.78 cfs @ 12.30 hrs, Volume= 0.359 af, Depth= 0.99"
Routed to Pond 19P : SMA-2 E (Design Point 5)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	4.330	53	
	4.330		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.3	50	0.0200	0.07		**Sheet Flow, SF** Woods: Light underbrush n= 0.400 P2= 3.84"
6.3	424	0.0500	1.12		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
17.6	474	Total			

Subcatchment 6 E: 6 E



Summary for Subcatchment 7 E: 7 E

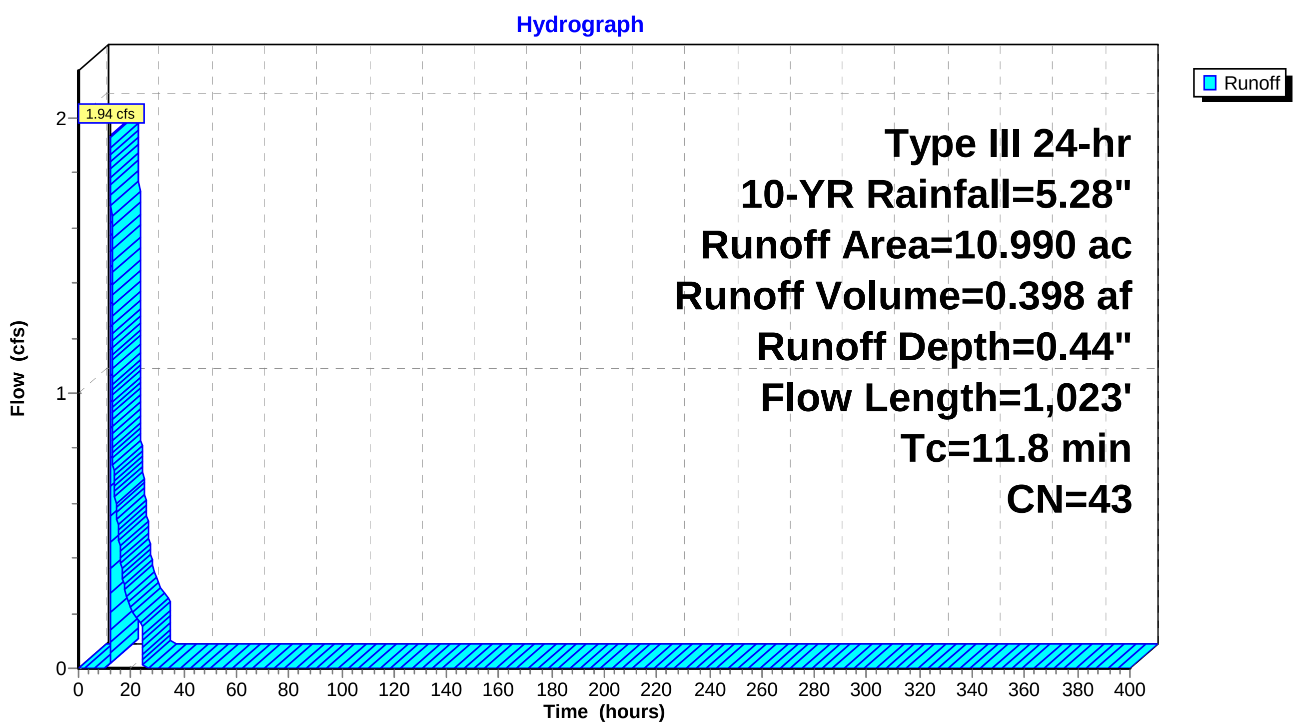
Runoff = 1.94 cfs @ 12.42 hrs, Volume= 0.398 af, Depth= 0.44"
Routed to Pond 23P : SMA4 E (Design Point 7)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	10.990	43	
	10.990		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.5	50	0.0200	0.11		**Sheet Flow, SF** Grass: Dense n= 0.240 P2= 3.84"
3.4	320	0.0500	1.57		**Shallow Concentrated Flow, SCF 1** Short Grass Pasture Kv= 7.0 fps
0.9	653	0.0640	11.48	68.85	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
11.8	1,023	Total			

Subcatchment 7 E: 7 E



Summary for Subcatchment 8 E: 8 E

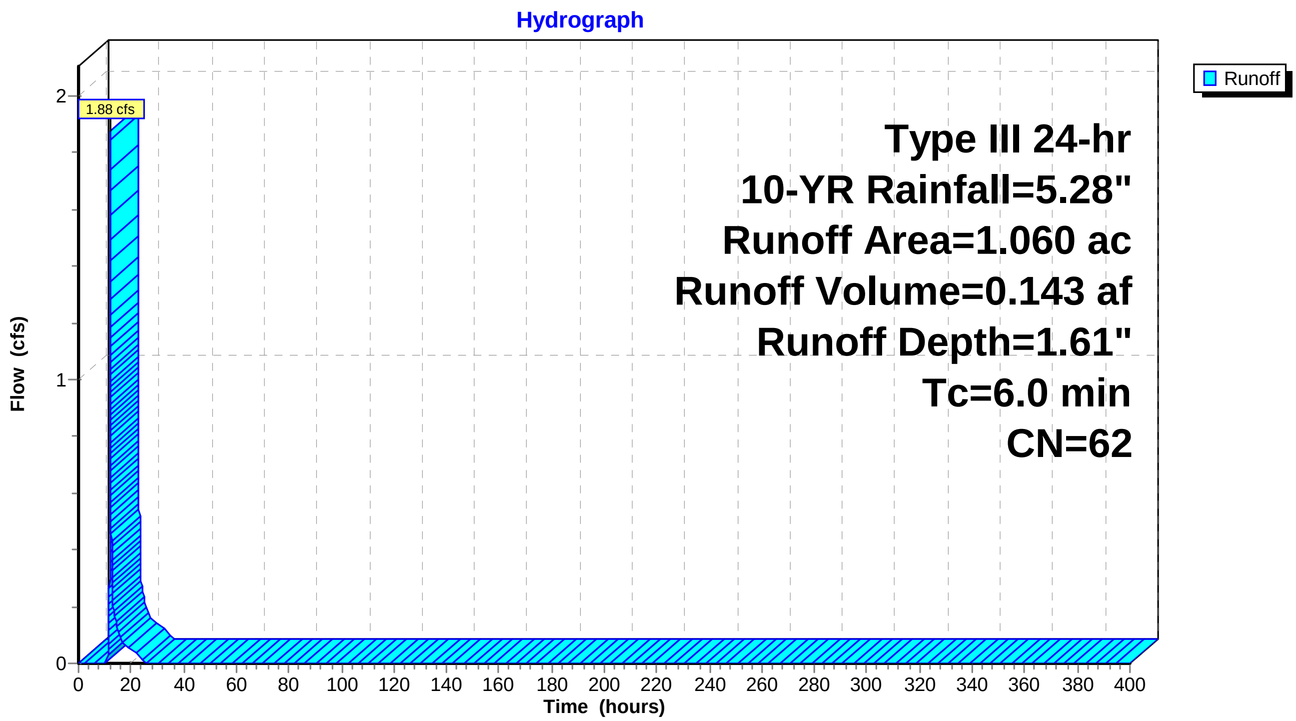
Runoff = 1.88 cfs @ 12.10 hrs, Volume= 0.143 af, Depth= 1.61"
Routed to Pond 22P : SMA3 E (Design Point 6)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	1.060	62	
	1.060		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment 8 E: 8 E



Summary for Subcatchment 9 E: 9 E (Design Point 8)

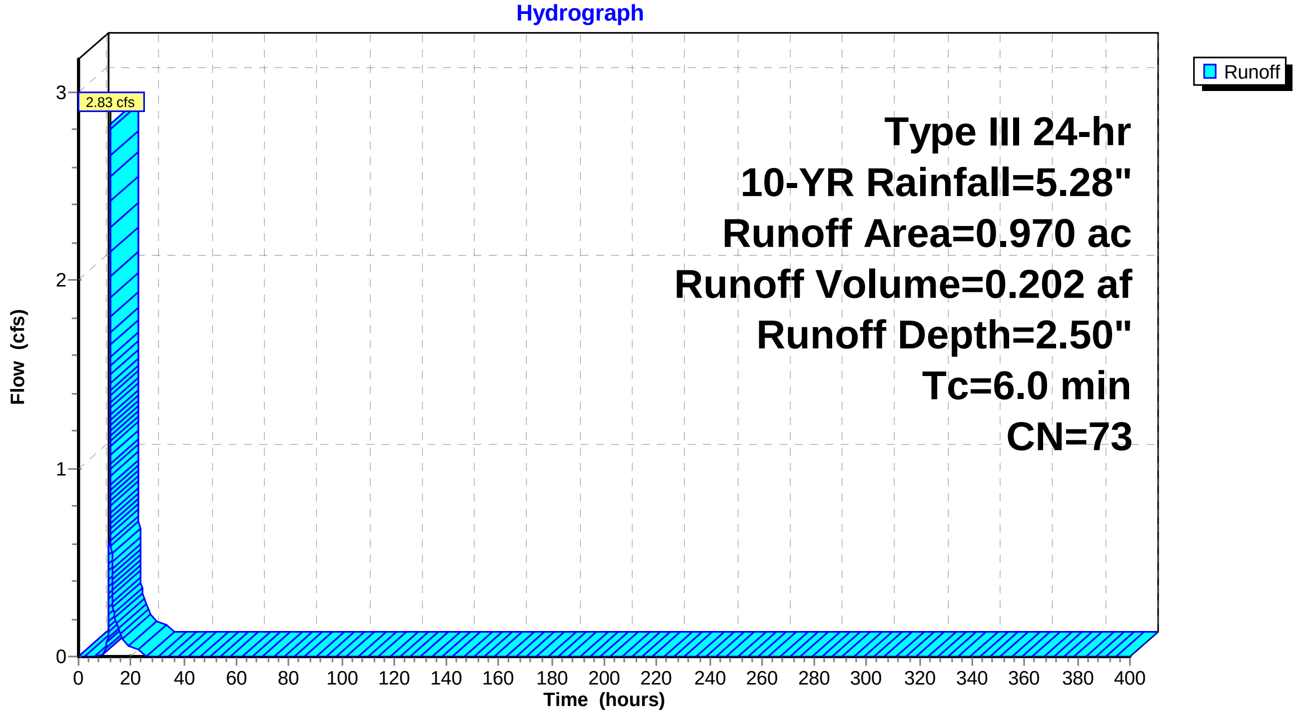
Runoff = 2.83 cfs @ 12.09 hrs, Volume= 0.202 af, Depth= 2.50"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	0.970	73	
	0.970		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, TR55 Min (calculation TC less than 6 minutes)**

Subcatchment 9 E: 9 E (Design Point 8)



Summary for Subcatchment 10 E: 10 E

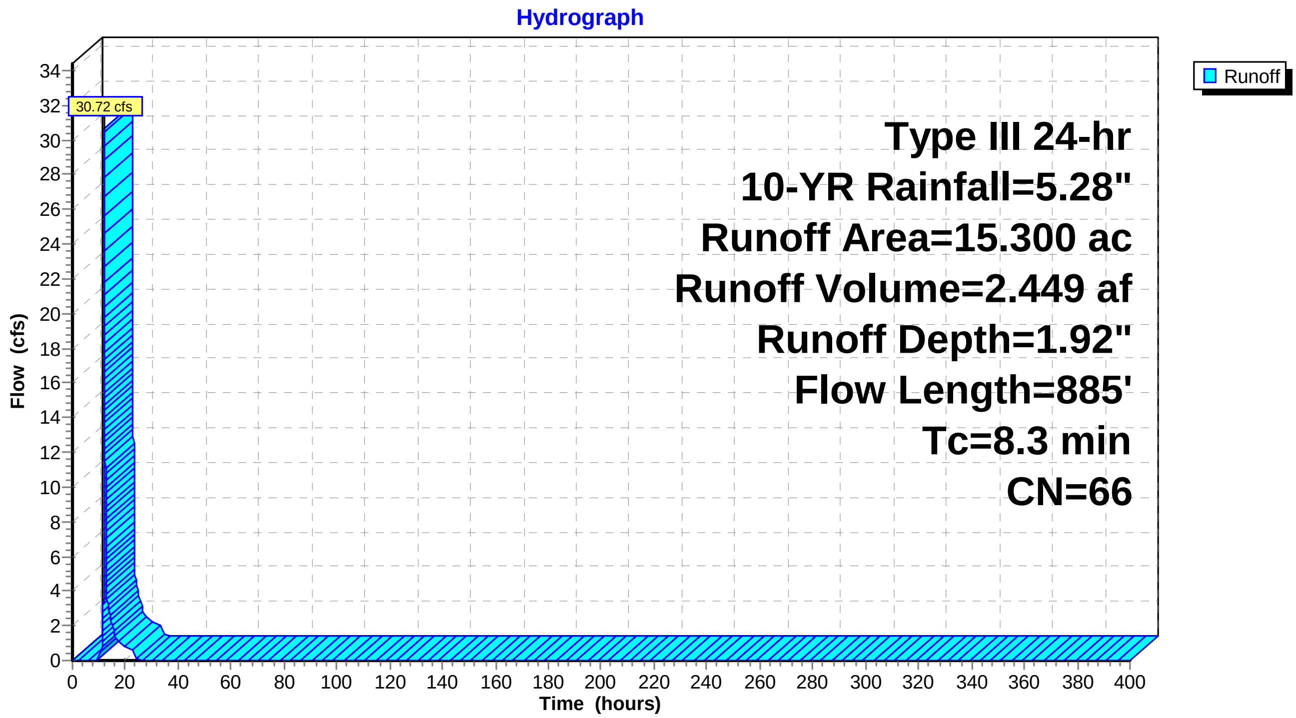
Runoff = 30.72 cfs @ 12.13 hrs, Volume= 2.449 af, Depth= 1.92"
Routed to Pond 1P : Existing Pond/SMA5 E

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	15.300	66	
	15.300		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	50	0.0440	0.15		**Sheet Flow, SF** Grass: Dense n= 0.240 P2= 3.84"
1.3	302	0.0590	3.91		**Shallow Concentrated Flow, SCF 1** Unpaved Kv= 16.1 fps
0.1	180	0.2860	24.26	145.55	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
1.4	353	0.0640	4.07		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
8.3	885	Total			

Subcatchment 10 E: 10 E



Summary for Reach 4R: Outfall Channel (Design Point 9)

[85] Warning: Oscillations may require smaller dt or Finer Routing (severity=1)

Inflow Area = 15.300 ac, 0.00% Impervious, Inflow Depth = 1.26" for 10-YR event
Inflow = 9.28 cfs @ 12.51 hrs, Volume= 1.601 af
Outflow = 9.28 cfs @ 12.51 hrs, Volume= 1.590 af, Atten= 0%, Lag= 0.0 min

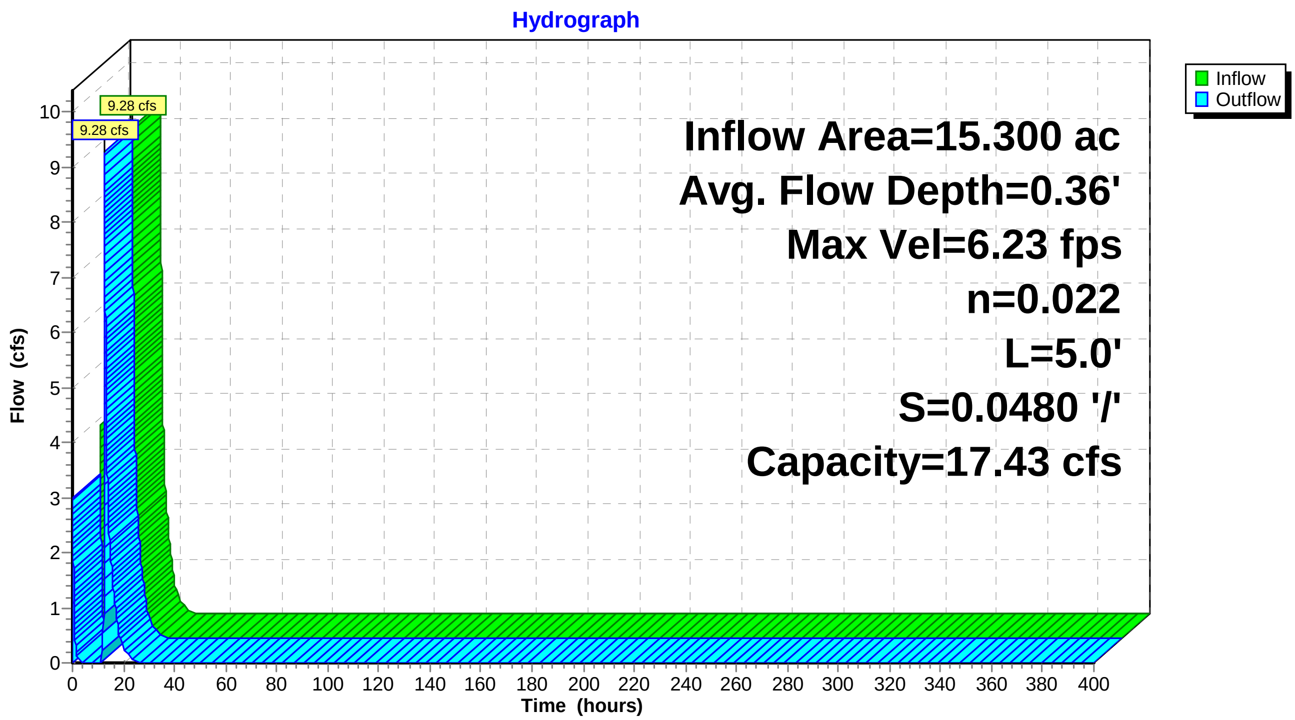
Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 2
Max. Velocity= 6.23 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 2.67 fps, Avg. Travel Time= 0.0 min

Peak Storage= 7 cf @ 12.51 hrs
Average Depth at Peak Storage= 0.36' , Surface Width= 5.35'
Bank-Full Depth= 0.50' Flow Area= 2.3 sf, Capacity= 17.43 cfs

3.00' x 0.50' deep channel, n= 0.022 Earth, clean & straight
Side Slope Z-value= 3.3 '/' Top Width= 6.30'
Length= 5.0' Slope= 0.0480 '/'
Inlet Invert= 949.68', Outlet Invert= 949.44'

‡

Reach 4R: Outfall Channel (Design Point 9)



Summary for Reach 21R: Wetland Ditch

[91] Warning: Storage range exceeded by 0.31'
[55] Hint: Peak inflow is 166% of Manning's capacity

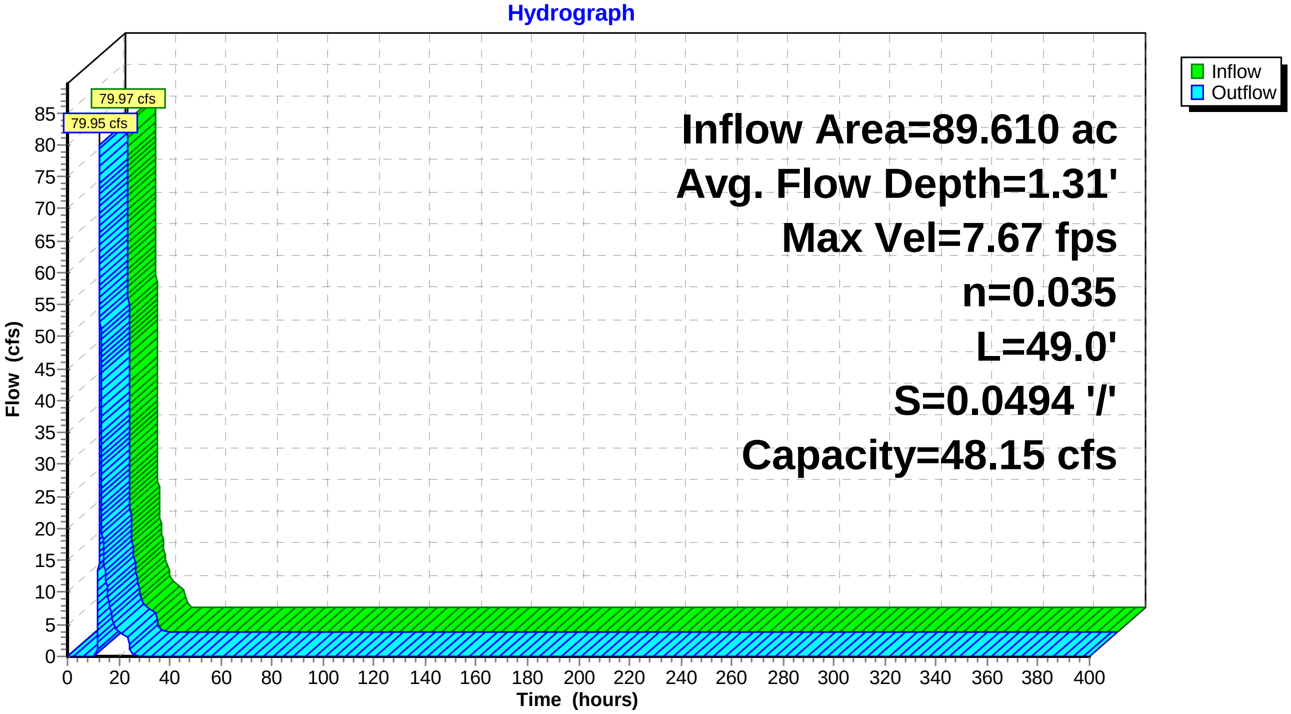
Inflow Area = 89.610 ac, 0.00% Impervious, Inflow Depth = 1.51" for 10-YR event
Inflow = 79.97 cfs @ 12.58 hrs, Volume= 11.263 af
Outflow = 79.95 cfs @ 12.58 hrs, Volume= 11.263 af, Atten= 0%, Lag= 0.1 min
Routed to Pond 21P : Existing Powerline Depression SMA-6 (Design Point 1)

Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Max. Velocity= 7.67 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 2.82 fps, Avg. Travel Time= 0.3 min

Peak Storage= 511 cf @ 12.58 hrs
Average Depth at Peak Storage= 1.31' , Surface Width= 13.50'
Bank-Full Depth= 1.00' Flow Area= 7.0 sf, Capacity= 48.15 cfs

3.00' x 1.00' deep channel, n= 0.035 Earth, dense weeds
Side Slope Z-value= 4.0 '/' Top Width= 11.00'
Length= 49.0' Slope= 0.0494 '/'
Inlet Invert= 984.59', Outlet Invert= 982.17'

Reach 21R: Wetland Ditch



Summary for Reach 22R: Pool Ditch

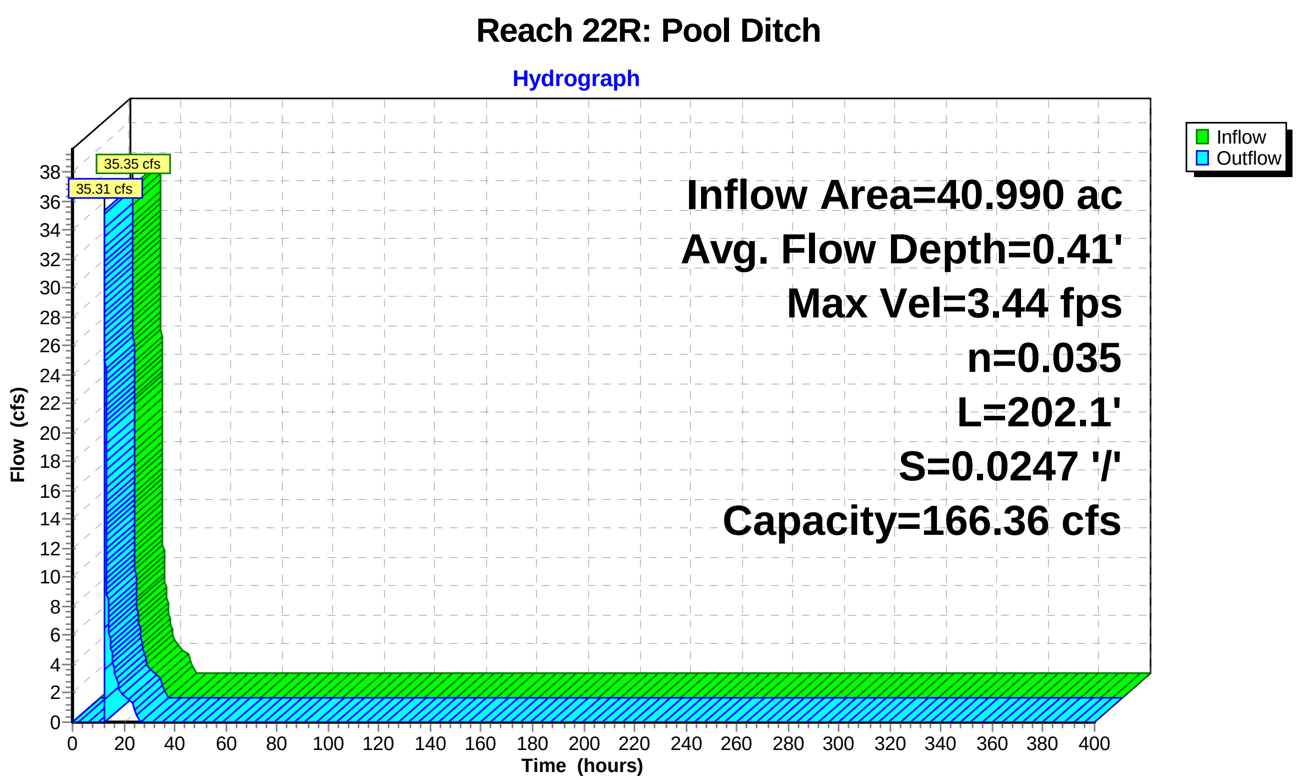
Inflow Area = 40.990 ac, 0.00% Impervious, Inflow Depth = 1.38" for 10-YR event
Inflow = 35.35 cfs @ 12.59 hrs, Volume= 4.723 af
Outflow = 35.31 cfs @ 12.61 hrs, Volume= 4.723 af, Atten= 0%, Lag= 1.6 min
Routed to Reach 21R : Wetland Ditch

Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.44 fps, Min. Travel Time= 1.0 min
Avg. Velocity = 1.04 fps, Avg. Travel Time= 3.2 min

Peak Storage= 2,073 cf @ 12.60 hrs
Average Depth at Peak Storage= 0.41' , Surface Width= 27.62'
Bank-Full Depth= 1.00' Flow Area= 28.8 sf, Capacity= 166.36 cfs

22.00' x 1.00' deep channel, n= 0.035
Side Slope Z-value= 6.8 '/' Top Width= 35.60'
Length= 202.1' Slope= 0.0247 '/'
Inlet Invert= 992.44', Outlet Invert= 987.45'

‡



Summary for Pond 1P: Existing Pond/SMA5 E

Inflow Area = 15.300 ac, 0.00% Impervious, Inflow Depth = 1.92" for 10-YR event
Inflow = 30.72 cfs @ 12.13 hrs, Volume= 2.449 af
Outflow = 9.87 cfs @ 12.51 hrs, Volume= 8.493 af, Atten= 68%, Lag= 23.3 min
Discarded = 0.60 cfs @ 12.51 hrs, Volume= 6.892 af
Primary = 9.28 cfs @ 12.51 hrs, Volume= 1.601 af
Routed to Reach 4R : Outfall Channel (Design Point 9)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Starting Elev= 949.90' Surf.Area= 1.245 ac Storage= 6.042 af
Peak Elev= 950.03' @ 12.51 hrs Surf.Area= 1.277 ac Storage= 6.212 af (0.170 af above start)

Plug-Flow detention time= 9,355.9 min calculated for 2.449 af (100% of inflow)
Center-of-Mass det. time= 3,922.8 min (4,779.8 - 857.0)

Volume	Invert	Avail.Storage	Storage Description
#1	940.00'	9.105 af	**Custom Stage Data (Conic)** Listed below (Recalc)

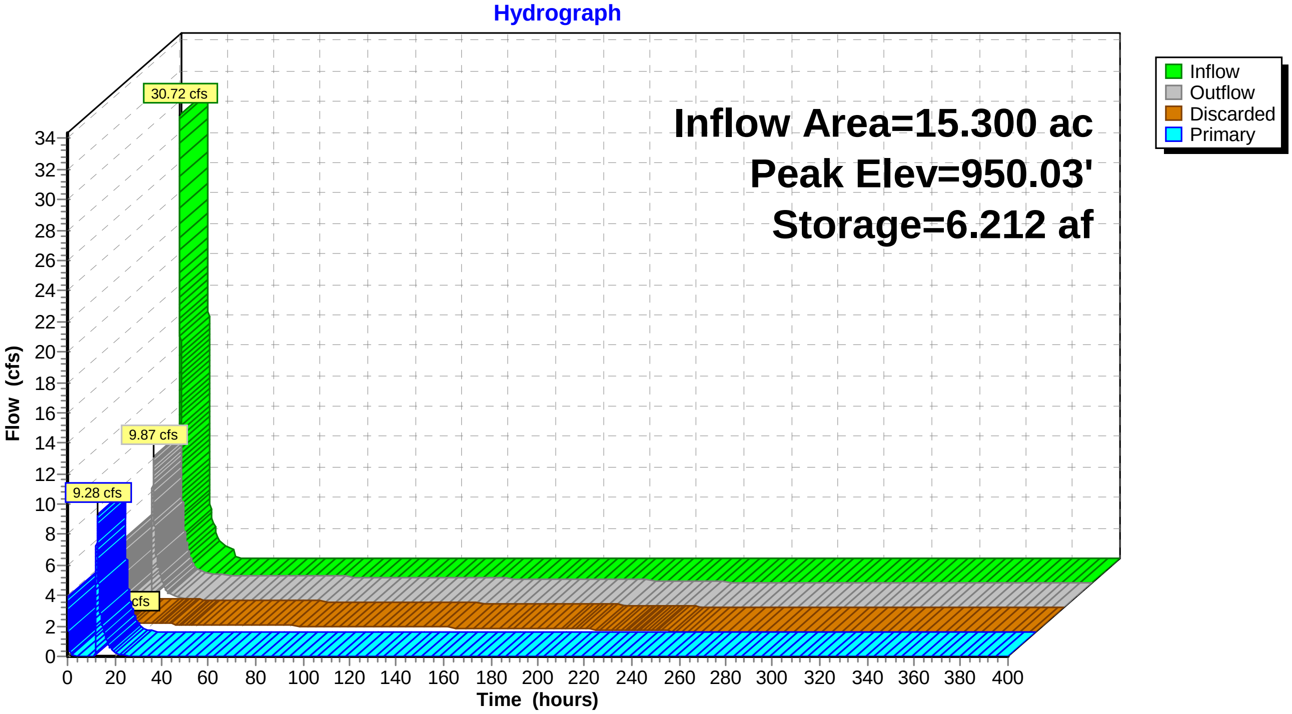
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
940.00	0.005	0.000	0.000	0.005
941.00	0.085	0.037	0.037	0.085
942.00	0.297	0.180	0.217	0.297
943.00	0.453	0.372	0.589	0.454
944.00	0.553	0.502	1.092	0.554
945.00	0.645	0.598	1.690	0.647
946.00	0.737	0.690	2.381	0.740
947.00	0.832	0.784	3.165	0.836
948.00	0.928	0.880	4.044	0.934
949.00	1.027	0.977	5.021	1.034
950.00	1.270	1.146	6.168	1.278
952.00	1.677	2.938	9.105	1.687

Device	Routing	Invert	Outlet Devices
#1	Discarded	940.00'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	949.68'	**Channel/Reach** using Reach 4R: Outfall Channel (Design Point 9)

Discarded OutFlow Max=0.60 cfs @ 12.51 hrs HW=950.03' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.60 cfs)

Primary OutFlow Max=9.18 cfs @ 12.51 hrs HW=950.03' (Free Discharge)
└─**2=Channel/Reach** (Channel Controls 9.18 cfs @ 6.21 fps)

Pond 1P: Existing Pond/SMA5 E



Summary for Pond 2P: SMA1 (Design Point 2)

Inflow Area = 24.910 ac, 0.00% Impervious, Inflow Depth = 1.33" for 10-YR event
Inflow = 18.64 cfs @ 12.51 hrs, Volume= 2.752 af
Outflow = 0.27 cfs @ 24.52 hrs, Volume= 2.752 af, Atten= 99%, Lag= 720.4 min
Discarded = 0.27 cfs @ 24.52 hrs, Volume= 2.752 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 21P : Existing Powerline Depression SMA-6 (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 6
Peak Elev= 997.57' @ 24.52 hrs Surf.Area= 0.694 ac Storage= 2.503 af

Plug-Flow detention time= 4,482.2 min calculated for 2.752 af (100% of inflow)
Center-of-Mass det. time= 4,482.1 min (5,384.5 - 902.4)

Volume	Invert	Avail.Storage	Storage Description
#1	992.00'	6.087 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

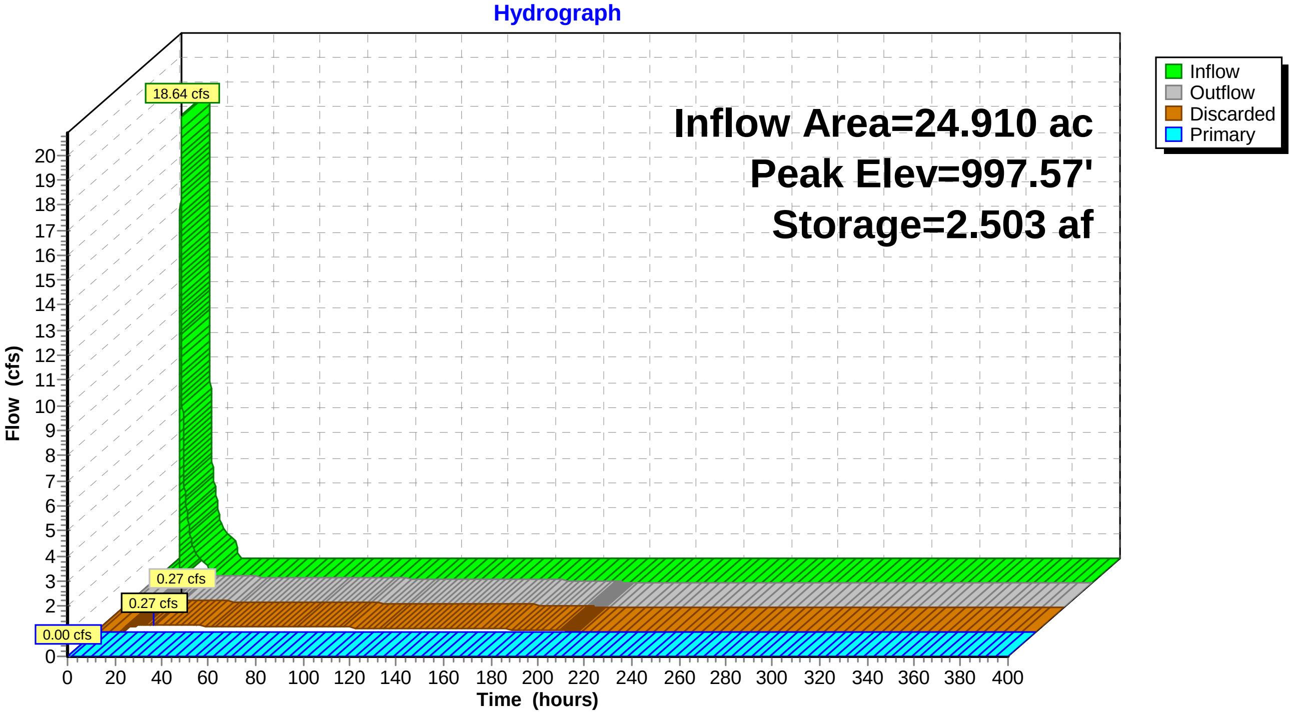
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
992.00	0.210	0.000	0.000
994.00	0.377	0.587	0.587
996.00	0.557	0.934	1.521
998.00	0.731	1.288	2.809
1,000.00	0.946	1.677	4.486
1,001.53	1.147	1.601	6.087

Device	Routing	Invert	Outlet Devices
#1	Discarded	992.00'	**0.380 in/hr Exfiltration over Surface area**
#2	Primary	1,001.52'	**16.0' long + 3.0 '/' SideZ x 36.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.27 cfs @ 24.52 hrs HW=997.57' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.27 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=992.00' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 2P: SMA1 (Design Point 2)



Summary for Pond 19P: SMA-2 E (Design Point 5)

[93] Warning: Storage range exceeded by 0.22'

Inflow Area =	4.330 ac,	0.00% Impervious, Inflow Depth = 0.99"	for 10-YR event	
Inflow =	2.78 cfs @	12.30 hrs, Volume=	0.359 af	
Outflow =	0.50 cfs @	12.52 hrs, Volume=	0.160 af,	Atten= 82%, Lag= 13.5 min
Discarded =	0.07 cfs @	12.52 hrs, Volume=	0.156 af	
Primary =	0.43 cfs @	12.52 hrs, Volume=	0.004 af	

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 6
Peak Elev= 1,026.77' @ 12.52 hrs Surf.Area= 0.178 ac Storage= 0.086 af

Plug-Flow detention time= 849.4 min calculated for 0.160 af (45% of inflow)
Center-of-Mass det. time= 696.1 min (1,602.0 - 905.9)

Volume	Invert	Avail.Storage	Storage Description
#1	1,025.60'	0.086 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

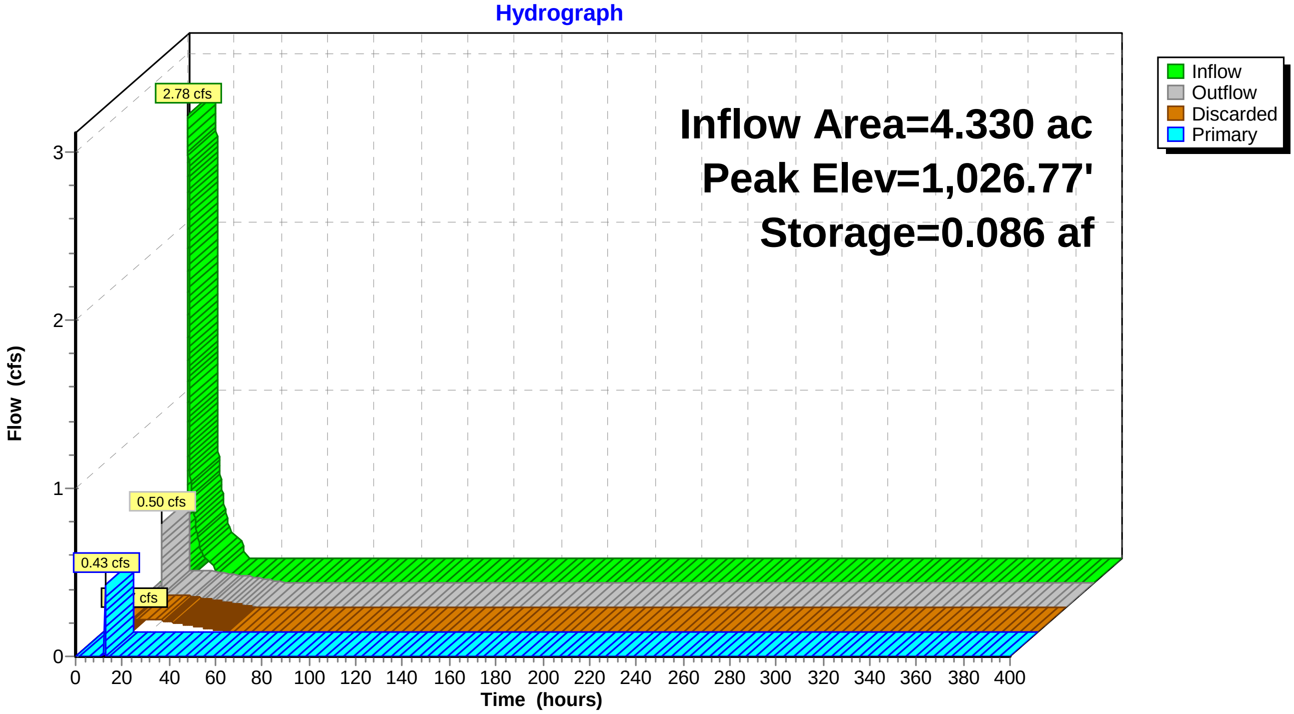
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,025.60	0.002	0.000	0.000
1,026.55	0.178	0.086	0.086

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,025.60'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	1,026.54'	**1.0' long + 3.0 '/' SideZ x 0.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32

Discarded OutFlow Max=0.07 cfs @ 12.52 hrs HW=1,026.75' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.07 cfs)

Primary OutFlow Max=0.38 cfs @ 12.52 hrs HW=1,026.74' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Weir Controls 0.38 cfs @ 1.16 fps)

Pond 19P: SMA-2 E (Design Point 5)



Summary for Pond 20P: Pool Existing

Inflow Area = 40.990 ac, 0.00% Impervious, Inflow Depth = 1.52" for 10-YR event
Inflow = 36.12 cfs @ 12.51 hrs, Volume= 5.208 af
Outflow = 35.35 cfs @ 12.59 hrs, Volume= 4.723 af, Atten= 2%, Lag= 4.5 min
Primary = 35.35 cfs @ 12.59 hrs, Volume= 4.723 af
Routed to Reach 22R : Pool Ditch

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Starting Elev= 991.00' Surf.Area= 0.198 ac Storage= 0.165 af
Peak Elev= 992.85' @ 12.59 hrs Surf.Area= 0.550 ac Storage= 0.862 af (0.698 af above start)

Plug-Flow detention time= 90.0 min calculated for 4.558 af (88% of inflow)
Center-of-Mass det. time= 25.4 min (918.7 - 893.2)

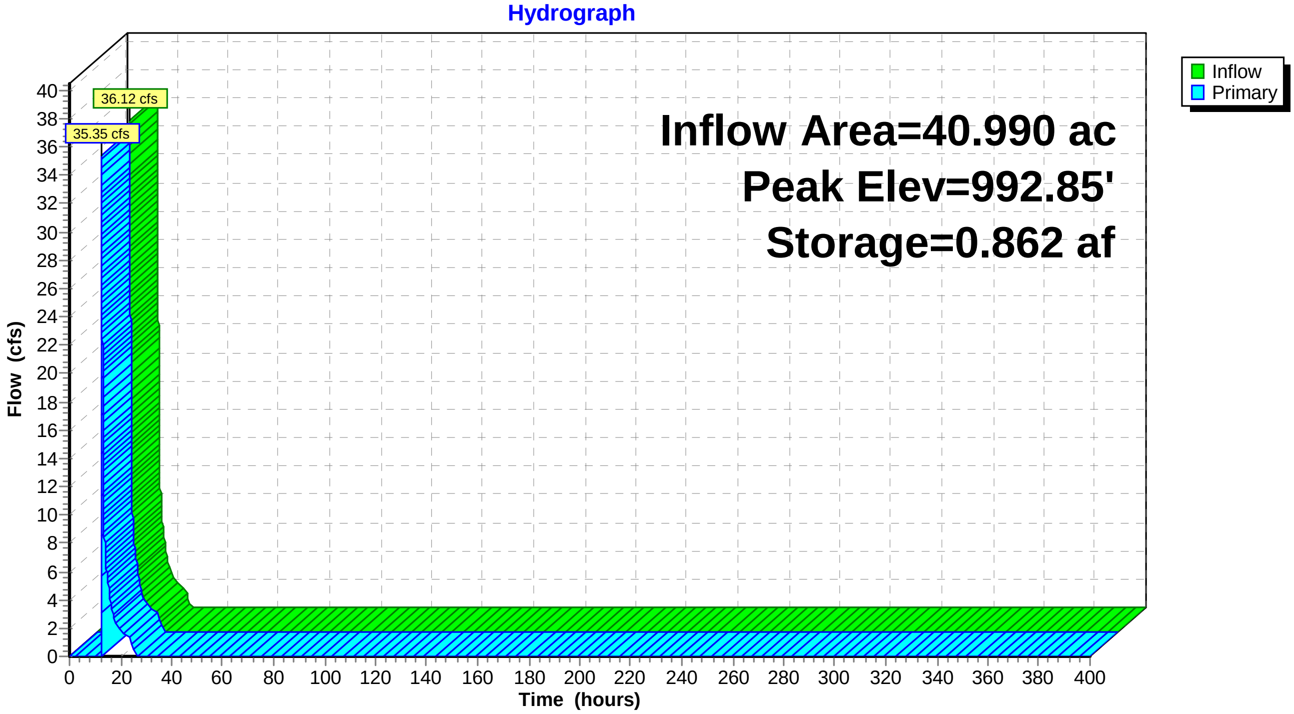
Volume	Invert	Avail.Storage	Storage Description
#1	988.50'	0.945 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
988.50	0.001	0.000	0.000
989.00	0.009	0.003	0.003
989.50	0.026	0.009	0.011
990.00	0.057	0.021	0.032
990.50	0.138	0.049	0.081
991.00	0.198	0.084	0.165
991.50	0.280	0.119	0.284
992.00	0.404	0.171	0.455
993.00	0.575	0.490	0.945

Device	Routing	Invert	Outlet Devices
#1	Primary	992.44'	**Channel/Reach** using Reach 22R: Pool Ditch

Primary OutFlow Max=35.30 cfs @ 12.59 hrs HW=992.85' (Free Discharge)
└─**1=Channel/Reach** (Channel Controls 35.30 cfs @ 3.44 fps)

Pond 20P: Pool Existing



Summary for Pond 21P: Existing Powerline Depression SMA-6 (Design Point 1)

[63] Warning: Exceeded Reach 21R INLET depth by 0.05' @ 16.18 hrs
[64] Warning: Exceeded Reach 21R outlet bank by 1.94' @ 15.01 hrs

Inflow Area = 120.280 ac, 0.00% Impervious, Inflow Depth = 1.14" for 10-YR event
Inflow = 80.33 cfs @ 12.58 hrs, Volume= 11.407 af
Outflow = 11.87 cfs @ 15.01 hrs, Volume= 11.407 af, Atten= 85%, Lag= 145.9 min
Discarded = 0.81 cfs @ 15.01 hrs, Volume= 6.112 af
Primary = 11.07 cfs @ 15.01 hrs, Volume= 5.295 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 2
Peak Elev= 985.11' @ 15.01 hrs Surf.Area= 1.742 ac Storage= 6.199 af

Plug-Flow detention time= 1,872.3 min calculated for 11.407 af (100% of inflow)
Center-of-Mass det. time= 1,872.5 min (2,777.9 - 905.4)

Volume	Invert	Avail.Storage	Storage Description
#1	978.00'	7.820 af	**Custom Stage Data (Conic)** Listed below

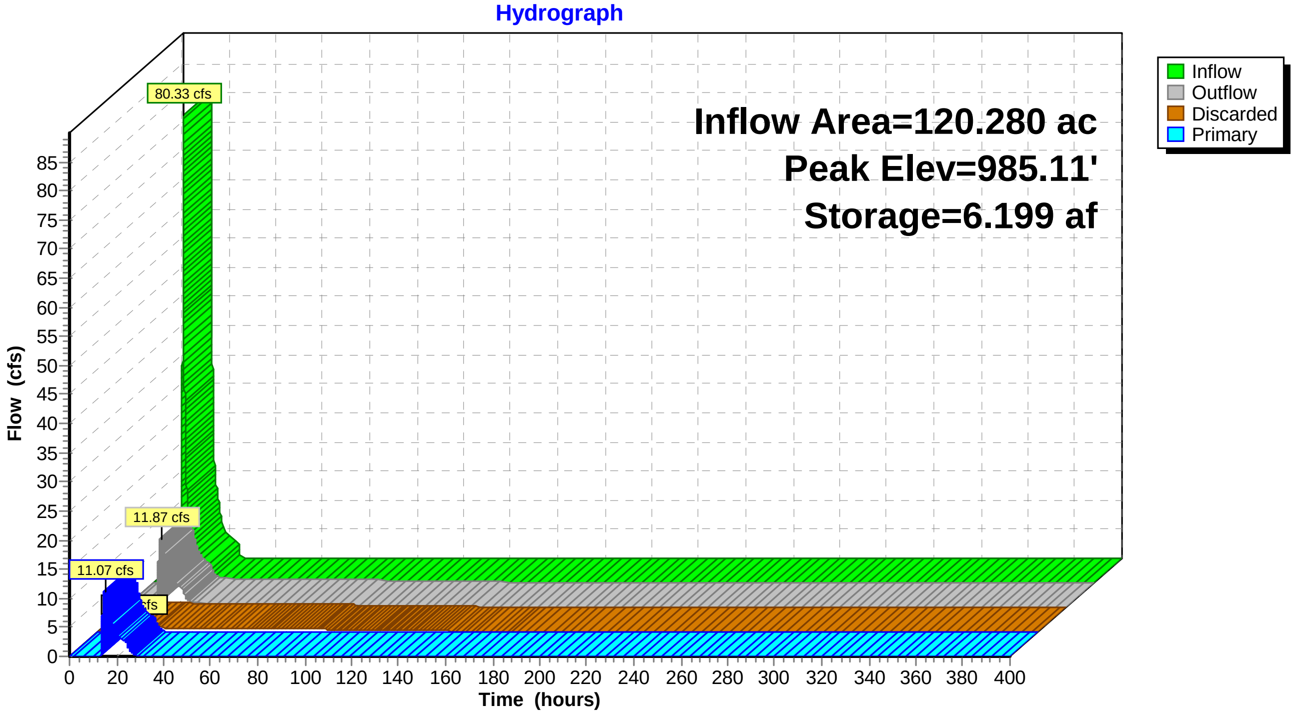
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
978.00	0.028	0.000	0.000	0.028
979.00	0.163	0.086	0.086	0.163
980.00	0.378	0.263	0.349	0.378
981.00	0.712	0.536	0.886	0.712
982.00	1.050	0.876	1.761	1.051
983.00	1.330	1.187	2.948	1.331
984.00	1.530	1.429	4.377	1.533
985.00	1.720	1.624	6.001	1.724
986.00	1.920	1.819	7.820	1.925

Device	Routing	Invert	Outlet Devices
#1	Primary	984.30'	**165.0 deg x 1.70' rise Sharp-Crested Vee/Trap Weir** Cv= 2.47 (C= 3.09)
#2	Discarded	978.00'	**0.460 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.81 cfs @ 15.01 hrs HW=985.11' (Free Discharge)
└─**2=Exfiltration** (Exfiltration Controls 0.81 cfs)

Primary OutFlow Max=11.04 cfs @ 15.01 hrs HW=985.11' (Free Discharge)
└─**1=Sharp-Crested Vee/Trap Weir** (Weir Controls 11.04 cfs @ 2.22 fps)

Pond 21P: Existing Powerline Depression SMA-6 (Design Point 1)



Summary for Pond 22P: SMA3 E (Design Point 6)

[93] Warning: Storage range exceeded by 0.09'

Inflow Area = 1.060 ac, 0.00% Impervious, Inflow Depth = 1.61" for 10-YR event
Inflow = 1.88 cfs @ 12.10 hrs, Volume= 0.143 af
Outflow = 0.35 cfs @ 12.19 hrs, Volume= 0.068 af, Atten= 81%, Lag= 5.8 min
Discarded = 0.03 cfs @ 12.19 hrs, Volume= 0.062 af
Primary = 0.33 cfs @ 12.19 hrs, Volume= 0.006 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 1,025.44' @ 12.19 hrs Surf.Area= 0.056 ac Storage= 0.035 af

Plug-Flow detention time= 825.3 min calculated for 0.068 af (48% of inflow)
Center-of-Mass det. time= 690.6 min (1,556.2 - 865.7)

Volume	Invert	Avail.Storage	Storage Description
#1	1,024.50'	0.035 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

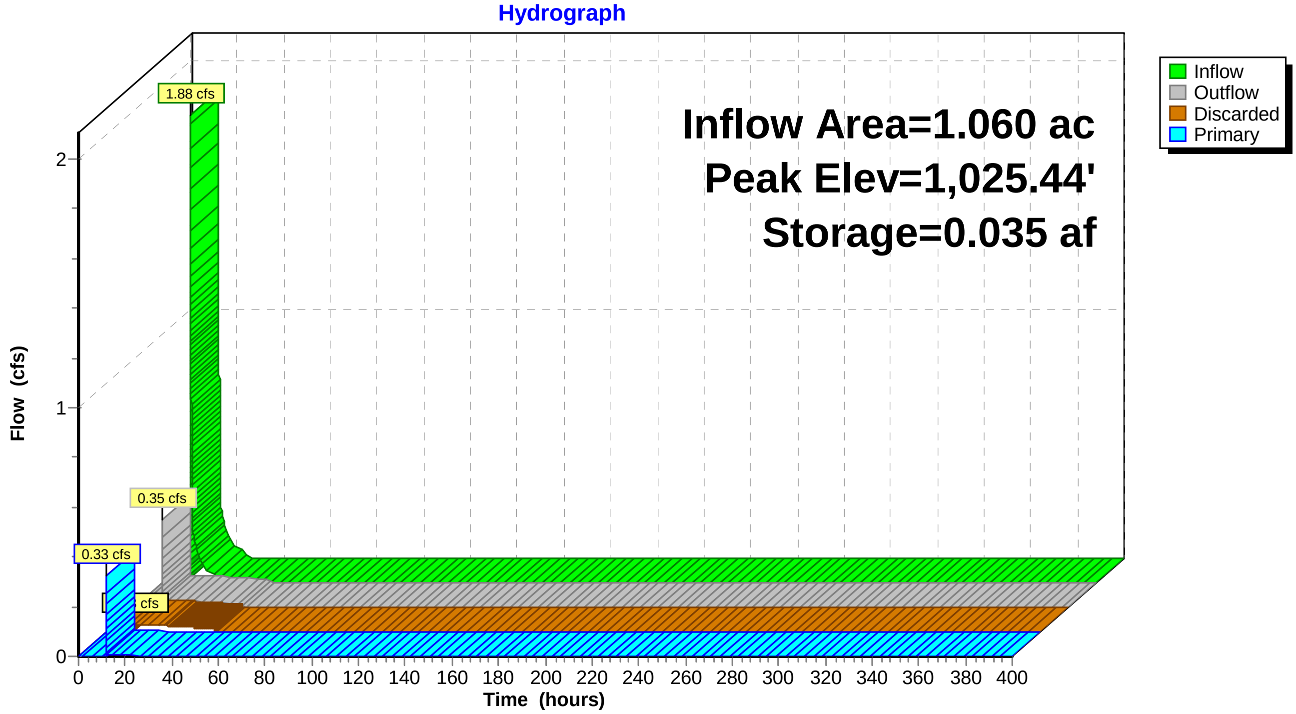
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,024.50	0.026	0.000	0.000
1,025.35	0.056	0.035	0.035

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,024.50'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,025.33'	**177.0 deg x 0.20' rise Sharp-Crested Vee/Trap Weir** Cv= 2.46 (C= 3.08)

Discarded OutFlow Max=0.03 cfs @ 12.19 hrs HW=1,025.43' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.03 cfs)

Primary OutFlow Max=0.28 cfs @ 12.19 hrs HW=1,025.43' (Free Discharge)
└─**2=Sharp-Crested Vee/Trap Weir** (Weir Controls 0.28 cfs @ 0.77 fps)

Pond 22P: SMA3 E (Design Point 6)



Summary for Pond 23P: SMA4 E (Design Point 7)

Inflow Area = 10.990 ac, 0.00% Impervious, Inflow Depth = 0.44" for 10-YR event
Inflow = 1.94 cfs @ 12.42 hrs, Volume= 0.398 af
Outflow = 1.50 cfs @ 12.58 hrs, Volume= 0.398 af, Atten= 22%, Lag= 10.1 min
Discarded = 0.02 cfs @ 12.58 hrs, Volume= 0.036 af
Primary = 1.48 cfs @ 12.58 hrs, Volume= 0.363 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 989.56' @ 12.58 hrs Surf.Area= 0.047 ac Storage= 0.039 af

Plug-Flow detention time= 69.4 min calculated for 0.398 af (100% of inflow)
Center-of-Mass det. time= 69.4 min (1,026.4 - 957.0)

Volume	Invert	Avail.Storage	Storage Description
#1	988.20'	0.247 af	**Custom Stage Data (Conic)** Listed below (Recalc)

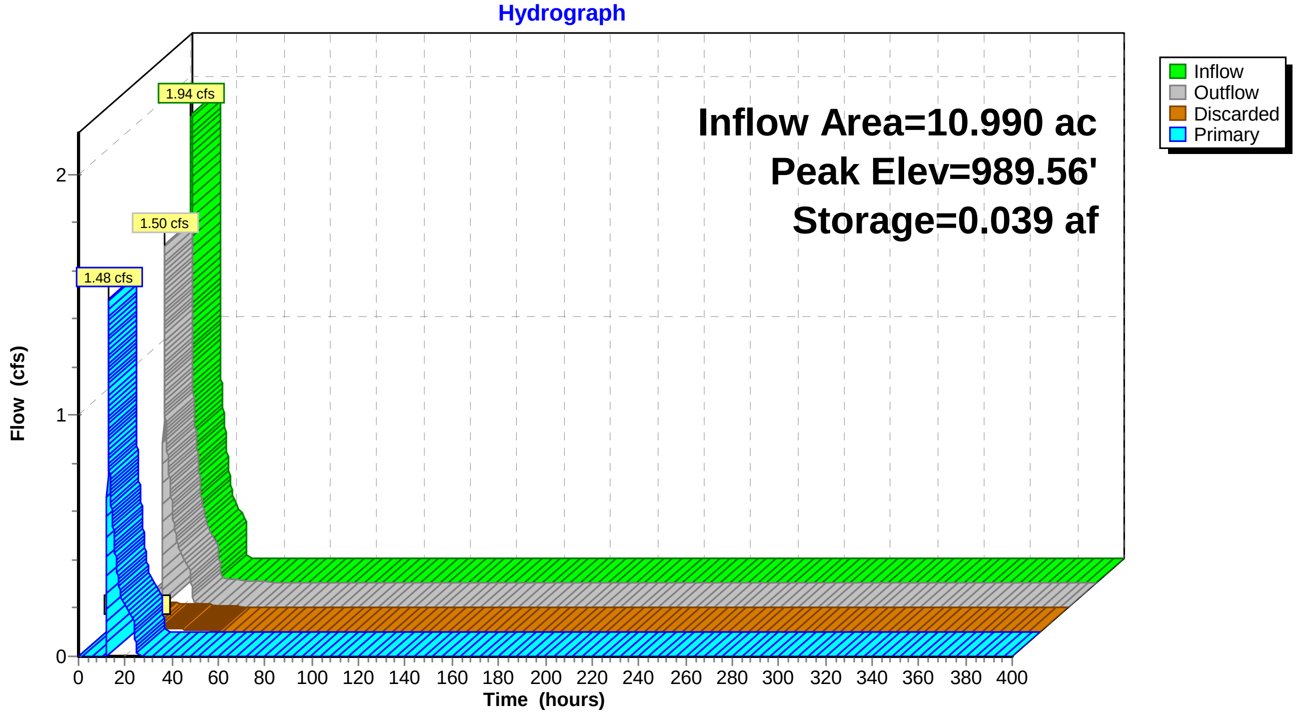
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
988.20	0.007	0.000	0.000	0.007
988.50	0.018	0.004	0.004	0.018
989.00	0.034	0.013	0.016	0.034
992.00	0.130	0.230	0.247	0.131

Device	Routing	Invert	Outlet Devices
#0	Primary	992.00'	**Automatic Storage Overflow** (Discharged without head)
#1	Discarded	988.20'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	988.91'	**121.0 deg x 4.00' rise Sharp-Crested Vee/Trap Weir** Cv= 2.48 (C= 3.10)

Discarded OutFlow Max=0.02 cfs @ 12.58 hrs HW=989.56' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=1.48 cfs @ 12.58 hrs HW=989.56' (Free Discharge)
└─**2=Sharp-Crested Vee/Trap Weir** (Weir Controls 1.48 cfs @ 2.00 fps)

Pond 23P: SMA4 E (Design Point 7)



Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1A E: 1A E Runoff Area=38.000 ac 0.00% Impervious Runoff Depth=4.44"
Flow Length=3,236' Tc=34.2 min CN=62 Runoff=104.84 cfs 14.072 af

Subcatchment 1B E: 1B-E Runoff Area=2.990 ac 0.00% Impervious Runoff Depth=2.00"
Flow Length=329' Tc=15.1 min CN=42 Runoff=4.41 cfs 0.499 af

Subcatchment 2A E: 2A E Runoff Area=48.620 ac 0.00% Impervious Runoff Depth=4.44"
Flow Length=4,073' Tc=34.0 min CN=62 Runoff=134.37 cfs 18.005 af

Subcatchment 2B E: 2B E Runoff Area=5.760 ac 0.00% Impervious Runoff Depth=1.77"
Flow Length=248' Tc=6.8 min CN=40 Runoff=9.24 cfs 0.851 af

Subcatchment 3 E: 3 E Runoff Area=24.910 ac 0.00% Impervious Runoff Depth=3.95"
Flow Length=3,460' Tc=32.8 min CN=58 Runoff=61.56 cfs 8.192 af

Subcatchment 4 E: 4 E (Design Point 3) Runoff Area=1.590 ac 0.00% Impervious Runoff Depth=2.24"
Flow Length=362' Tc=6.6 min CN=44 Runoff=3.59 cfs 0.297 af

Subcatchment 5 E: 5 E (Design Point 4) Runoff Area=1.830 ac 0.00% Impervious Runoff Depth=3.70"
Flow Length=270' Tc=6.7 min CN=56 Runoff=7.60 cfs 0.564 af

Subcatchment 6 E: 6 E Runoff Area=4.330 ac 0.00% Impervious Runoff Depth=3.33"
Flow Length=474' Tc=17.6 min CN=53 Runoff=11.55 cfs 1.201 af

Subcatchment 7 E: 7 E Runoff Area=10.990 ac 0.00% Impervious Runoff Depth=2.12"
Flow Length=1,023' Tc=11.8 min CN=43 Runoff=19.26 cfs 1.943 af

Subcatchment 8 E: 8 E Runoff Area=1.060 ac 0.00% Impervious Runoff Depth=4.44"
Tc=6.0 min CN=62 Runoff=5.51 cfs 0.393 af

Subcatchment 9 E: 9 E (Design Point 8) Runoff Area=0.970 ac 0.00% Impervious Runoff Depth=5.81"
Tc=6.0 min CN=73 Runoff=6.58 cfs 0.470 af

Subcatchment 10 E: 10 E Runoff Area=15.300 ac 0.00% Impervious Runoff Depth=4.94"
Flow Length=885' Tc=8.3 min CN=66 Runoff=81.86 cfs 6.302 af

Reach 4R: Outfall Channel (Design Avg. Flow Depth=0.50' Max Vel=7.50 fps Inflow=17.43 cfs 5.385 af
n=0.022 L=5.0' S=0.0480 '/' Capacity=17.43 cfs Outflow=17.43 cfs 5.374 af

Reach 21R: Wetland Ditch Avg. Flow Depth=2.90' Max Vel=8.69 fps Inflow=242.10 cfs 32.092 af
n=0.035 L=49.0' S=0.0494 '/' Capacity=48.15 cfs Outflow=242.05 cfs 32.092 af

Reach 22R: Pool Ditch Avg. Flow Depth=0.78' Max Vel=5.03 fps Inflow=111.48 cfs 14.087 af
n=0.035 L=202.1' S=0.0247 '/' Capacity=166.36 cfs Outflow=107.78 cfs 14.087 af

Pond 1P: Existing Pond/SMA5 E Peak Elev=951.13' Storage=7.729 af Inflow=81.86 cfs 6.302 af
Discarded=0.70 cfs 6.960 af Primary=17.43 cfs 5.385 af Outflow=18.13 cfs 12.345 af

Pond 2P: SMA1 (Design Point 2) Peak Elev=1,001.83' Storage=6.087 af Inflow=61.56 cfs 8.192 af
Discarded=0.44 cfs 6.541 af Primary=7.86 cfs 2.997 af Outflow=8.30 cfs 9.537 af

Pond 19P: SMA-2 E (Design Point 5) Peak Elev=1,027.45' Storage=0.086 af Inflow=11.55 cfs 1.201 af
Discarded=0.07 cfs 0.161 af Primary=9.25 cfs 0.347 af Outflow=9.32 cfs 0.508 af

Pond 20P: Pool Existing Peak Elev=993.24' Storage=0.945 af Inflow=107.84 cfs 14.572 af
Outflow=111.48 cfs 14.087 af

Pond 21P: Existing Powerline Peak Elev=987.91' Storage=7.820 af Inflow=245.69 cfs 35.940 af
Discarded=0.89 cfs 6.265 af Primary=159.64 cfs 26.045 af Outflow=160.54 cfs 32.310 af

Pond 22P: SMA3 E (Design Point 6) Peak Elev=1,026.06' Storage=0.035 af Inflow=5.51 cfs 0.393 af
Discarded=0.03 cfs 0.065 af Primary=5.43 cfs 0.276 af Outflow=5.46 cfs 0.341 af

Pond 23P: SMA4 E (Design Point 7) Peak Elev=990.68' Storage=0.110 af Inflow=19.26 cfs 1.943 af
Discarded=0.04 cfs 0.040 af Primary=18.26 cfs 1.903 af Outflow=18.30 cfs 1.943 af

Total Runoff Area = 156.350 ac Runoff Volume = 52.790 af Average Runoff Depth = 4.05"
100.00% Pervious = 156.350 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 1A E: 1A E

[47] Hint: Peak is 161% of capacity of segment #5

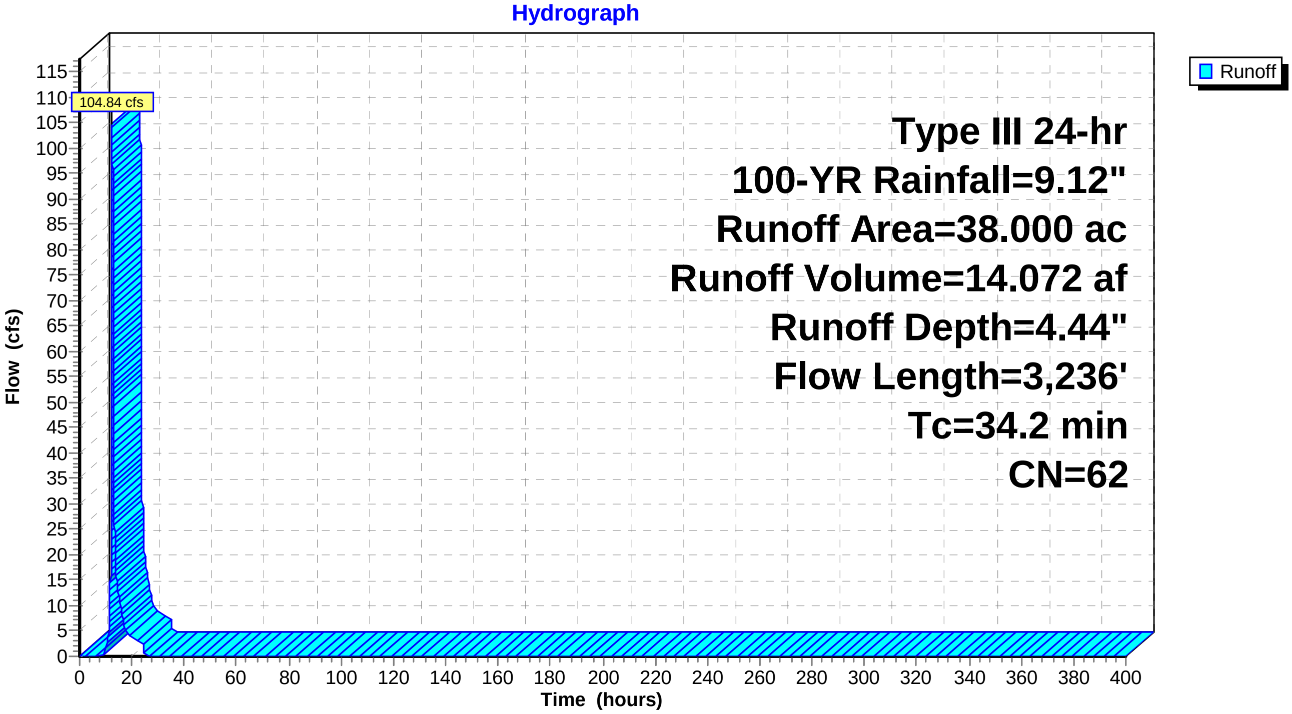
Runoff = 104.84 cfs @ 12.50 hrs, Volume= 14.072 af, Depth= 4.44"
Routed to Pond 20P : Pool Existing

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	38.000	62	
	38.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	50	0.0400	0.06		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.7	228	0.0790	1.41		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
7.9	1,488	0.3970	3.15		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
8.1	1,050	0.1850	2.15		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.6	420	0.0570	10.83	64.98	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
34.2	3,236	Total			

Subcatchment 1A E: 1A E



Summary for Subcatchment 1B E: 1B-E

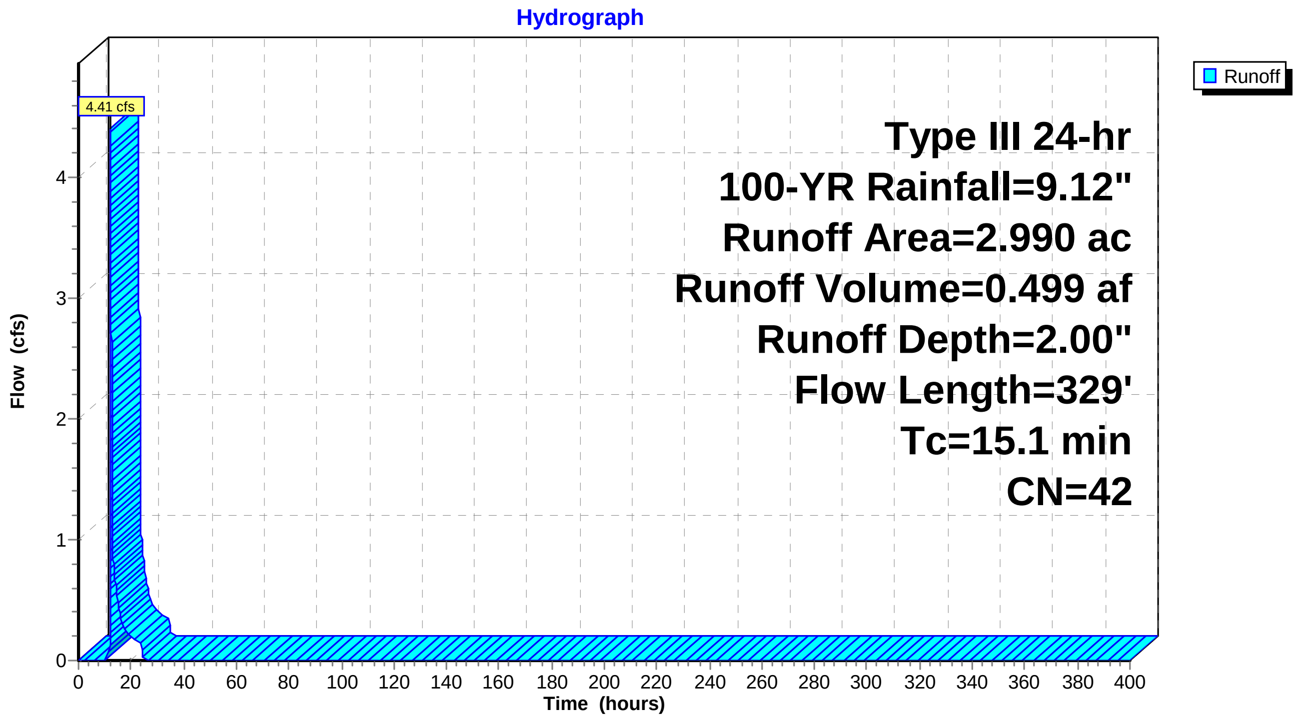
Runoff = 4.41 cfs @ 12.24 hrs, Volume= 0.499 af, Depth= 2.00"
Routed to Pond 20P : Pool Existing

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	2.990	42	From CN Spreadsheet
	2.990		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.6	50	0.0750	0.07		**Sheet Flow, Sheet** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.9	159	0.0330	0.91		**Shallow Concentrated Flow, SCF-1** Woodland Kv= 5.0 fps
0.1	58	0.1720	18.81	112.88	**Channel Flow, CF-1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.5	62	0.1510	1.94		**Shallow Concentrated Flow, SCF-2** Woodland Kv= 5.0 fps
15.1	329	Total			

Subcatchment 1B E: 1B-E



Summary for Subcatchment 2A E: 2A E

[47] Hint: Peak is 103% of capacity of segment #6
[47] Hint: Peak is 225% of capacity of segment #7
[47] Hint: Peak is 225% of capacity of segment #8
[47] Hint: Peak is 225% of capacity of segment #9

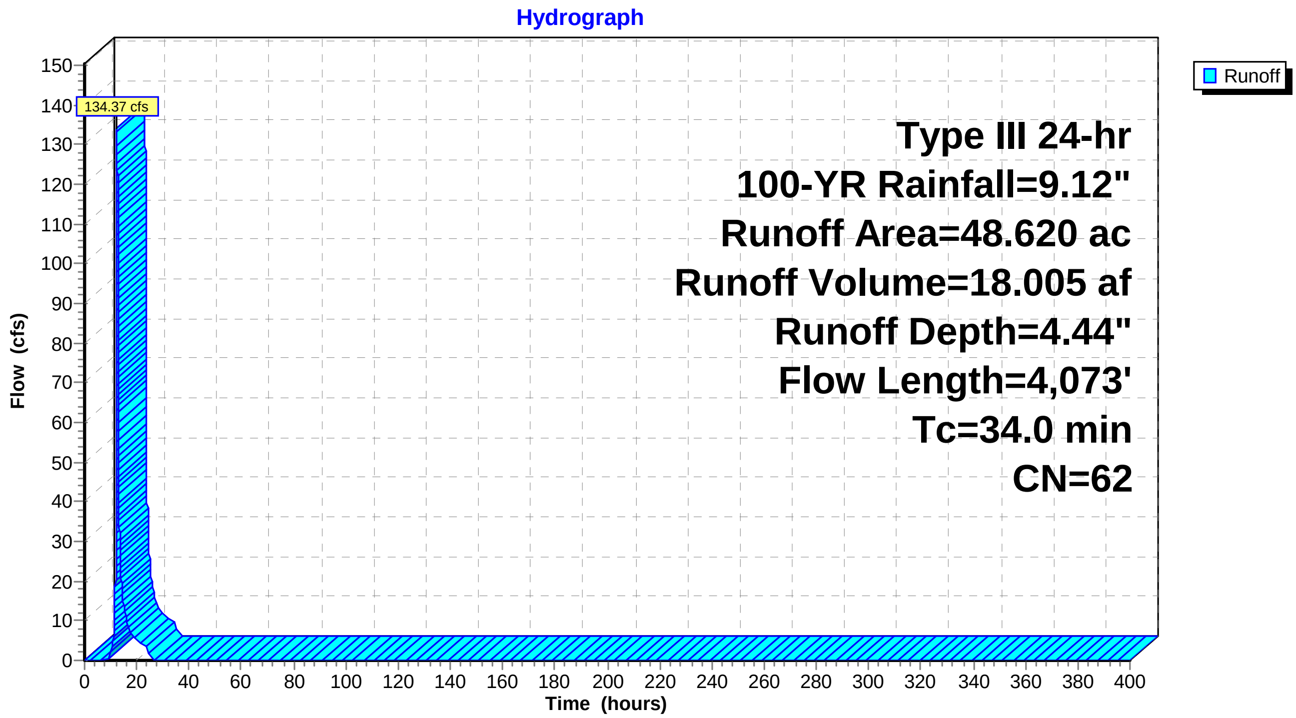
Runoff = 134.37 cfs @ 12.50 hrs, Volume= 18.005 af, Depth= 4.44"
Routed to Reach 21R : Wetland Ditch

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	48.620	62	From CN Spreadsheet
	48.620		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	50	0.0400	0.06		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.3	207	0.0870	1.47		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
2.4	337	0.2140	2.31		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
2.2	464	0.4830	3.47		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.4	592	0.2570	23.00	137.98	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
1.1	1,448	0.2280	21.66	129.96	**Channel Flow, CF 2** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.3	152	0.0480	9.94	59.63	**Channel Flow, CF-5** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.2	138	0.0480	9.94	59.63	**Channel Flow, CF-3** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.2	148	0.0480	9.94	59.63	**Channel Flow, CF-4** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
10.0	537	0.0320	0.89		**Shallow Concentrated Flow, SCF-4** Woodland Kv= 5.0 fps
34.0	4,073	Total			

Subcatchment 2A E: 2A E



Summary for Subcatchment 2B E: 2B E

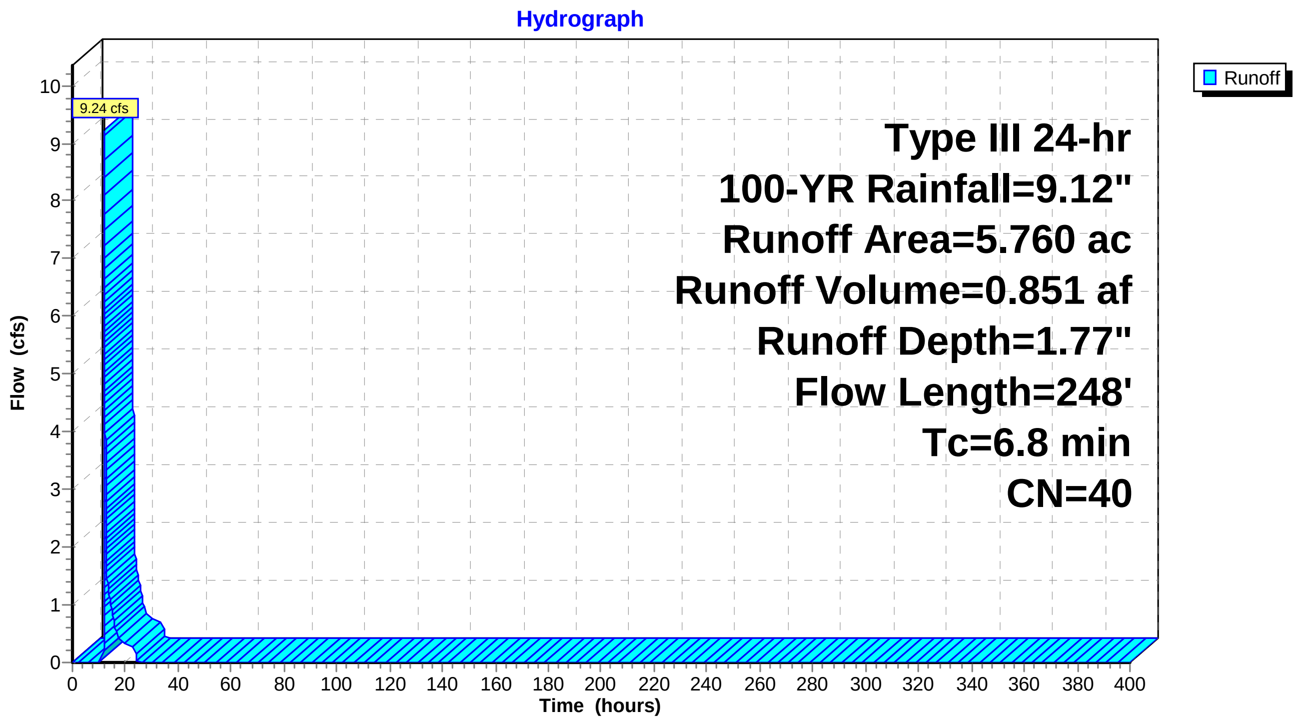
Runoff = 9.24 cfs @ 12.12 hrs, Volume= 0.851 af, Depth= 1.77"
Routed to Pond 21P : Existing Powerline Depression SMA-6 (Design Point 1)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	5.760	40	
	5.760		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	50	0.1410	0.16		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.84"
1.6	198	0.1720	2.07		**Shallow Concentrated Flow, SCF-1** Woodland Kv= 5.0 fps
6.8	248	Total			

Subcatchment 2B E: 2B E



Summary for Subcatchment 3 E: 3 E

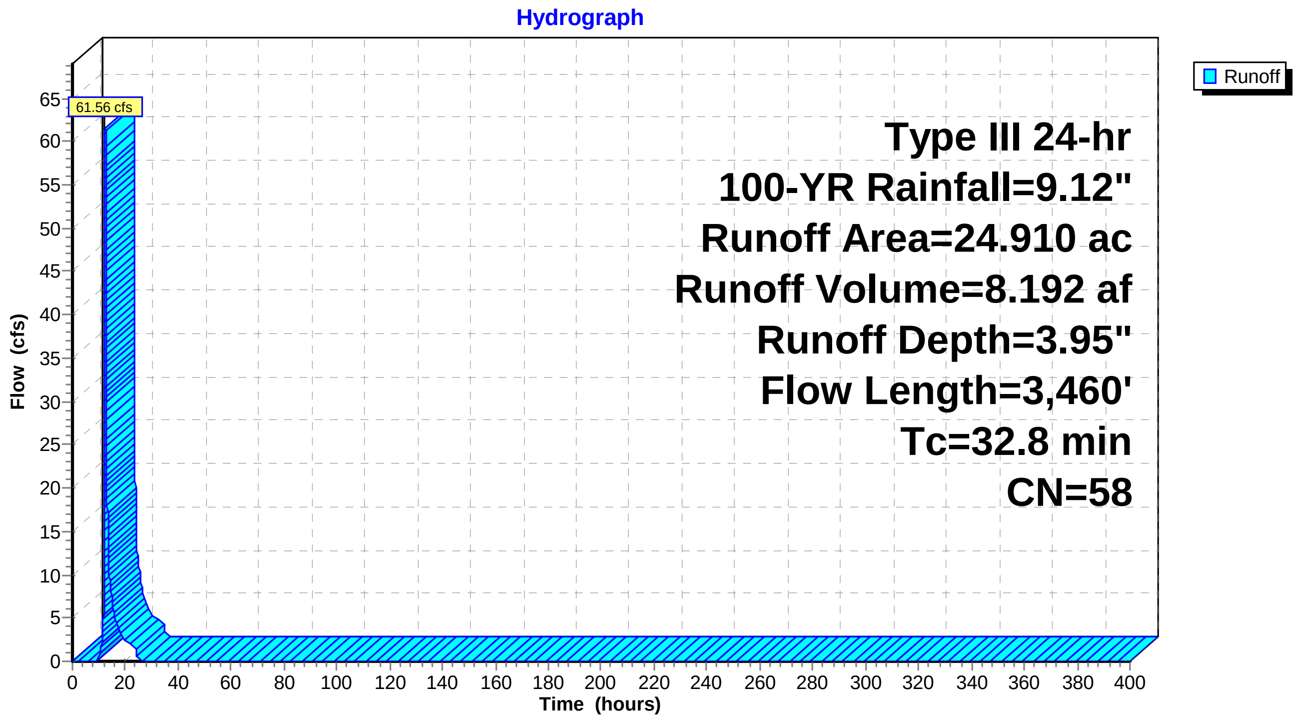
Runoff = 61.56 cfs @ 12.47 hrs, Volume= 8.192 af, Depth= 3.95"
Routed to Pond 2P : SMA1 (Design Point 2)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	24.910	58	
	24.910		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.6	50	0.1200	0.09		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
5.9	657	0.1390	1.86		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
6.7	1,207	0.3630	3.01		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
10.1	1,240	0.1690	2.06		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.5	306	0.0590	11.02	66.11	**Channel Flow, CF** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
32.8	3,460	Total			

Subcatchment 3 E: 3 E



Summary for Subcatchment 4 E: 4 E (Design Point 3)

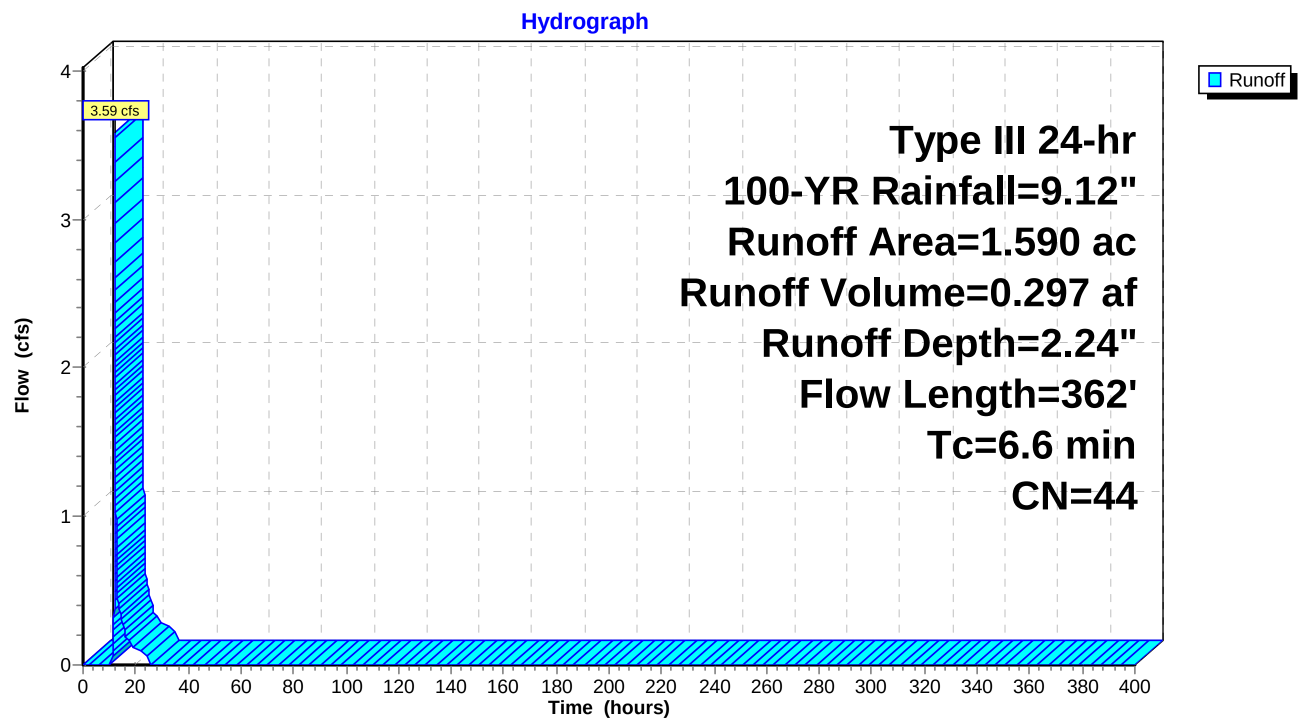
Runoff = 3.59 cfs @ 12.11 hrs, Volume= 0.297 af, Depth= 2.24"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	1.590	44	
	1.590		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.9	50	0.1600	0.17		**Sheet Flow, SF** Woods: Light underbrush n= 0.400 P2= 3.84"
1.3	126	0.1110	1.67		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
0.4	186	0.0320	8.11	48.69	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
6.6	362	Total			

Subcatchment 4 E: 4 E (Design Point 3)



Summary for Subcatchment 5 E: 5 E (Design Point 4)

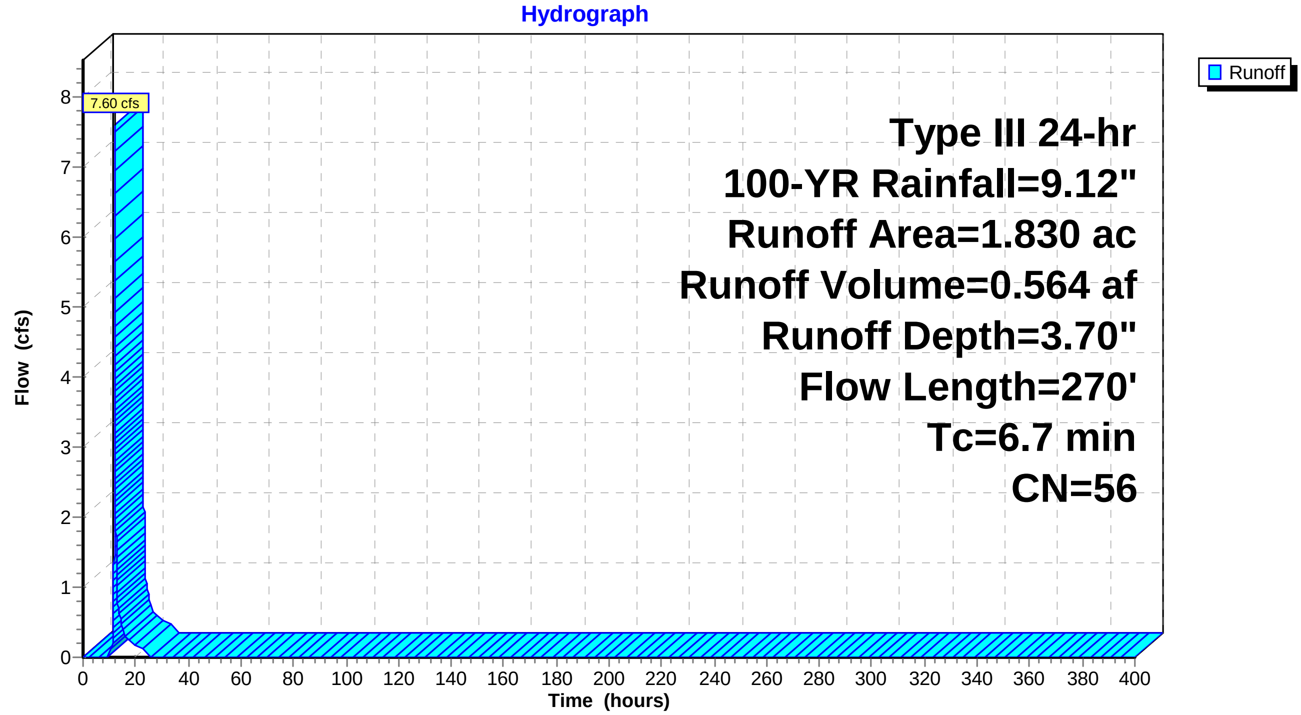
Runoff = 7.60 cfs @ 12.10 hrs, Volume= 0.564 af, Depth= 3.70"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	1.830	56	
	1.830		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	50	0.1200	0.15		**Sheet Flow, SF** Woods: Light underbrush n= 0.400 P2= 3.84"
0.8	95	0.1550	1.97		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
0.4	125	0.0120	4.97	29.81	**Channel Flow,** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
6.7	270	Total			

Subcatchment 5 E: 5 E (Design Point 4)



Summary for Subcatchment 6 E: 6 E

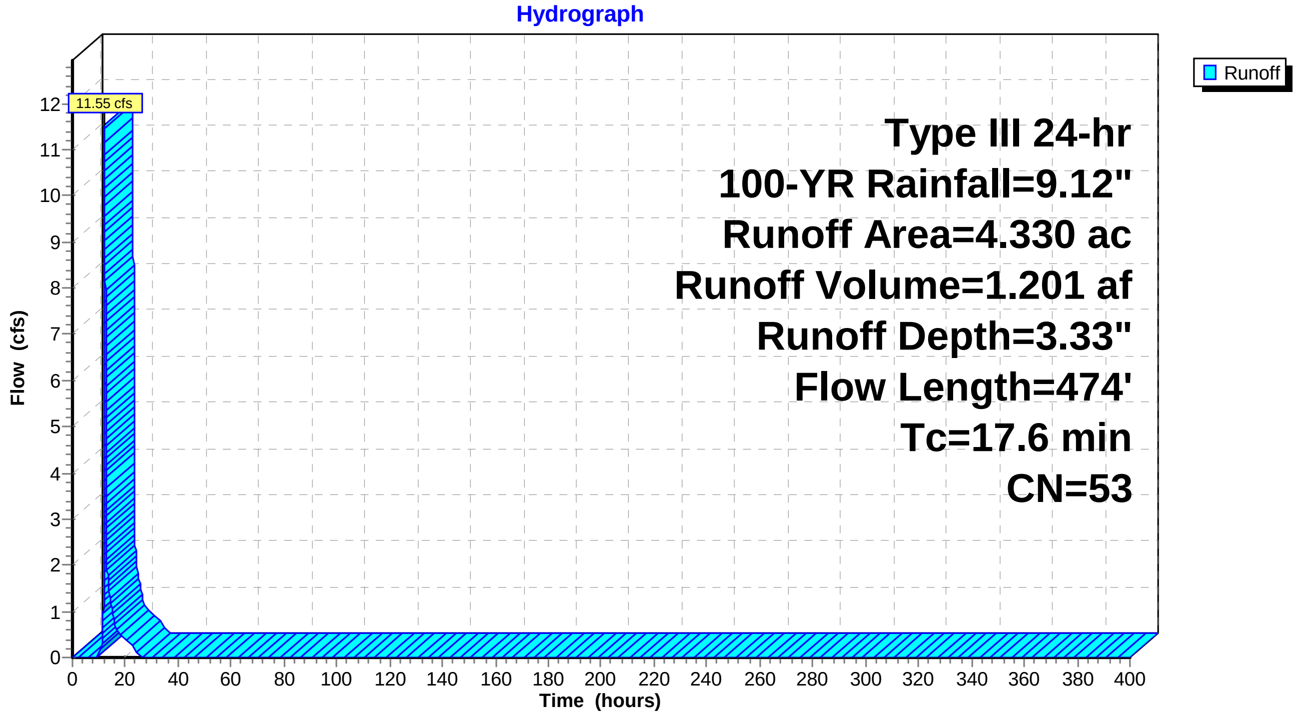
Runoff = 11.55 cfs @ 12.26 hrs, Volume= 1.201 af, Depth= 3.33"
Routed to Pond 19P : SMA-2 E (Design Point 5)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	4.330	53	
	4.330		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.3	50	0.0200	0.07		**Sheet Flow, SF** Woods: Light underbrush n= 0.400 P2= 3.84"
6.3	424	0.0500	1.12		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
17.6	474	Total			

Subcatchment 6 E: 6 E



Summary for Subcatchment 7 E: 7 E

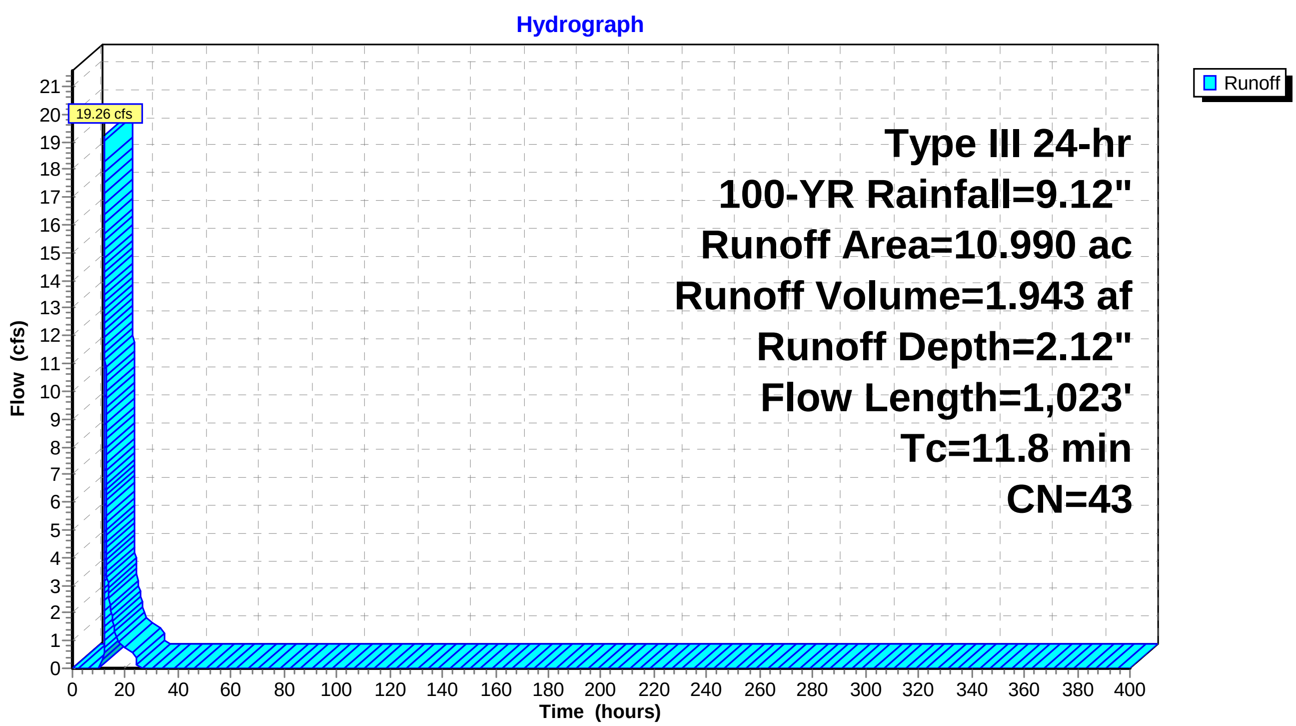
Runoff = 19.26 cfs @ 12.18 hrs, Volume= 1.943 af, Depth= 2.12"
Routed to Pond 23P : SMA4 E (Design Point 7)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	10.990	43	
	10.990		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.5	50	0.0200	0.11		**Sheet Flow, SF** Grass: Dense n= 0.240 P2= 3.84"
3.4	320	0.0500	1.57		**Shallow Concentrated Flow, SCF 1** Short Grass Pasture Kv= 7.0 fps
0.9	653	0.0640	11.48	68.85	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
11.8	1,023	Total			

Subcatchment 7 E: 7 E



Summary for Subcatchment 8 E: 8 E

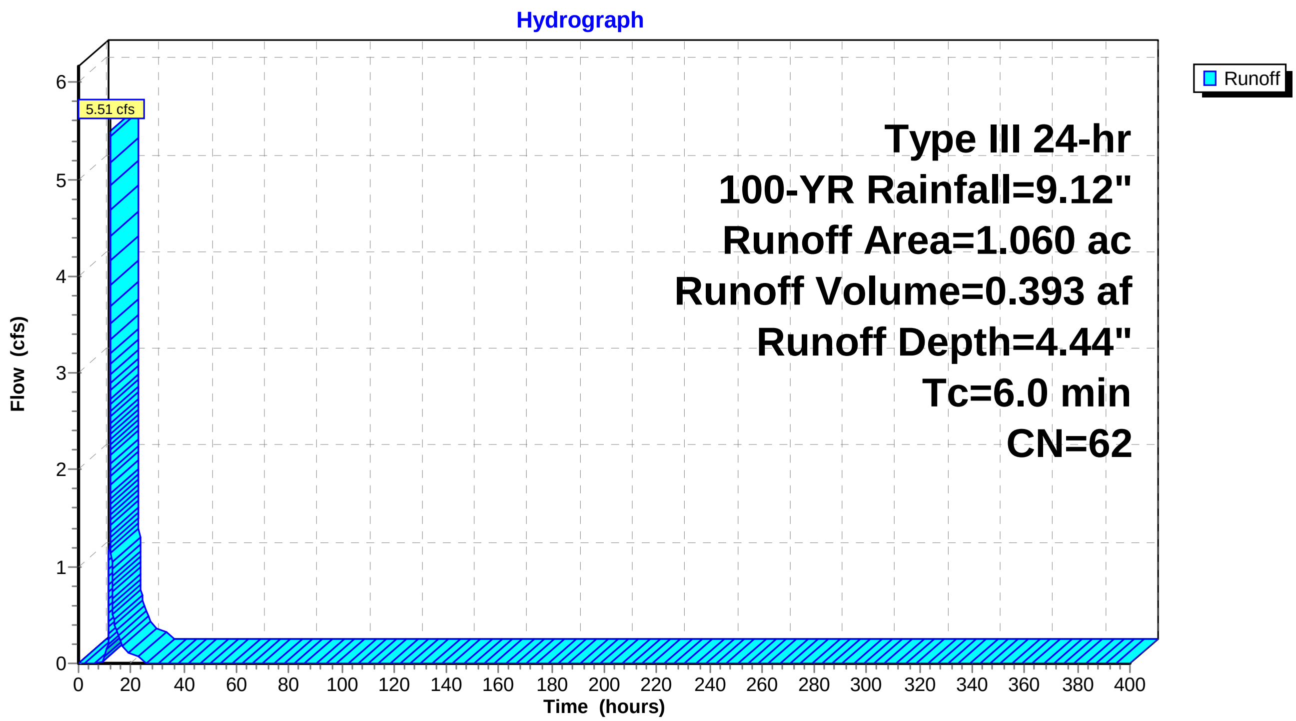
Runoff = 5.51 cfs @ 12.09 hrs, Volume= 0.393 af, Depth= 4.44"
Routed to Pond 22P : SMA3 E (Design Point 6)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	1.060	62	
	1.060		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment 8 E: 8 E



Summary for Subcatchment 9 E: 9 E (Design Point 8)

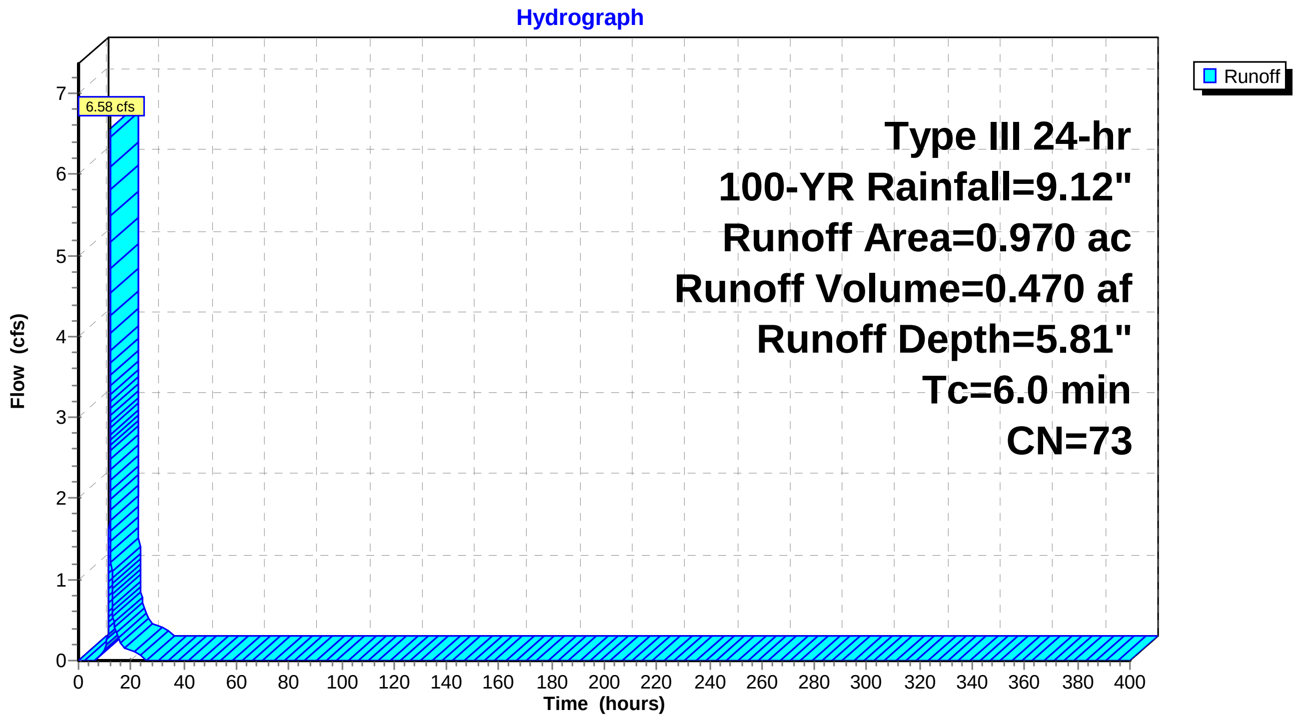
Runoff = 6.58 cfs @ 12.09 hrs, Volume= 0.470 af, Depth= 5.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	0.970	73	
	0.970		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, TR55 Min (calculation TC less than 6 minutes)**

Subcatchment 9 E: 9 E (Design Point 8)



Summary for Subcatchment 10 E: 10 E

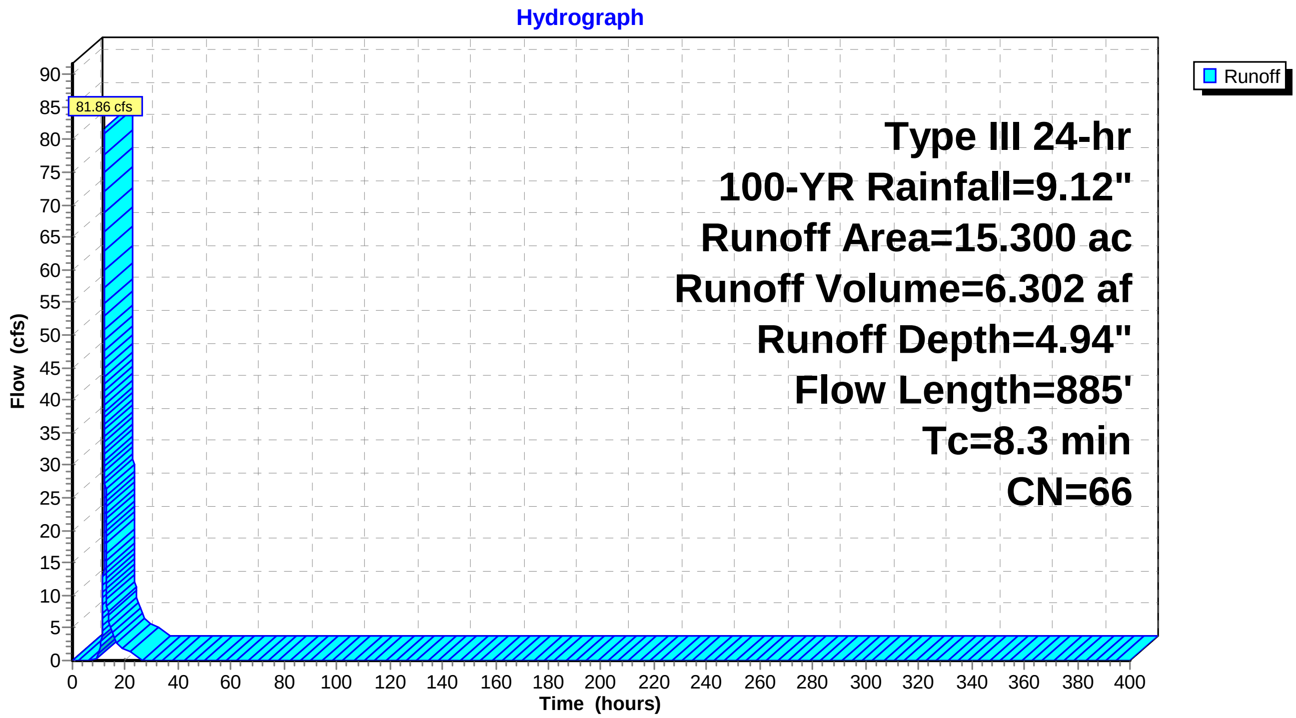
Runoff = 81.86 cfs @ 12.12 hrs, Volume= 6.302 af, Depth= 4.94"
Routed to Pond 1P : Existing Pond/SMA5 E

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	15.300	66	
	15.300		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	50	0.0440	0.15		**Sheet Flow, SF** Grass: Dense n= 0.240 P2= 3.84"
1.3	302	0.0590	3.91		**Shallow Concentrated Flow, SCF 1** Unpaved Kv= 16.1 fps
0.1	180	0.2860	24.26	145.55	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
1.4	353	0.0640	4.07		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
8.3	885	Total			

Subcatchment 10 E: 10 E



Summary for Reach 4R: Outfall Channel (Design Point 9)

[85] Warning: Oscillations may require smaller dt or Finer Routing (severity=1)

Inflow Area = 15.300 ac, 0.00% Impervious, Inflow Depth = 4.22" for 100-YR event
Inflow = 17.43 cfs @ 12.04 hrs, Volume= 5.385 af
Outflow = 17.43 cfs @ 13.30 hrs, Volume= 5.374 af, Atten= 0%, Lag= 75.6 min

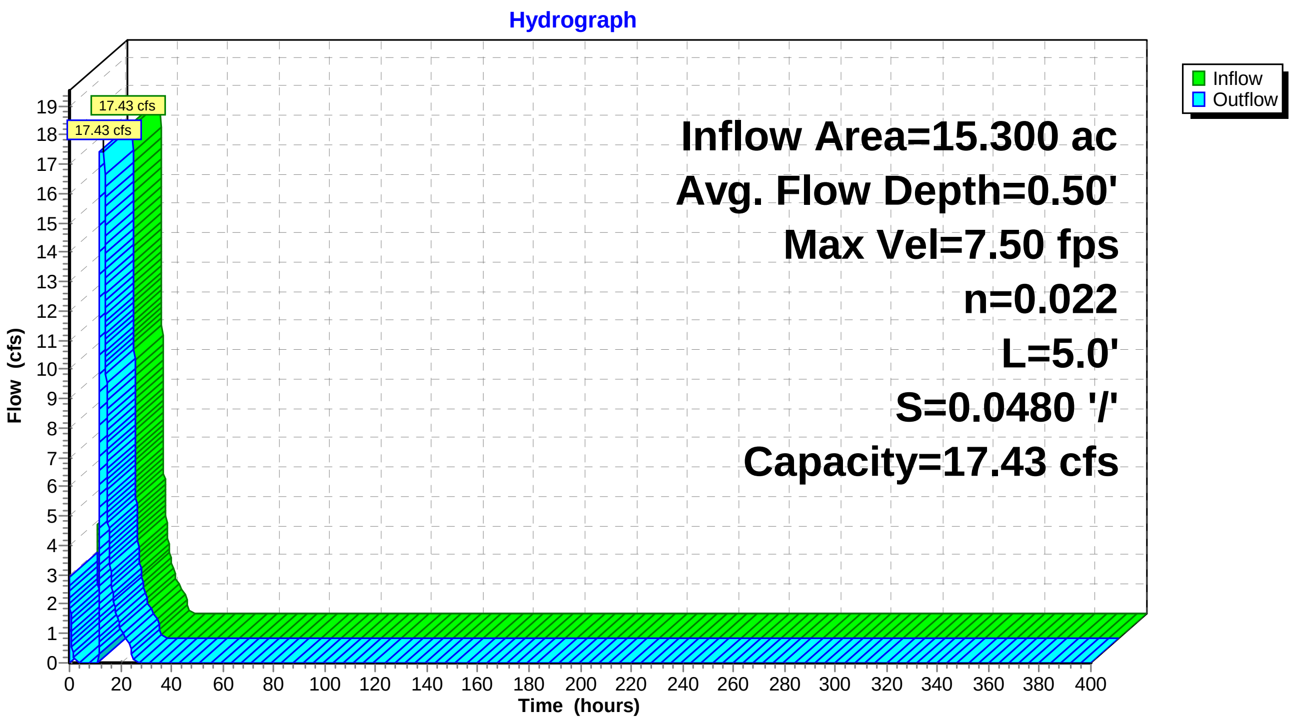
Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 2
Max. Velocity= 7.50 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 3.82 fps, Avg. Travel Time= 0.0 min

Peak Storage= 12 cf @ 13.30 hrs
Average Depth at Peak Storage= 0.50' , Surface Width= 6.30'
Bank-Full Depth= 0.50' Flow Area= 2.3 sf, Capacity= 17.43 cfs

3.00' x 0.50' deep channel, n= 0.022 Earth, clean & straight
Side Slope Z-value= 3.3 '/' Top Width= 6.30'
Length= 5.0' Slope= 0.0480 '/'
Inlet Invert= 949.68', Outlet Invert= 949.44'

‡

Reach 4R: Outfall Channel (Design Point 9)



Summary for Reach 21R: Wetland Ditch

[91] Warning: Storage range exceeded by 1.90'
[55] Hint: Peak inflow is 503% of Manning's capacity
[61] Hint: Exceeded Reach 22R outlet invert by 0.04' @ 12.50 hrs

Inflow Area = 89.610 ac, 0.00% Impervious, Inflow Depth = 4.30" for 100-YR event
Inflow = 242.10 cfs @ 12.50 hrs, Volume= 32.092 af
Outflow = 242.05 cfs @ 12.50 hrs, Volume= 32.092 af, Atten= 0%, Lag= 0.1 min
Routed to Pond 21P : Existing Powerline Depression SMA-6 (Design Point 1)

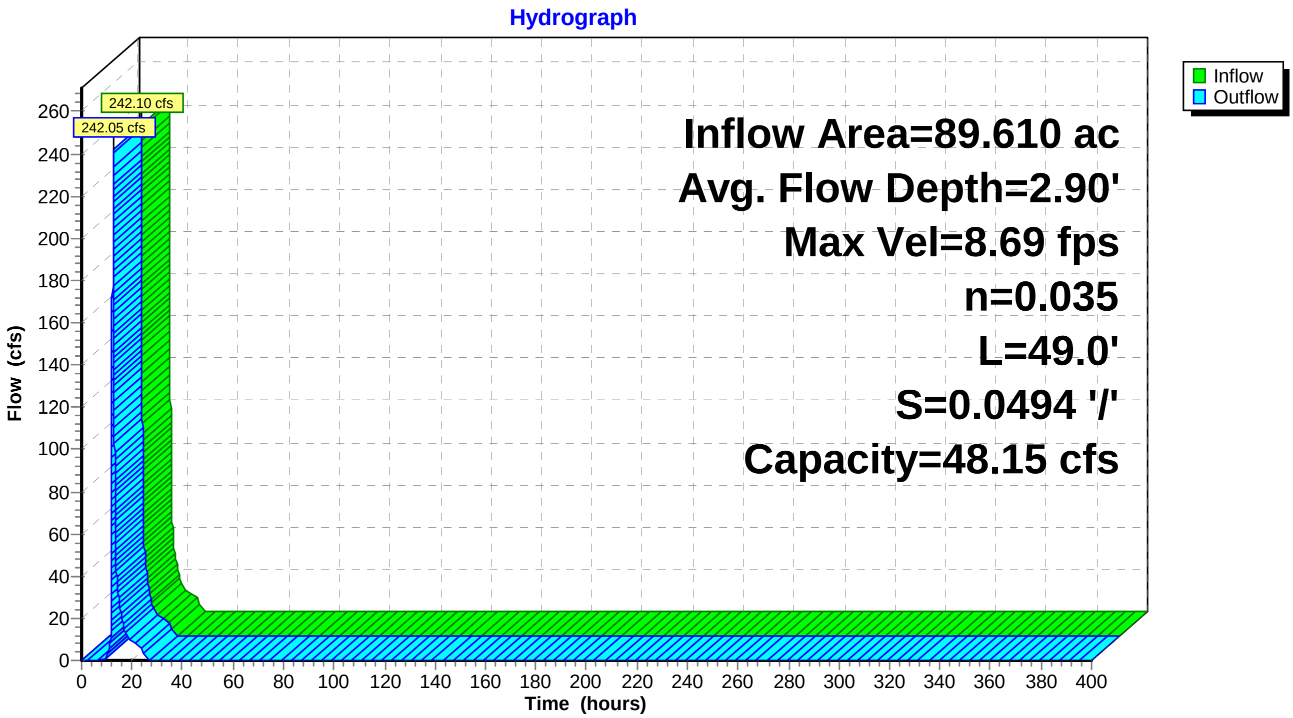
Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Max. Velocity= 8.69 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 3.51 fps, Avg. Travel Time= 0.2 min

Peak Storage= 1,365 cf @ 12.50 hrs
Average Depth at Peak Storage= 2.90' , Surface Width= 26.22'
Bank-Full Depth= 1.00' Flow Area= 7.0 sf, Capacity= 48.15 cfs

3.00' x 1.00' deep channel, n= 0.035 Earth, dense weeds
Side Slope Z-value= 4.0 '/' Top Width= 11.00'
Length= 49.0' Slope= 0.0494 '/'
Inlet Invert= 984.59', Outlet Invert= 982.17'

‡

Reach 21R: Wetland Ditch



Summary for Reach 22R: Pool Ditch

Inflow Area = 40.990 ac, 0.00% Impervious, Inflow Depth = 4.12" for 100-YR event
Inflow = 111.48 cfs @ 12.50 hrs, Volume= 14.087 af
Outflow = 107.78 cfs @ 12.51 hrs, Volume= 14.087 af, Atten= 3%, Lag= 0.4 min
Routed to Reach 21R : Wetland Ditch

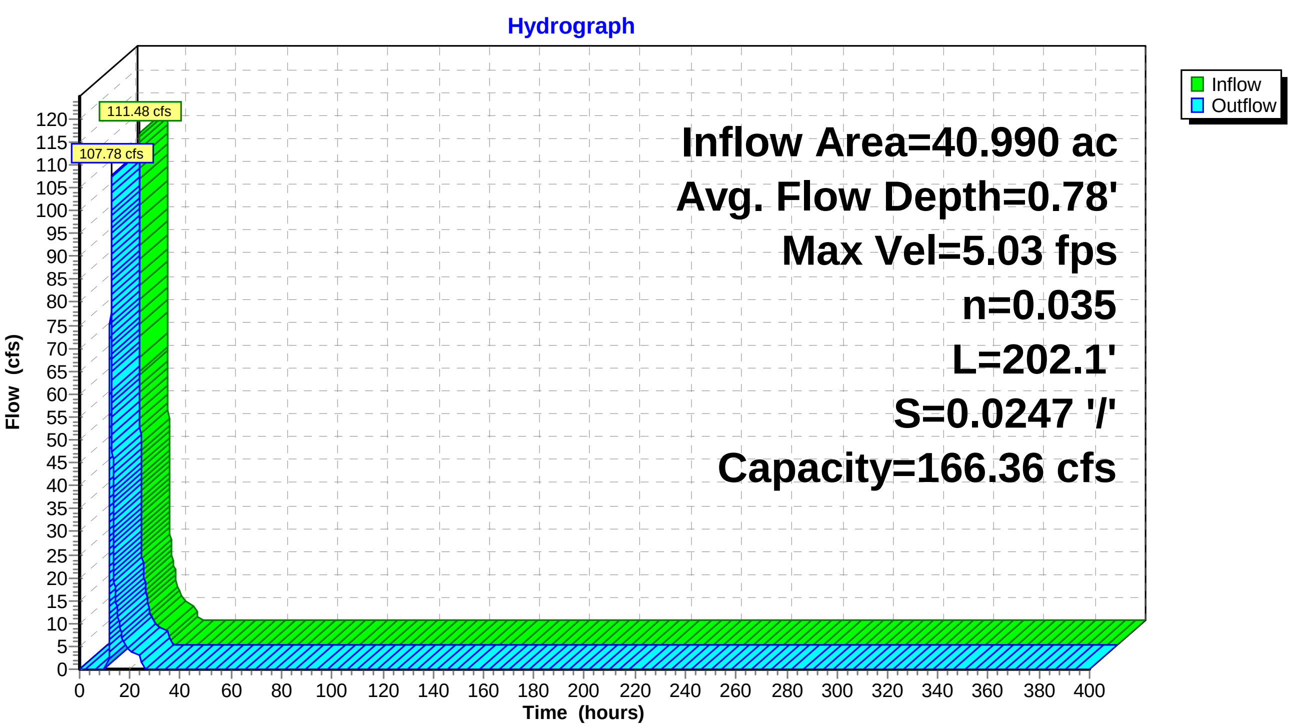
Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Max. Velocity= 5.03 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.44 fps, Avg. Travel Time= 2.3 min

Peak Storage= 4,333 cf @ 12.50 hrs
Average Depth at Peak Storage= 0.78' , Surface Width= 32.67'
Bank-Full Depth= 1.00' Flow Area= 28.8 sf, Capacity= 166.36 cfs

22.00' x 1.00' deep channel, n= 0.035
Side Slope Z-value= 6.8 '/' Top Width= 35.60'
Length= 202.1' Slope= 0.0247 '/'
Inlet Invert= 992.44', Outlet Invert= 987.45'

‡

Reach 22R: Pool Ditch



Summary for Pond 1P: Existing Pond/SMA5 E

[96] Warning: Channel Outlet #2 depth exceeded by 0.95'

Inflow Area = 15.300 ac, 0.00% Impervious, Inflow Depth = 4.94" for 100-YR event
Inflow = 81.86 cfs @ 12.12 hrs, Volume= 6.302 af
Outflow = 18.13 cfs @ 12.57 hrs, Volume= 12.345 af, Atten= 78%, Lag= 27.2 min
Discarded = 0.70 cfs @ 12.57 hrs, Volume= 6.960 af
Primary = 17.43 cfs @ 12.04 hrs, Volume= 5.385 af
Routed to Reach 4R : Outfall Channel (Design Point 9)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Starting Elev= 949.90' Surf.Area= 1.245 ac Storage= 6.042 af
Peak Elev= 951.13' @ 12.57 hrs Surf.Area= 1.493 ac Storage= 7.729 af (1.688 af above start)

Plug-Flow detention time= 5,441.5 min calculated for 6.301 af (100% of inflow)
Center-of-Mass det. time= 2,757.4 min (3,586.7 - 829.3)

Volume	Invert	Avail.Storage	Storage Description
#1	940.00'	9.105 af	**Custom Stage Data (Conic)** Listed below (Recalc)

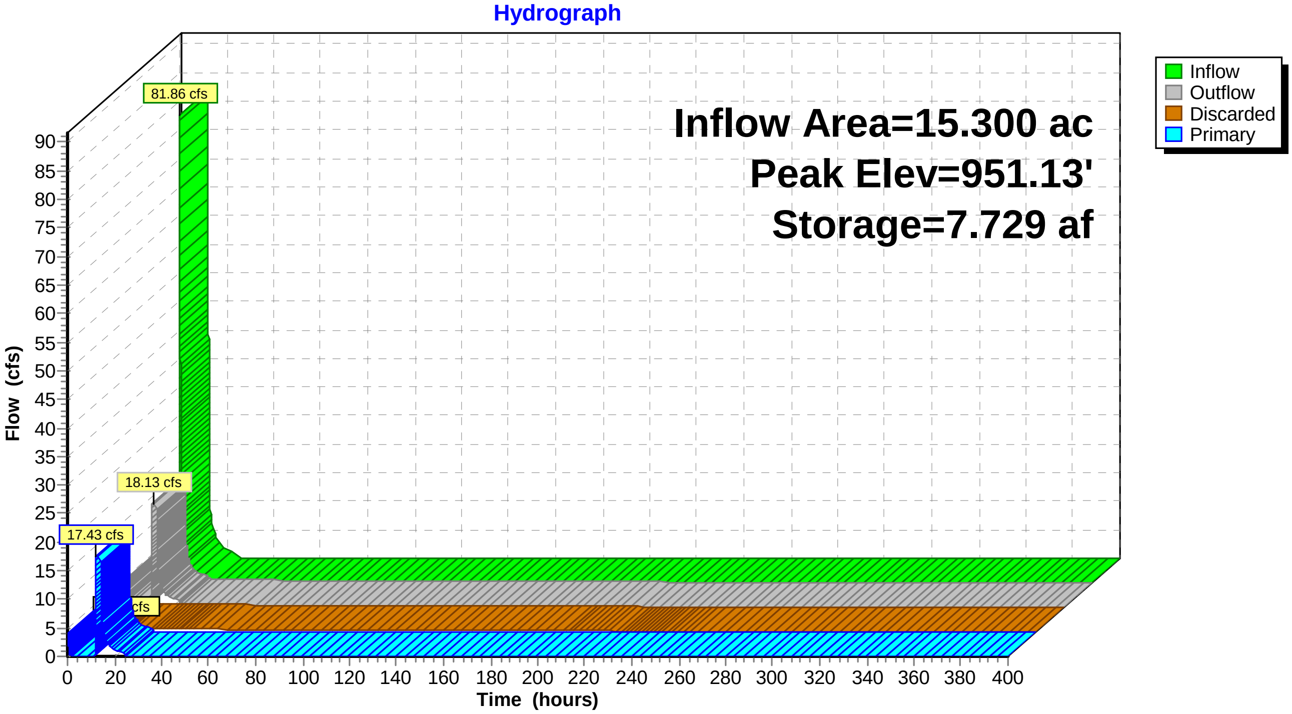
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
940.00	0.005	0.000	0.000	0.005
941.00	0.085	0.037	0.037	0.085
942.00	0.297	0.180	0.217	0.297
943.00	0.453	0.372	0.589	0.454
944.00	0.553	0.502	1.092	0.554
945.00	0.645	0.598	1.690	0.647
946.00	0.737	0.690	2.381	0.740
947.00	0.832	0.784	3.165	0.836
948.00	0.928	0.880	4.044	0.934
949.00	1.027	0.977	5.021	1.034
950.00	1.270	1.146	6.168	1.278
952.00	1.677	2.938	9.105	1.687

Device	Routing	Invert	Outlet Devices
#1	Discarded	940.00'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	949.68'	**Channel/Reach** using Reach 4R: Outfall Channel (Design Point 9)

Discarded OutFlow Max=0.70 cfs @ 12.57 hrs HW=951.13' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.70 cfs)

Primary OutFlow Max=17.43 cfs @ 12.04 hrs HW=950.21' (Free Discharge)
└─**2=Channel/Reach** (Channel Controls 17.43 cfs @ 7.50 fps)

Pond 1P: Existing Pond/SMA5 E



Summary for Pond 2P: SMA1 (Design Point 2)

[93] Warning: Storage range exceeded by 0.30'

Inflow Area = 24.910 ac, 0.00% Impervious, Inflow Depth = 3.95" for 100-YR event
Inflow = 61.56 cfs @ 12.47 hrs, Volume= 8.192 af
Outflow = 8.30 cfs @ 15.64 hrs, Volume= 9.537 af, Atten= 87%, Lag= 190.1 min
Discarded = 0.44 cfs @ 15.64 hrs, Volume= 6.541 af
Primary = 7.86 cfs @ 15.64 hrs, Volume= 2.997 af
Routed to Pond 21P : Existing Powerline Depression SMA-6 (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 6
Peak Elev= 1,001.83' @ 15.64 hrs Surf.Area= 1.147 ac Storage= 6.087 af

Plug-Flow detention time= 3,280.1 min calculated for 8.192 af (100% of inflow)
Center-of-Mass det. time= 4,889.3 min (5,757.8 - 868.5)

Volume	Invert	Avail.Storage	Storage Description
#1	992.00'	6.087 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

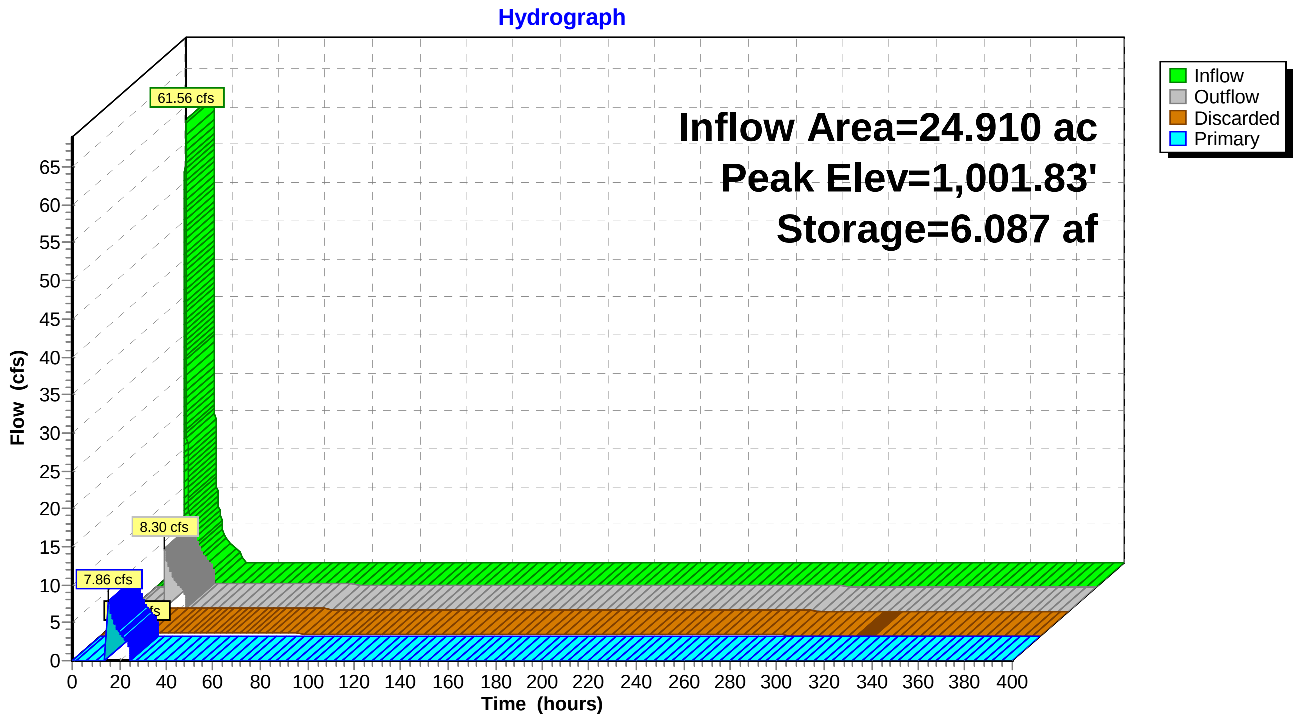
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
992.00	0.210	0.000	0.000
994.00	0.377	0.587	0.587
996.00	0.557	0.934	1.521
998.00	0.731	1.288	2.809
1,000.00	0.946	1.677	4.486
1,001.53	1.147	1.601	6.087

Device	Routing	Invert	Outlet Devices
#1	Discarded	992.00'	**0.380 in/hr Exfiltration over Surface area**
#2	Primary	1,001.52'	**16.0' long + 3.0 '/' SideZ x 36.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.44 cfs @ 15.64 hrs HW=1,001.83' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.44 cfs)

Primary OutFlow Max=7.81 cfs @ 15.64 hrs HW=1,001.83' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Weir Controls 7.81 cfs @ 1.48 fps)

Pond 2P: SMA1 (Design Point 2)



Summary for Pond 19P: SMA-2 E (Design Point 5)

[93] Warning: Storage range exceeded by 0.90'

Inflow Area = 4.330 ac, 0.00% Impervious, Inflow Depth = 3.33" for 100-YR event
Inflow = 11.55 cfs @ 12.26 hrs, Volume= 1.201 af
Outflow = 9.32 cfs @ 12.26 hrs, Volume= 0.508 af, Atten= 19%, Lag= 0.0 min
Discarded = 0.07 cfs @ 12.04 hrs, Volume= 0.161 af
Primary = 9.25 cfs @ 12.26 hrs, Volume= 0.347 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 6
Peak Elev= 1,027.45' @ 12.26 hrs Surf.Area= 0.178 ac Storage= 0.086 af

Plug-Flow detention time= 281.6 min calculated for 0.508 af (42% of inflow)
Center-of-Mass det. time= 149.1 min (1,014.6 - 865.5)

Volume	Invert	Avail.Storage	Storage Description
#1	1,025.60'	0.086 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

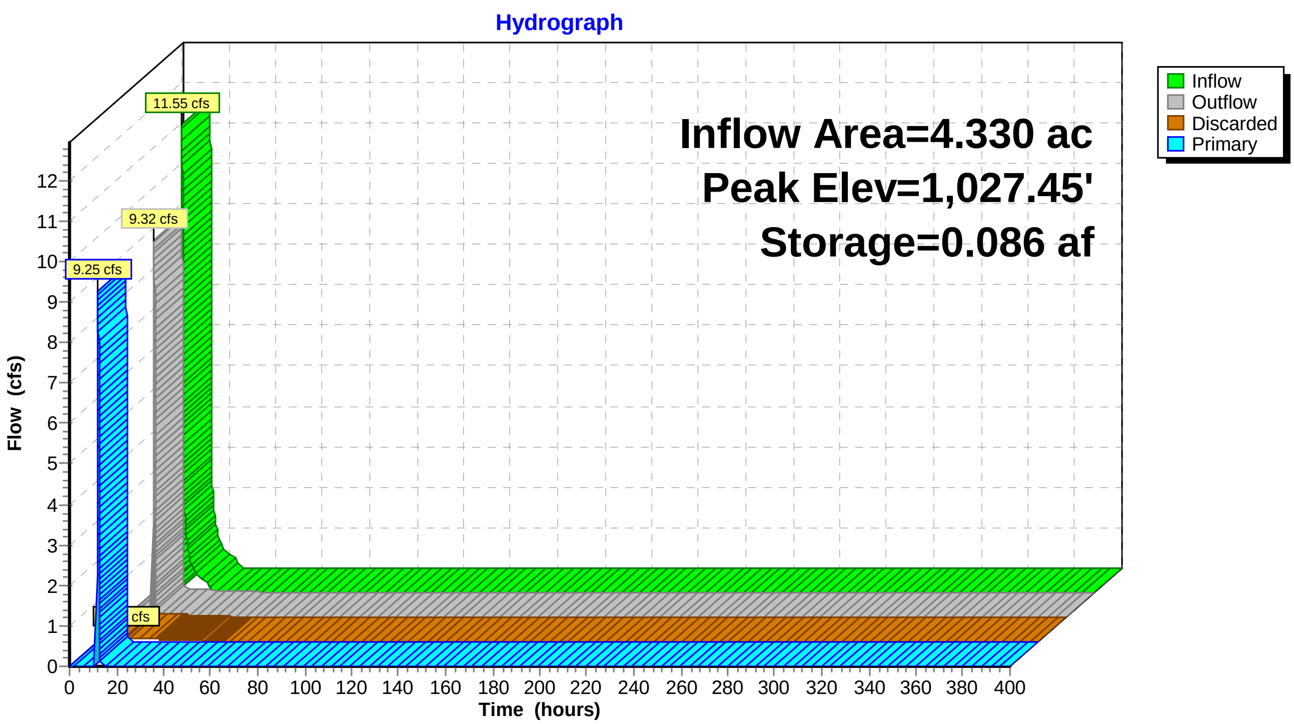
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,025.60	0.002	0.000	0.000
1,026.55	0.178	0.086	0.086

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,025.60'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	1,026.54'	**1.0' long + 3.0 '/' SideZ x 0.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32

Discarded OutFlow Max=0.07 cfs @ 12.04 hrs HW=1,027.03' (Free Discharge)
└—**1=Exfiltration** (Exfiltration Controls 0.07 cfs)

Primary OutFlow Max=9.24 cfs @ 12.26 hrs HW=1,027.45' (Free Discharge)
└—**2=Broad-Crested Rectangular Weir** (Weir Controls 9.24 cfs @ 2.70 fps)

Pond 19P: SMA-2 E (Design Point 5)



Summary for Pond 20P: Pool Existing

[93] Warning: Storage range exceeded by 0.24'
[88] Warning: Qout>Qin may require smaller dt or Finer Routing
[85] Warning: Oscillations may require smaller dt or Finer Routing (severity=30)

Inflow Area = 40.990 ac, 0.00% Impervious, Inflow Depth = 4.27" for 100-YR event
Inflow = 107.84 cfs @ 12.50 hrs, Volume= 14.572 af
Outflow = 111.48 cfs @ 12.50 hrs, Volume= 14.087 af, Atten= 0%, Lag= 0.3 min
Primary = 111.48 cfs @ 12.50 hrs, Volume= 14.087 af
Routed to Reach 22R : Pool Ditch

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Starting Elev= 991.00' Surf.Area= 0.198 ac Storage= 0.165 af
Peak Elev= 993.24' @ 12.50 hrs Surf.Area= 0.575 ac Storage= 0.945 af (0.780 af above start)

Plug-Flow detention time= 39.2 min calculated for 13.922 af (96% of inflow)
Center-of-Mass det. time= 12.6 min (875.1 - 862.5)

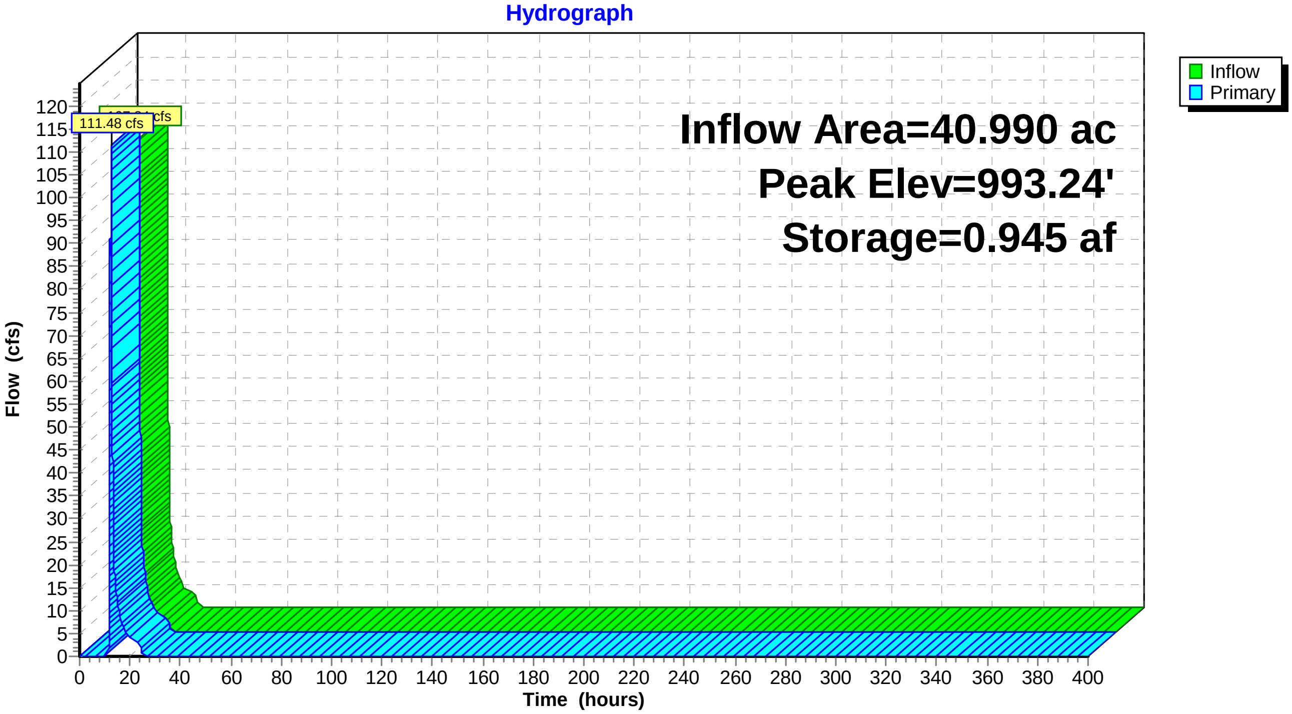
Volume	Invert	Avail.Storage	Storage Description
#1	988.50'	0.945 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
988.50	0.001	0.000	0.000
989.00	0.009	0.003	0.003
989.50	0.026	0.009	0.011
990.00	0.057	0.021	0.032
990.50	0.138	0.049	0.081
991.00	0.198	0.084	0.165
991.50	0.280	0.119	0.284
992.00	0.404	0.171	0.455
993.00	0.575	0.490	0.945

Device	Routing	Invert	Outlet Devices
#1	Primary	992.44'	**Channel/Reach** using Reach 22R: Pool Ditch

Primary OutFlow Max=111.36 cfs @ 12.50 hrs HW=993.24' (Free Discharge)
↑—**1=Channel/Reach** (Channel Controls 111.36 cfs @ 5.08 fps)

Pond 20P: Pool Existing



Summary for Pond 21P: Existing Powerline Depression SMA-6 (Design Point 1)

[93] Warning: Storage range exceeded by 1.91'
[95] Warning: Outlet Device #1 rise exceeded
[63] Warning: Exceeded Reach 21R INLET depth by 0.42' @ 12.50 hrs
[64] Warning: Exceeded Reach 21R outlet bank by 4.74' @ 12.50 hrs

Inflow Area = 120.280 ac, 0.00% Impervious, Inflow Depth = 3.59" for 100-YR event
Inflow = 245.69 cfs @ 12.50 hrs, Volume= 35.940 af
Outflow = 160.54 cfs @ 12.50 hrs, Volume= 32.310 af, Atten= 35%, Lag= 0.3 min
Discarded = 0.89 cfs @ 12.50 hrs, Volume= 6.265 af
Primary = 159.64 cfs @ 12.50 hrs, Volume= 26.045 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 2
Peak Elev= 987.91' @ 12.50 hrs Surf.Area= 1.920 ac Storage= 7.820 af

Plug-Flow detention time= 759.8 min calculated for 32.309 af (90% of inflow)
Center-of-Mass det. time= 710.2 min (1,602.5 - 892.3)

Volume	Invert	Avail.Storage	Storage Description
#1	978.00'	7.820 af	**Custom Stage Data (Conic)** Listed below

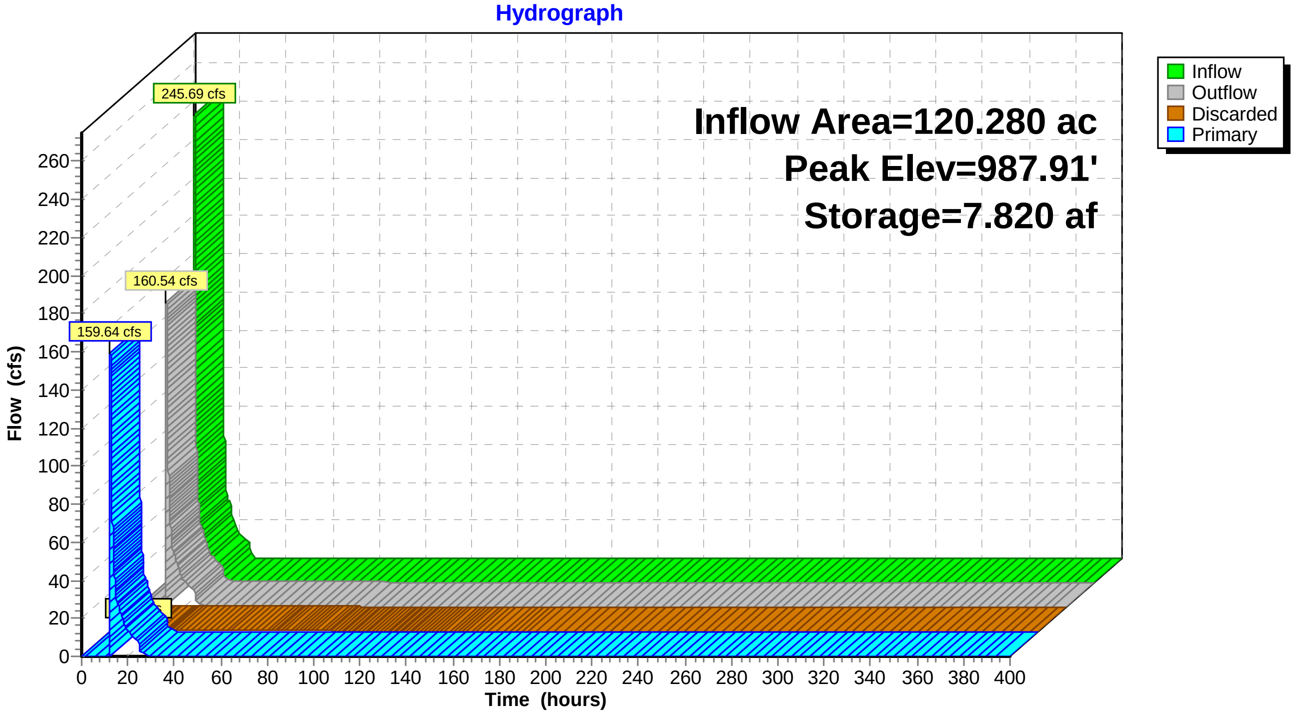
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
978.00	0.028	0.000	0.000	0.028
979.00	0.163	0.086	0.086	0.163
980.00	0.378	0.263	0.349	0.378
981.00	0.712	0.536	0.886	0.712
982.00	1.050	0.876	1.761	1.051
983.00	1.330	1.187	2.948	1.331
984.00	1.530	1.429	4.377	1.533
985.00	1.720	1.624	6.001	1.724
986.00	1.920	1.819	7.820	1.925

Device	Routing	Invert	Outlet Devices
#1	Primary	984.30'	**165.0 deg x 1.70' rise Sharp-Crested Vee/Trap Weir** Cv= 2.47 (C= 3.09)
#2	Discarded	978.00'	**0.460 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.89 cfs @ 12.50 hrs HW=987.91' (Free Discharge)
↑—**2=Exfiltration** (Exfiltration Controls 0.89 cfs)

Primary OutFlow Max=159.65 cfs @ 12.50 hrs HW=987.91' (Free Discharge)
↑—**1=Sharp-Crested Vee/Trap Weir** (Orifice Controls 159.65 cfs @ 7.27 fps)

Pond 21P: Existing Powerline Depression SMA-6 (Design Point 1)



Summary for Pond 22P: SMA3 E (Design Point 6)

[93] Warning: Storage range exceeded by 0.71'
[95] Warning: Outlet Device #2 rise exceeded

Inflow Area = 1.060 ac, 0.00% Impervious, Inflow Depth = 4.44" for 100-YR event
Inflow = 5.51 cfs @ 12.09 hrs, Volume= 0.393 af
Outflow = 5.46 cfs @ 12.09 hrs, Volume= 0.341 af, Atten= 1%, Lag= 0.0 min
Discarded = 0.03 cfs @ 11.79 hrs, Volume= 0.065 af
Primary = 5.43 cfs @ 12.09 hrs, Volume= 0.276 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 1,026.06' @ 12.09 hrs Surf.Area= 0.056 ac Storage= 0.035 af

Plug-Flow detention time= 163.5 min calculated for 0.341 af (87% of inflow)
Center-of-Mass det. time= 103.5 min (938.7 - 835.3)

Volume	Invert	Avail.Storage	Storage Description
#1	1,024.50'	0.035 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

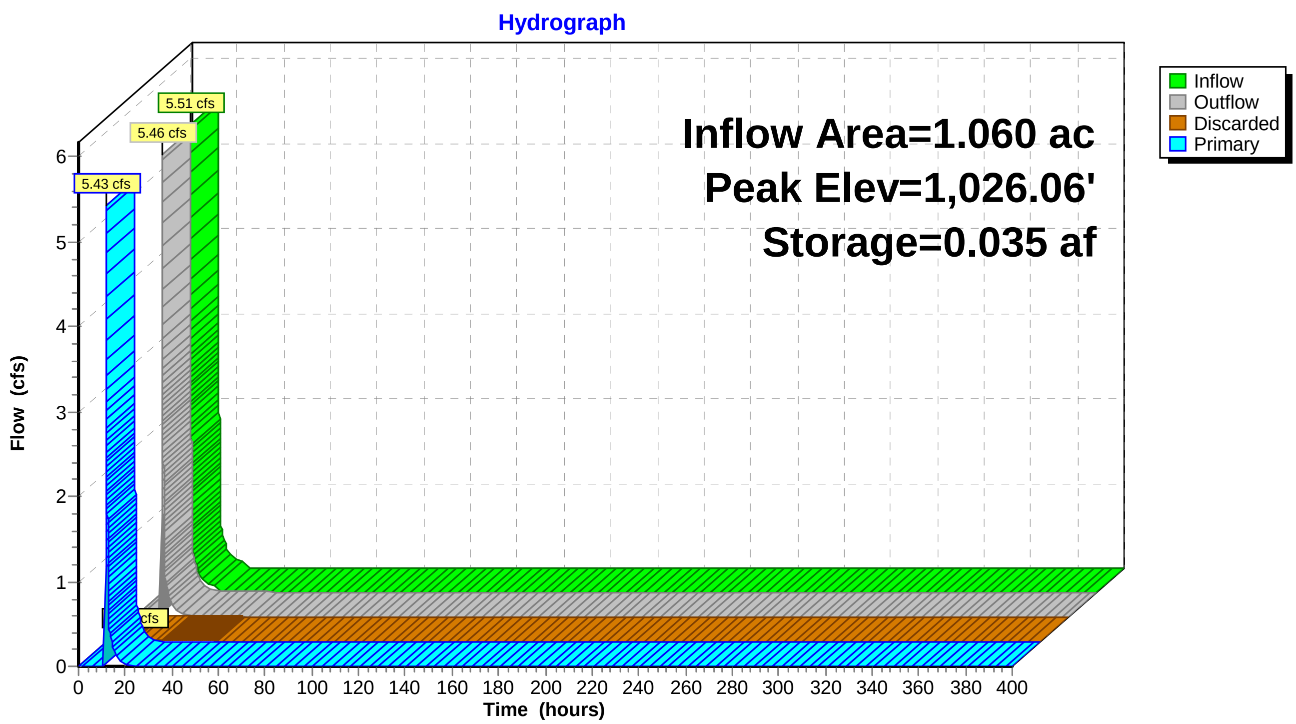
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,024.50	0.026	0.000	0.000
1,025.35	0.056	0.035	0.035

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,024.50'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,025.33'	**177.0 deg x 0.20' rise Sharp-Crested Vee/Trap Weir** Cv= 2.46 (C= 3.08)

Discarded OutFlow Max=0.03 cfs @ 11.79 hrs HW=1,025.50' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.03 cfs)

Primary OutFlow Max=5.43 cfs @ 12.09 hrs HW=1,026.06' (Free Discharge)
└─**2=Sharp-Crested Vee/Trap Weir** (Orifice Controls 5.43 cfs @ 3.55 fps)

Pond 22P: SMA3 E (Design Point 6)



Summary for Pond 23P: SMA4 E (Design Point 7)

Inflow Area = 10.990 ac, 0.00% Impervious, Inflow Depth = 2.12" for 100-YR event
Inflow = 19.26 cfs @ 12.18 hrs, Volume= 1.943 af
Outflow = 18.30 cfs @ 12.23 hrs, Volume= 1.943 af, Atten= 5%, Lag= 2.8 min
Discarded = 0.04 cfs @ 12.23 hrs, Volume= 0.040 af
Primary = 18.26 cfs @ 12.23 hrs, Volume= 1.903 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 990.68' @ 12.23 hrs Surf.Area= 0.080 ac Storage= 0.110 af

Plug-Flow detention time= 19.6 min calculated for 1.943 af (100% of inflow)
Center-of-Mass det. time= 19.6 min (907.1 - 887.5)

Volume	Invert	Avail.Storage	Storage Description
#1	988.20'	0.247 af	**Custom Stage Data (Conic)** Listed below (Recalc)

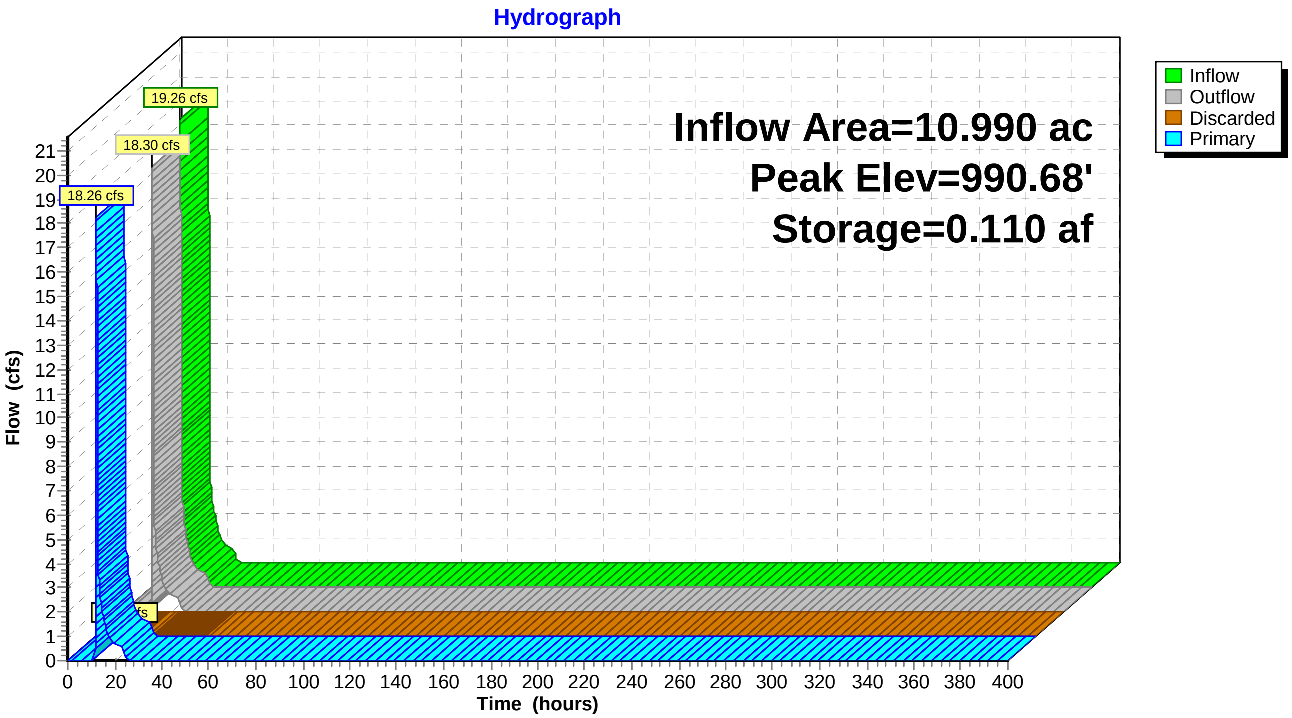
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
988.20	0.007	0.000	0.000	0.007
988.50	0.018	0.004	0.004	0.018
989.00	0.034	0.013	0.016	0.034
992.00	0.130	0.230	0.247	0.131

Device	Routing	Invert	Outlet Devices
#0	Primary	992.00'	**Automatic Storage Overflow** (Discharged without head)
#1	Discarded	988.20'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	988.91'	**121.0 deg x 4.00' rise Sharp-Crested Vee/Trap Weir** Cv= 2.48 (C= 3.10)

Discarded OutFlow Max=0.04 cfs @ 12.23 hrs HW=990.68' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.04 cfs)

Primary OutFlow Max=18.26 cfs @ 12.23 hrs HW=990.68' (Free Discharge)
└─**2=Sharp-Crested Vee/Trap Weir** (Weir Controls 18.26 cfs @ 3.30 fps)

Pond 23P: SMA4 E (Design Point 7)



Attachment 3

Custom Soil Resource Report for Berkshire County, Massachusetts (September 27, 2023)

United States Department of Agriculture

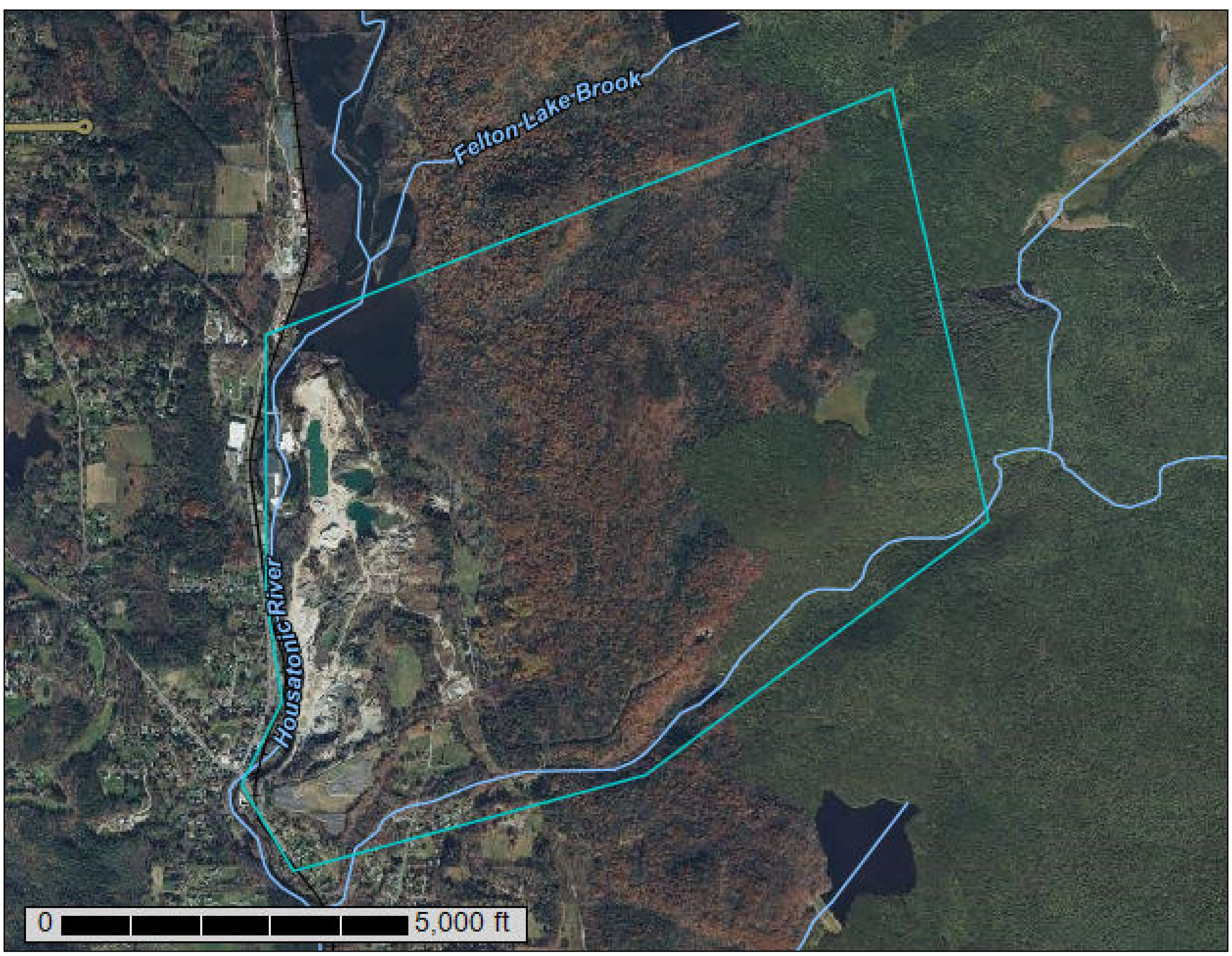
NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Berkshire County, Massachusetts



September 27, 2023

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

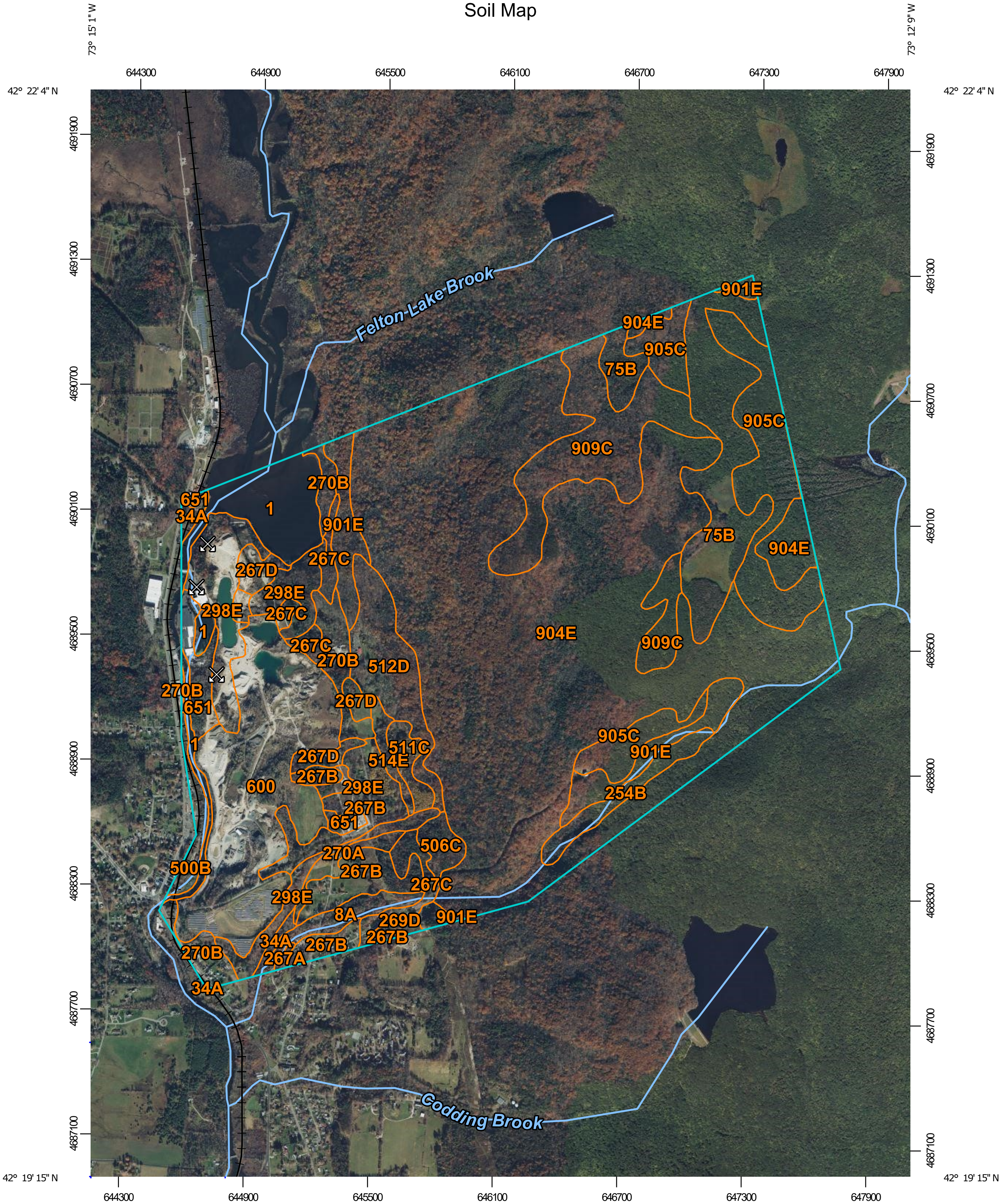
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map



Map Scale: 1:25,400 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 350, 700, 1400, 2100

Feet: 0, 1000, 2000, 4000, 6000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Berkshire County, Massachusetts
Survey Area Data: Version 17, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 15, 2021—Nov 8, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Cwater	61.3	3.4%
8A	Limerick silt loam, 0 to 3 percent slopes, frequently flooded	16.1	0.9%
34A	Fredon fine sandy loam, 0 to 3 percent slopes	7.4	0.4%
75B	Pillsbury fine sandy loam, 0 to 8 percent slopes, very stony	107.9	6.1%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	19.7	1.1%
267A	Copake fine sandy loam, 0 to 3 percent slopes	1.4	0.1%
267B	Copake fine sandy loam, 3 to 8 percent slopes	74.4	4.2%
267C	Copake fine sandy loam, 8 to 15 percent slopes	30.8	1.7%
267D	Copake fine sandy loam, 15 to 25 percent slopes	19.5	1.1%
269D	Groton gravelly sandy loam, 15 to 25 percent slopes	3.5	0.2%
270A	Hero loam, 0 to 3 percent slopes	9.4	0.5%
270B	Hero loam, 3 to 8 percent slopes	38.6	2.2%
298E	Groton and Hinckley soils, 25 to 35 percent slopes	85.4	4.8%
500B	Amenia silt loam, 3 to 8 percent slopes	12.3	0.7%
506C	Nellis loam, 8 to 15 percent slopes, very stony	10.9	0.6%
511C	Pittsfield loam, 8 to 15 percent slopes, very stony	11.3	0.6%
512D	Pittsfield loam, 15 to 25 percent slopes, extremely stony	49.2	2.8%
514E	Pittsfield and Nellis loams, 25 to 35 percent slopes, extremely stony	7.7	0.4%
600	Pits, gravel	168.7	9.5%
651	Udorthents, smoothed	22.1	1.2%
901E	Berkshire-Marlow association, 15 to 45 percent slopes, extremely stony	51.4	2.9%
904E	Lyman-Tunbridge association, 15 to 60 percent slopes, extremely stony	755.4	42.4%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
905C	Peru-Marlow association, 3 to 15 percent slopes, extremely stony	112.7	6.3%
909C	Tunbridge-Lyman association, 3 to 15 percent slopes, extremely stony	106.2	6.0%
Totals for Area of Interest		**1,783.3**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Berkshire County, Massachusetts

1—Cwater

Map Unit Setting

National map unit symbol: 98sq
Mean annual precipitation: 32 to 52 inches
Mean annual air temperature: 37 to 50 degrees F
Farmland classification: Not prime farmland

Map Unit Composition

Cwater: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

8A—Limerick silt loam, 0 to 3 percent slopes, frequently flooded

Map Unit Setting

National map unit symbol: 2zvd3
Elevation: 50 to 500 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Limerick and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Limerick

Setting

Landform: Alluvial flats
Landform position (two-dimensional): Toeslope
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Coarse-silty alluvium

Typical profile

H1 - 0 to 10 inches: silt loam
H2 - 10 to 34 inches: silt loam
H3 - 34 to 65 inches: very fine sandy loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 6 to 10 inches
Frequency of flooding: Frequent

Frequency of ponding: None
Available water supply, 0 to 60 inches: Very high (about 13.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: B/D
Ecological site: F144BY120ME - Small Floodplain Riparian Complex (reserved), F144BY110ME - Broad Floodplain Riparian Complex
Hydric soil rating: Yes

Minor Components

Pootatuck

Percent of map unit: 5 percent

Saco

Percent of map unit: 5 percent
Landform: Alluvial flats
Hydric soil rating: Yes

Winooski

Percent of map unit: 5 percent
Hydric soil rating: No

34A—Fredon fine sandy loam, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 98t1
Elevation: 250 to 1,200 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Fredon and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Fredon

Setting

Landform: Depressions
Landform position (two-dimensional): Footslope
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Friable coarse-loamy eolian deposits over loose sandy and gravelly glaciofluvial deposits derived from slate and/or loose sandy glaciofluvial deposits derived from slate

Typical profile

H1 - 0 to 8 inches: fine sandy loam
H2 - 8 to 26 inches: fine sandy loam
H3 - 26 to 64 inches: stratified sand to loamy fine sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: About 6 to 12 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: B/D
Ecological site: F144BY303ME - Acidic Swamp
Hydric soil rating: Yes

Minor Components

Halsey

Percent of map unit: 10 percent
Landform: Depressions
Hydric soil rating: Yes

Hero

Percent of map unit: 5 percent
Hydric soil rating: No

75B—Pillsbury fine sandy loam, 0 to 8 percent slopes, very stony

Map Unit Setting

National map unit symbol: 2ty6x
Elevation: 360 to 2,070 feet
Mean annual precipitation: 31 to 95 inches
Mean annual air temperature: 27 to 52 degrees F
Frost-free period: 90 to 140 days
Farmland classification: Not prime farmland

Map Unit Composition

Pillsbury, very stony, and similar soils: 79 percent
Minor components: 21 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pillsbury, Very Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainbase, base slope, interfluve
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Loamy lodgment till derived from gneiss and/or loamy lodgment till derived from mica schist and/or loamy lodgment till derived from granite

Typical profile

Oe - 0 to 1 inches: mucky peat
A - 1 to 6 inches: fine sandy loam
Bg1 - 6 to 13 inches: cobbly fine sandy loam
Bg2 - 13 to 23 inches: cobbly fine sandy loam
Cd - 23 to 65 inches: cobbly fine sandy loam

Properties and qualities

Slope: 0 to 8 percent
Surface area covered with cobbles, stones or boulders: 1.1 percent
Depth to restrictive feature: 21 to 43 inches to densic material
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.01 to 1.42 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 3.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: D
Ecological site: F144BY305ME - Wet Loamy Flat
Hydric soil rating: Yes

Minor Components

Peru, very stony

Percent of map unit: 9 percent
Landform: Mountains, hills
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Mountainbase, interfluve, base slope
Microfeatures of landform position: Rises, rises
Down-slope shape: Convex
Across-slope shape: Linear, convex
Hydric soil rating: No

Peacham, very stony

Percent of map unit: 5 percent
Landform: Hills, mountains
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainbase, base slope, interfluve
Microfeatures of landform position: Closed depressions, closed depressions

Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Wonsqueak

Percent of map unit: 4 percent
Landform: Hills, mountains
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainbase, base slope, interfluve
Microfeatures of landform position: Closed depressions, closed depressions
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Lyman, very stony

Percent of map unit: 3 percent
Landform: Mountains, hills
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Mountainbase, interfluve, base slope
Microfeatures of landform position: Rises, rises
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

254B—Merrimac fine sandy loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 2tyqs
Elevation: 0 to 1,290 feet
Mean annual precipitation: 36 to 71 inches
Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 140 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Merrimac and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Merrimac

Setting

Landform: Outwash plains, outwash terraces, moraines, eskers, kames
Landform position (two-dimensional): Backslope, footslope, summit, shoulder
Landform position (three-dimensional): Side slope, crest, riser, tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy glaciofluvial deposits derived from granite, schist, and gneiss over sandy and gravelly glaciofluvial deposits derived from granite, schist, and gneiss

Typical profile

Ap - 0 to 10 inches: fine sandy loam
Bw1 - 10 to 22 inches: fine sandy loam
Bw2 - 22 to 26 inches: stratified gravel to gravelly loamy sand
2C - 26 to 65 inches: stratified gravel to very gravelly sand

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat excessively drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to very high (1.42 to 99.90 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 2 percent
Maximum salinity: Nonsaline (0.0 to 1.4 mmhos/cm)
Sodium adsorption ratio, maximum: 1.0
Available water supply, 0 to 60 inches: Low (about 4.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2s
Hydrologic Soil Group: A
Ecological site: F145XY008MA - Dry Outwash
Hydric soil rating: No

Minor Components

Sudbury

Percent of map unit: 5 percent
Landform: Deltas, terraces, outwash plains
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Tread, dip
Down-slope shape: Concave
Across-slope shape: Linear
Hydric soil rating: No

Hinckley

Percent of map unit: 5 percent
Landform: Deltas, kames, eskers, outwash plains
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Nose slope, side slope, crest, head slope, rise
Down-slope shape: Convex
Across-slope shape: Convex, linear
Hydric soil rating: No

Windsor

Percent of map unit: 3 percent
Landform: Outwash terraces, dunes, deltas, outwash plains
Landform position (two-dimensional): Shoulder
Landform position (three-dimensional): Tread, riser
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex

Hydric soil rating: No

Agawam

Percent of map unit: 2 percent
Landform: Outwash plains, outwash terraces, moraines, stream terraces, eskers, kames
Landform position (three-dimensional): Rise
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

267A—Copake fine sandy loam, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 98sr
Elevation: 570 to 1,340 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Copake and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Copake

Setting

Landform: Ridges
Landform position (two-dimensional): Summit
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over loose sandy glaciofluvial deposits derived from limestone and/or loose sandy and gravelly glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 4 inches: fine sandy loam
H2 - 4 to 26 inches: gravelly fine sandy loam
H3 - 26 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches

Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 1
Hydrologic Soil Group: A
Ecological site: F144AY044VT - Semi-Rich Well Drained Outwash
Hydric soil rating: No

Minor Components

Hero

Percent of map unit: 7 percent
Hydric soil rating: No

Groton

Percent of map unit: 5 percent
Hydric soil rating: No

Fredon

Percent of map unit: 3 percent
Landform: Terraces
Hydric soil rating: Yes

267B—Copake fine sandy loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 98ss
Elevation: 560 to 1,390 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Copake and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Copake

Setting

Landform: Ridges
Landform position (two-dimensional): Shoulder
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over loose sandy and gravelly glaciofluvial deposits derived from limestone and/or loose sandy glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 4 inches: fine sandy loam
H2 - 4 to 26 inches: gravelly fine sandy loam
H3 - 26 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: A
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Groton

Percent of map unit: 5 percent
Hydric soil rating: No

Hero

Percent of map unit: 3 percent
Hydric soil rating: No

Fredon

Percent of map unit: 2 percent
Landform: Terraces
Hydric soil rating: Yes

267C—Copake fine sandy loam, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: 98st
Elevation: 620 to 1,540 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Copake and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Copake

Setting

Landform: Ridges
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over loose sandy glaciofluvial deposits derived from limestone and/or loose sandy and gravelly glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 4 inches: fine sandy loam
H2 - 4 to 26 inches: gravelly fine sandy loam
H3 - 26 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: A
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Groton

Percent of map unit: 6 percent
Hydric soil rating: No

Hero

Percent of map unit: 4 percent
Hydric soil rating: No

267D—Copake fine sandy loam, 15 to 25 percent slopes

Map Unit Setting

National map unit symbol: 98sv
Elevation: 620 to 1,380 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Copake and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Copake

Setting

Landform: Ridges
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over loose sandy and gravelly glaciofluvial deposits derived from limestone and/or loose sandy glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 4 inches: fine sandy loam
H2 - 4 to 26 inches: gravelly fine sandy loam
H3 - 26 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 15 to 25 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: A
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Groton

Percent of map unit: 10 percent
Hydric soil rating: No

Hero

Percent of map unit: 5 percent
Hydric soil rating: No

269D—Groton gravelly sandy loam, 15 to 25 percent slopes

Map Unit Setting

National map unit symbol: 98t6
Elevation: 640 to 1,510 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Groton and similar soils: 95 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Groton

Setting

Landform: Terraces
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over loose sandy and gravelly glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 6 inches: gravelly sandy loam
H2 - 6 to 15 inches: gravelly sandy loam
H3 - 15 to 64 inches: very gravelly sand

Properties and qualities

Slope: 15 to 25 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): High to very high (2.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None

Available water supply, 0 to 60 inches: Low (about 4.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: A
Ecological site: F144BY601ME - Dry Sand
Hydric soil rating: No

Minor Components

Copake

Percent of map unit: 5 percent
Hydric soil rating: No

270A—Hero loam, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 98tb
Elevation: 560 to 1,790 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Hero and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hero

Setting

Landform: Terraces
Landform position (two-dimensional): Toeslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over friable sandy and gravelly glaciofluvial deposits derived from limestone and/or friable sandy glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 8 inches: loam
H2 - 8 to 32 inches: gravelly fine sandy loam
H3 - 32 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained

Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: About 18 to 30 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 5.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydrologic Soil Group: B
Ecological site: F144BY505ME - Loamy over Sandy, F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Copake

Percent of map unit: 6 percent
Hydric soil rating: No

Fredon

Percent of map unit: 4 percent
Landform: Terraces
Hydric soil rating: Yes

270B—Hero loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 98tc
Elevation: 620 to 1,620 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Hero and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hero

Setting

Landform: Terraces
Landform position (two-dimensional): Toeslope
Down-slope shape: Convex
Across-slope shape: Convex

Parent material: Friable coarse-loamy eolian deposits over friable sandy glaciofluvial deposits derived from limestone and/or friable sandy and gravelly glaciofluvial deposits derived from limestone

Typical profile

H1 - 0 to 8 inches: loam
H2 - 8 to 32 inches: gravelly fine sandy loam
H3 - 32 to 64 inches: stratified gravelly loamy fine sand to very gravelly coarse sand

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: About 18 to 30 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 5.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: B
Ecological site: F144BY505ME - Loamy over Sandy, F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Copake

Percent of map unit: 12 percent
Hydric soil rating: No

Fredon

Percent of map unit: 3 percent
Landform: Terraces
Hydric soil rating: Yes

298E—Groton and Hinckley soils, 25 to 35 percent slopes

Map Unit Setting

National map unit symbol: 2svls
Elevation: 640 to 1,270 feet
Mean annual precipitation: 36 to 71 inches
Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Groton and similar soils: 50 percent
Hinckley and similar soils: 40 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Groton

Setting

Landform: Kames, eskers, outwash terraces
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Crest, head slope, nose slope, side slope, riser
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Sandy and gravelly glaciofluvial deposits derived from limestone and dolomite and/or schist

Typical profile

Ap - 0 to 8 inches: gravelly sandy loam
Bw1 - 8 to 18 inches: very gravelly sandy loam
Bw2 - 18 to 24 inches: very gravelly loamy sand
Bw3 - 24 to 30 inches: very gravelly loamy sand
C1 - 30 to 52 inches: stratified extremely gravelly coarse sand to very gravelly loamy fine sand
C2 - 52 to 72 inches: stratified extremely gravelly coarse sand to gravelly loamy fine sand

Properties and qualities

Slope: 25 to 35 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 10 percent
Available water supply, 0 to 60 inches: Very low (about 2.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: F144BY601ME - Dry Sand
Hydric soil rating: No

Description of Hinckley

Setting

Landform: Outwash deltas, outwash terraces, moraines, eskers, kames, outwash plains, kame terraces
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Nose slope, side slope, crest, head slope, riser

Down-slope shape: Concave, convex, linear
Across-slope shape: Convex, linear, concave
Parent material: Sandy and gravelly glaciofluvial deposits derived from gneiss and/or granite and/or schist

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 8 inches: loamy sand
Bw1 - 8 to 11 inches: gravelly loamy sand
Bw2 - 11 to 16 inches: gravelly loamy sand
BC - 16 to 19 inches: very gravelly loamy sand
C - 19 to 65 inches: very gravelly sand

Properties and qualities

Slope: 25 to 35 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to very high (1.42 to 99.90 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 3.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: F144BY601ME - Dry Sand
Hydric soil rating: No

Minor Components

Merrimac

Percent of map unit: 5 percent
Landform: Outwash plains, kame terraces, outwash terraces, moraines, eskers, kames
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope, crest, head slope, nose slope, riser
Down-slope shape: Concave, convex, linear
Across-slope shape: Convex, linear, concave
Hydric soil rating: No

Copake

Percent of map unit: 5 percent
Landform: Kames, outwash terraces
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Crest, head slope, nose slope, side slope, riser
Down-slope shape: Linear
Across-slope shape: Convex
Hydric soil rating: No

500B—Amenia silt loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 98sc
Elevation: 590 to 1,670 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Amenia and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Amenia

Setting

Landform: Depressions
Landform position (two-dimensional): Shoulder
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Friable coarse-loamy eolian deposits over dense coarse-loamy lodgment till derived from limestone; friable coarse-loamy eolian deposits over dense coarse-loamy lodgment till derived from limestone

Typical profile

H1 - 0 to 8 inches: silt loam
H2 - 8 to 27 inches: silt loam
H3 - 27 to 64 inches: gravelly loam

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 18 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: C
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Stockbridge

Percent of map unit: 7 percent
Hydric soil rating: No

Kendaia

Percent of map unit: 5 percent
Landform: Depressions
Hydric soil rating: Yes

Lyons

Percent of map unit: 3 percent
Landform: Depressions
Hydric soil rating: Yes

506C—Nellis loam, 8 to 15 percent slopes, very stony

Map Unit Setting

National map unit symbol: 98v9
Elevation: 150 to 800 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Nellis and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Nellis

Setting

Landform: Drumlinoid ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over firm coarse-loamy lodgment till derived from limestone

Typical profile

H1 - 0 to 7 inches: loam
H2 - 7 to 32 inches: gravelly loam
H3 - 32 to 64 inches: gravelly loam

Properties and qualities

Slope: 8 to 15 percent
Surface area covered with cobbles, stones or boulders: 1.6 percent
Depth to restrictive feature: More than 80 inches

Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water supply, 0 to 60 inches: Moderate (about 7.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: B
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Amenia

Percent of map unit: 10 percent
Hydric soil rating: No

Farmington

Percent of map unit: 3 percent
Hydric soil rating: No

Kendaia

Percent of map unit: 2 percent
Landform: Depressions
Hydric soil rating: Yes

511C—Pittsfield loam, 8 to 15 percent slopes, very stony

Map Unit Setting

National map unit symbol: 98vv
Elevation: 0 to 1,000 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Pittsfield and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pittsfield

Setting

Landform: Drumlinoid ridges

Landform position (two-dimensional): Backslope, shoulder
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over friable, calcareous coarse-loamy basal till derived from limestone

Typical profile
H1 - 0 to 9 inches: loam
H2 - 9 to 32 inches: fine sandy loam
H3 - 32 to 64 inches: gravelly sandy loam

Properties and qualities
Slope: 8 to 15 percent
Surface area covered with cobbles, stones or boulders: 1.6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 8.4 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: A
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Amenia
Percent of map unit: 10 percent
Hydric soil rating: No

Farmington
Percent of map unit: 4 percent
Hydric soil rating: No

Kendaia
Percent of map unit: 1 percent
Landform: Depressions
Hydric soil rating: Yes

512D—Pittsfield loam, 15 to 25 percent slopes, extremely stony

Map Unit Setting
National map unit symbol: 98vz
Elevation: 0 to 1,000 feet

Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Pittsfield and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pittsfield

Setting

Landform: Drumlinoid ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over friable, calcareous coarse-loamy basal till derived from limestone

Typical profile

H1 - 0 to 9 inches: loam
H2 - 9 to 32 inches: fine sandy loam
H3 - 32 to 64 inches: gravelly sandy loam

Properties and qualities

Slope: 15 to 25 percent
Surface area covered with cobbles, stones or boulders: 9.0 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 8.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: A
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Farmington

Percent of map unit: 6 percent
Hydric soil rating: No

Amenia

Percent of map unit: 4 percent
Hydric soil rating: No

514E—Pittsfield and Nellis loams, 25 to 35 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 98w0
Elevation: 0 to 1,000 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Pittsfield and similar soils: 45 percent
Nellis and similar soils: 40 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pittsfield

Setting

Landform: Drumlinoid ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over friable, calcareous coarse-loamy basal till derived from limestone

Typical profile

H1 - 0 to 9 inches: loam
H2 - 9 to 32 inches: fine sandy loam
H3 - 32 to 64 inches: gravelly sandy loam

Properties and qualities

Slope: 25 to 35 percent
Surface area covered with cobbles, stones or boulders: 9.0 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 8.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: A

Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Description of Nellis

Setting

Landform: Drumlinoid ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable coarse-loamy eolian deposits over friable, calcareous coarse-loamy lodgment till derived from limestone

Typical profile

H1 - 0 to 7 inches: loam
H2 - 7 to 32 inches: gravelly loam
H3 - 32 to 60 inches: gravelly loam

Properties and qualities

Slope: 25 to 35 percent
Surface area covered with cobbles, stones or boulders: 9.0 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water supply, 0 to 60 inches: Moderate (about 7.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: B
Ecological site: F144BY506ME - Semi-rich Till Slope
Hydric soil rating: No

Minor Components

Farmington

Percent of map unit: 15 percent
Hydric soil rating: No

600—Pits, gravel

Map Unit Setting

National map unit symbol: 98vn

Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 120 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Pits, gravel: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pits, Gravel

Setting

Parent material: Loose sandy and gravelly glaciofluvial deposits derived from igneous and metamorphic rock

651—Udorthents, smoothed

Map Unit Setting

National map unit symbol: 98wc
Elevation: 640 to 1,620 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 120 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Udorthents, smoothed and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Udorthents, Smoothed

Setting

Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Excavated and filled land over loose glaciofluvial deposits derived from igneous and metamorphic rock and/or friable basal till derived from igneous and metamorphic rock

Properties and qualities

Depth to restrictive feature: More than 80 inches
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None

901E—Berkshire-Marlow association, 15 to 45 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 2wlnm
Elevation: 750 to 2,070 feet
Mean annual precipitation: 31 to 95 inches
Mean annual air temperature: 27 to 52 degrees F
Frost-free period: 90 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Berkshire, extremely stony, and similar soils: 55 percent
Marlow, extremely stony, and similar soils: 30 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Berkshire, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Backslope, summit, shoulder
Landform position (three-dimensional): Mountainflank, side slope, nose slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy supraglacial meltout till derived from phyllite and/or granite and gneiss and/or mica schist

Typical profile

Oi - 0 to 2 inches: slightly decomposed plant material
A - 2 to 4 inches: fine sandy loam
E - 4 to 5 inches: fine sandy loam
Bs1 - 5 to 7 inches: fine sandy loam
Bs2 - 7 to 13 inches: fine sandy loam
Bs3 - 13 to 21 inches: fine sandy loam
BC1 - 21 to 28 inches: fine sandy loam
BC2 - 28 to 33 inches: fine sandy loam
C - 33 to 65 inches: fine sandy loam

Properties and qualities

Slope: 15 to 45 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to high (0.14 to 14.17 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)

Available water supply, 0 to 60 inches: High (about 10.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: B
Ecological site: F144BY501ME - Loamy Slope (Northern Hardwoods)
Hydric soil rating: No

Description of Marlow, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Mountainflank, nose slope, side slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy lodgment till derived from mica schist and/or granite and/or phyllite

Typical profile

Oi - 0 to 2 inches: slightly decomposed plant material
A - 2 to 5 inches: fine sandy loam
E - 5 to 8 inches: fine sandy loam
Bs1 - 8 to 15 inches: fine sandy loam
Bs2 - 15 to 19 inches: fine sandy loam
BC - 19 to 33 inches: gravelly fine sandy loam
Cd - 33 to 65 inches: fine sandy loam

Properties and qualities

Slope: 15 to 45 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 20 to 41 inches to densic material
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.01 to 1.42 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 5.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: C
Ecological site: F144BY501ME - Loamy Slope (Northern Hardwoods)
Hydric soil rating: No

Minor Components

Lyman, extremely stony

Percent of map unit: 9 percent
Landform: Mountains, hills
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Mountainflank, side slope, crest
Down-slope shape: Convex

Across-slope shape: Convex
Hydric soil rating: No

Peru, extremely stony

Percent of map unit: 4 percent
Landform: Hills, mountains
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Mountainflank, nose slope, side slope
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Pillsbury, extremely stony

Percent of map unit: 1 percent
Landform: Hills, mountains
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Mountainflank, side slope, nose slope, interfluve
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Peacham, extremely stony

Percent of map unit: 1 percent
Landform: Mountains, hills
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainflank, interfluve, base slope
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

904E—Lyman-Tunbridge association, 15 to 60 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 2ty75
Elevation: 850 to 2,360 feet
Mean annual precipitation: 31 to 95 inches
Mean annual air temperature: 27 to 52 degrees F
Frost-free period: 60 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Lyman, extremely stony, and similar soils: 45 percent
Tunbridge, extremely stony, and similar soils: 40 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Lyman, Extremely Stony

Setting

Landform: Hills, mountains
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Mountainflank, mountaintop, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy supraglacial till derived from granite and gneiss and/or loamy supraglacial till derived from phyllite and/or loamy supraglacial till derived from mica schist

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 3 inches: loam
E - 3 to 5 inches: fine sandy loam
Bhs - 5 to 7 inches: loam
Bs1 - 7 to 11 inches: loam
Bs2 - 11 to 18 inches: channery loam
R - 18 to 28 inches: bedrock

Properties and qualities

Slope: 15 to 60 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 11 to 24 inches to lithic bedrock
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to high (0.00 to 14.03 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 3.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: D
Ecological site: F144BY702ME - Shallow and Moderately-deep Till
Hydric soil rating: No

Description of Tunbridge, Extremely Stony

Setting

Landform: Hills, mountains
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Mountainflank, mountaintop, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy supraglacial till derived from granite and gneiss and/or loamy supraglacial till derived from phyllite and/or loamy supraglacial till derived from mica schist

Typical profile

Oe - 0 to 3 inches: moderately decomposed plant material

Oa - 3 to 5 inches: highly decomposed plant material
E - 5 to 8 inches: fine sandy loam
Bhs - 8 to 11 inches: fine sandy loam
Bs - 11 to 26 inches: fine sandy loam
BC - 26 to 28 inches: fine sandy loam
R - 28 to 38 inches: bedrock

Properties and qualities

Slope: 15 to 60 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 20 to 40 inches to lithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to high (0.00 to 14.03 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 6.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: C
Ecological site: F144BY702ME - Shallow and Moderately-deep Till
Hydric soil rating: No

Minor Components

Berkshire, extremely stony

Percent of map unit: 9 percent
Landform: Mountains, hills
Landform position (two-dimensional): Backslope, summit, shoulder
Landform position (three-dimensional): Mountainflank, mountaintop, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Wonsqueak

Percent of map unit: 2 percent
Landform: Mountains, hills
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountaintop, mountainbase, side slope, crest
Microfeatures of landform position: Open depressions, open depressions
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Pillsbury, extremely stony

Percent of map unit: 2 percent
Landform: Hills, mountains
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Mountainflank, mountaintop, side slope, crest
Microfeatures of landform position: Open depressions, open depressions
Down-slope shape: Concave

Across-slope shape: Concave
Hydric soil rating: Yes

Peacham, extremely stony

Percent of map unit: 2 percent
Landform: Mountains, hills
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainflank, mountaintop, side slope, crest
Microfeatures of landform position: Open depressions, open depressions
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

905C—Peru-Marlow association, 3 to 15 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 2ty7p
Elevation: 790 to 2,100 feet
Mean annual precipitation: 31 to 95 inches
Mean annual air temperature: 27 to 52 degrees F
Frost-free period: 90 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Peru, extremely stony, and similar soils: 61 percent
Marlow, extremely stony, and similar soils: 20 percent
Minor components: 19 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Peru, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Mountainbase, mountainflank, side slope, nose slope, interfluve
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Loamy lodgment till derived from granite and/or loamy lodgment till derived from mica schist and/or loamy lodgment till derived from phyllite

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 5 inches: fine sandy loam
E - 5 to 6 inches: fine sandy loam
Bs1 - 6 to 7 inches: fine sandy loam
Bs2 - 7 to 13 inches: fine sandy loam
Bs3 - 13 to 18 inches: fine sandy loam

BC - 18 to 21 inches: fine sandy loam
Cd1 - 21 to 37 inches: fine sandy loam
Cd2 - 37 to 65 inches: fine sandy loam

Properties and qualities

Slope: 3 to 15 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 21 to 43 inches to densic material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.01 to 1.42 in/hr)
Depth to water table: About 17 to 34 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 3.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: C/D
Ecological site: F144BY501ME - Loamy Slope (Northern Hardwoods)
Hydric soil rating: No

Description of Marlow, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Mountainflank, mountainbase, side slope, nose slope, interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy lodgment till derived from granite and/or loamy lodgment till derived from mica schist and/or loamy lodgment till derived from phyllite

Typical profile

Oi - 0 to 2 inches: slightly decomposed plant material
A - 2 to 5 inches: fine sandy loam
E - 5 to 8 inches: fine sandy loam
Bs1 - 8 to 15 inches: fine sandy loam
Bs2 - 15 to 19 inches: fine sandy loam
BC - 19 to 33 inches: gravelly fine sandy loam
Cd - 33 to 65 inches: fine sandy loam

Properties and qualities

Slope: 3 to 15 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 20 to 41 inches to densic material
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.01 to 1.42 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 5.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: C
Ecological site: F144BY501ME - Loamy Slope (Northern Hardwoods)
Hydric soil rating: No

Minor Components

Lyman, extremely stony

Percent of map unit: 6 percent
Landform: Mountains, hills
Landform position (two-dimensional): Shoulder, summit, backslope
Landform position (three-dimensional): Mountainbase, mountainflank, nose slope, interfluve, side slope
Microfeatures of landform position: Rises, rises
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Berkshire, extremely stony

Percent of map unit: 5 percent
Landform: Hills, mountains
Landform position (two-dimensional): Backslope, summit, shoulder
Landform position (three-dimensional): Mountainbase, mountainflank, interfluve, side slope, nose slope
Microfeatures of landform position: Rises, rises
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Pillsbury, extremely stony

Percent of map unit: 5 percent
Landform: Hills, mountains
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Mountainbase, mountainflank, interfluve, side slope, nose slope
Microfeatures of landform position: Closed depressions, closed depressions, open depressions, open depressions
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Monadnock, extremely stony

Percent of map unit: 3 percent
Landform: Mountains, hills
Landform position (two-dimensional): Backslope, summit, shoulder
Landform position (three-dimensional): Mountainflank, mountainbase, side slope, nose slope, interfluve
Microfeatures of landform position: Rises, rises
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

909C—Tunbridge-Lyman association, 3 to 15 percent slopes, extremely stony

Map Unit Setting

National map unit symbol: 2trrm
Elevation: 1,080 to 2,390 feet
Mean annual precipitation: 31 to 95 inches
Mean annual air temperature: 27 to 52 degrees F
Frost-free period: 60 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Tunbridge, extremely stony, and similar soils: 50 percent
Lyman, extremely stony, and similar soils: 35 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Tunbridge, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Mountainbase, mountainflank, mountaintop, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy supraglacial till derived from granite and gneiss and/or loamy supraglacial till derived from phyllite and/or loamy supraglacial till derived from mica schist

Typical profile

Oe - 0 to 3 inches: moderately decomposed plant material
Oa - 3 to 5 inches: highly decomposed plant material
E - 5 to 8 inches: fine sandy loam
Bhs - 8 to 11 inches: fine sandy loam
Bs - 11 to 26 inches: fine sandy loam
BC - 26 to 28 inches: fine sandy loam
R - 28 to 38 inches: bedrock

Properties and qualities

Slope: 3 to 15 percent
Surface area covered with cobbles, stones or boulders: 7.1 percent
Depth to restrictive feature: 20 to 40 inches to lithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to high (0.00 to 14.03 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None

Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 6.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: C
Ecological site: F143XY702ME - Shallow And Moderately Deep Till, F143XY703ME - Shallow And Moderately Deep Humic Till
Hydric soil rating: No

Description of Lyman, Extremely Stony

Setting

Landform: Mountains, hills
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Mountainbase, mountainflank, mountaintop, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy supraglacial till derived from granite and gneiss and/or loamy supraglacial till derived from phyllite and/or loamy supraglacial till derived from mica schist

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 3 inches: loam
E - 3 to 5 inches: fine sandy loam
Bhs - 5 to 7 inches: loam
Bs1 - 7 to 11 inches: loam
Bs2 - 11 to 18 inches: channery loam
R - 18 to 28 inches: bedrock

Properties and qualities

Slope: 3 to 15 percent
Surface area covered with cobbles, stones or boulders: 6.0 percent
Depth to restrictive feature: 11 to 24 inches to lithic bedrock
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to high (0.00 to 14.03 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 3.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: D
Ecological site: F143XY702ME - Shallow And Moderately Deep Till
Hydric soil rating: No

Minor Components

Berkshire, extremely stony

Percent of map unit: 8 percent
Landform: Mountains, hills

Landform position (two-dimensional): Backslope, summit, shoulder
Landform position (three-dimensional): Mountainflank, mountainbase, side slope, interfluve, nose slope
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Peacham, extremely stony

Percent of map unit: 4 percent
Landform: Mountains, hills
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Mountainbase, base slope, interfluve
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Pillsbury, extremely stony

Percent of map unit: 3 percent
Landform: Hills, mountains
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Mountainbase, mountainflank, side slope, nose slope, interfluve
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Soil Information for All Uses

Soil Properties and Qualities

The Soil Properties and Qualities section includes various soil properties and qualities displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each property or quality.

Soil Erosion Factors

Soil Erosion Factors are soil properties and interpretations used in evaluating the soil for potential erosion. Example soil erosion factors can include K factor for the whole soil or on a rock free basis, T factor, wind erodibility group and wind erodibility index.

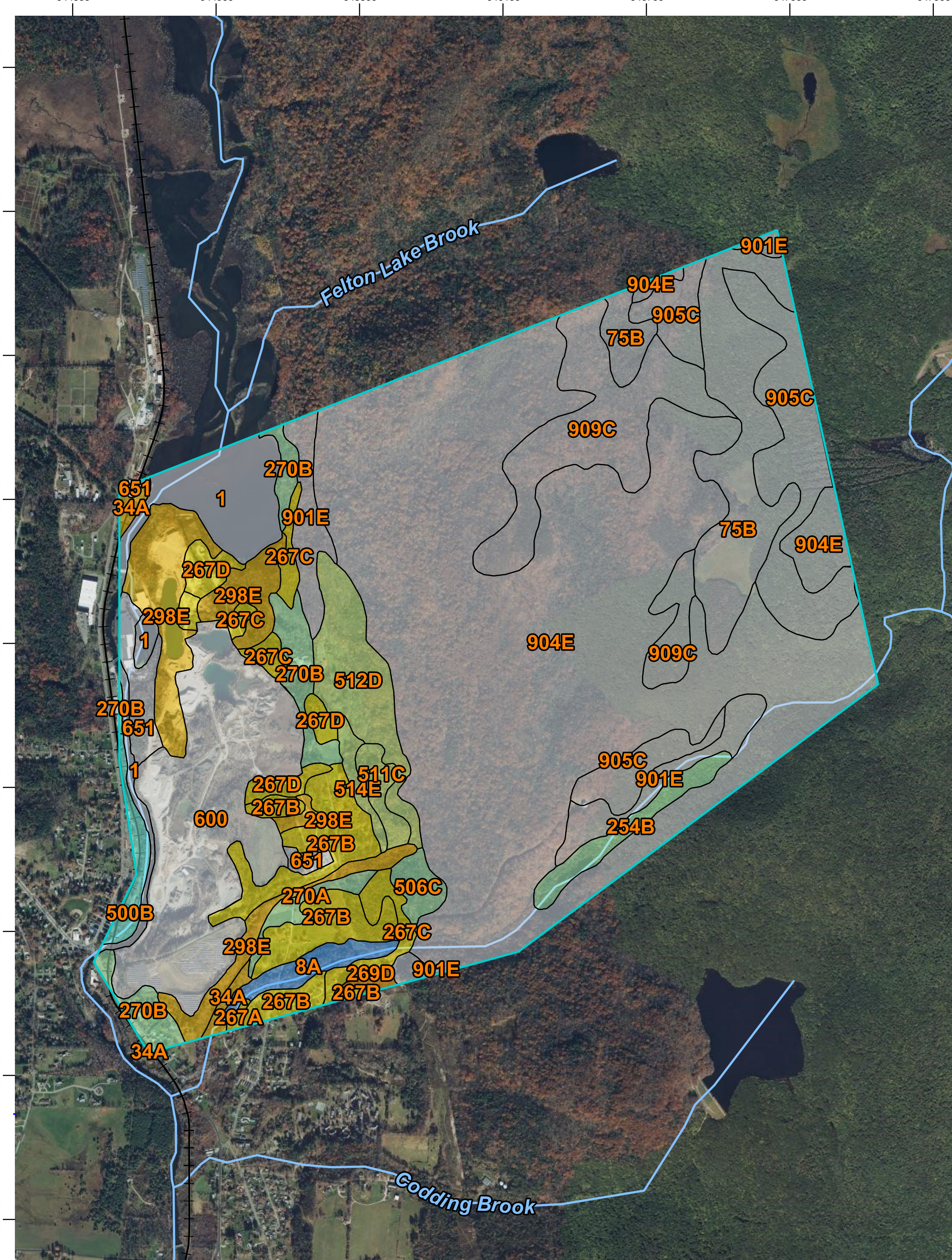
K Factor, Whole Soil

Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity (Ksat). Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

"Erosion factor Kw (whole soil)" indicates the erodibility of the whole soil. The estimates are modified by the presence of rock fragments.

Factor K does not apply to organic horizons and is not reported for those layers.

Map—K Factor, Whole Soil



Map Scale: 1:25,400 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 350, 700, 1400, 2100

Feet: 0, 1000, 2000, 4000, 6000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- .02
- .05
- .10
- .15
- .17
- .20
- .24
- .28
- .32
- .37
- .43
- .49
- .55
- .64
- Not rated or not available

Soil Rating Lines

- .02
- .05
- .10
- .15
- .17
- .20
- .24
- .28
- .32
- .37
- .43
- .49
- .55
- .64
- Not rated or not available

Soil Rating Points

- .02
- .05
- .10
- .15
- .17
- .20
- .24
- .28
- .32
- .37
- .43
- .49
- .55
- .64
- Not rated or not available

assumed K factor

Water Features

Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Berkshire County, Massachusetts
Survey Area Data: Version 17, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 15, 2021—Nov 8, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Table—K Factor, Whole Soil

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
1	Cwater		61.3	3.4%
8A	Limerick silt loam, 0 to 3 percent slopes, frequently flooded	.43	16.1	0.9%
34A	Fredon fine sandy loam, 0 to 3 percent slopes	.15	7.4	0.4%
75B	Pillsbury fine sandy loam, 0 to 8 percent slopes, very stony		107.9	6.1%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	.28	19.7	1.1%
267A	Copake fine sandy loam, 0 to 3 percent slopes	.17	1.4	0.1%
267B	Copake fine sandy loam, 3 to 8 percent slopes	.17	74.4	4.2%
267C	Copake fine sandy loam, 8 to 15 percent slopes	.17	30.8	1.7%
267D	Copake fine sandy loam, 15 to 25 percent slopes	.17	19.5	1.1%
269D	Groton gravelly sandy loam, 15 to 25 percent slopes	.10	3.5	0.2%
270A	Hero loam, 0 to 3 percent slopes	.28	9.4	0.5%
270B	Hero loam, 3 to 8 percent slopes	.28	38.6	2.2%
298E	Groton and Hinckley soils, 25 to 35 percent slopes	.15	85.4	4.8%
500B	Amenia silt loam, 3 to 8 percent slopes	.32	12.3	0.7%
506C	Nellis loam, 8 to 15 percent slopes, very stony	.28	10.9	0.6%
511C	Pittsfield loam, 8 to 15 percent slopes, very stony	.24	11.3	0.6%
512D	Pittsfield loam, 15 to 25 percent slopes, extremely stony	.24	49.2	2.8%
514E	Pittsfield and Nellis loams, 25 to 35 percent slopes, extremely stony	.24	7.7	0.4%
600	Pits, gravel		168.7	9.5%
651	Udorthents, smoothed		22.1	1.2%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
901E	Berkshire-Marlow association, 15 to 45 percent slopes, extremely stony		51.4	2.9%
904E	Lyman-Tunbridge association, 15 to 60 percent slopes, extremely stony		755.4	42.4%
905C	Peru-Marlow association, 3 to 15 percent slopes, extremely stony		112.7	6.3%
909C	Tunbridge-Lyman association, 3 to 15 percent slopes, extremely stony		106.2	6.0%
Totals for Area of Interest			**1,783.3**	**100.0%**

Rating Options—K Factor, Whole Soil

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Layer Options (Horizon Aggregation Method): Surface Layer (Not applicable)

Soil Qualities and Features

Soil qualities are behavior and performance attributes that are not directly measured, but are inferred from observations of dynamic conditions and from soil properties. Example soil qualities include natural drainage, and frost action. Soil features are attributes that are not directly part of the soil. Example soil features include slope and depth to restrictive layer. These features can greatly impact the use and management of the soil.

Hydrologic Soil Group

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

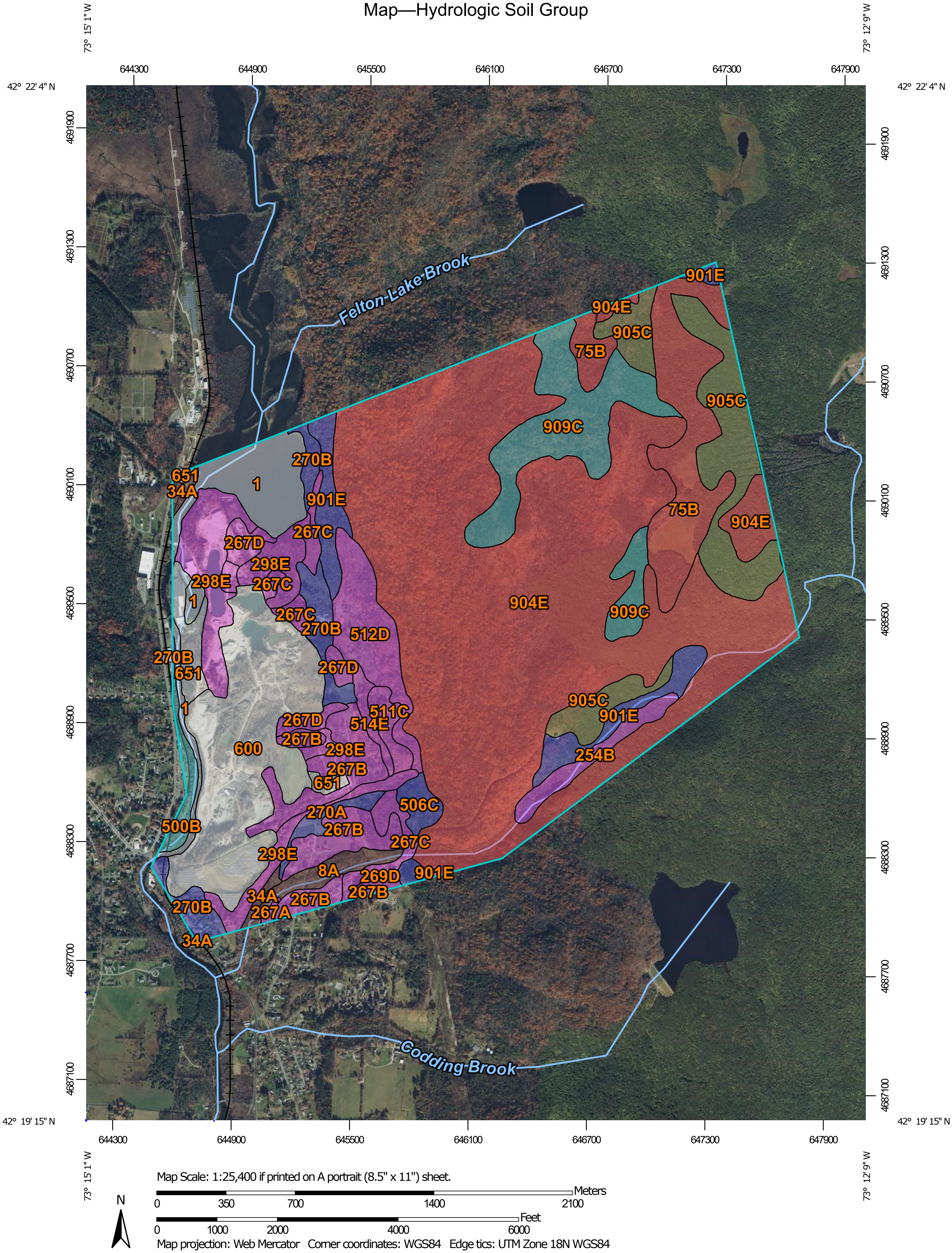
Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Map—Hydrologic Soil Group



MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Berkshire County, Massachusetts
Survey Area Data: Version 17, Sep 9, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 15, 2021—Nov 8, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Table—Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
1	Cwater		61.3	3.4%
8A	Limerick silt loam, 0 to 3 percent slopes, frequently flooded	B/D	16.1	0.9%
34A	Fredon fine sandy loam, 0 to 3 percent slopes	B/D	7.4	0.4%
75B	Pillsbury fine sandy loam, 0 to 8 percent slopes, very stony	D	107.9	6.1%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	A	19.7	1.1%
267A	Copake fine sandy loam, 0 to 3 percent slopes	A	1.4	0.1%
267B	Copake fine sandy loam, 3 to 8 percent slopes	A	74.4	4.2%
267C	Copake fine sandy loam, 8 to 15 percent slopes	A	30.8	1.7%
267D	Copake fine sandy loam, 15 to 25 percent slopes	A	19.5	1.1%
269D	Groton gravelly sandy loam, 15 to 25 percent slopes	A	3.5	0.2%
270A	Hero loam, 0 to 3 percent slopes	B	9.4	0.5%
270B	Hero loam, 3 to 8 percent slopes	B	38.6	2.2%
298E	Groton and Hinckley soils, 25 to 35 percent slopes	A	85.4	4.8%
500B	Amenia silt loam, 3 to 8 percent slopes	C	12.3	0.7%
506C	Nellis loam, 8 to 15 percent slopes, very stony	B	10.9	0.6%
511C	Pittsfield loam, 8 to 15 percent slopes, very stony	A	11.3	0.6%
512D	Pittsfield loam, 15 to 25 percent slopes, extremely stony	A	49.2	2.8%
514E	Pittsfield and Nellis loams, 25 to 35 percent slopes, extremely stony	A	7.7	0.4%
600	Pits, gravel		168.7	9.5%
651	Udorthents, smoothed		22.1	1.2%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
901E	Berkshire-Marlow association, 15 to 45 percent slopes, extremely stony	B	51.4	2.9%
904E	Lyman-Tunbridge association, 15 to 60 percent slopes, extremely stony	D	755.4	42.4%
905C	Peru-Marlow association, 3 to 15 percent slopes, extremely stony	C/D	112.7	6.3%
909C	Tunbridge-Lyman association, 3 to 15 percent slopes, extremely stony	C	106.2	6.0%
Totals for Area of Interest			**1,783.3**	**100.0%**

Rating Options—Hydrologic Soil Group

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

References

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United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1043084

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242

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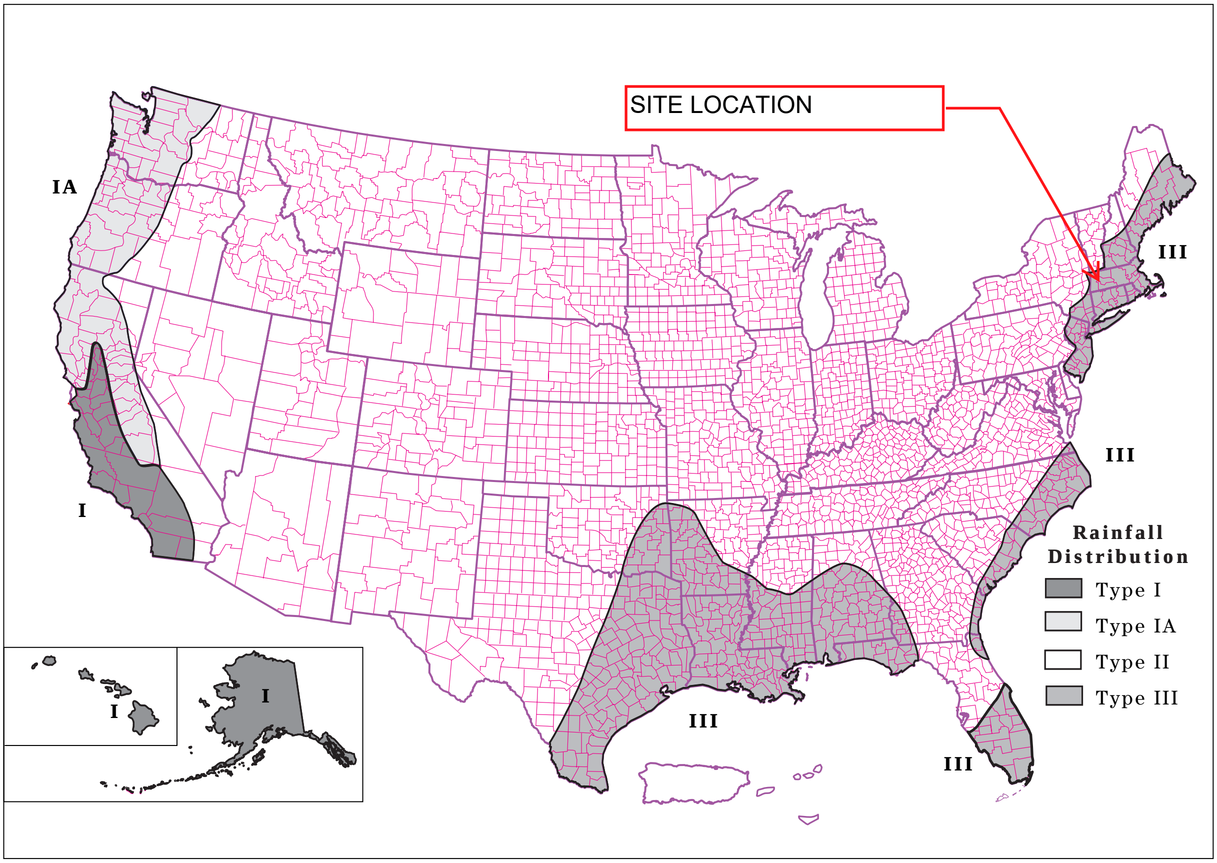
United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052290.pdf

Attachment 4

SDS Rainfall Distribution Map

Figure B-2 Approximate geographic boundaries for NRCS (SCS) rainfall distributions



Rainfall data sources

This section lists the most current 24-hour rainfall data published by the National Weather Service (NWS) for various parts of the country. Because NWS Technical Paper 40 (TP-40) is out of print, the 24-hour rainfall maps for areas east of the 105th meridian are included here as figures B-3 through B-8. For the area generally west of the 105th meridian, TP-40 has been superseded by NOAA Atlas 2, the Precipitation-Frequency Atlas of the Western United States, published by the National Ocean and Atmospheric Administration.

East of 105th meridian

Hershfield, D.M. 1961. Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 40. Washington, DC. 155 p.

West of 105th meridian

Miller, J.F., R.H. Frederick, and R.J. Tracey. 1973. Precipitation-frequency atlas of the Western United States. Vol. I Montana; Vol. II, Wyoming; Vol III, Colorado; Vol. IV, New Mexico; Vol V, Idaho; Vol. VI, Utah; Vol. VII, Nevada; Vol. VIII, Arizona; Vol. IX, Washington; Vol. X, Oregon; Vol. XI, California. U.S. Dept. of Commerce, National Weather Service, NOAA Atlas 2. Silver Spring, MD.

Alaska

Miller, John F. 1963. Probable maximum precipitation and rainfall-frequency data for Alaska for areas to 400 square miles, durations to 24 hours and return periods from 1 to 100 years. U.S. Dept. of Commerce, Weather Bur. Tech. Pap. No. 47. Washington, DC. 69 p.

Hawaii

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Puerto Rico and Virgin Islands

Weather Bureau. 1961. Generalized estimates of probable maximum precipitation and rainfall-frequency data for Puerto Rico and Virgin Islands for areas to 400 square miles, durations to 24 hours, and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 42. Washington, DC. 94 P.

Attachment 5

Infiltration Testing and Boring Spreadsheet

Table 3D
Summary of Soil Infiltration Testing
PDI Summary Report for Upland Disposal Facility Area
GE-Pittsfield/Housatonic River Site

ARCADIS

Test Location ID	Soil Infiltration Rate Hydraulic Conductivity, K (in/hr)	HSG
NB-1	0.74	C
NB-2	No Test	N/A
NB-3	No Test	N/A
NB-4	No Test	N/A
NB-5	35.11	A
NB-6	No Test	N/A
NB-7	1.14	C
NB-8	No Test	N/A
NB-9	No Test	N/A
NB-10	No Test	N/A
NB-11	0.82	C
NB-12	78.61	A
NB-13	No Test	N/A
NB-14	No Test	N/A
NB-15	0.96	C
SB-1	No Test	N/A
SB-2	0.79	C
SB-3	0.76	C

Notes:

1. Some test locations required multiple test iterations to achieve a successful test condition. Only the final test results are shown.

2. Test locations NB-5 and NB-12 had K values high enough that water overflow at the maximum pump rate was not achievable during the test procedure. As a result, constant head testing at these locations was conducted with a water level head maintained below the overflow outlet.

Boring ID	Depth (ftbg)	Group Symbol	HSG
NB-1	14-15	GP-GM	A
NB-1	16-17	SM	B
NB-11	4-6	ML	C
NB-11	6-7.8	GM	A
NB-11 DEEP	6-8	SM	B
NB-11 DEEP	8-12	SM	B
NB-11 DEEP	17.5-19	SM	B
NB-11 DEEP	19-20	ML	C
NB-11 DEEP	20-20.5	SM	B
NB-11 DEEP	20.5-21	SM	B
NB-11 DEEP	21-24	SM	B
NB-11 DEEP	27-28	SM	B
NB-11 DEEP	28-28.5	ML	C
NB-11 DEEP	28.5-29	SM	B
NB-11 DEEP	29-30	GP-GM	A
NB-12	16-17	SM	B
NB-12	17-19	SM	B
NB-12	19-19.5	SM	B
NB-12	19.5-20.1	SM	B
NB-15	4-8	SM	B
NB-15	8-12	SM	B
NB-15	12-16	SM	B
NB-15	16-20	SM	B
NB-15	20-22	SM	B
NB-15	22-23.5	SM	B
NB-15	23.5-24	GM	A
NB-5	24-26.6	SP-SM	A/B
NB-7	20-20.5	SP-SM	A/B
NB-7	20.5-21	SP-SM	A/B
NB-7	21-22	SM	B
NB-7	22-23.5	SM	B
SB-1	6.2-7	SP-SM	A/B
SB-1-DEEP	6-8	SP-SM	A/B
SB-1-DEEP	8-10	SP-SM	A/B
SB-1-DEEP	10-12	SP-SM	A/B
SB-1-DEEP	12-14	SP-SM	A/B
SB-1-DEEP	14-16	SM	B
SB-1-DEEP	16-20	GP-GM	A
SB-1-DEEP	21-24	SM	B
SB-1-DEEP	24-28	ML	C
SB-2A	4-6.3	ML	C
SB-2B	2.2-4.2	GW-GM	A
SB-2B	4.2-5.2	SM	B
SB-2B	5.2-6.2	ML	C
SB-3A	4-4.5	GM	A
SB-3A	4.5-6.1	ML	C
SB-3B	2.1-4.1	GM	A
SB-3B	4.1-5.1	ML	C
SB-3B	5.1-6.1	ML	C
SB-3C	7-11	ML	C

Table C3. Converting USCS to HSG Soil Type

SCS Hydrologic Soil Group	Soil Textures	Corresponding Unified Soil Classification System Category
A	Gravel, sandy gravel, and silty gravels	GW – Well-graded gravels, sandy gravels GP – gap-graded or uniform gravels, sandy gravels GM – silty gravels, silty sandy gravels SW – well-graded, gravelly sands
	Sand, loamy sand, or sandy loam	SP – Gap-graded or uniform sands, gravelly sands
B	Silty sands, silty loam	SM – Silty sands, silty gravelly sands
	Loam	MH – Micaceous silts, diatomaceous silts, volcanic ash
C	Sandy clay loam	ML – Silts, very fine sands, silty or clayey fine sands
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay	GC – Clayey gravels, clayey sandy gravels SC – Clayey sands, clayey gravelly sands CL – Low plasticity clays, sandy or silty clays OL – Organic silts and clays of low plasticity CH – Highly plastic clays and sandy clays OH – Organic silts and clays of high plasticity

Source: Adapted from the Minnesota Stormwater Manual (2013), which presents compiled infiltration rate recommendations based on a review of 30 guidance manuals and many other stormwater references.

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** | **Arcadis Project No.:** **30197838**

Calc No.: **G-3** | **Subject:** **Channel Design**

Prepared By: **CSH** | **Date:** **January 2024**

Reviewed By: **BMS** | **Date:** **February 2024**

Objective

Design channels for managing stormwater runoff within the Upland Disposal Facility (UDF) area. Demonstrate that the geometry of each channel provides adequate hydraulic capacity to convey the estimated peak discharge (e.g., design flow rate) to the given channel resulting from the Design Precipitation Event. Demonstrate that each channel lining is stable while conveying the design flow rate.

References

1. Arcadis U.S., Inc. *Calculation Brief G-1: Design Storm*. February 2024.
2. Arcadis U.S., Inc. *Calculation Brief G-2: Existing Stormwater Conditions*. February 2024.
3. Massachusetts Department of Environmental Protection (MassDEP). *Massachusetts Stormwater Handbook and Stormwater Standards Volume 3, Chapter 1*. 2008.
4. National Resources Conservation Service - United States Department of Agriculture (NRCS-USDA). *Web Soil Survey.* http://websoilsurvey.sc.egov.usda.gov/. Accessed April, 2023.
5. HydroCAD Software Solutions, LLC. *HydroCAD Version 10.2*. Computer Software, 2022.
6. Natural Resource Conservation Service. *Urban Hydrology for Small Watersheds.* Technical Release 55 (TR-55). June 1986
7. United States Department of Transportation Federal Highway Administration (USDOT FHWA). *Design of Roadside Channels with Flexible Linings*. Hydrologic Engineering Circular No. 15 (HEC-15), Third Edition. 2005.
8. MassDEP Division of Watershed Management. *Hydrology Handbook for Conservation Commissioners.* March 2002.
9. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 8: Final Grading Plan.* February 2024.
10. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 9: Stormwater Management Plan.* February 2024.
11. Massachusetts Department of Environmental Protection (MassDEP). *310 CMR 19.000 Solid Waste Management Facility Regulations*. June 2022.

12. North American Green. Specification Sheet – Vmax C350 Turf Reinforcement Mat. 2019.

Assumptions

1. Channels will be either V-shaped or trapezoidal, vegetated, and designed to convey stormwater discharges resulting from the 25-year, 24-hour storm. The eastern and western perimeter ditches will be designed to convey the 100-year, 24-hour storm to prevent stormwater runoff from entering the active portion of the landfill during severe precipitation events (Reference 11). A figure depicting each channel alignment is attached (Figure 1). Channel dimensions are as follows:

Table 1: Channel Dimensions

Channel Number	Location	Side Slopes (Horizontal:Vertical)		Channel Longitudinal Slope	Base Width (feet)
		Left	Right		
1	Perimeter Ditch (West)	3:1	3:1	1.9%	0
2	Final Cover Diversion Berm (West)	10:1	3:1	2.4%	0
3	Final Cover Plateau Ditch	3:1	3:1	3.0%	2
4	Final Cover Diversion Berm (East)	3:1	10:1	2.2%	0
5	Perimeter Ditch (East)	3:1	3:1	2.2%	0
6	East Exterior Ditch	3:1	3:1	2.2%	0
7	Southwest Exterior Ditch (North)	3:1	3:1	4.4%	0
8	Southwest Exterior Ditch (South)	3:1	3:1	6.2%	0
9	Southeast Exterior Ditch	3:1	3:1	1.0%	2
10	North Slope Diversion Berm (North)	3:1	10:1	2.2%	0
11	North Slope Diversion Berm (South)	10:1	3:1	2.0%	0
12	Plateau Access Road Ditch (North)	3:1	3:1	9.6%	0
13	Plateau Access Road Ditch (South)	3:1	3:1	14.7%	0
14	South Access Road Ditch	3:1	3:1	9.6%	0
15	North Access Road Ditch	3:1	3:1	7.1%	0

2. Stormwater conditions within each contributing subcatchment are determined using Reference 5, which utilizes the NRCS curve number (CN) method to convert rainfall to runoff. CNs are selected from Reference 6 based on hydrologic soil groups (HSGs) and ground cover types present under proposed conditions, as summarized below.

   - Soil Types: Soil types will be maintained according to determinations made and discussed in Reference 2.

   - Cover Types: Ground outside of the limits of work will be maintained according to determinations made and discussed in Reference 2. In proposed conditions, all roads and operations areas within UDF are assumed to be gravel cover type. The UDF final cover area is assumed to be Pasture, Grassland, or Range, in Fair Condition.

   - Considering soil and cover types, CN values are as follows (Reference 6):

Cover Type	**CN for Indicated HSG**			
	A	**B**	**C**	**D**
Woods, Good Condition	30	55	70	77
Pasture, Grassland, or Range, Poor Condition (<50% Coverage)	68	79		
Pasture, Grassland, or Range, Fair Condition (50% to 75% Coverage)	49	69		
Brush, Good Condition	30	48		
Gravel	96	96		

3. The design flow rate for each channel is based on the following hydrologic parameters:

   - Hydrograph simulation performed using the NRCS TR-55/TR-20 approach (Reference 5).

   - Watershed areas contributing to each channel (as illustrated in Figure 2) are shown in Table 2 below in the following section.

   - Time of concentration (Tc) paths are delineated based on design grades (Reference 9).

     i. For the purposes of capacity and stability evaluation, Manning's n coefficients are calculated for each channel based on USDOT FHWA design guidance (Reference 7).

     ii. A minimum time of concentration of 6 minutes is used (Reference 6).

4. Flow in channels is uniform (i.e., water surface slope parallels bed slope).

5. Acceleration due to gravity (i.e., gravitational constant) is 32.2 ft/s^2 (9.8 m/s^2).

6. Specific weight of water is 62.4 lb/ft^3 (1000 kg/m^3).

7. All analyzed hydraulic channels are assumed to have a uniform bed slope from inlet to outlet. Hydraulic calculations performed to confirm lining stability and to confirm adequate hydraulic capacity will use the channel's uniform slope.

8. Kinematic viscosity of water is 1.131x10^{-6} m^2/s at 15.5 degrees Celsius and 1.217x10-5 ft^2/s at 60 degrees Fahrenheit.

9. Minimum required channel freeboard depth is 0.3 feet (Reference 8).

10. The Manning's roughness coefficient of the grass lining is based on:

    - Vegetation Retardance Class C (Table 4.1, Reference 7), which assumes a general grass stem height of 6"-12".

- Grass roughness coefficient (Cn) of 0.22 (Table 4.4, Reference 7), which is based on the assumed Vegetation Retardance Class C.

11. All channels will receive permanent turf reinforcement mat (TRM) to increase the durability of the vegetation to the forces of flowing water. The proposed TRM is C350 as manufactured by North American Green and has a permissible shear stress of 12 psf once fully vegetated (Reference 12).
12. Estimated Cover Factor, C_f, is 0.75 based on grass with a mixed growth form (i.e., combination of sod and bunch types) and a good cover condition (Reference 7).
13. Soil grain roughness, n_s, is 0.016 (Reference 7).

Calculations

1. Hydrologic Evaluation of Channels

HydroCAD software (Reference 5) was used to model the catchment areas draining to each channel. Conditions listed under Assumptions 1 and 2 were utilized to calculate design flow rates. HydroCAD modeling inputs and results are provided as Attachment 1. The following table summarizes hydrologic input parameters and the calculated design flow rates to the perimeter channels based on the Design Precipitation Event:

Table 2: Channel Hydrologic Evaluation

Channel Number	Location	Design Storm	Contributing Drainage Area (ac)	Composite CN	Tc (min)[1]	Peak Flow Rate (cfs)
1	Perimeter Ditch (West)	100-yr, 24-hr	5.22	68	6.0	31.62
2	Final Cover Diversion Berm (West)	25-yr, 24-hr	2.10	61	6.0	5.52
3	Final Cover Plateau Ditch		3.05	61	9.8	7.03
4	Final Cover Diversion Berm (East)		3.46	61	6.0	9.10
5	Perimeter Ditch (East)	100-yr, 24-hr	4.65	71	6.0	30.12 [2]
6	East Exterior Ditch	25-yr, 24-hr	0.90	61	6.0	2.37
7	Southwest Exterior Ditch (North)		1.25	67	6.0	4.19
8	Southwest Exterior Ditch (South)		1.67	74	6.0	7.00
9	Southeast Exterior Ditch		1.87	92	6.0	11.27
10	North Slope Diversion Berm (North)		0.61	61	6.0	1.60
11	North Slope Diversion Berm (South)		1.27	61	6.0	3.34
12	Plateau Access Road Ditch (North)		0.33	65	6.0	1.03
13	Plateau Access Road Ditch (South)		0.16	68	6.0	0.56
14	South Access Road Ditch		0.60	70	18.6	1.55
15	North Access Road Ditch		0.45	73	6.0	1.83

Notes:
1. Tc of 6.0 minutes assumed based on the minimum input value for TR-55 (Assumption 3).
2. Channel 5 design flow includes discharge from Channel 6 which enters Channel 5 via a culvert under the perimeter access road.

2. Channel Hydraulic Capacity (Flow Depth)

To determine the cross-sectional flow area within a given channel, Manning's equation is used:

$$Q = \frac{1.49}{n} AR^{\frac{2}{3}} S_f^{\frac{1}{2}}$$

Where,

- Q = Design flow rate (m^3/s or cfs; summarized above)
- A = Cross sectional flow area (unknown, function of flow depth)
- R = Hydraulic radius = A/P, where
  - P = Wetted perimeter (unknown, function of flow depth)
- S_f = Bed slope (Assumption 7)
- n = Manning's n coefficient for the channel lining material (calculated below)

$$n = (0.213) C_n \tau_o^{-.4}$$ (Reference 7)

Where,

- C_n = 0.22 (Assumption 10)
- τ_o = mean boundary shear stress, psf
- τ_o = $\gamma * RS$ (unknown, function of flow depth)
- A = Cross sectional flow area, ft^2 (unknown, function of flow depth)
- R = Hydraulic radius = A/P, where
  - P = Wetted perimeter, ft (unknown, function of flow depth)
- S = Bed Slope (Assumption 7)
- γ = unit weight of water = 62.4 lb/ft3 (Assumption 6)

Flow depth is determined by iteratively solving Manning's equation, using trial flow depths, until the calculated flow rate matches the peak discharge resulting from the design storm event. The following table summarizes peak hydraulic conditions in each channel during the design storm event.

Table 3: Channel Capacity Evaluation

Channel Number	Channel Slope	Design Flow Rate (cfs)	Manning's n Coefficient	Calculated Flow Depth (ft)	Required Channel Depth (ft)	Provided Channel Depth (ft)
1	1.9%	31.62	0.048	1.69	1.99	3.0
2	2.4%	5.52	0.062	0.68	0.98	1.5
3	3.0%	7.03	0.052	0.64	0.94	1.0
4	2.2%	9.10	0.059	0.83	1.13	1.5
5	2.2%	30.12	0.046	1.59	1.89	3.0

Channel Number	Channel Slope	Design Flow Rate (cfs)	Manning's n Coefficient	Calculated Flow Depth (ft)	Required Channel Depth (ft)	Provided Channel Depth (ft)
6	2.2%	2.37	0.064	0.69	0.99	1.5
7	4.4%	4.19	0.049	0.68	0.98	3.0
8	6.2%	7.00	0.042	0.73	1.03	3.0
9	1.0%	11.27	0.066	1.17	1.47	2.0
10	2.2%	1.60	0.074	0.47	0.77	1.5
11	2.0%	3.34	0.069	0.61	0.91	1.5
12	9.6%	1.03	0.047	0.34	0.64	1.0
13	14.7%	0.56	0.045	0.25	0.55	1.0
14	9.6%	1.55	0.045	0.39	0.69	1.0
15	7.1%	1.83	0.048	0.45	0.75	1.0

3. Channel Lining Stability

Channel stability is assessed by comparing maximum applied and permissible shear stresses. The permissible shear stress for each channel is 12 psf based on the presence of a permanent TRM and fully vegetated conditions (Assumption 11). The perimeter drainage ditch on the inside of the perimeter access road (Channel 1 and Channel 5) will have stone check dams at intervals of 1-foot elevation contours. For the purposes of this analysis the presence of check dams within the perimeter ditch is disregarded, thereby disregarding the mitigation of flow velocity within the channel and rendering the stability analysis for this channel conservative.

The maximum shear stress on the vegetated lining can be approximated by calculating the component of the weight of the fluid that is parallel to the slope of the channel. This relationship is summarized as:

$\tau_d = \Upsilon * d * S$ (Reference 7),

Where,

- τ_d = Shear stress in channel at maximum depth, psf (unknown)
- γ = Unit weight of water = 62.4lb/ft3 (Assumption 8)
- d = Flow depth (calculated above)
- S = Bed slope (Assumption 7)

The maximum shear stress on the vegetated lining is calculated by solving for τ_d. A factor of safety is calculated by comparing the permissible and maximum applied shear stresses. The following table summarizes the stability of each lining under vegetated conditions during the previously specified design storms:

Table 4: Channel Stability Evaluation

Channel Number	TRM Design Shear Stress	Shear Stress in Channel at Max Depth (psf)	Calculated Safety Factor
1	12	2.00	6.00
2	12	1.02	11.76
3	12	1.20	10.00
4	12	1.13	10.62
5	12	2.18	5.50
6	12	0.95	12.63
7	12	1.87	6.42
8	12	2.82	4.26
9	12	0.73	16.44
10	12	0.64	18.75
11	12	0.76	15.79
12	12	2.06	5.83
13	12	2.28	5.26
14	12	2.35	5.11
15	12	2.01	5.97

Summary

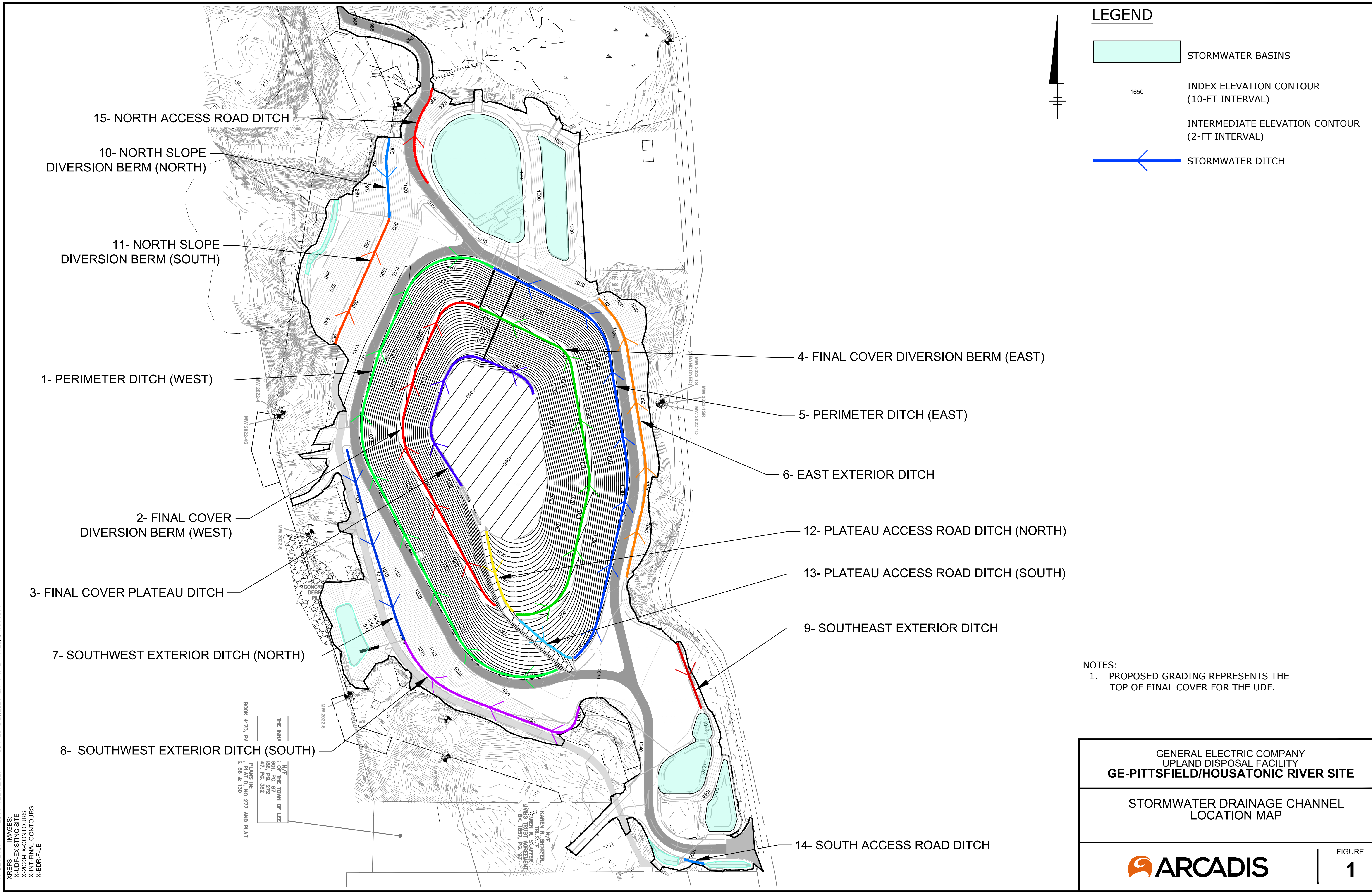
Based on the above calculations, the channel configurations presented in Table 1 provide sufficient capacity to convey the design flow rate under anticipated post-construction conditions. The calculations demonstrate that the channel lining material will remain stable while conveying the design flow rate.

Figures

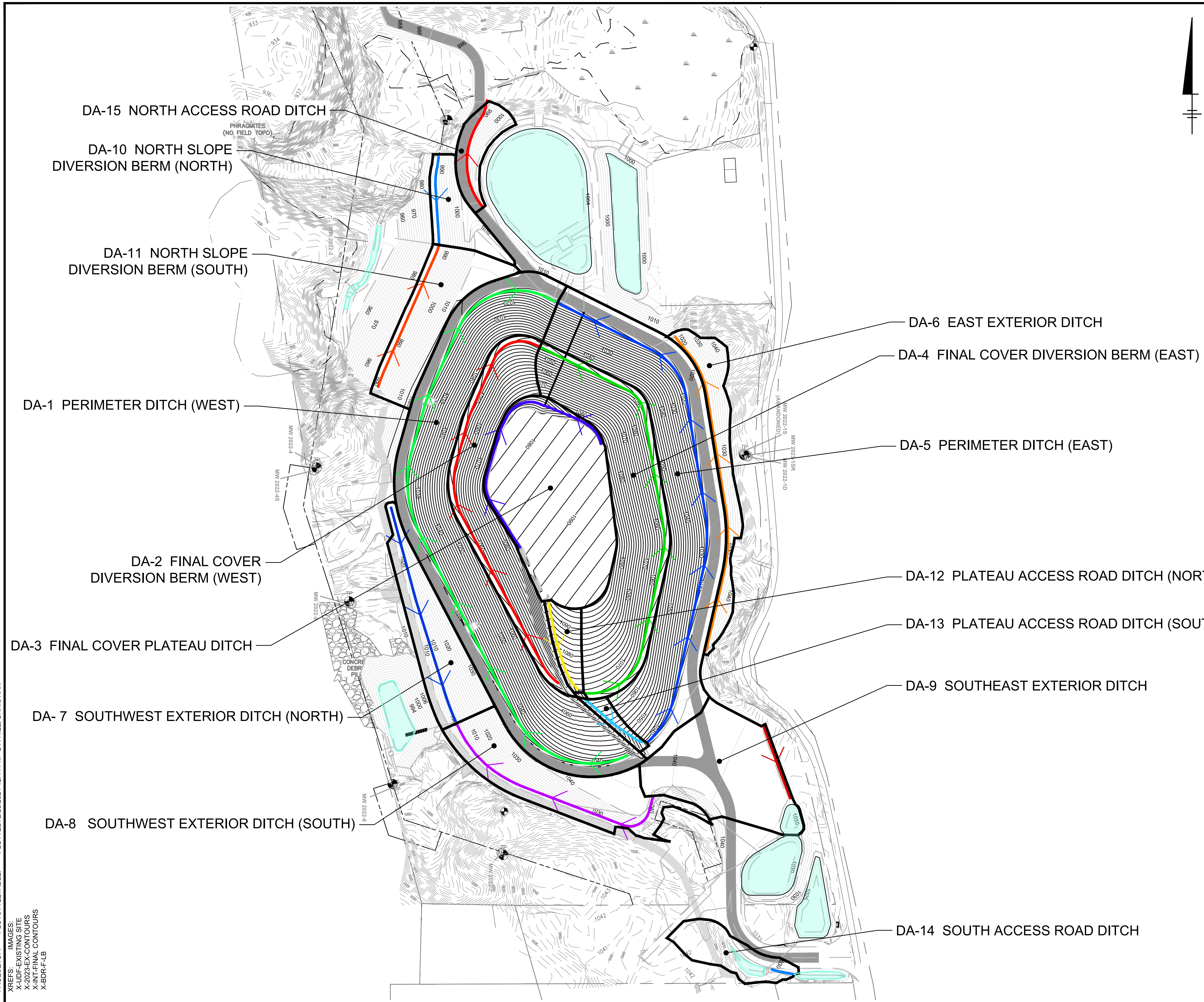
1. Stormwater Drainage Channel Location Map
2. Channel Drainage Area Map

Attachments

1. HydroCAD Channel Modeling Input and Results
2. HEC-15 Stability Calculation Sheets
3. North American Green – ROLLMAX Vmax C350 Turf Reinforcement Mat Specification Sheet



LEGEND
STORMWATER BASINS
1650
INDEX ELEVATION CONTOUR (10-FT INTERVAL)
INTERMEDIATE ELEVATION CONTOUR (2-FT INTERVAL)
STORMWATER DITCH
15- NORTH ACCESS ROAD DITCH
10- NORTH SLOPE DIVERSION BERM (NORTH)
11- NORTH SLOPE DIVERSION BERM (SOUTH)
1- PERIMETER DITCH (WEST)
2- FINAL COVER DIVERSION BERM (WEST)
3- FINAL COVER PLATEAU DITCH
7- SOUTHWEST EXTERIOR DITCH (NORTH)
8- SOUTHWEST EXTERIOR DITCH (SOUTH)
4- FINAL COVER DIVERSION BERM (EAST)
5- PERIMETER DITCH (EAST)
6- EAST EXTERIOR DITCH
12- PLATEAU ACCESS ROAD DITCH (NORTH)
13- PLATEAU ACCESS ROAD DITCH (SOUTH)
9- SOUTHEAST EXTERIOR DITCH
14- SOUTH ACCESS ROAD DITCH
NOTES:
1. PROPOSED GRADING REPRESENTS THE TOP OF FINAL COVER FOR THE UDF.
GENERAL ELECTRIC COMPANY
UPLAND DISPOSAL FACILITY
GE-PITTSFIELD/HOUSATONIC RIVER SITE
STORMWATER DRAINAGE CHANNEL LOCATION MAP
ARCADIS
FIGURE
1



LEGEND

STORMWATER BASINS

1650 INDEX ELEVATION CONTOUR (10-FT INTERVAL)

INTERMEDIATE ELEVATION CONTOUR (2-FT INTERVAL)

STORMWATER DITCH

DRAINAGE AREA BOUNDARY

NOTES:
1. PROPOSED GRADING REPRESENTS THE TOP OF FINAL COVER FOR THE UDF.

GENERAL ELECTRIC COMPANY
UPLAND DISPOSAL FACILITY
GE-PITTSFIELD/HOUSATONIC RIVER SITE

STORMWATER DRAINAGE CHANNEL
DRAINAGE AREA MAP

ARCADIS

FIGURE
2

C:\Users\CSHILL\ARCADIS\GE Upland Disposal Facility - Documents\UDF Design\Final Design Plan\Final Design Plan Report\Appendices\Appendix G - Stormwater Design Calculations\G-3_Channel Design\04_CAD\Channel Locations.dwg LAYOUT: 2 SAVED: 2/27/2024 1:16 PM ACADVER: 24.2S (LMS TECH)
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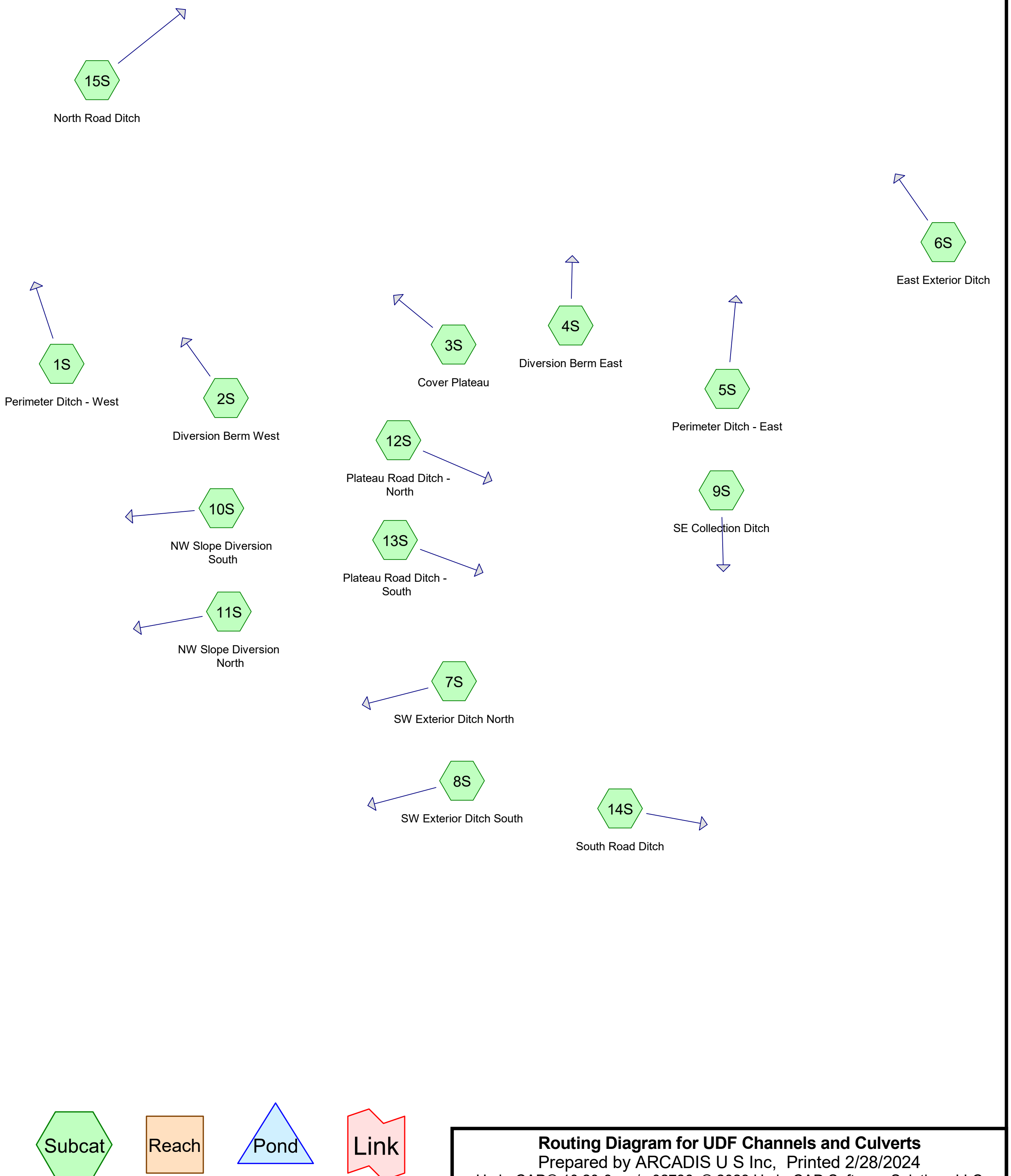
ARCADIS

Attachment 1:

HydroCAD Channel Modeling Input and Results



Routing Diagram for UDF Channels and Culverts
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Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	25-YR	Type III 24-hr		Default	24.00	1	6.48	2
2	100-YR	Type III 24-hr		Default	24.00	1	9.12	2

Summary for Subcatchment 1S: Perimeter Ditch - West

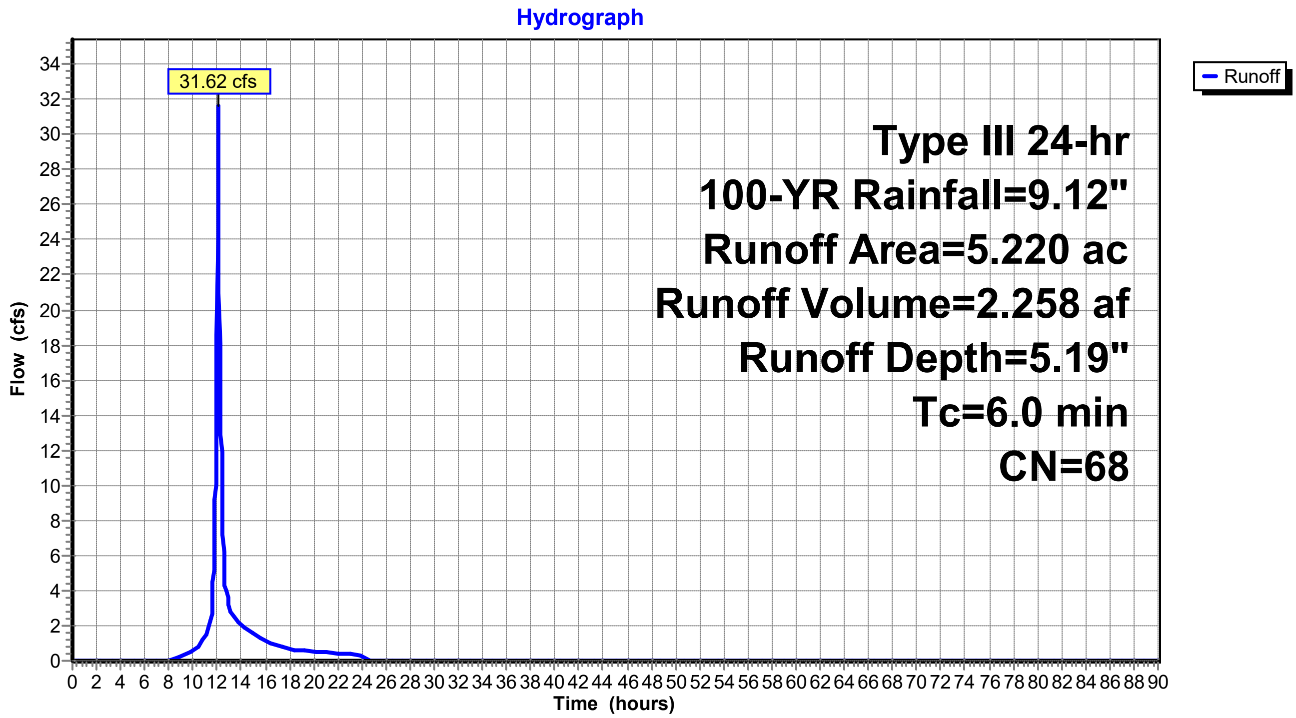
Runoff = 31.62 cfs @ 12.09 hrs, Volume= 2.258 af, Depth= 5.19"
Routed to Reach 1R : Perimeter Ditch West

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 100-YR Rainfall=9.12"

Area (ac)	CN	Description
1.100	96	Gravel surface, HSG B
4.120	61	Pasture/grassland/range, Good, HSG B
5.220	68	Weighted Average
5.220		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55**

Subcatchment 1S: Perimeter Ditch - West



Summary for Subcatchment 2S: Diversion Berm West

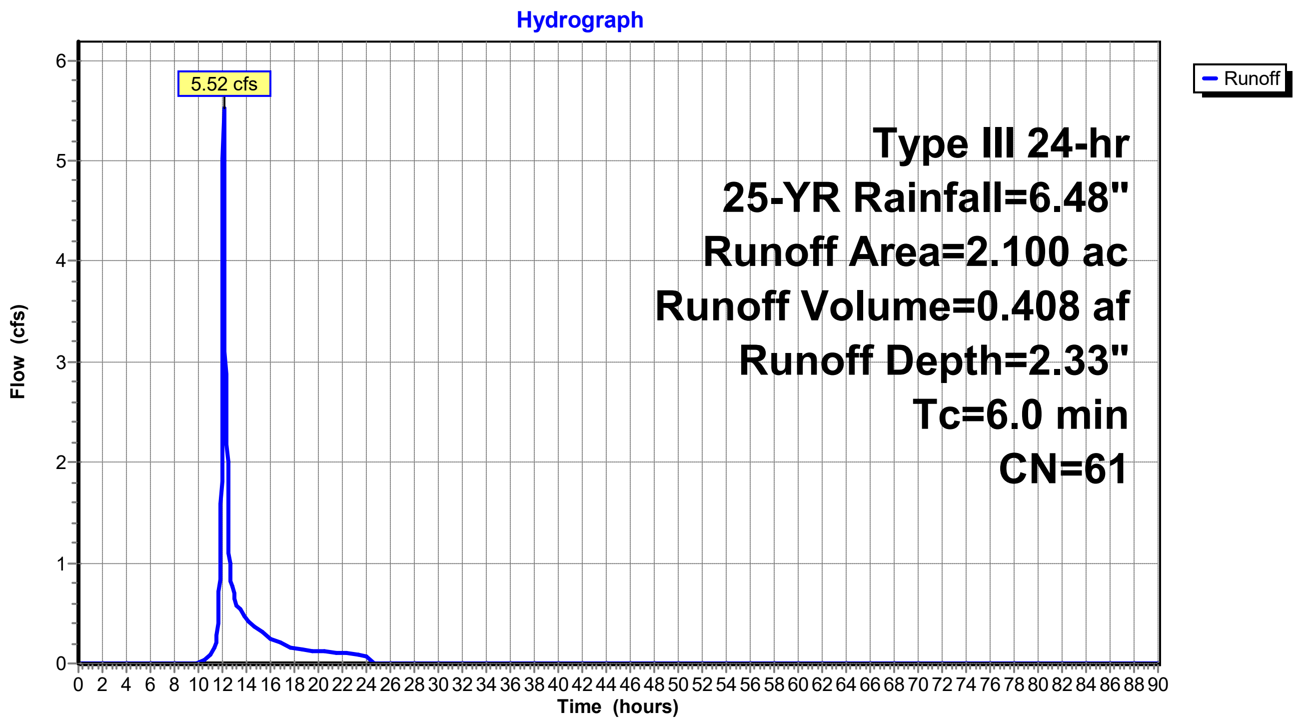
Runoff = 5.52 cfs @ 12.10 hrs, Volume= 0.408 af, Depth= 2.33"
Routed to Reach 2R : Diversion Berm West

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
2.100	61	Pasture/grassland/range, Good, HSG B
2.100		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55 Value**

Subcatchment 2S: Diversion Berm West



Summary for Subcatchment 3S: Cover Plateau

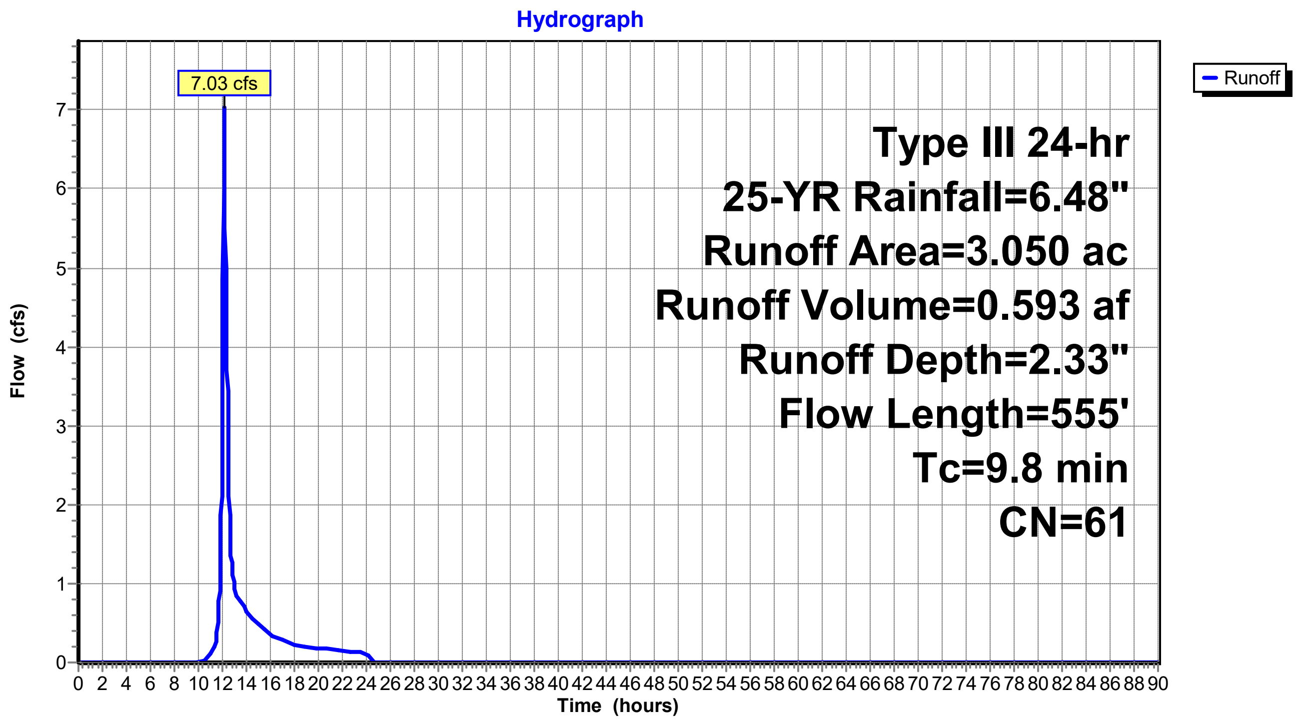
Runoff = 7.03 cfs @ 12.15 hrs, Volume= 0.593 af, Depth= 2.33"
Routed to Reach 3R : Cover Plateau Ditch

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
3.050	61	Pasture/grassland/range, Good, HSG B
3.050		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.2	100	0.0500	0.27		**Sheet Flow,** Range n= 0.130 P2= 3.04"
3.1	295	0.0500	1.57		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.5	160	0.0200	5.79	23.15	**Channel Flow, Ditch Flow** Area= 4.0 sf Perim= 7.0' r= 0.57' n= 0.025 Earth, grassed & winding
9.8	555	Total			

Subcatchment 3S: Cover Plateau



Summary for Subcatchment 4S: Diversion Berm East

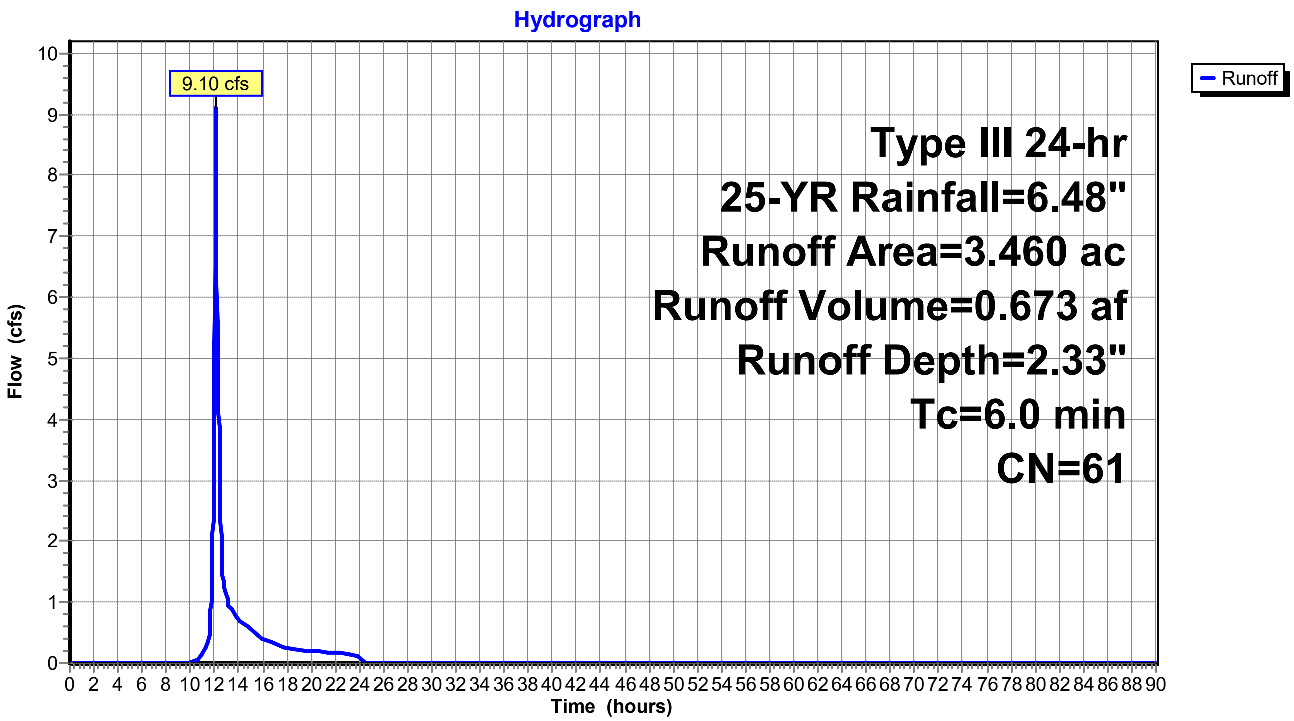
Runoff = 9.10 cfs @ 12.10 hrs, Volume= 0.673 af, Depth= 2.33"
Routed to Reach 4R : Diversion Berm East

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
3.460	61	Pasture/grassland/range, Good, HSG B
3.460		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55**

Subcatchment 4S: Diversion Berm East



Summary for Subcatchment 5S: Perimeter Ditch - East

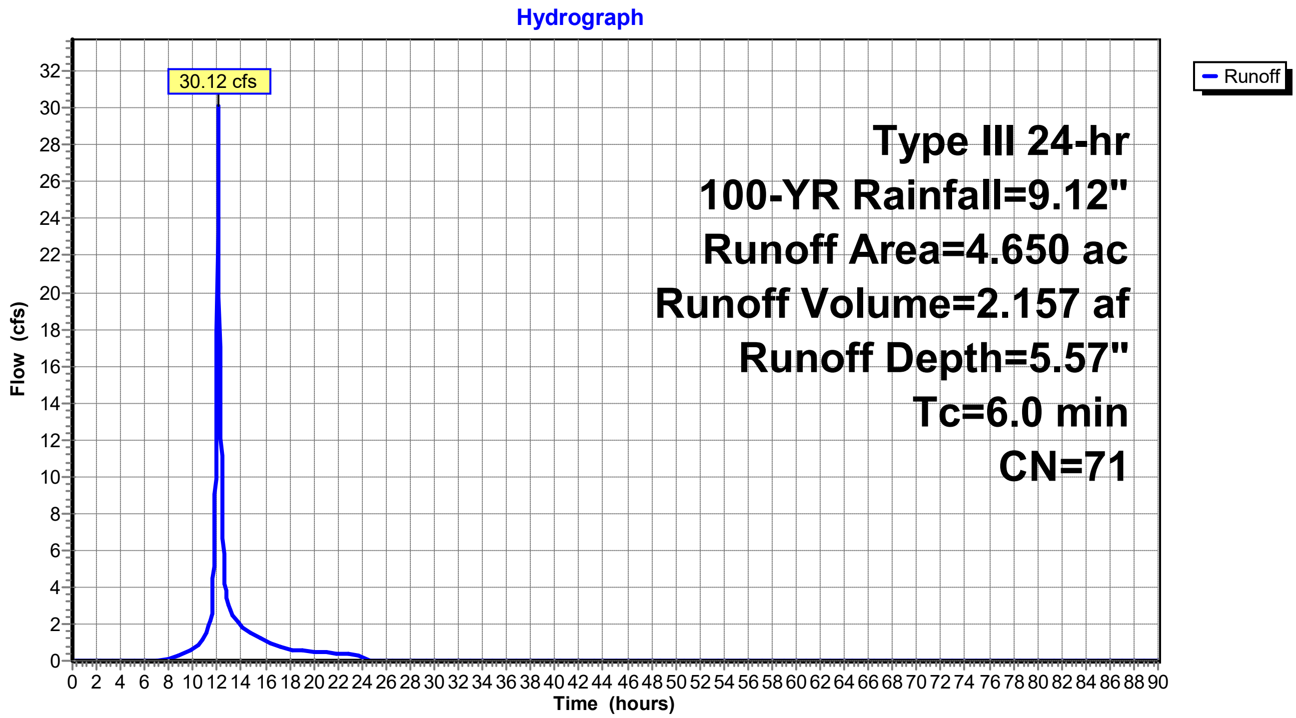
Runoff = 30.12 cfs @ 12.09 hrs, Volume= 2.157 af, Depth= 5.57"
Routed to Reach 5R : Perimeter Ditch East

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 100-YR Rainfall=9.12"

Area (ac)	CN	Description
1.330	96	Gravel surface, HSG B
3.320	61	Pasture/grassland/range, Good, HSG B
4.650	71	Weighted Average
4.650		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55**

Subcatchment 5S: Perimeter Ditch - East



Summary for Subcatchment 6S: East Exterior Ditch

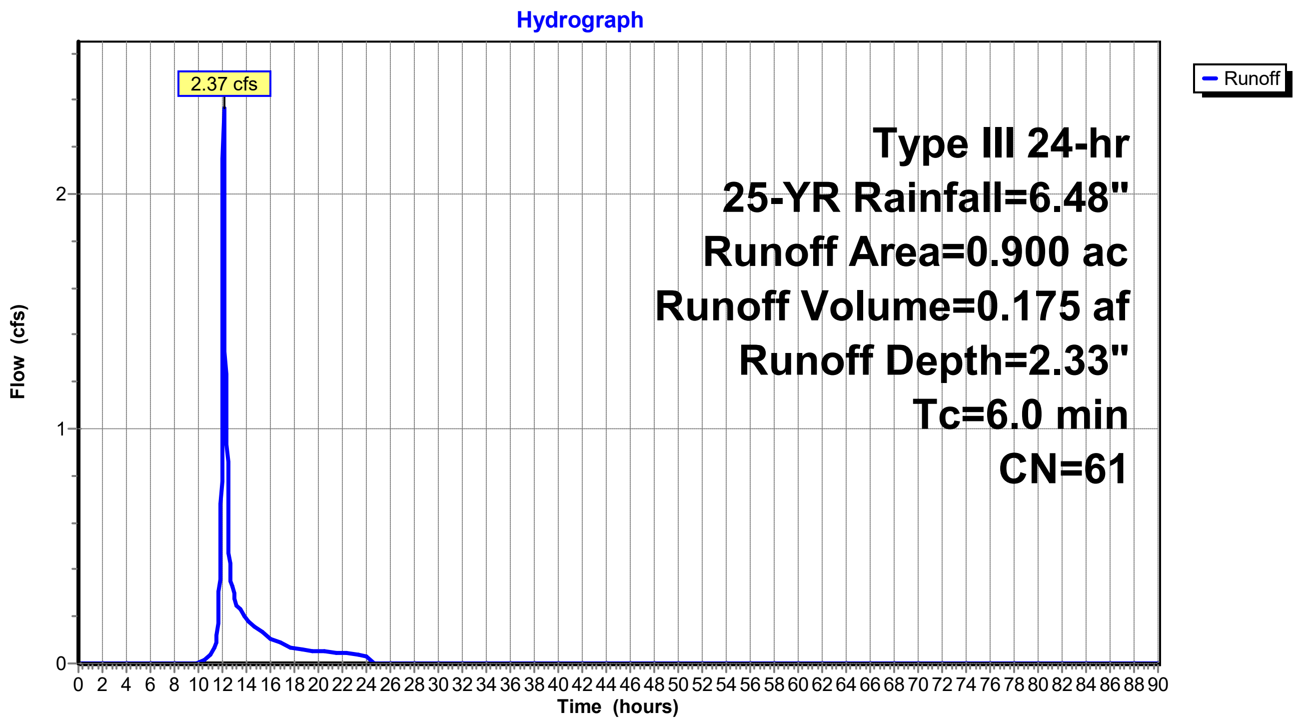
Runoff = 2.37 cfs @ 12.10 hrs, Volume= 0.175 af, Depth= 2.33"
Routed to Reach 6R : East Exterior Ditch

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
0.900	61	Pasture/grassland/range, Good, HSG B
0.900		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55**

Subcatchment 6S: East Exterior Ditch



Summary for Subcatchment 7S: SW Exterior Ditch North

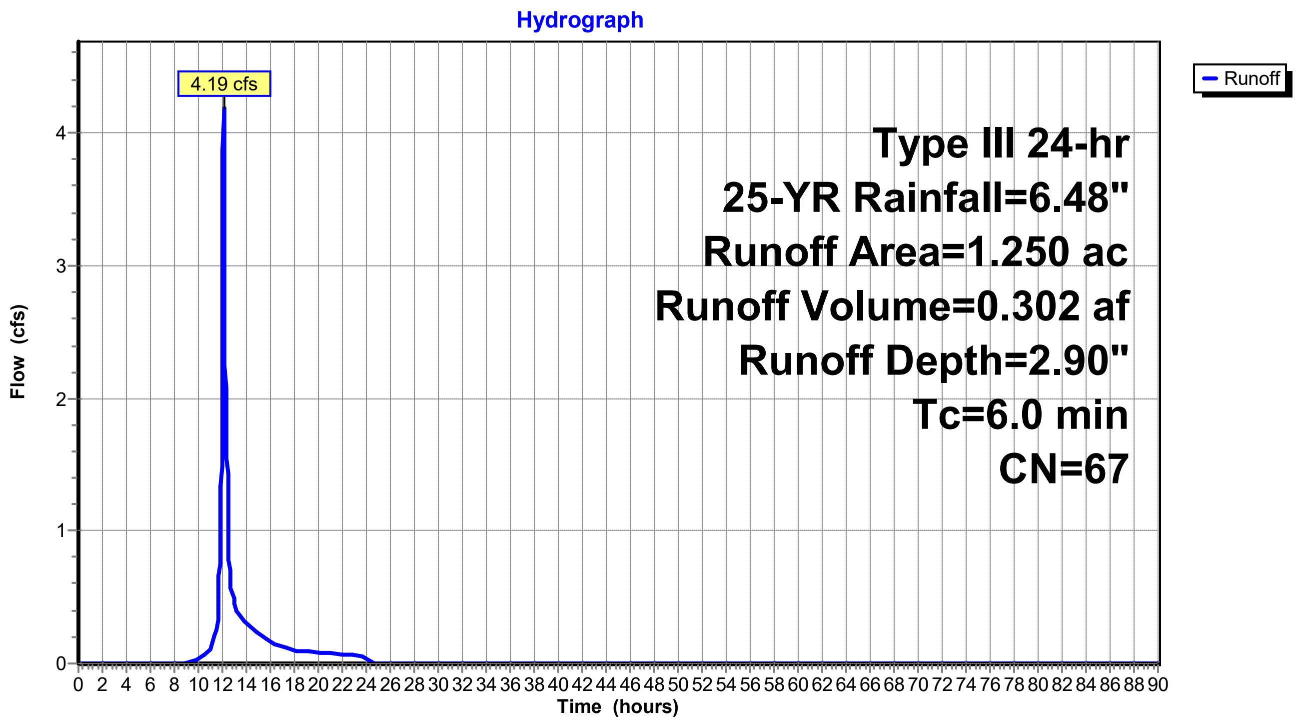
Runoff = 4.19 cfs @ 12.09 hrs, Volume= 0.302 af, Depth= 2.90"
Routed to Reach 7R : SW Exterior Ditch North

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

	Area (ac)	CN	Description
*	1.250	67	
	1.250		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55 Value**

Subcatchment 7S: SW Exterior Ditch North



Summary for Subcatchment 8S: SW Exterior Ditch South

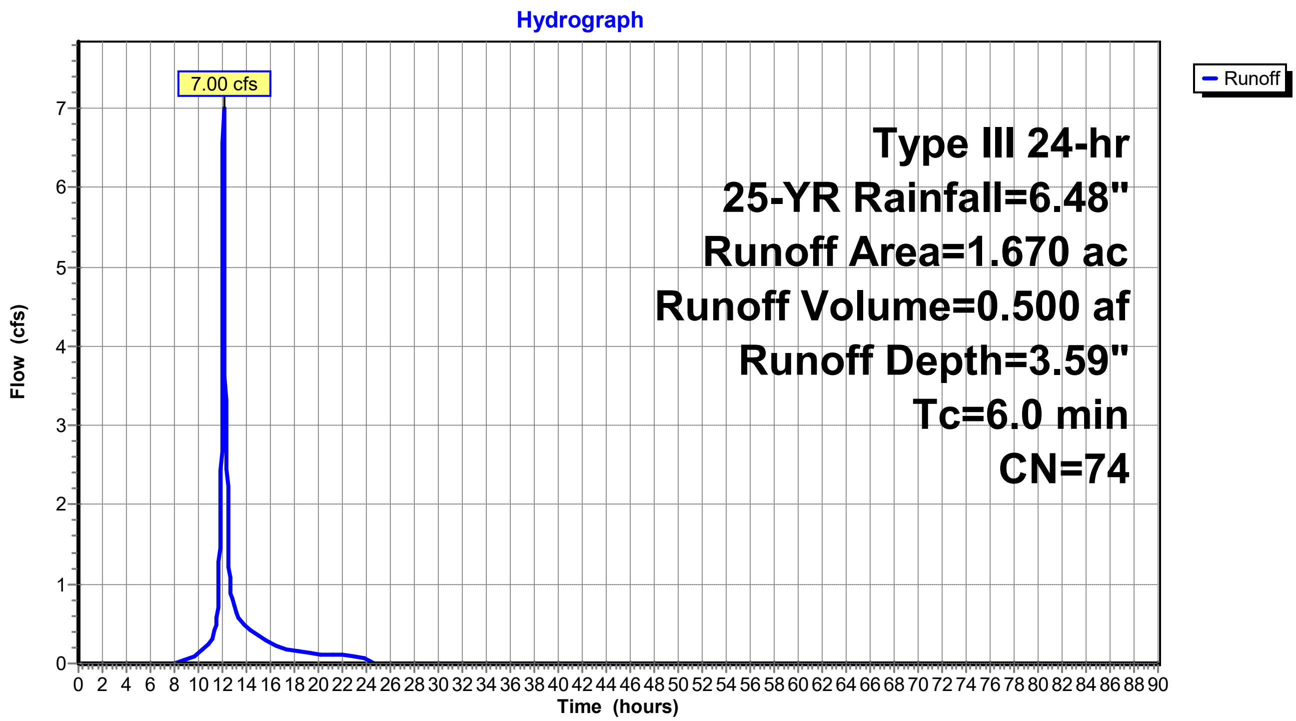
Runoff = 7.00 cfs @ 12.09 hrs, Volume= 0.500 af, Depth= 3.59"
Routed to Reach 8R : SW Exterior Ditch South

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

	Area (ac)	CN	Description
*	1.670	74	
	1.670		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55 Value**

Subcatchment 8S: SW Exterior Ditch South



Summary for Subcatchment 9S: SE Collection Ditch

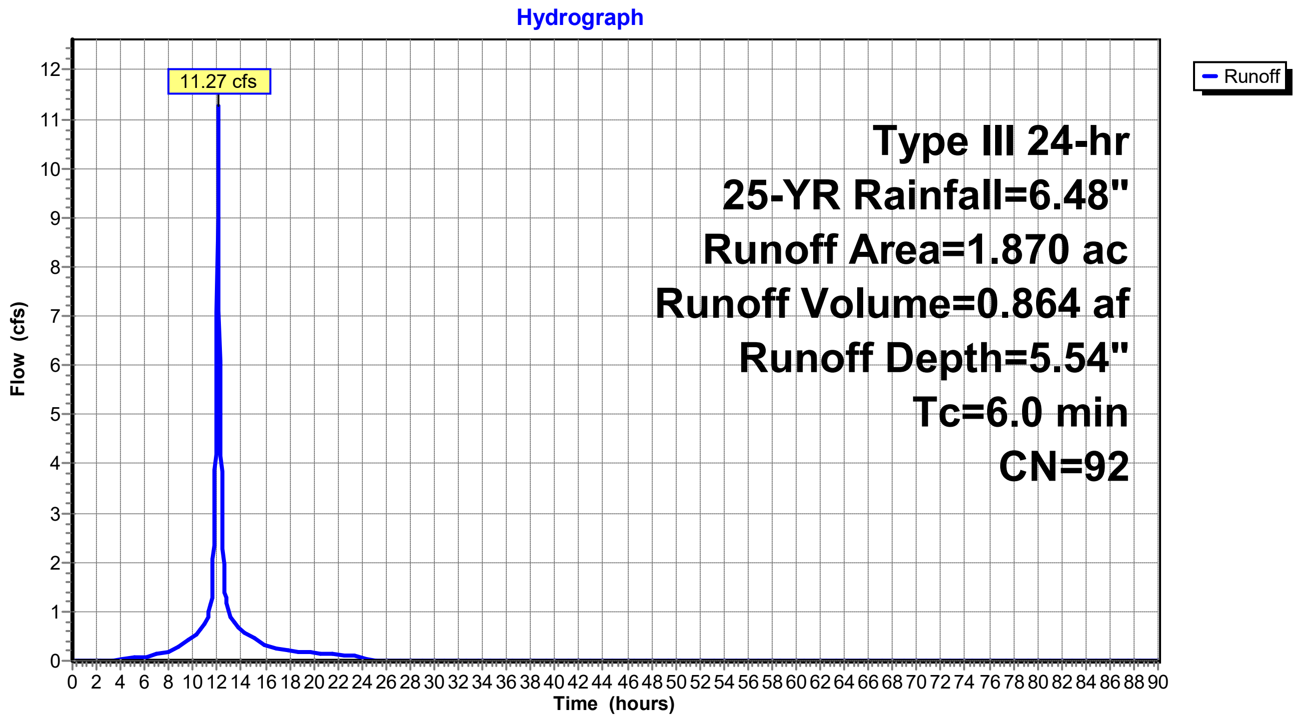
Runoff = 11.27 cfs @ 12.09 hrs, Volume= 0.864 af, Depth= 5.54"
Routed to Reach 9R : Southeastern Collection Ditch

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
0.220	61	Pasture/grassland/range, Good, HSG B
1.650	96	Gravel surface, HSG C
1.870	92	Weighted Average
1.870		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55 Value**

Subcatchment 9S: SE Collection Ditch



Summary for Subcatchment 10S: NW Slope Diversion South

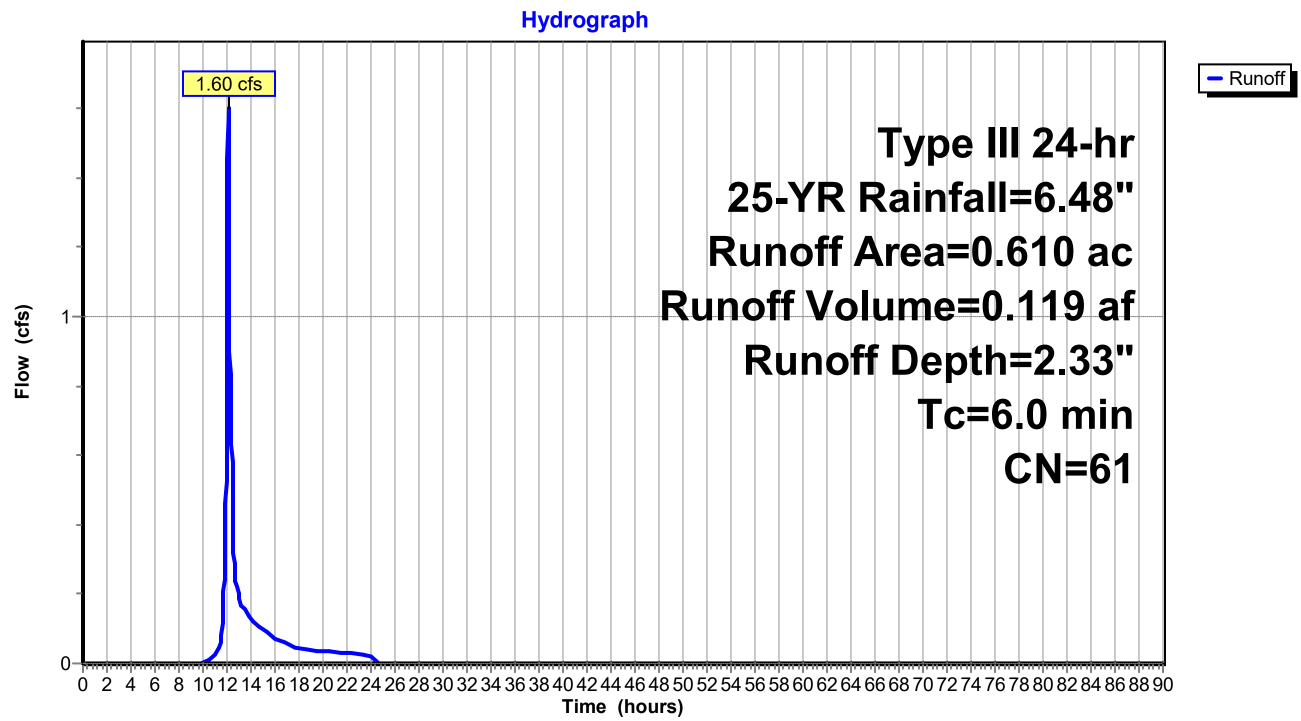
Runoff = 1.60 cfs @ 12.10 hrs, Volume= 0.119 af, Depth= 2.33"
Routed to Reach 10R : NW Slope Diversion South

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
0.610	61	Pasture/grassland/range, Good, HSG B
0.610		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55 Value**

Subcatchment 10S: NW Slope Diversion South



Summary for Subcatchment 11S: NW Slope Diversion North

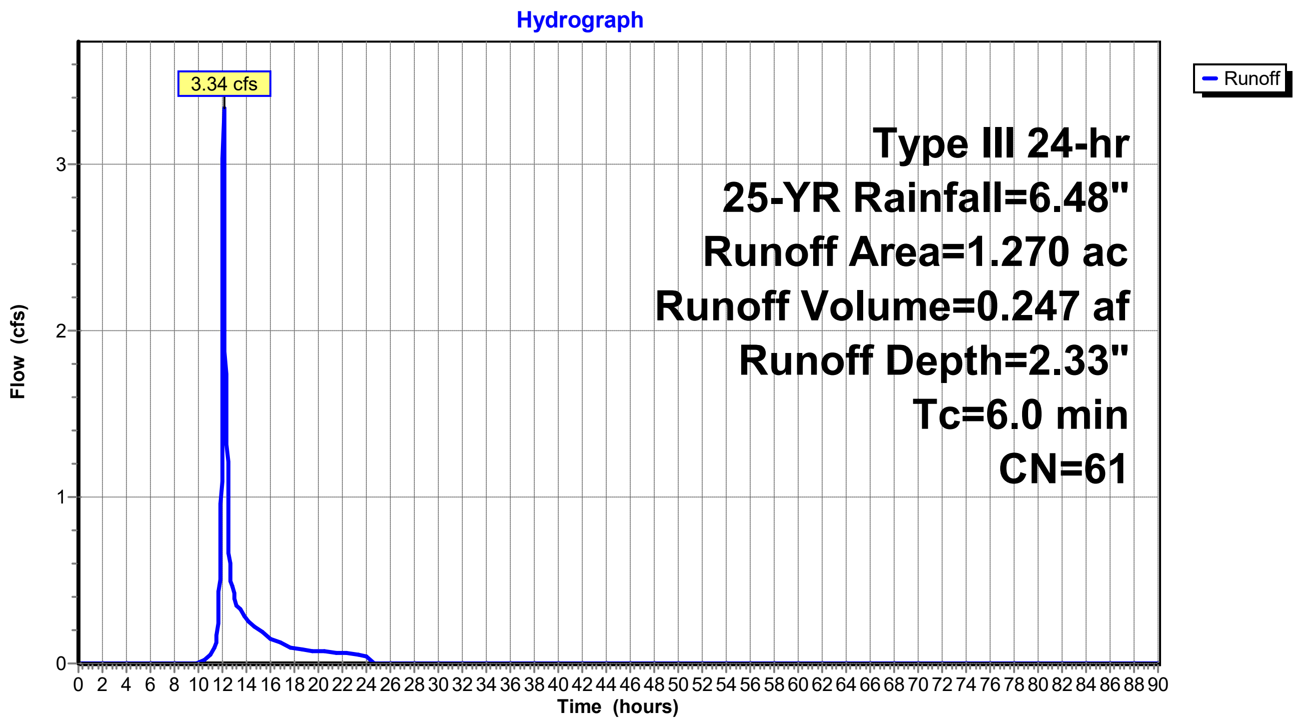
Runoff = 3.34 cfs @ 12.10 hrs, Volume= 0.247 af, Depth= 2.33"
Routed to Reach 11R : NW Slope Diversion North

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
1.270	61	Pasture/grassland/range, Good, HSG B
1.270		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55 Value**

Subcatchment 11S: NW Slope Diversion North



Summary for Subcatchment 12S: Plateau Road Ditch - North

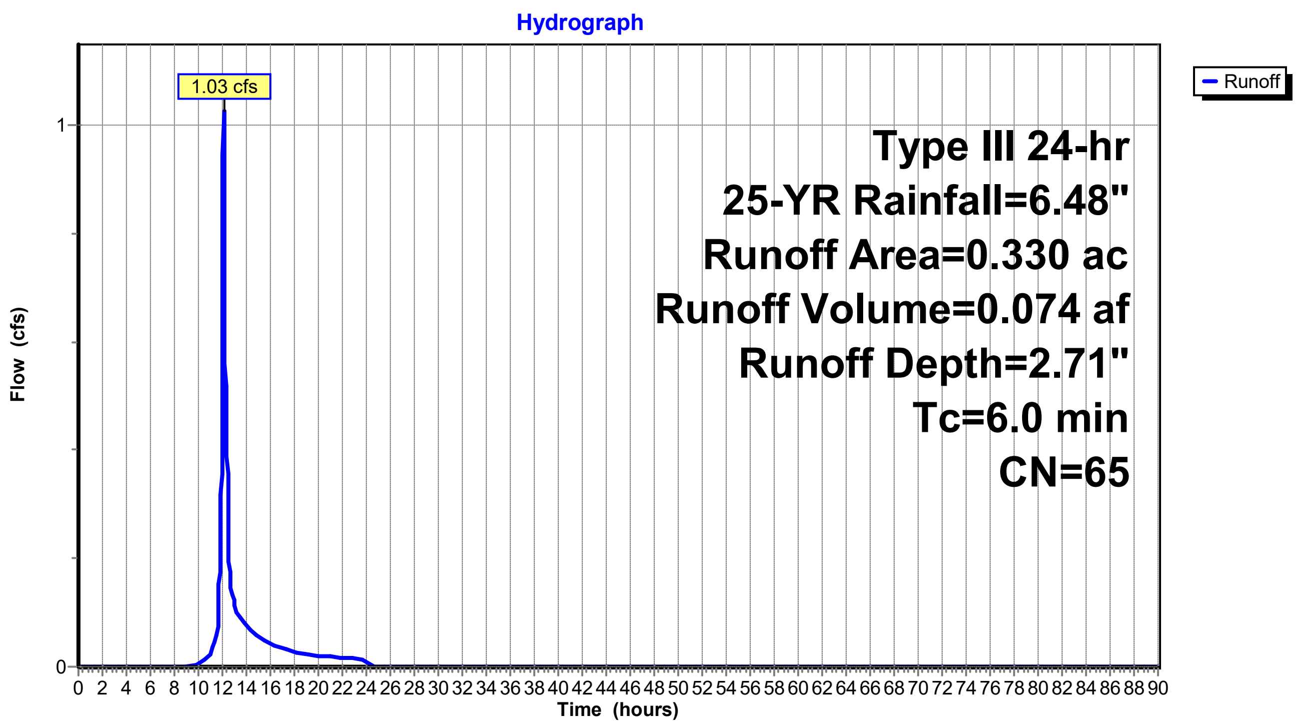
Runoff = 1.03 cfs @ 12.09 hrs, Volume= 0.074 af, Depth= 2.71"
Routed to Reach 12R : Plateau Road Ditch - North

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
0.040	96	Gravel surface, HSG B
0.290	61	Pasture/grassland/range, Good, HSG B
0.330	65	Weighted Average
0.330		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55**

Subcatchment 12S: Plateau Road Ditch - North



Summary for Subcatchment 13S: Plateau Road Ditch - South

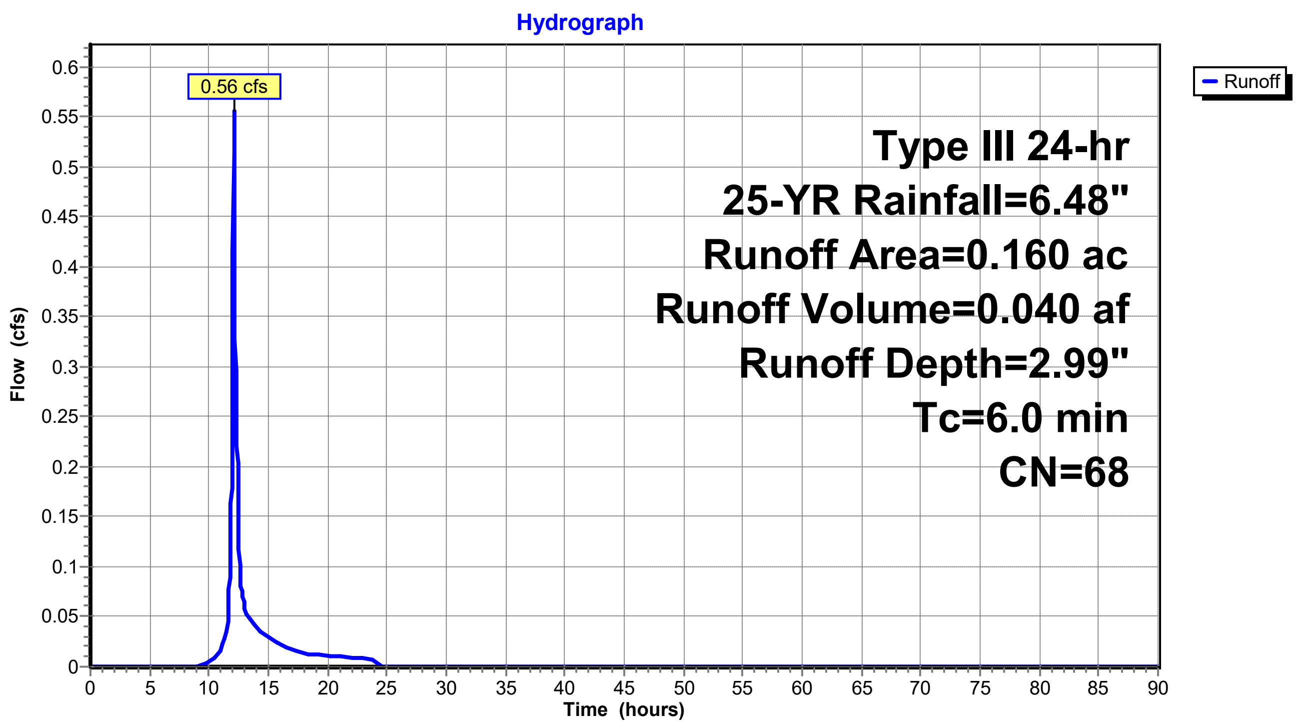
Runoff = 0.56 cfs @ 12.09 hrs, Volume= 0.040 af, Depth= 2.99"
Routed to Reach 13R : Plateau Road Ditch - South

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
0.030	96	Gravel surface, HSG B
0.130	61	Pasture/grassland/range, Good, HSG B
0.160	68	Weighted Average
0.160		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55**

Subcatchment 13S: Plateau Road Ditch - South



Summary for Subcatchment 14S: South Road Ditch

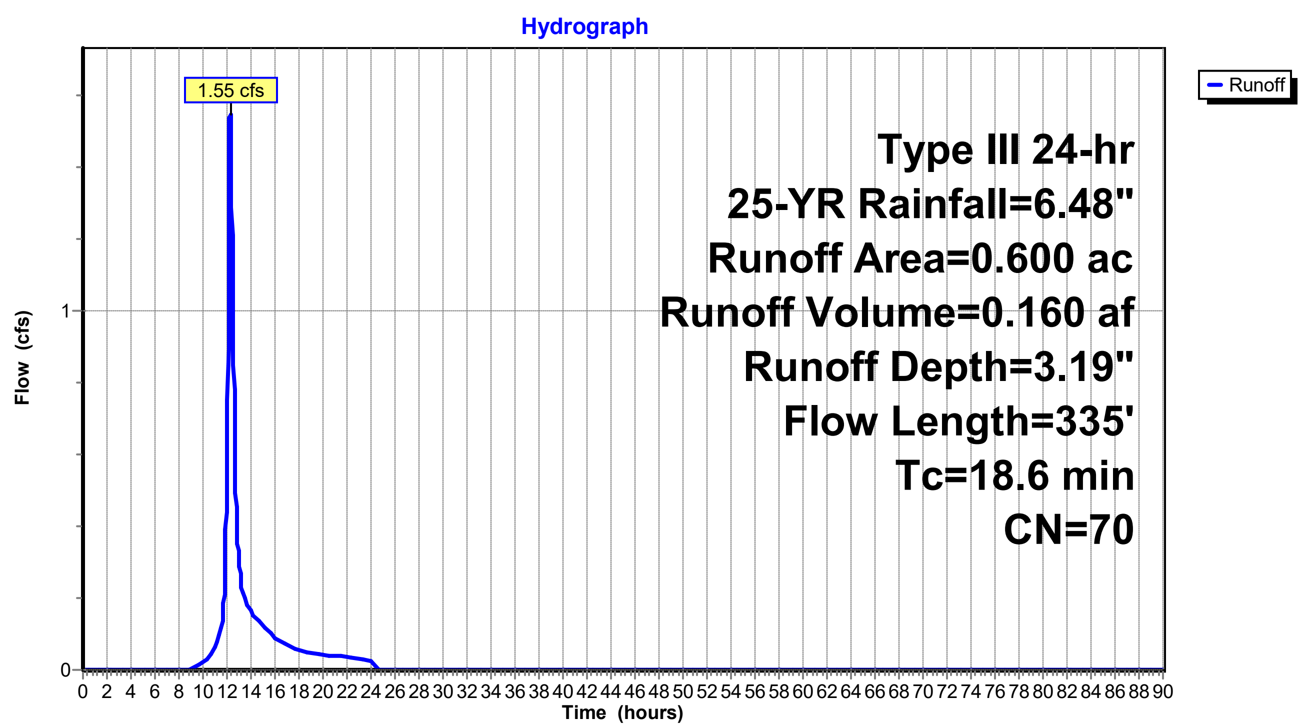
Runoff = 1.55 cfs @ 12.26 hrs, Volume= 0.160 af, Depth= 3.19"
Routed to Reach 14R : South Road Ditch

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
0.440	61	Pasture/grassland/range, Good, HSG B
0.160	96	Gravel surface, HSG B
0.600	70	Weighted Average
0.600		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
16.0	100	0.0160	0.10		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.04"
2.6	235	0.0470	1.52		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
18.6	335	Total			

Subcatchment 14S: South Road Ditch



Summary for Subcatchment 15S: North Road Ditch

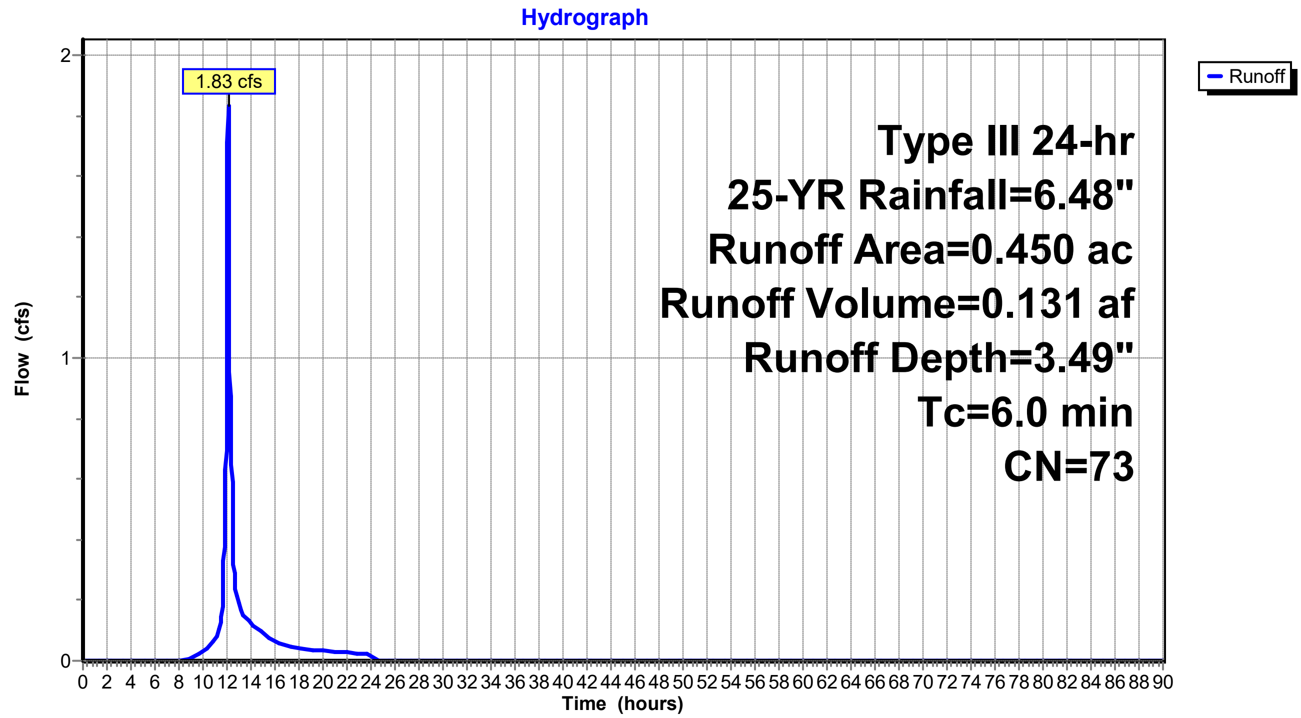
Runoff = 1.83 cfs @ 12.09 hrs, Volume= 0.131 af, Depth= 3.49"
Routed to Reach 15R : North Road Ditch

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Type III 24-hr 25-YR Rainfall=6.48"

Area (ac)	CN	Description
0.290	61	Pasture/grassland/range, Good, HSG B
0.160	96	Gravel surface, HSG B
0.450	73	Weighted Average
0.450		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Min TR-55 Value**

Subcatchment 15S: North Road Ditch



ARCADIS

Attachment 2:
HEC-15 Stability Calculation Sheets

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 1- Perimeter Ditch (West)

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	31.62	100-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.019	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	0.72	
Manning "n"	0.048	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	31.62
Required Flow Depth (ft)	1.69
Resulting Flow Velocity (ft/s)	3.70
Resulting Flow Width at Top (ft)	10.13
Resulting Flow Area (ft^2)	8.54
Resulting Wetted Perimeter (ft)	10.67
Resulting Hydraulic Radius (ft)	0.80
Maximum Shear Stress (psf)	2.00
Average Shear Stress (psf)	0.95

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings*. September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

Row	*Col*	*6*	*7*	*8*	*9*	*10*
	Cover / Density	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 2- Final Cover Diversion Berm (West)

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	5.52	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	10.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.024	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	1.19	
Manning "n"	0.062	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	5.52
Required Flow Depth (ft)	0.68
Resulting Flow Velocity (ft/s)	1.81
Resulting Flow Width at Top (ft)	8.90
Resulting Flow Area (ft^2)	3.04
Resulting Wetted Perimeter (ft)	9.04
Resulting Hydraulic Radius (ft)	0.34
Maximum Shear Stress (psf)	1.02
Average Shear Stress (psf)	0.50

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings*. September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 3- Final Cover Plateau Ditch

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	7.03	25-year
Base Width (ft)	2.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.030	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	0.84	
Manning "n"	0.052	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	7.03
Required Flow Depth (ft)	0.64
Resulting Flow Velocity (ft/s)	2.78
Resulting Flow Width at Top (ft)	5.86
Resulting Flow Area (ft^2)	2.53
Resulting Wetted Perimeter (ft)	6.07
Resulting Hydraulic Radius (ft)	0.42
Maximum Shear Stress (psf)	1.20
Average Shear Stress (psf)	0.78

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings*. September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 4- Final Cover Diversion Berm (East)

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	9.10	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	10.00	
Bed Slope	0.022	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	1.09	
Manning "n"	0.059	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	9.10
Required Flow Depth (ft)	0.83
Resulting Flow Velocity (ft/s)	2.05
Resulting Flow Width at Top (ft)	10.74
Resulting Flow Area (ft^2)	4.44
Resulting Wetted Perimeter (ft)	10.92
Resulting Hydraulic Radius (ft)	0.41
Maximum Shear Stress (psf)	1.13
Average Shear Stress (psf)	0.56

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings*. September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 5- Perimeter Ditch (East)

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	30.12	100-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.022	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	0.67	
Manning "n"	0.046	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	30.12
Required Flow Depth (ft)	1.59
Resulting Flow Velocity (ft/s)	3.97
Resulting Flow Width at Top (ft)	9.55
Resulting Flow Area (ft^2)	7.60
Resulting Wetted Perimeter (ft)	10.06
Resulting Hydraulic Radius (ft)	0.75
Maximum Shear Stress (psf)	2.18
Average Shear Stress (psf)	1.04

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings* . September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 6- East Exterior Ditch

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	2.37	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.022	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	1.29	
Manning "n"	0.064	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	2.37
Required Flow Depth (ft)	0.69
Resulting Flow Velocity (ft/s)	1.64
Resulting Flow Width at Top (ft)	4.17
Resulting Flow Area (ft^2)	1.45
Resulting Wetted Perimeter (ft)	4.39
Resulting Hydraulic Radius (ft)	0.33
Maximum Shear Stress (psf)	0.95
Average Shear Stress (psf)	0.45

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings*. September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 7- Southwest Exterior Ditch (North)

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	4.19	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.044	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	0.75	
Manning "n"	0.049	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	4.19
Required Flow Depth (ft)	0.68
Resulting Flow Velocity (ft/s)	3.00
Resulting Flow Width at Top (ft)	4.09
Resulting Flow Area (ft^2)	1.40
Resulting Wetted Perimeter (ft)	4.32
Resulting Hydraulic Radius (ft)	0.32
Maximum Shear Stress (psf)	1.87
Average Shear Stress (psf)	0.89

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings* . September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 8- Southwest Exterior Ditch (South)

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	7.00	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.062	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	0.54	
Manning "n"	0.042	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	7.00
Required Flow Depth (ft)	0.73
Resulting Flow Velocity (ft/s)	4.39
Resulting Flow Width at Top (ft)	4.38
Resulting Flow Area (ft^2)	1.60
Resulting Wetted Perimeter (ft)	4.61
Resulting Hydraulic Radius (ft)	0.35
Maximum Shear Stress (psf)	2.82
Average Shear Stress (psf)	1.34

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings*. September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 9- Southeast Exterior Ditch

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	11.27	25-year
Base Width (ft)	2.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.010	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	1.36	
Manning "n"	0.066	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	11.27
Required Flow Depth (ft)	1.17
Resulting Flow Velocity (ft/s)	1.76
Resulting Flow Width at Top (ft)	9.00
Resulting Flow Area (ft^2)	6.42
Resulting Wetted Perimeter (ft)	9.38
Resulting Hydraulic Radius (ft)	0.68
Maximum Shear Stress (psf)	0.73
Average Shear Stress (psf)	0.43

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings*. September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	B	0.55	0.47	0.50	0.41	0.53
23	M	0.82	0.70	0.75	0.62	0.79
24	S	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 10- North Slope Diversion Berm (North)

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	1.60	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	10.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.022	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	1.72	
Manning "n"	0.074	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	1.60
Required Flow Depth (ft)	0.47
Resulting Flow Velocity (ft/s)	1.12
Resulting Flow Width at Top (ft)	6.10
Resulting Flow Area (ft^2)	1.43
Resulting Wetted Perimeter (ft)	6.19
Resulting Hydraulic Radius (ft)	0.23
Maximum Shear Stress (psf)	0.64
Average Shear Stress (psf)	0.32

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings*. September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213)CnTo^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 11- North Slope Diversion Berm (South)

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	3.34	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	10.00	
Bed Slope	0.020	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	1.50	
Manning "n"	0.069	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	3.34
Required Flow Depth (ft)	0.61
Resulting Flow Velocity (ft/s)	1.37
Resulting Flow Width at Top (ft)	7.97
Resulting Flow Area (ft^2)	2.44
Resulting Wetted Perimeter (ft)	8.10
Resulting Hydraulic Radius (ft)	0.30
Maximum Shear Stress (psf)	0.76
Average Shear Stress (psf)	0.38

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings*. September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 12- Plateau Access Road Ditch (North)

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	1.03	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.096	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	0.70	
Manning "n"	0.047	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	1.03
Required Flow Depth (ft)	0.34
Resulting Flow Velocity (ft/s)	2.91
Resulting Flow Width at Top (ft)	2.06
Resulting Flow Area (ft^2)	0.35
Resulting Wetted Perimeter (ft)	2.17
Resulting Hydraulic Radius (ft)	0.16
Maximum Shear Stress (psf)	2.06
Average Shear Stress (psf)	0.98

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings* . September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

Row	*Col*	*6*	*7*	*8*	*9*	*10*
	Cover / Density	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213) Cn To^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 13- Plateau Access Road Ditch (South)

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	0.56	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.147	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	0.64	
Manning "n"	0.045	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	0.56
Required Flow Depth (ft)	0.25
Resulting Flow Velocity (ft/s)	3.02
Resulting Flow Width at Top (ft)	1.49
Resulting Flow Area (ft^2)	0.19
Resulting Wetted Perimeter (ft)	1.57
Resulting Hydraulic Radius (ft)	0.12
Maximum Shear Stress (psf)	2.28
Average Shear Stress (psf)	1.08

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings* . September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213)CnTo^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 14- South Access Road Ditch

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	1.55	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.096	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	0.63	
Manning "n"	0.045	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	1.55
Required Flow Depth (ft)	0.39
Resulting Flow Velocity (ft/s)	3.35
Resulting Flow Width at Top (ft)	2.35
Resulting Flow Area (ft^2)	0.46
Resulting Wetted Perimeter (ft)	2.48
Resulting Hydraulic Radius (ft)	0.19
Maximum Shear Stress (psf)	2.35
Average Shear Stress (psf)	1.12

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings* . September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213)CnTo^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

Project: Upland Disposal Facility - GE Pittsfield/Housatonic River Site
Subject: UDF Vegetated Swales - Channel 15- North Access Road Ditch

By: CSH
Date: 02/28/24

Vegetated Lining

Channel Design (Input)		
Flow Capacity (cfs)	1.84	25-year
Base Width (ft)	0.00	
Left Side Slope (x:1)	3.00	
Right Side Slope (x:1)	3.00	
Bed Slope	0.071	
Vegetative Retardance Class (A, B, C, D, or E)	C	
Vegetative Growth Form (Sod [S], Bunch [B], or Mixed [M])	M	
Cover Density (Excellent [E], Very Good [VG], Good [G], Fair [F], Poor [P])	G	
Maximum Allowable Shear Stress (psf)	0.71	
Manning "n"	0.048	

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	1.84
Required Flow Depth (ft)	0.45
Resulting Flow Velocity (ft/s)	2.98
Resulting Flow Width at Top (ft)	2.72
Resulting Flow Area (ft^2)	0.62
Resulting Wetted Perimeter (ft)	2.87
Resulting Hydraulic Radius (ft)	0.22
Maximum Shear Stress (psf)	2.01
Average Shear Stress (psf)	0.95

**ALL CACULATIONS SHOULD BE CHECKED BY HAND TO CONFIRM THE ACCURACY OF THE FINAL RESULTS.

REFERENCE:

USDOT FHWA. Hydrologic Engineering Circular No. 15 (HEC-15). *Design of Roadside Channels with Flexible Linings*. September 2005.

TABLES:

Grass Roughness Coefficients (Table 4.4)

Cn = 0.22

Retardance Class	Cn
A	0.605
B	0.418
C	0.220
D	0.147
E	0.093

Cover Factor Values for Uniform Stands of Grass (Table 4.5)

Cf = 0.75

	Col	*6*	*7*	*8*	*9*	*10*
Row	**Cover / Density**	**E**	**F**	**G**	**P**	**VG**
22	**B**	0.55	0.47	0.50	0.41	0.53
23	**M**	0.82	0.70	0.75	0.62	0.79
24	**S**	0.98	0.84	0.90	0.75	0.95

(Table 4.1)

Vegetation Class	Stem Ht.
A	24"-36"
B	12"-24"
C	6"-12"
D	2"-6"
E	0"-2"

EQUATIONS:

$$n = (0.213)CnTo^{-0.4}$$ Eq. 4.2

Cn = Grass roughness coefficient (Table 4.4)
To = mean boundary shear stress (psf) = γRS

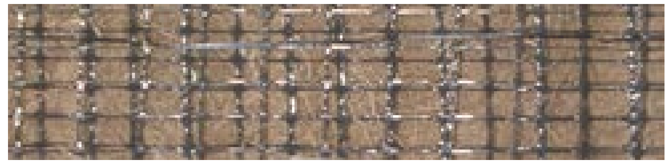
ARCADIS

Attachment 3:

North American Green – ROLLMAX Vmax C350 Turf Reinforcement Mat Specification Sheet

ROLLMAX™
ROLLED EROSION CONTROL

Specification Sheet
VMax® C350® Turf Reinforcement Mat



DESCRIPTION

The composite turf reinforcement mat (C-TRM) shall be a machine-produced mat of 100% coconut fiber matrix incorporated into permanent three-dimensional turf reinforcement matting. The matrix shall be evenly distributed across the entire width of the matting and stitch bonded between super heavy duty UV-stabilized nettings with 0.50 x 0.50 in. (1.27 x 1.27 cm) openings, an ultra heavy duty UV-stabilized, dramatically corrugated (crimped) intermediate netting with 0.5 x 0.5 in. (1.27 x 1.27 cm) openings, and covered by a super heavy duty UV-stabilized nettings with 0.50 x 0.50 in. (1.27 x 1.27 cm) openings. The middle corrugated netting shall form prominent closely spaced ridges across the entire width of the mat. The three nettings shall be stitched together on 1.50 in. (3.81 cm) centers with UV-stabilized polypropylene thread to form permanent three-dimensional turf reinforcement matting. All mats shall be manufactured with colored thread stitched along both outer edges as an overlap guide for adjacent mats.

The C350 shall meet Type 5A, B and C specification requirements established by the Erosion Control Technology Council (ECTC) and Federal Highway Administration's (FHWA) *FP-03 Section 713.18*.

Material Content		
Matrix	100% Coconut Fiber	0.5 lb/sy (0.27 kg/sm)
Netting	Top and Bottom, UV-Stabilized Polypropylene	8 lb/1000 sf (3.91 kg/100 sm)
	Middle, Corrugated UV-Stabilized Polypropylene	24 lb/1000 sf (11.7 kg/100 sm)
Thread	Polypropylene, UV Stable	

Standard Roll Sizes		
Width	6.5 ft (2.0 m)	8 ft (2.44 m)
Length	55.5 ft (16.9 m)	90 ft (27.4 m)
Weight ± 10%	37 lbs (16.8 kg)	74 lbs (33.6 kg)
Thread	40 sy (33.4 sm)	80 sy (66.8 sm)

Index Property	Test Method	Typical
Thickness	ASTM D6525	0.73 in. (18.54 mm)
Resiliency	ASTM D6524	90%
Density	ASTM D792	0.917 g/cm^3
Mass/Unit Area	ASTM D6566	18.36 oz/sy (624 g/sm)
UV Stability	ASTM D4355/ 1000 HR	80%
Porosity	ECTC Guidelines	99%
Stiffness	ASTM D1388	0.24 in.-lb (275990 mg-cm)
Light Penetration	ASTM D6567	7.2%
Tensile Strength – MD	ASTM D6818	585.8 lbs/ft (8.70 kN/m)
Elongation – MD	ASTM D6818	45.3%
Tensile Strength – TD	ASTM D6818	687.6 lbs/ft (10.20 kN/m)
Elongation – TD	ASTM D6818	19.5%
Biomass Improvement	ASTM D7322	380%

Design Permissible Shear Stress		
	Short Duration	**Long Duration**
Phase 1 Unvegetated	3.2 psf (153 Pa)	3.0 psf (144 Pa)
Phase 2 Partially Veg.	10.0 psf (480 Pa)	10.0 psf (480 Pa)
Phase 3 Fully Veg.	12.0 psf (576 Pa)	10.0 psf (480 Pa)
Unvegetated Velocity	10.5 fps (3.2 m/s)	
Vegetated Velocity	20 fps (6.0 m/s)	

Slope Design Data: C Factors			
	Slope Gradients (S)		
Slope Length (L)	≤ 3:1	3:1 – 2:1	≥ 2:1
≤ 20 ft (6 m)	0.0005	0.015	0.043
20-50 ft	0.018	0.031	0.050
≥ 50 ft (15.2 m)	0.035	0.047	0.057

Roughness Coefficients – Unveg.	
Flow Depth	Manning's n
≤ 0.50 ft (0.15 m)	0.041
0.50 – 2.0 ft	0.040-0.013
≥ 2.0 ft (0.60 m)	0.012

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Western Green
4609 E. Boonville-New Harmony Rd.
Evansville, IN 47725

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800-772-2040

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **G-4** **Subject:** **Stormwater Basin Design**

Prepared By: **MTA** **Date:** **February 2024**

Reviewed By: **BMS** **Date:** **February 2024**

Objective

Evaluate the performance of two proposed infiltration basins for managing stormwater runoff management from the Upland Disposal Facility (UDF).

References

1. Arcadis U.S., Inc. *Calculation Brief G-1: Design Storm*. February 2024.
2. Arcadis U.S., Inc. *Calculation Brief G-2: Existing Stormwater Conditions*. February 2024.
3. Autodesk, Inc. *Civil3D*. Computer Software. 2023.
4. Massachusetts Department of Environmental Protection (MassDEP). *Massachusetts Stormwater Handbook and Stormwater Standards Volume 3, Chapter 1*. 2008.
5. HydroCAD Software Solutions, LLC. *HydroCAD Version 10.2*. Computer Software, 2022.
6. NOAA's National Weather Service (NOAA). *NOAA Atlas 14-Point Precipitation Frequency Estimates*, Town of Lee, MA.
7. Natural Resource Conservation Service. *Urban Hydrology for Small Watersheds.* Technical Release 55 (TR-55). June 1986.
8. MassDEP Division of Watershed Management. *Hydrology Handbook for Conservation Commissioners.* March 2002.
9. MassDEP. *Massachusetts Stormwater Handbook and Stormwater Standards Volume 2, Chapter 2*. 2008.
10. Arcadis U.S., Inc. *Calculation Brief G-7: Proposed Stormwater Conditions*. February 2024.
11. OpenFlows FlowMaster CONNECT. Edition Update 3. 2020.
12. Arcadis U.S., Inc. *Pre-Design Investigation Summary Report for Upland Disposal Facility Area.* February 2024.
13. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 8: Final Grading Plan.* February 2024.

Assumptions

1. Two infiltration basins (to the north and south of the UDF) are proposed to treat stormwater runoff through infiltration and attenuate peak runoff flow rates from the 2, 10, and 100-year 24-hour storm events to replicate existing hydrologic conditions at design points along the perimeter of the property.
2. Revegetated areas on site are considered hydrologic soil group (HSG) B soils as explained in Reference 2. The infiltration values measured in the proposed area for the North and South Basins are reported in Reference 12 and included in Attachment 2.
3. Design requirements regarding sizing, basin geometry, and infiltration rates of the basins are based on standards set forth in Reference 4.
4. Conditions within each basin are determined by routing the drainage area hydrograph through the basin using Reference 5. This accounts for the storage volume available in the basin, inclusive of the forebay, and outflow via infiltration into the subsurface. Both basins are also equipped with emergency overflow devices, and these are also simulated using Reference 5. The basins are assumed to be empty at the beginning of each storm event.
5. The "*Dynamic Field*" method was used to aid in basin sizing for the North Basin and South Basin (Reference 4). The average infiltration rate used in the design of all basins is from Reference 11 and has been reduced by 50% to meet Massachusetts DEP (MassDEP) standards. The infiltration rate used to model the North Basin is 0.46 inches/hour. The infiltration rate used to model the South Basin is 0.39 inches/hour.

Calculations

1. Contributing Drainage Areas and Hydrologic Conditions

The contributing drainage areas to the two basins are delineated based on proposed topography associated with the construction and closure of the UDF (Reference 13). The drainage areas are depicted on the watershed area map in Figure 1. Table 1 below presents the delineated drainage area to each of the basins, along with the runoff volumes and peak flow rates anticipated during each of the design storms.

Table 1: Contributing Drainage Areas

Basin	Drainage Area	Area (ac)	Composite CN	Tc (min)	2-yr, 24-hr		10-yr, 24-hr		100-yr, 24-hr	
					Vol. (ac-ft)	Rate (cfs)	Vol. (ac-ft)	Rate (cfs)	Vol. (ac-ft)	Rate (cfs)
North	UDF	21.81	65	8.9	18.90	3.35	40.85	8.76	111.48	18.90
South	South Basin	2.73	85	7.4	0.527	7.05	0.825	10.93	1.660	21.29

HydroCAD output is included in Attachment 1.

2. Stormwater Basin Routing Calculations

The stormwater runoff hydrograph from each basin's drainage area is routed through the respective basin to determine peak water surface elevation and discharge to the surface for each design storm. Table 2 below summarizes the peak inflow and outflows for both basins. Note that the peak outflow excludes infiltration. Detailed routing information and results can be found in Attachment 1.

Table 2 – Peak Inflows and Outflows

Basin	Peak Inflow (cfs)			Peak Outflow (cfs)		
	2-yr, 24-hr	10-yr, 24-hr	100-yr, 24-hr	2-yr, 24-hr	10-yr, 24-hr	100-yr, 24-hr
North Basin	3.35	8.76	18.90	0.00	0.00	4.18
South Basin	7.05	10.93	21.29	0.00	0.00	0.41

Outflow from the basins via infiltration is accounted for using a constant velocity of 0.46 and 0.39 inches/hour for the North and South Basins, respectively. See Attachment 2 for infiltration testing values. Table 3 below summarizes the peak infiltration occurring in each both for the indicated design storm events.

Table 3 – Peak Basin Infiltration

Design Storm Event	Peak Basin Infiltration (cfs)	
	North Basin	South Basin
2-Year	0.56	0.11
10-Year	0.61	0.12
100-Year	0.72	0.15

Table 4 below summarizes the peak water surface elevations and resulting freeboards for both basins. Freeboard is calculated with respect to the design top of berm elevation.

Table 4 – Peak Water Surface Elevations and Resulting Freeboards

Basin	Peak Water Surface El. (ft)			Freeboard (ft)		
	2-yr, 24-hr	10-yr, 24-hr	100-yr, 24-hr	2-yr, 24-hr	10-yr, 24-hr	100-yr, 24-hr
North Basin (Containment El. 1007)	1001.57	1002.80	1005.44	5.43	4.20	1.56
South Basin (Containment El. 1034.5)	1030.11	1031.08	1033.27	4.39	3.42	1.23

HydroCAD output for the basin routing calculations is included in Attachment 1.

3. Required Recharge Volume and Storage Volume

The Required Recharge Volume is calculated to ensure the stormwater infiltration basins are adequately sized to meet stormwater quality requirements (Reference 4). The Required Recharge Volume is based on the HSG and the proposed impervious area within the basin's drainage area. The Required Recharge Volume must only leave the basin by means of infiltration. This requires that the Recharge Volume is below the outfall device.

Per Table 2.3.2 (Reference 4), for HSG B (Assumption 2), the target depth factor (F) is 0.35-inch. The following equation is used to determine the required recharge volume for each basin:

$$Recharge\ Volume\ (Rv) = F\ x\ impervious\ area\ (\boldsymbol{equation\ 1})$$

$$North\ Basin: Rv = \frac{0.35\ in}{12\ in/ft} * \frac{2.46\ ac}{\frac{1\ ac}{43{,}560\ ft^2}} = 3125.43\ ft^3$$

$$South\ Basin: Rv = \frac{0.35\ in}{12\ in/ft} * \frac{1.86\ ac}{\frac{1\ ac}{43{,}560\ ft^2}} = \ \ 2363.13\ ft^3$$

In addition to manually calculating the required recharge volume, truncated hydrographs were modelled for each stormwater basin with a time span of 6 to 18 hours for compliance with MassDEP requirements for the *Dynamic Field* method.

Truncated Hydrographs were created using Reference 6 and the previously calculated required recharge volume. A 24-hour storm event was then determined for both the North and South Basin that generates the Required Water Quality Volume over a 12-hour period. This storm event will henceforth be referred to as the Recharge Volume Storm. Each basin is designed to completely infiltrate the Required Recharge Volume calculated above and so that runoff generated by the Recharge Volume Storm (i.e., the Required Water Quality Volume) cannot be discarded via discharge through a culvert, spillway, etc. The same is true of the Required Recharge Volume. Resulting hydrographs can be found in Attachment 1.

The truncated hydrographs are required by MassDEP (Reference 4) to ensure that the recharge volume contained below the outlet of the stormwater basin. See Attachment 3 for truncated hydrograph report.

4. Water Quality

Water Quality Treatment Volume

In addition to the required recharge volume calculated above, the North and South Basins are sized to provide water quality treatment volume beneath the elevation of the emergency spillway and/or other means of surface water discharge (Reference 4). The water quality treatment volume is determined by the following equation:

$$V_{WQ} = (D_{WQ} \div 12\ in/ft) * (A_{IMP} * 43{,}560\ square\ feet/acre)\ (\boldsymbol{Equation\ 2})$$

$$V_{WQ}\ = Water\ Quality\ Treatment\ Volume$$

$$D_{WQ} = Water\ Quality\ Depth\ (1"\ per\ Reference\ 4)$$

$$A_{IMP} = Impervious\ Area\ (acres)$$

$$V_{WQ} = (1"\ \div 12\ in/ft) * (2.46\ ac * 43{,}560\ ft/ac)\ =\ 8{,}893\ CF\ (North\ Basin)$$

$$V_{WQ} = (1"\ \div 12\ in/ft) * (1.86\ ac * 43{,}560\ ft/ac)\ =\ 6{,}751\ CF\ (South\ Basin)$$

Using the average end-area method, the North Basin has a cumulative storage capacity below the invert of the emergency spillway of 250,799 cubic feet. The South Basin has a cumulative storage capacity below the invert of the outfall culvert of 11,872 cubic feet. The required water quality treatment volume from above is retained within both basins, therefore meeting water quality treatment volume requirements.

Total Suspended Solids (TSS) Removal Percentage

Due to Massachusetts DEP regulations for sizing infiltration basins using the *Dynamic Field Method,* the on-site runoff must achieve TSS pretreatment. Pre-treatment is achieved through three methods: sediment forebay, water quality treatment swales, and check dams.

The following equation is used the find the required forebay volume:

$$Minimum\ Volume_{Forebay} = 0.1" \div 12\ in/ft\ *\ Impervious\ area\ (cf)\ (\boldsymbol{Equation\ 3})$$

$$Minimum\ Volume_{North\ Basin\ Forebay} = 0.1" \div 12\ in/ft\ *\ 107{,}158\ cf\ =\ 893\ cf$$

$$Minimum\ Volume_{South\ Basin\ Forebay} = 0.1"\ \div\ 12\ in/ft\ *\ 81{,}022\ cf\ =\ 675\ cf$$

The provided volume in the forebay is 11,872 cubic feet for the North Basin. The volume provided in the South Basin forebay is 11,380 cubic feet. The storage volume in both forebays is therefore adequate. See Attachment 4 for forebay calculations.

5. Required Drawdown Time for Infiltration

According to Reference 4, each infiltration basin needs to infiltrate the Required Recharge Volume within 72 hours. Using the determined infiltration rates of 0.46 in/hr and 0.39 in/hr (Assumption 5), the drawdown time for the Required Water Quality Volume in the North and South Basin is calculated using the following equation (Reference 4):

$$Time_{Drawdown} = \frac{Required\ Recharge\ Volume\ (eq\ 2, ft^3)}{Infiltration\ rate\ \left(\frac{in}{hr}\right) * Bottom\ of\ Basin\ Area\ (ft^2)}\ (\boldsymbol{Equation\ 3})$$

$$North\ Basin\ Time_{drawdown} = \frac{3125.43\ ft^3}{\frac{0.46in}{hr*12\ in/ft} * 50{,}734\ ft^2} = 1.61\ hours$$

$$South\ Basin\ Time_{drawdown} = \frac{2363.13\ ft^3}{\frac{0.39\ in}{hr*12\ in/ft} * 10{,}712\ ft^2} = 6.79\ hours$$

As shown above, the Required Recharge Volume in both basins infiltrate within 72 hours and are therefore compliant.

Summary

The performance of the North and South Basins for both water quantity and quality is evaluated herein. The design of the basins adheres to the sizing requirements set forth by the MassDEP.

Figures

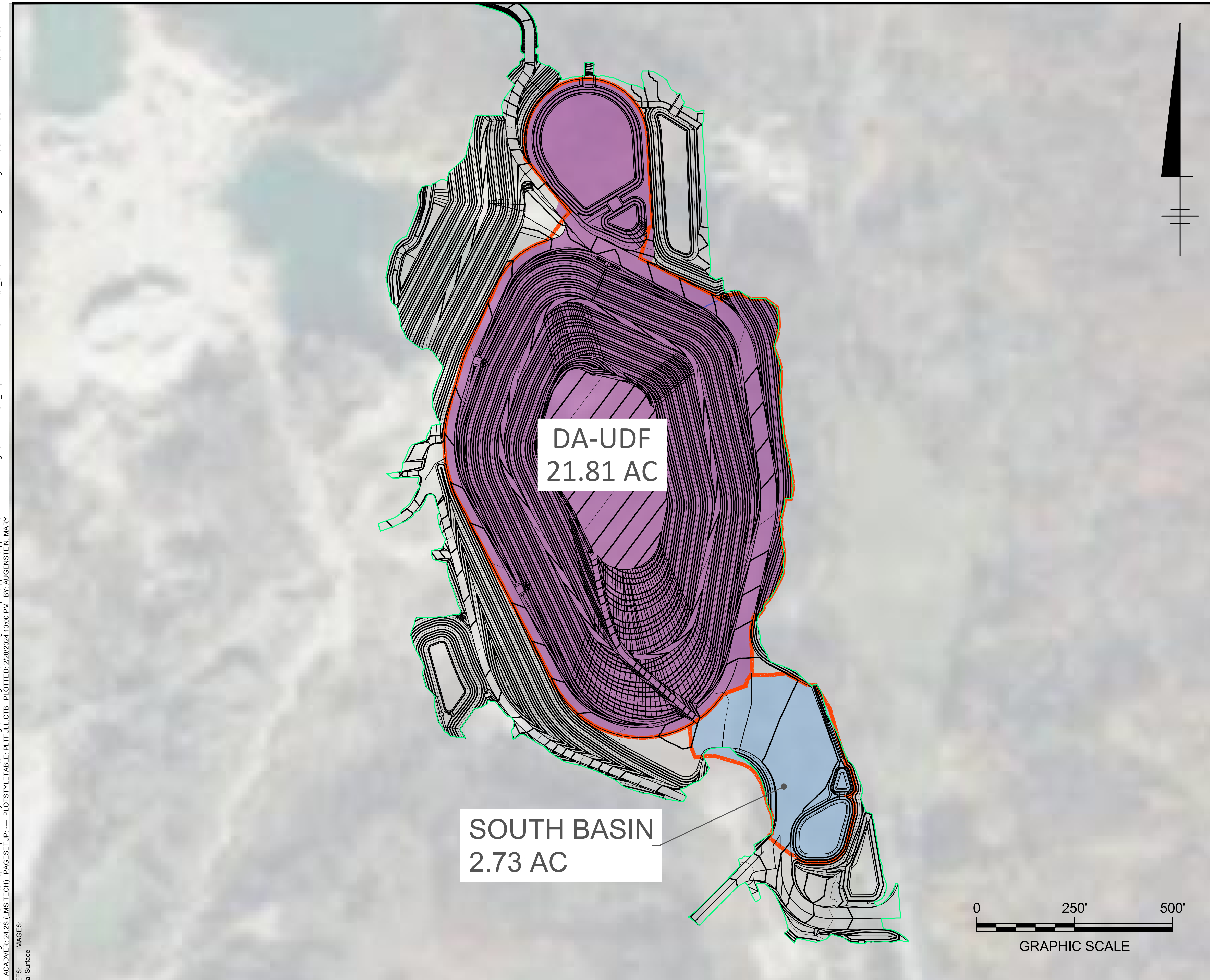
1. Stormwater Basin Drainage Area Boundaries

Attachments

1. HydroCAD Basin Results
2. Infiltration Testing Values
3. Truncated Hydrographs and Test Drainage Areas
4. Forebay Calculations
5. TSS Removal Spreadsheet

Figure 1

Stormwater Basin Drainage Area Boundaries



LEGEND

- NORTH BASIN DRAINAGE AREA
- SOUTH BASIN DRAINAGE AREA
- DRAINAGE AREA BOUNDARY

GENERAL ELECTRIC COMPANY
UPLAND DISPOSAL FACILITY
GE HOUSATONIC RIVER SITE

INFILTRATION BASIN DRAINAGE AREA BOUNDARIES

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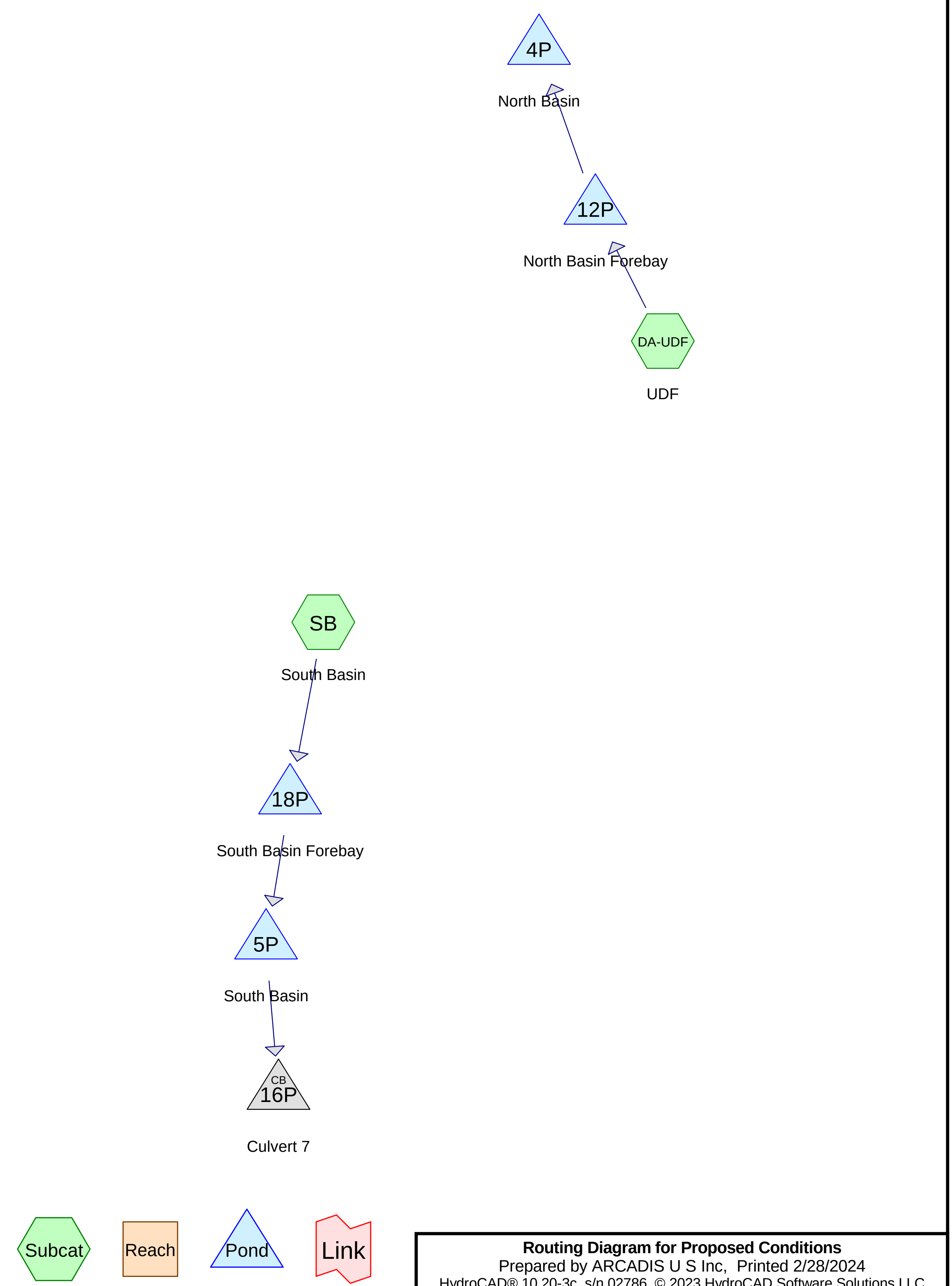
FIGURE
1

Attachment 1

HydroCAD Basin Results



Routing Diagram for Proposed Conditions
Prepared by ARCADIS U S Inc, Printed 2/28/2024
HydroCAD® 10.20-3c s/n 02786 © 2023 HydroCAD Software Solutions LLC

Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment UDF: UDF Runoff Area=21.810 ac 0.00% Impervious Runoff Depth=0.94"
Flow Length=1,810' Tc=8.9 min CN=65 Runoff=18.90 cfs 1.703 af

Pond 4P: North Basin Peak Elev=1,001.57' Storage=29,472 cf Inflow=7.92 cfs 1.203 af
Discarded=0.56 cfs 1.203 af Primary=0.00 cfs 0.000 af Outflow=0.56 cfs 1.203 af

Pond 12P: North Basin Forebay Peak Elev=1,004.81' Storage=23,872 cf Inflow=18.90 cfs 1.703 af
Outflow=7.92 cfs 1.203 af

Total Runoff Area = 21.810 ac Runoff Volume = 1.703 af Average Runoff Depth = 0.94"
100.00% Pervious = 21.810 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment UDF: UDF

Runoff = 18.90 cfs @ 12.14 hrs, Volume= 1.703 af, Depth= 0.94"
Routed to Pond 12P : North Basin Forebay

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	21.810	65	From CN Calc Spreadsheet
	21.810		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.1	50	0.0900	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.84"
0.9	152	0.1500	2.71		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.6	1,365	0.2280	14.39	43.16	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.00' Z= 3.0 '/' Top.W=6.00' n= 0.030 Earth, grassed & winding
2.1	152	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	91	0.0100	7.20	22.62	**Pipe Channel,** 24.0" Round Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Corrugated PE, smooth interior
8.9	1,810	Total			

Summary for Pond 12P: North Basin Forebay

Inflow Area = 21.810 ac, 0.00% Impervious, Inflow Depth = 0.94" for 2-YR event
Inflow = 18.90 cfs @ 12.14 hrs, Volume= 1.703 af
Outflow = 7.92 cfs @ 12.50 hrs, Volume= 1.203 af, Atten= 58%, Lag= 21.5 min
Primary = 7.92 cfs @ 12.50 hrs, Volume= 1.203 af
Routed to Pond 4P : North Basin

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,004.81' @ 12.50 hrs Surf.Area= 10,149 sf Storage= 23,872 cf

Plug-Flow detention time= 177.3 min calculated for 1.203 af (71% of inflow)
Center-of-Mass det. time= 70.8 min (952.7 - 882.0)

Volume	Invert	Avail.Storage	Storage Description
#1	1,001.00'	50,991 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,001.00	2,383	0	0
1,007.00	14,614	50,991	50,991

Device	Routing	Invert	Outlet Devices
#1	Primary	1,004.60'	**30.0' long + 3.0 '/' SideZ x 30.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=7.85 cfs @ 12.50 hrs HW=1,004.81' (Free Discharge)
↑—**1=Broad-Crested Rectangular Weir** (Weir Controls 7.85 cfs @ 1.22 fps)

Summary for Pond 4P: North Basin

Inflow Area = 21.810 ac, 0.00% Impervious, Inflow Depth = 0.66" for 2-YR event
Inflow = 7.92 cfs @ 12.50 hrs, Volume= 1.203 af
Outflow = 0.56 cfs @ 21.02 hrs, Volume= 1.203 af, Atten= 93%, Lag= 511.4 min
Discarded = 0.56 cfs @ 21.02 hrs, Volume= 1.203 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,001.57' @ 21.02 hrs Surf.Area= 52,945 sf Storage= 29,472 cf

Plug-Flow detention time= 579.4 min calculated for 1.203 af (100% of inflow)
Center-of-Mass det. time= 579.4 min (1,532.2 - 952.7)

Volume	Invert	Avail.Storage	Storage Description
#1	1,001.00'	374,394 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,001.00	50,734	0	0
1,007.00	74,064	374,394	374,394

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,001.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,005.30'	**30.0' long + 3.0 '/' SideZ x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.56 cfs @ 21.02 hrs HW=1,001.57' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.56 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,001.00' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment UDF: UDF Runoff Area=21.810 ac 0.00% Impervious Runoff Depth=1.84"
Flow Length=1,810' Tc=8.9 min CN=65 Runoff=40.85 cfs 3.349 af

Pond 4P: North Basin Peak Elev=1,002.80' Storage=97,619 cf Inflow=36.03 cfs 2.849 af
Discarded=0.61 cfs 2.849 af Primary=0.00 cfs 0.000 af Outflow=0.61 cfs 2.849 af

Pond 12P: North Basin Forebay Peak Elev=1,005.17' Storage=27,610 cf Inflow=40.85 cfs 3.349 af
Outflow=36.03 cfs 2.849 af

Total Runoff Area = 21.810 ac Runoff Volume = 3.349 af Average Runoff Depth = 1.84"
100.00% Pervious = 21.810 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment UDF: UDF

Runoff = 40.85 cfs @ 12.13 hrs, Volume= 3.349 af, Depth= 1.84"
Routed to Pond 12P : North Basin Forebay

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	21.810	65	From CN Calc Spreadsheet
	21.810		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.1	50	0.0900	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.84"
0.9	152	0.1500	2.71		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.6	1,365	0.2280	14.39	43.16	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.00' Z= 3.0 '/' Top.W=6.00' n= 0.030 Earth, grassed & winding
2.1	152	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	91	0.0100	7.20	22.62	**Pipe Channel,** 24.0" Round Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Corrugated PE, smooth interior
8.9	1,810	Total			

Summary for Pond 12P: North Basin Forebay

Inflow Area = 21.810 ac, 0.00% Impervious, Inflow Depth = 1.84" for 10-YR event
Inflow = 40.85 cfs @ 12.13 hrs, Volume= 3.349 af
Outflow = 36.03 cfs @ 12.19 hrs, Volume= 2.849 af, Atten= 12%, Lag= 3.4 min
Primary = 36.03 cfs @ 12.19 hrs, Volume= 2.849 af
Routed to Pond 4P : North Basin

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,005.17' @ 12.19 hrs Surf.Area= 10,874 sf Storage= 27,610 cf

Plug-Flow detention time= 98.2 min calculated for 2.849 af (85% of inflow)
Center-of-Mass det. time= 31.5 min (891.7 - 860.2)

Volume	Invert	Avail.Storage	Storage Description
#1	1,001.00'	50,991 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,001.00	2,383	0	0
1,007.00	14,614	50,991	50,991

Device	Routing	Invert	Outlet Devices
#1	Primary	1,004.60'	**30.0' long + 3.0 '/' SideZ x 30.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=35.97 cfs @ 12.19 hrs HW=1,005.17' (Free Discharge)
└─**1=Broad-Crested Rectangular Weir** (Weir Controls 35.97 cfs @ 2.01 fps)

Summary for Pond 4P: North Basin

Inflow Area = 21.810 ac, 0.00% Impervious, Inflow Depth = 1.57" for 10-YR event
Inflow = 36.03 cfs @ 12.19 hrs, Volume= 2.849 af
Outflow = 0.61 cfs @ 24.12 hrs, Volume= 2.849 af, Atten= 98%, Lag= 716.1 min
Discarded = 0.61 cfs @ 24.12 hrs, Volume= 2.849 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,002.80' @ 24.12 hrs Surf.Area= 57,733 sf Storage= 97,619 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 1,574.5 min (2,466.2 - 891.7)

Volume	Invert	Avail.Storage	Storage Description
#1	1,001.00'	374,394 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,001.00	50,734	0	0
1,007.00	74,064	374,394	374,394

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,001.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,005.30'	**30.0' long + 3.0 '/' SideZ x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.61 cfs @ 24.12 hrs HW=1,002.80' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.61 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,001.00' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment UDF: UDF Runoff Area=21.810 ac 0.00% Impervious Runoff Depth=4.82"
Flow Length=1,810' Tc=8.9 min CN=65 Runoff=111.48 cfs 8.756 af

Pond 4P: North Basin Peak Elev=1,005.44' Storage=263,450 cf Inflow=108.57 cfs 8.256 af
Discarded=0.72 cfs 6.629 af Primary=4.18 cfs 1.627 af Outflow=4.90 cfs 8.256 af

Pond 12P: North Basin Forebay Peak Elev=1,005.76' Storage=34,476 cf Inflow=111.48 cfs 8.756 af
Outflow=108.57 cfs 8.256 af

Total Runoff Area = 21.810 ac Runoff Volume = 8.756 af Average Runoff Depth = 4.82"
100.00% Pervious = 21.810 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment UDF: UDF

Runoff = 111.48 cfs @ 12.13 hrs, Volume= 8.756 af, Depth= 4.82"
Routed to Pond 12P : North Basin Forebay

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	21.810	65	From CN Calc Spreadsheet
	21.810		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.1	50	0.0900	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.84"
0.9	152	0.1500	2.71		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.6	1,365	0.2280	14.39	43.16	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.00' Z= 3.0 '/' Top.W=6.00' n= 0.030 Earth, grassed & winding
2.1	152	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	91	0.0100	7.20	22.62	**Pipe Channel,** 24.0" Round Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Corrugated PE, smooth interior
8.9	1,810	Total			

Summary for Pond 12P: North Basin Forebay

Inflow Area = 21.810 ac, 0.00% Impervious, Inflow Depth = 4.82" for 100-YR event
Inflow = 111.48 cfs @ 12.13 hrs, Volume= 8.756 af
Outflow = 108.57 cfs @ 12.15 hrs, Volume= 8.256 af, Atten= 3%, Lag= 1.4 min
Primary = 108.57 cfs @ 12.15 hrs, Volume= 8.256 af
Routed to Pond 4P : North Basin

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,005.76' @ 12.15 hrs Surf.Area= 12,093 sf Storage= 34,476 cf

Plug-Flow detention time= 46.5 min calculated for 8.256 af (94% of inflow)
Center-of-Mass det. time= 15.8 min (847.7 - 831.9)

Volume	Invert	Avail.Storage	Storage Description
#1	1,001.00'	50,991 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,001.00	2,383	0	0
1,007.00	14,614	50,991	50,991

Device	Routing	Invert	Outlet Devices
#1	Primary	1,004.60'	**30.0' long + 3.0 '/' SideZ x 30.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=108.52 cfs @ 12.15 hrs HW=1,005.76' (Free Discharge)
└—**1=Broad-Crested Rectangular Weir** (Weir Controls 108.52 cfs @ 2.79 fps)

Summary for Pond 4P: North Basin

Inflow Area = 21.810 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-YR event
Inflow = 108.57 cfs @ 12.15 hrs, Volume= 8.256 af
Outflow = 4.90 cfs @ 15.83 hrs, Volume= 8.256 af, Atten= 95%, Lag= 220.6 min
Discarded = 0.72 cfs @ 15.83 hrs, Volume= 6.629 af
Primary = 4.18 cfs @ 15.83 hrs, Volume= 1.627 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,005.44' @ 15.83 hrs Surf.Area= 67,990 sf Storage= 263,450 cf

Plug-Flow detention time= 2,806.2 min calculated for 8.256 af (100% of inflow)
Center-of-Mass det. time= 2,806.2 min (3,653.9 - 847.7)

Volume	Invert	Avail.Storage	Storage Description
#1	1,001.00'	374,394 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,001.00	50,734	0	0
1,007.00	74,064	374,394	374,394

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,001.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,005.30'	**30.0' long + 3.0 '/' SideZ x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.72 cfs @ 15.83 hrs HW=1,005.44' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.72 cfs)

Primary OutFlow Max=4.17 cfs @ 15.83 hrs HW=1,005.44' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Weir Controls 4.17 cfs @ 0.99 fps)

Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment SB: South Basin Runoff Area=2.730 ac 0.00% Impervious Runoff Depth=2.32"
Flow Length=410' Tc=7.4 min CN=85 Runoff=7.05 cfs 0.527 af

Pond 5P: South Basin Peak Elev=1,030.11' Storage=12,757 cf Inflow=6.72 cfs 0.398 af
Discarded=0.11 cfs 0.398 af Primary=0.00 cfs 0.000 af Outflow=0.11 cfs 0.398 af

Pond 16P: Culvert 7 Peak Elev=1,030.40' Inflow=0.50 cfs 0.050 af
12.0" Round Culvert n=0.012 L=563.0' S=0.0103 '/' Outflow=0.50 cfs 0.050 af

Pond 18P: South Basin Forebay Peak Elev=1,033.11' Storage=0.146 af Inflow=7.05 cfs 0.527 af
Outflow=6.72 cfs 0.398 af

Total Runoff Area = 2.730 ac Runoff Volume = 0.527 af Average Runoff Depth = 2.32"
100.00% Pervious = 2.730 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment SB: South Basin

Runoff = 7.05 cfs @ 12.11 hrs, Volume= 0.527 af, Depth= 2.32"
Routed to Pond 18P : South Basin Forebay

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	2.730	85	From CN Calc Spreadsheet
	2.730		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.3	50	0.0310	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.84"
3.1	360	0.0141	1.91		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
7.4	410	Total			

Summary for Pond 18P: South Basin Forebay

Inflow Area = 2.730 ac, 0.00% Impervious, Inflow Depth = 2.32" for 2-YR event
Inflow = 7.05 cfs @ 12.11 hrs, Volume= 0.527 af
Outflow = 6.72 cfs @ 12.13 hrs, Volume= 0.398 af, Atten= 5%, Lag= 1.7 min
Primary = 6.72 cfs @ 12.13 hrs, Volume= 0.398 af
Routed to Pond 5P : South Basin

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,033.11' @ 12.13 hrs Surf.Area= 0.060 ac Storage= 0.146 af

Plug-Flow detention time= 135.1 min calculated for 0.398 af (76% of inflow)
Center-of-Mass det. time= 49.1 min (868.6 - 819.5)

Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	0.208 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,029.00	0.016	0.000	0.000
1,030.00	0.024	0.020	0.020
1,031.00	0.034	0.029	0.049
1,032.00	0.045	0.039	0.088
1,033.00	0.058	0.052	0.140
1,034.00	0.079	0.068	0.208

Device	Routing	Invert	Outlet Devices
#1	Primary	1,032.80'	**14.0' long + 3.0 '/' SideZ x 14.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.64 2.67 2.70 2.65 2.64 2.65 2.65 2.63

Primary OutFlow Max=6.69 cfs @ 12.13 hrs HW=1,033.11' (Free Discharge)
└─**1=Broad-Crested Rectangular Weir** (Weir Controls 6.69 cfs @ 1.46 fps)

Summary for Pond 5P: South Basin

Inflow Area = 2.730 ac, 0.00% Impervious, Inflow Depth = 1.75" for 2-YR event
Inflow = 6.72 cfs @ 12.13 hrs, Volume= 0.398 af
Outflow = 0.11 cfs @ 21.28 hrs, Volume= 0.398 af, Atten= 98%, Lag= 549.0 min
Discarded = 0.11 cfs @ 21.28 hrs, Volume= 0.398 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 16P : Culvert 7

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,030.11' @ 21.28 hrs Surf.Area= 12,161 sf Storage= 12,757 cf

Plug-Flow detention time= 1,209.8 min calculated for 0.398 af (100% of inflow)
Center-of-Mass det. time= 1,209.8 min (2,078.4 - 868.6)

Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	79,299 cf	**SE Basin Storage (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,029.00	10,755	0	0
1,030.00	12,012	11,384	11,384
1,031.00	13,323	12,668	24,051
1,032.00	14,691	14,007	38,058
1,033.00	16,113	15,402	53,460
1,034.00	17,592	16,853	70,313
1,034.50	18,352	8,986	79,299

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,029.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	1,033.00'	**48.0" x 48.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.11 cfs @ 21.28 hrs HW=1,030.11' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.11 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,029.00' (Free Discharge)
↑—**2=Orifice/Grate** (Controls 0.00 cfs)

Summary for Pond 16P: Culvert 7

Inflow Area = 3.550 ac, 0.00% Impervious, Inflow Depth = 0.17" for 2-YR event
Inflow = 0.50 cfs @ 12.15 hrs, Volume= 0.050 af
Outflow = 0.50 cfs @ 12.15 hrs, Volume= 0.050 af, Atten= 0%, Lag= 0.0 min
Primary = 0.50 cfs @ 12.15 hrs, Volume= 0.050 af
Routed to Pond 11P : SW Ditch Low Point

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,030.40' @ 12.15 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	1,030.00'	**12.0" Round Culvert** L= 563.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 1,030.00' / 1,024.20' S= 0.0103 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Primary OutFlow Max=0.50 cfs @ 12.15 hrs HW=1,030.40' (Free Discharge)
└─**1=Culvert** (Inlet Controls 0.50 cfs @ 1.70 fps)

Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment SB: South Basin Runoff Area=2.730 ac 0.00% Impervious Runoff Depth=3.63"
Flow Length=410' Tc=7.4 min CN=85 Runoff=10.93 cfs 0.825 af

Pond 5P: South Basin Peak Elev=1,031.08' Storage=25,055 cf Inflow=10.70 cfs 0.697 af
Discarded=0.12 cfs 0.697 af Primary=0.00 cfs 0.000 af Outflow=0.12 cfs 0.697 af

Pond 16P: Culvert 7 Peak Elev=1,030.67' Inflow=1.22 cfs 0.105 af
12.0" Round Culvert n=0.012 L=563.0' S=0.0103 '/' Outflow=1.22 cfs 0.105 af

Pond 18P: South Basin Forebay Peak Elev=1,033.21' Storage=0.153 af Inflow=10.93 cfs 0.825 af
Outflow=10.70 cfs 0.697 af

Total Runoff Area = 2.730 ac Runoff Volume = 0.825 af Average Runoff Depth = 3.63"
100.00% Pervious = 2.730 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment SB: South Basin

Runoff = 10.93 cfs @ 12.10 hrs, Volume= 0.825 af, Depth= 3.63"
Routed to Pond 18P : South Basin Forebay

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-YR Rainfall=5.28"

	Area (ac)	CN	Description
*	2.730	85	From CN Calc Spreadsheet
	2.730		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.3	50	0.0310	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.84"
3.1	360	0.0141	1.91		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
7.4	410	Total			

Summary for Pond 18P: South Basin Forebay

Inflow Area = 2.730 ac, 0.00% Impervious, Inflow Depth = 3.63" for 10-YR event
Inflow = 10.93 cfs @ 12.10 hrs, Volume= 0.825 af
Outflow = 10.70 cfs @ 12.12 hrs, Volume= 0.697 af, Atten= 2%, Lag= 1.1 min
Primary = 10.70 cfs @ 12.12 hrs, Volume= 0.697 af
Routed to Pond 5P : South Basin

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,033.21' @ 12.12 hrs Surf.Area= 0.062 ac Storage= 0.153 af

Plug-Flow detention time= 101.8 min calculated for 0.697 af (84% of inflow)
Center-of-Mass det. time= 36.1 min (842.8 - 806.7)

Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	0.208 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,029.00	0.016	0.000	0.000
1,030.00	0.024	0.020	0.020
1,031.00	0.034	0.029	0.049
1,032.00	0.045	0.039	0.088
1,033.00	0.058	0.052	0.140
1,034.00	0.079	0.068	0.208

Device	Routing	Invert	Outlet Devices
#1	Primary	1,032.80'	**14.0' long + 3.0 '/' SideZ x 14.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.64 2.67 2.70 2.65 2.64 2.65 2.65 2.63

Primary OutFlow Max=10.67 cfs @ 12.12 hrs HW=1,033.21' (Free Discharge)
└─**1=Broad-Crested Rectangular Weir** (Weir Controls 10.67 cfs @ 1.69 fps)

Summary for Pond 5P: South Basin

Inflow Area = 2.730 ac, 0.00% Impervious, Inflow Depth = 3.06" for 10-YR event
Inflow = 10.70 cfs @ 12.12 hrs, Volume= 0.697 af
Outflow = 0.12 cfs @ 23.78 hrs, Volume= 0.697 af, Atten= 99%, Lag= 699.5 min
Discarded = 0.12 cfs @ 23.78 hrs, Volume= 0.697 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 16P : Culvert 7

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,031.08' @ 23.78 hrs Surf.Area= 13,426 sf Storage= 25,055 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 2,068.7 min (2,911.6 - 842.8)

Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	79,299 cf	**SE Basin Storage (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,029.00	10,755	0	0
1,030.00	12,012	11,384	11,384
1,031.00	13,323	12,668	24,051
1,032.00	14,691	14,007	38,058
1,033.00	16,113	15,402	53,460
1,034.00	17,592	16,853	70,313
1,034.50	18,352	8,986	79,299

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,029.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	1,033.00'	**48.0" x 48.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.12 cfs @ 23.78 hrs HW=1,031.08' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.12 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,029.00' (Free Discharge)
└─**2=Orifice/Grate** (Controls 0.00 cfs)

Summary for Pond 16P: Culvert 7

Inflow Area =	3.550 ac,	0.00% Impervious,	Inflow Depth = 0.36"	for 10-YR event
Inflow =	1.22 cfs @	12.14 hrs, Volume=	0.105 af	
Outflow =	1.22 cfs @	12.14 hrs, Volume=	0.105 af,	Atten= 0%, Lag= 0.0 min
Primary =	1.22 cfs @	12.14 hrs, Volume=	0.105 af	

Routed to Pond 11P : SW Ditch Low Point

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,030.67' @ 12.14 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	1,030.00'	**12.0" Round Culvert** L= 563.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 1,030.00' / 1,024.20' S= 0.0103 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Primary OutFlow Max=1.22 cfs @ 12.14 hrs HW=1,030.67' (Free Discharge)
└─**1=Culvert** (Inlet Controls 1.22 cfs @ 2.19 fps)

Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment SB: South Basin Runoff Area=2.730 ac 0.00% Impervious Runoff Depth=7.30"
Flow Length=410' Tc=7.4 min CN=85 Runoff=21.29 cfs 1.660 af

Pond 5P: South Basin Peak Elev=1,033.03' Storage=54,022 cf Inflow=20.96 cfs 1.532 af
Discarded=0.15 cfs 1.391 af Primary=0.41 cfs 0.141 af Outflow=0.56 cfs 1.532 af

Pond 16P: Culvert 7 Peak Elev=1,031.40' Inflow=2.83 cfs 0.436 af
12.0" Round Culvert n=0.012 L=563.0' S=0.0103 '/' Outflow=2.83 cfs 0.436 af

Pond 18P: South Basin Forebay Peak Elev=1,033.43' Storage=0.167 af Inflow=21.29 cfs 1.660 af
Outflow=20.96 cfs 1.532 af

Total Runoff Area = 2.730 ac Runoff Volume = 1.660 af Average Runoff Depth = 7.30"
100.00% Pervious = 2.730 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment SB: South Basin

Runoff = 21.29 cfs @ 12.10 hrs, Volume= 1.660 af, Depth= 7.30"
Routed to Pond 18P : South Basin Forebay

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	2.730	85	From CN Calc Spreadsheet
	2.730		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.3	50	0.0310	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.84"
3.1	360	0.0141	1.91		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
7.4	410	Total			

Summary for Pond 18P: South Basin Forebay

Inflow Area = 2.730 ac, 0.00% Impervious, Inflow Depth = 7.30" for 100-YR event
Inflow = 21.29 cfs @ 12.10 hrs, Volume= 1.660 af
Outflow = 20.96 cfs @ 12.12 hrs, Volume= 1.532 af, Atten= 2%, Lag= 0.9 min
Primary = 20.96 cfs @ 12.12 hrs, Volume= 1.532 af
Routed to Pond 5P : South Basin

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,033.43' @ 12.12 hrs Surf.Area= 0.067 ac Storage= 0.167 af

Plug-Flow detention time= 66.8 min calculated for 1.532 af (92% of inflow)
Center-of-Mass det. time= 26.5 min (813.9 - 787.4)

Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	0.208 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,029.00	0.016	0.000	0.000
1,030.00	0.024	0.020	0.020
1,031.00	0.034	0.029	0.049
1,032.00	0.045	0.039	0.088
1,033.00	0.058	0.052	0.140
1,034.00	0.079	0.068	0.208

Device	Routing	Invert	Outlet Devices
#1	Primary	1,032.80'	**14.0' long + 3.0 '/' SideZ x 14.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.64 2.67 2.70 2.65 2.64 2.65 2.65 2.63

Primary OutFlow Max=20.93 cfs @ 12.12 hrs HW=1,033.43' (Free Discharge)
└─**1=Broad-Crested Rectangular Weir** (Weir Controls 20.93 cfs @ 2.09 fps)

Summary for Pond 5P: South Basin

Inflow Area = 2.730 ac, 0.00% Impervious, Inflow Depth = 6.73" for 100-YR event
Inflow = 20.96 cfs @ 12.12 hrs, Volume= 1.532 af
Outflow = 0.56 cfs @ 16.77 hrs, Volume= 1.532 af, Atten= 97%, Lag= 278.9 min
Discarded = 0.15 cfs @ 16.77 hrs, Volume= 1.391 af
Primary = 0.41 cfs @ 16.77 hrs, Volume= 0.141 af
Routed to Pond 16P : Culvert 7

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,033.03' @ 16.77 hrs Surf.Area= 16,165 sf Storage= 54,022 cf

Plug-Flow detention time= 3,343.8 min calculated for 1.532 af (100% of inflow)
Center-of-Mass det. time= 3,343.8 min (4,157.7 - 813.9)

Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	79,299 cf	**SE Basin Storage (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,029.00	10,755	0	0
1,030.00	12,012	11,384	11,384
1,031.00	13,323	12,668	24,051
1,032.00	14,691	14,007	38,058
1,033.00	16,113	15,402	53,460
1,034.00	17,592	16,853	70,313
1,034.50	18,352	8,986	79,299

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,029.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	1,033.00'	**48.0" x 48.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.15 cfs @ 16.77 hrs HW=1,033.03' (Free Discharge)
└**1=Exfiltration** (Exfiltration Controls 0.15 cfs)

Primary OutFlow Max=0.34 cfs @ 16.77 hrs HW=1,033.03' (Free Discharge)
└**2=Orifice/Grate** (Weir Controls 0.34 cfs @ 0.61 fps)

Summary for Pond 16P: Culvert 7

Inflow Area = 3.550 ac, 0.00% Impervious, Inflow Depth = 1.47" for 100-YR event
Inflow = 2.83 cfs @ 12.18 hrs, Volume= 0.436 af
Outflow = 2.83 cfs @ 12.18 hrs, Volume= 0.436 af, Atten= 0%, Lag= 0.0 min
Primary = 2.83 cfs @ 12.18 hrs, Volume= 0.436 af
Routed to Pond 11P : SW Ditch Low Point

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,031.40' @ 12.18 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	1,030.00'	**12.0" Round Culvert** L= 563.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 1,030.00' / 1,024.20' S= 0.0103 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Primary OutFlow Max=2.83 cfs @ 12.18 hrs HW=1,031.40' (Free Discharge)
↑—**1=Culvert** (Inlet Controls 2.83 cfs @ 3.60 fps)

Attachment 2

Infiltration Testing Values

Table 3D
Summary of Soil Infiltration Testing
PDI Summary Report for Upland Disposal Facility Area
GE-Pittsfield/Housatonic River Site

ARCADIS

Test Location ID	Soil Infiltration Rate Hydraulic Conductivity, K (in/hr)	HSG
NB-1	0.74	C
NB-2	No Test	N/A
NB-3	No Test	N/A
NB-4	No Test	N/A
NB-5	35.11	A
NB-6	No Test	N/A
NB-7	1.14	C
NB-8	No Test	N/A
NB-9	No Test	N/A
NB-10	No Test	N/A
NB-11	0.82	C
NB-12	78.61	A
NB-13	No Test	N/A
NB-14	No Test	N/A
NB-15	0.96	C
SB-1	No Test	N/A
SB-2	0.79	C
SB-3	0.76	C

Notes:

1. Some test locations required multiple test iterations to achieve a successful test condition. Only the final test results are shown.

2. Test locations NB-5 and NB-12 had K values high enough that water overflow at the maximum pump rate was not achievable during the test procedure. As a result, constant head testing at these locations was conducted with a water level head maintained below the overflow outlet.

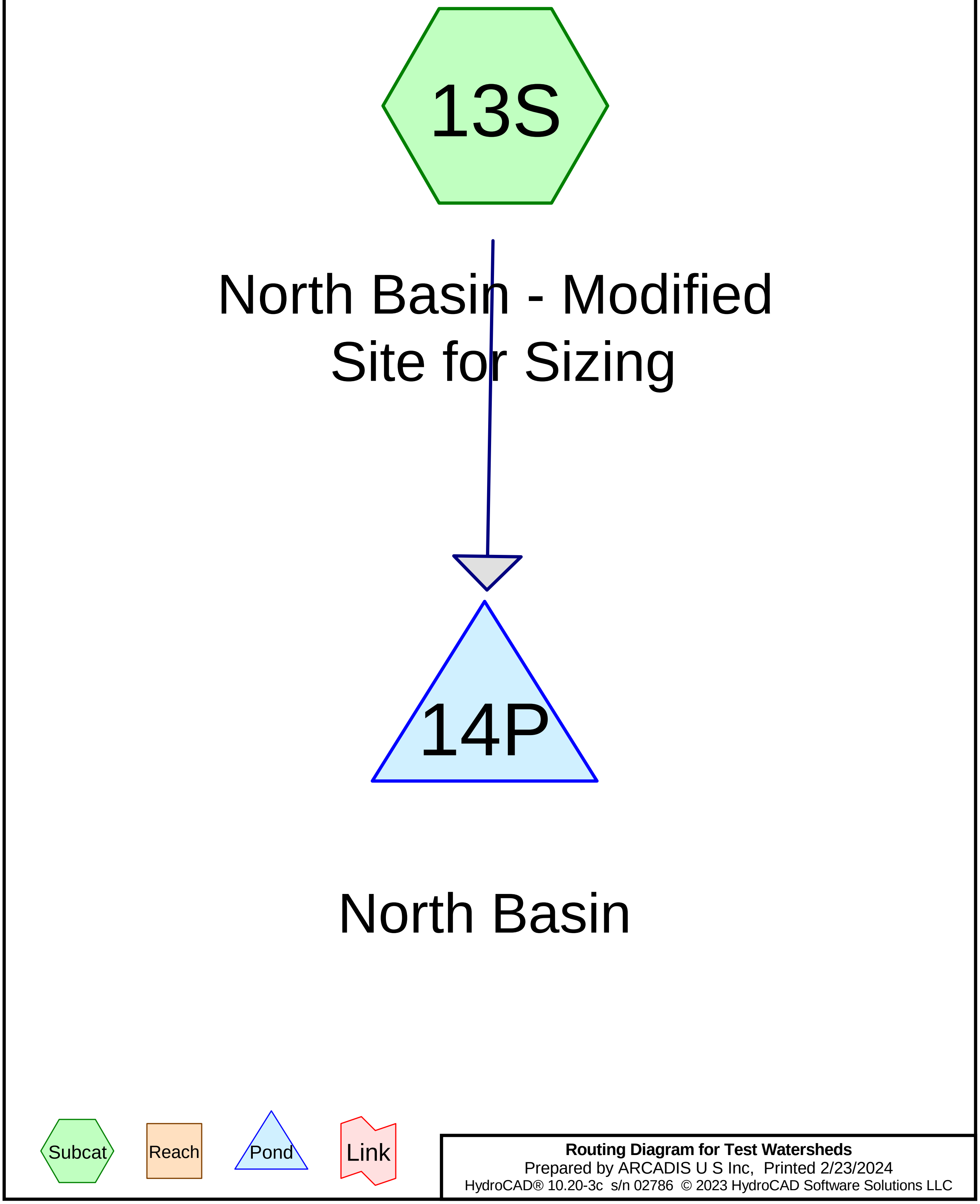
3. HSG values are derived from the relationship between K and HSG found on page 7-2 of the following reference:
https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba

4. Red cells indicate values removed from weighted average due to high values.

Weighted Average for NB	**0.91**	0.46
Weighted Average for SB	**0.77**	0.39

Attachment 3

Truncated Hydrographs and Test Drainage Areas (MassDEP Regulations)



Routing Diagram for Test Watersheds
Prepared by ARCADIS U S Inc, Printed 2/23/2024
HydroCAD® 10.20-3c s/n 02786 © 2023 HydroCAD Software Solutions LLC

Time span=6.00-18.00 hrs, dt=0.05 hrs, 241 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 13S: North Basin - Modified Runoff Area=2.460 ac 0.00% Impervious Runoff Depth>1.03"
Tc=26.0 min CN=96 Runoff=1.95 cfs 0.210 af

Pond 14P: North Basin Peak Elev=1,002.55' Storage=3,428 cf Inflow=1.95 cfs 0.210 af
Discarded=0.71 cfs 0.201 af Primary=0.00 cfs 0.000 af Outflow=0.71 cfs 0.201 af

Total Runoff Area = 2.460 ac Runoff Volume = 0.210 af Average Runoff Depth = 1.03"
100.00% Pervious = 2.460 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 13S: North Basin - Modified Site for Sizing

A soils

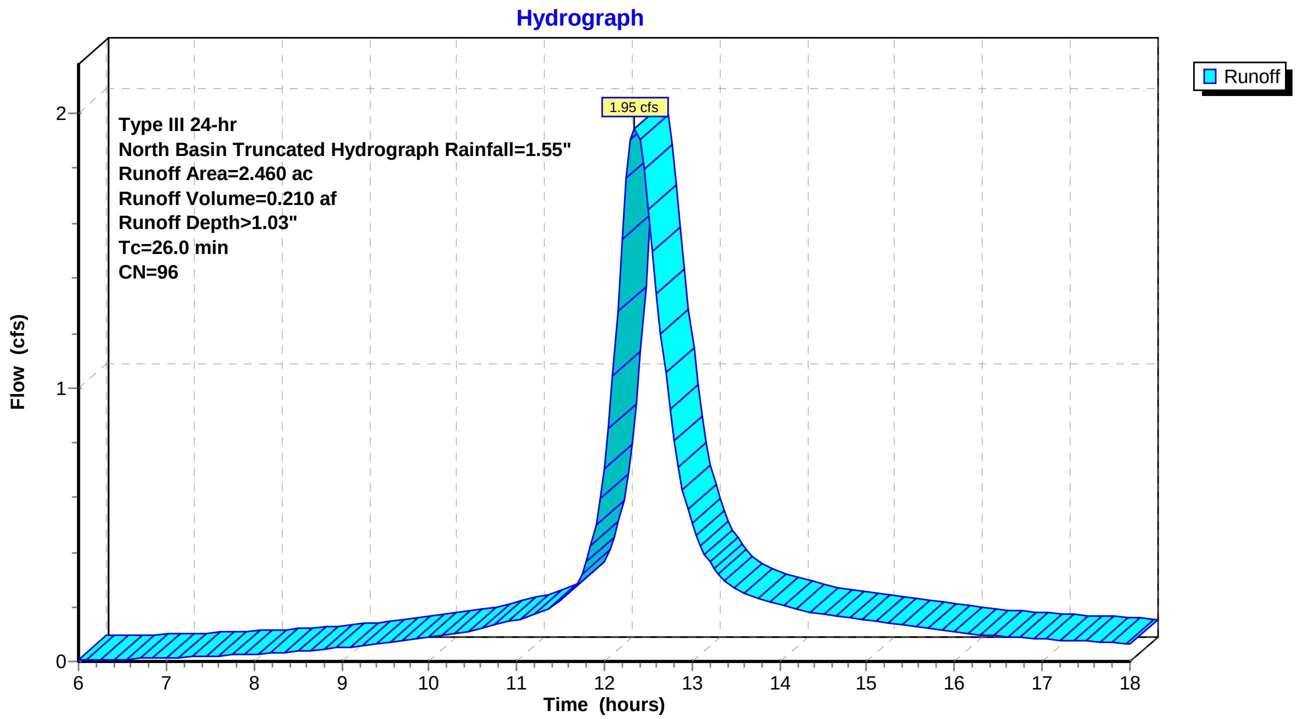
Runoff = 1.95 cfs @ 12.35 hrs, Volume= 0.210 af, Depth> 1.03"
Routed to Pond 14P : North Basin

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 6.00-18.00 hrs, dt= 0.05 hrs
Type III 24-hr North Basin Truncated Hydrograph Rainfall=1.55"

Area (ac)	CN	Description
2.460	96	Gravel surface, HSG B
2.460		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
26.0					**Direct Entry,**

Subcatchment 13S: North Basin - Modified Site for Sizing



Summary for Pond 14P: North Basin

[82] Warning: Early inflow requires earlier time span

Inflow Area = 2.460 ac, 0.00% Impervious, Inflow Depth > 1.03" for North Basin Truncated Hydrograph eve
Inflow = 1.95 cfs @ 12.35 hrs, Volume= 0.210 af
Outflow = 0.71 cfs @ 12.85 hrs, Volume= 0.201 af, Atten= 64%, Lag= 30.1 min
Discarded = 0.71 cfs @ 12.85 hrs, Volume= 0.201 af
Primary = 0.00 cfs @ 6.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 6.00-18.00 hrs, dt= 0.05 hrs
Peak Elev= 1,002.55' @ 12.85 hrs Surf.Area= 66,367 sf Storage= 3,428 cf

Plug-Flow detention time= 69.5 min calculated for 0.200 af (95% of inflow)
Center-of-Mass det. time= 56.5 min (823.8 - 767.3)

Volume	Invert	Avail.Storage	Storage Description
#1	1,002.50'	352,492 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

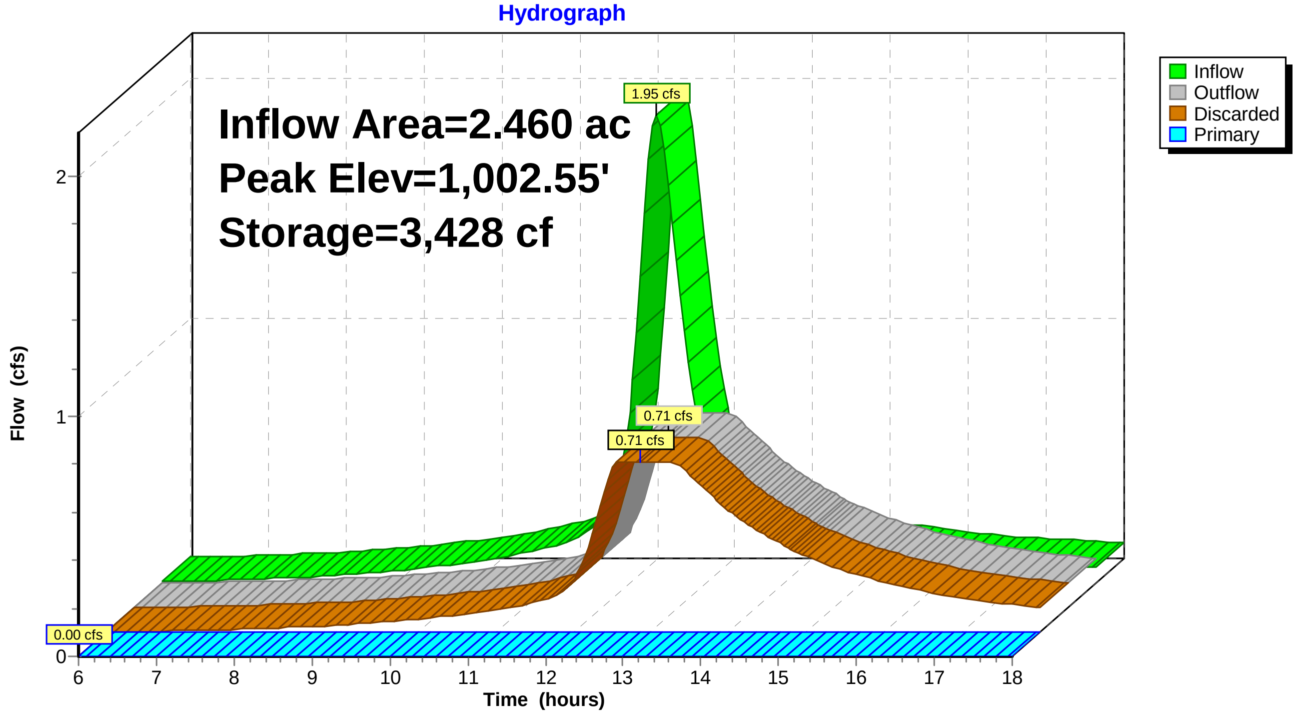
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,002.50	66,085	0	0
1,007.00	90,578	352,492	352,492

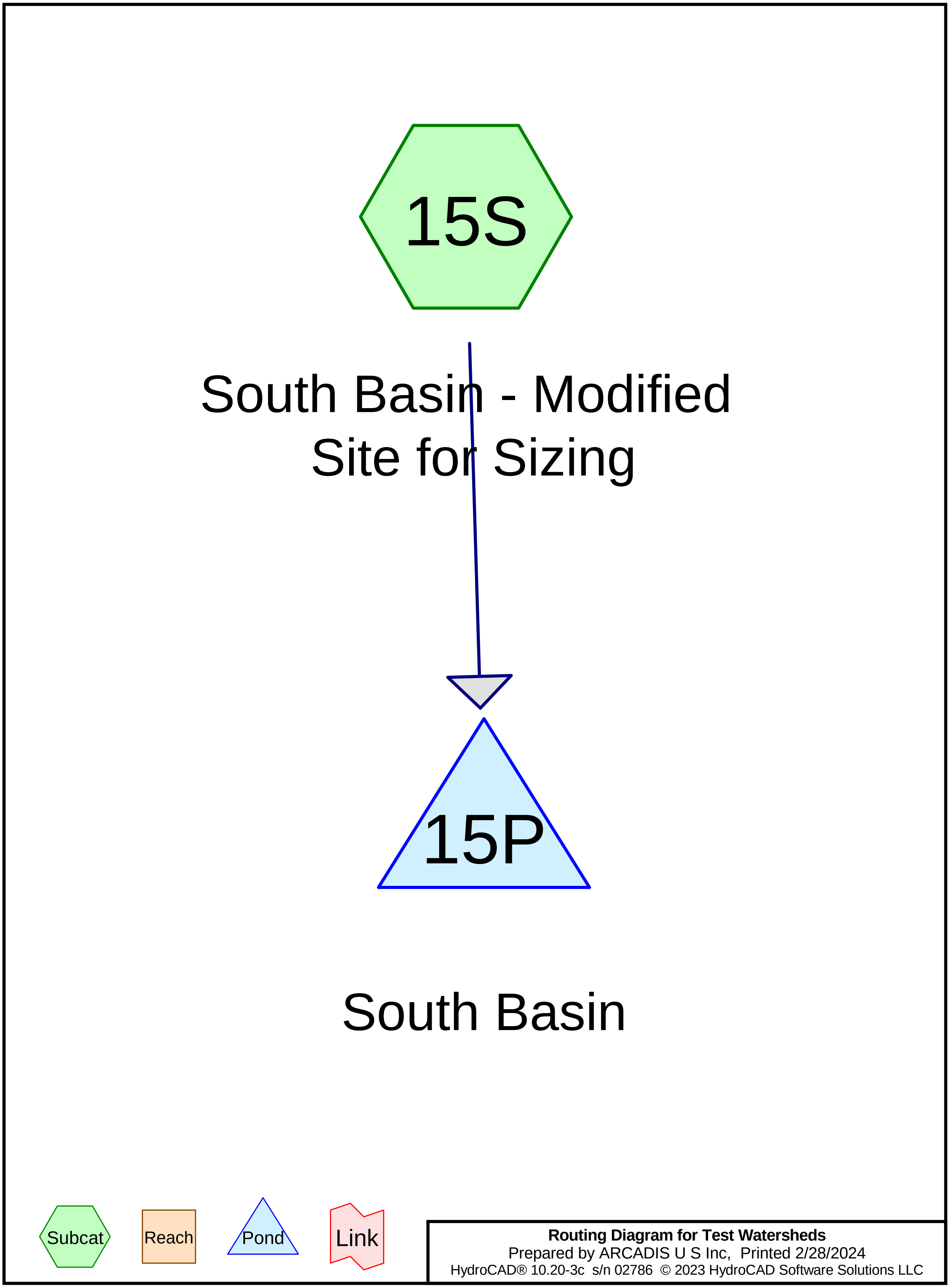
Device	Routing	Invert	Outlet Devices
#1	Discarded	1,002.50'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,005.30'	**30.0' long + 3.0 '/' SideZ x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.71 cfs @ 12.85 hrs HW=1,002.55' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.71 cfs)

Primary OutFlow Max=0.00 cfs @ 6.00 hrs HW=1,002.50' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 14P: North Basin





Routing Diagram for Test Watersheds
Prepared by ARCADIS U S Inc, Printed 2/28/2024
HydroCAD® 10.20-3c s/n 02786 © 2023 HydroCAD Software Solutions LLC

Summary for Subcatchment 15S: South Basin - Modified Site for Sizing

A soils

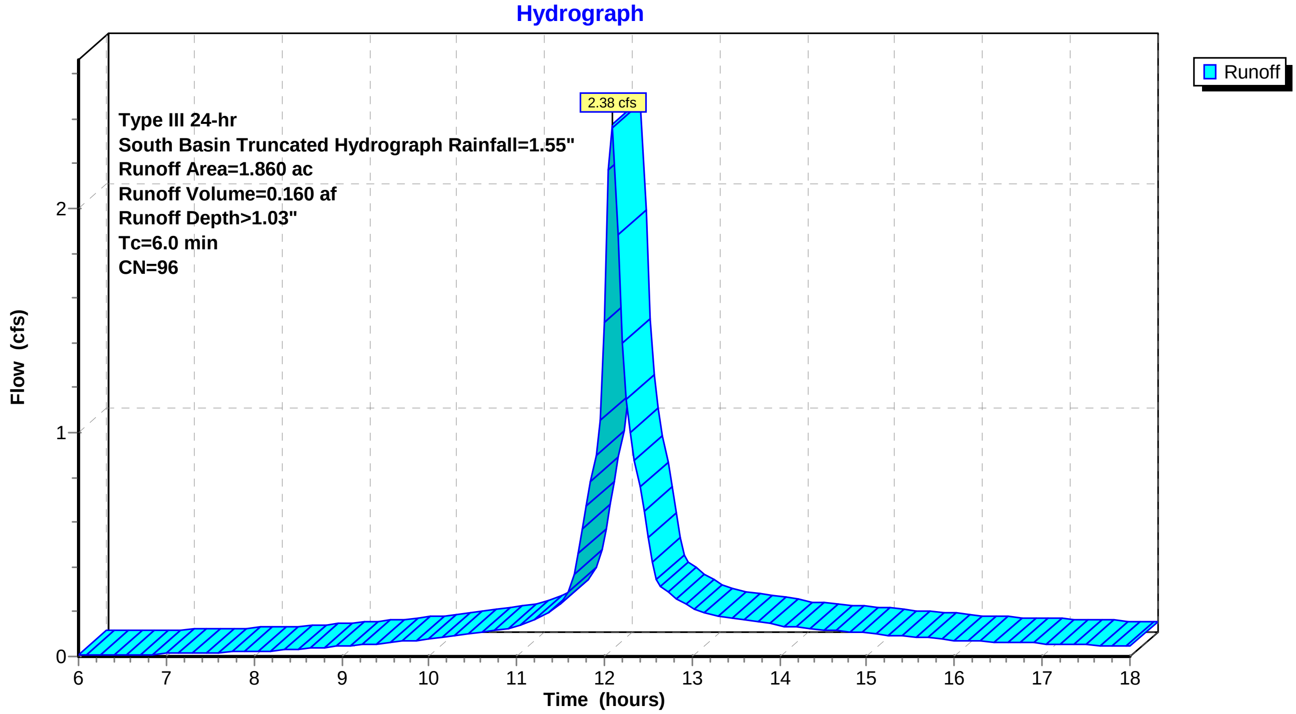
Runoff = 2.38 cfs @ 12.09 hrs, Volume= 0.160 af, Depth> 1.03"
Routed to Pond 15P : South Basin

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 6.00-18.00 hrs, dt= 0.05 hrs
Type III 24-hr South Basin Truncated Hydrograph Rainfall=1.55"

Area (ac)	CN	Description
1.860	96	Gravel surface, HSG B
1.860		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment 15S: South Basin - Modified Site for Sizing



Summary for Pond 15P: South Basin

[82] Warning: Early inflow requires earlier time span

Inflow Area = 1.860 ac, 0.00% Impervious, Inflow Depth > 1.03" for South Basin Truncated Hydrograph ev
Inflow = 2.38 cfs @ 12.09 hrs, Volume= 0.160 af
Outflow = 0.20 cfs @ 13.11 hrs, Volume= 0.122 af, Atten= 92%, Lag= 61.5 min
Discarded = 0.20 cfs @ 13.11 hrs, Volume= 0.122 af
Primary = 0.00 cfs @ 6.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 6.00-18.00 hrs, dt= 0.05 hrs
Peak Elev= 1,029.32' @ 13.11 hrs Surf.Area= 10,984 sf Storage= 3,409 cf

Plug-Flow detention time= 143.0 min calculated for 0.122 af (76% of inflow)
Center-of-Mass det. time= 95.7 min (847.2 - 751.5)

Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	72,848 cf	**SE Basin Storage (Prismatic)** Listed below (Recalc)

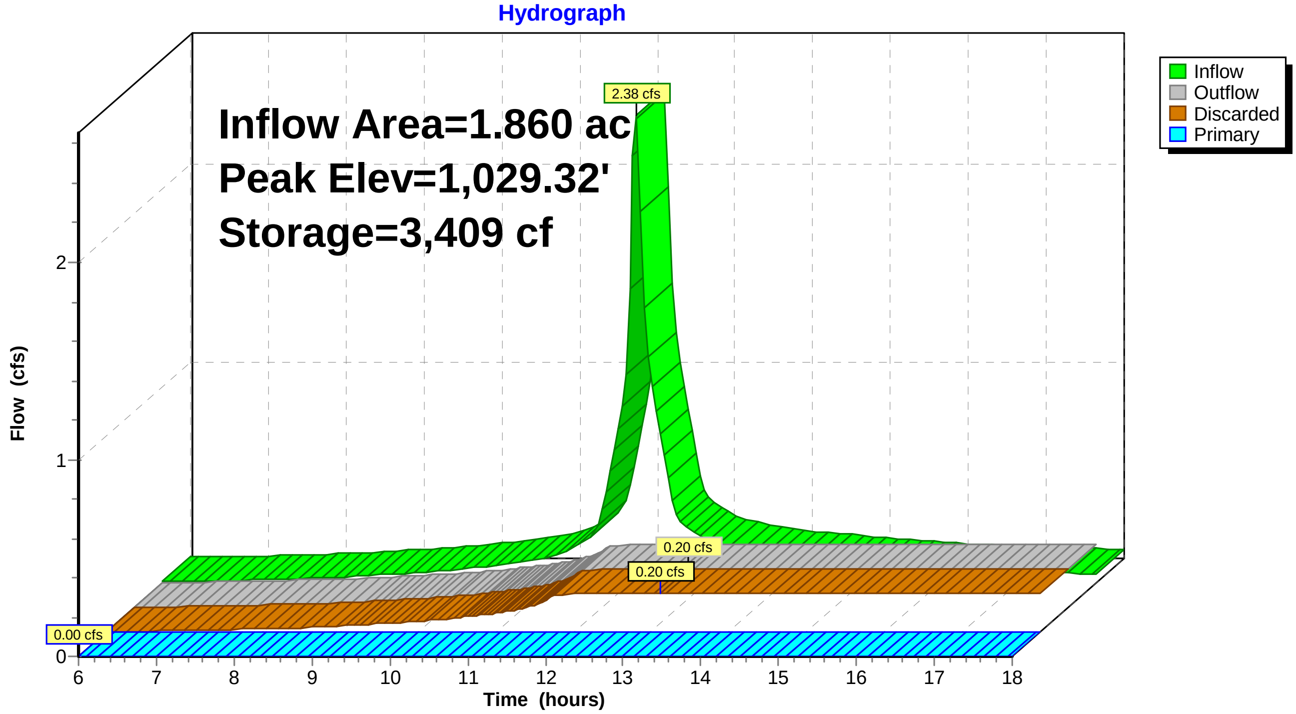
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,029.00	10,570	0	0
1,030.00	11,880	11,225	11,225
1,031.00	13,450	12,665	23,890
1,032.00	15,310	14,380	38,270
1,033.00	17,273	16,292	54,562
1,034.00	19,300	18,287	72,848

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,029.00'	**0.775 in/hr Exfiltration over Surface area**
#2	Primary	1,030.00'	**12.0" Round Culvert** L= 563.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 1,030.00' / 1,024.20' S= 0.0103 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#3	Device 2	1,033.00'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.20 cfs @ 13.11 hrs HW=1,029.32' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.20 cfs)

Primary OutFlow Max=0.00 cfs @ 6.00 hrs HW=1,029.00' (Free Discharge)
└─**2=Culvert** (Controls 0.00 cfs)
  └─**3=Orifice/Grate** (Controls 0.00 cfs)

Pond 15P: South Basin



Attachment 4

Forebay Calculations

North Basin			
Drainage Area (ac):	21.81		
Imperv. Area (ac):	2.46		
			Min.
			Required
Minimum Storage			**Forebay Size**
Forebay (ac-ft)	0.0205	**892.98**	**(cf)**

Avg. End-Area Method for Storage Volume				
Elev. (ft)	Area (ft2)	Volume		
1029	11245.5	11571620		
1030	12500	12875000		
				Provided
				Forebay
			11872.75	**Size (cf)**

South Basin			
Drainage Area (ac):	2.73		
Imperv. Area (ac):	1.86		
Minimum Storage Forebay (ac-ft)	0.0155	**675.18**	**Min. Required Forebay Size (cf)**

Avg. End-Area Method for Storage Volume			
Elev. (ft)	Area (ft2)	Volume	
1029	696.96	717171.84	
1034.5	3441.24	3559962.8	
		11380.05	**Provided Forebay Size (cf)**

Attachment 5

TSS Removal Spreadsheet

INSTRUCTIONS:
1. In BMP Column, click on Blue Cell to Activate Drop Down Menu
2. Select BMP from Drop Down Menu
3. After BMP is selected, TSS Removal and other Columns are automatically completed.

Version 1, Automated: Mar. 4, 2008

Location: Upland Disposal Facility

TSS Removal Calculation Worksheet

B BMP[1]	C TSS Removal Rate[1]	D Starting TSS Load*	E Amount Removed (C*D)	F Remaining Load (D-E)
Grass Channel	0.50	1.00	0.50	0.50
Sediment Forebay	0.25	0.50	0.13	0.38
Infiltration Basin	0.80	0.38	0.30	0.08
	0.00	0.08	0.00	0.08
	0.00	0.08	0.00	0.08

Total TSS Removal = 93%

Separate Form Needs to be Completed for Each Outlet or BMP Train

Project: Upland Disposal Facility
Prepared By: Arcadis, Inc.
Date: Feb-24

*Equals remaining load from previous BMP (E) which enters the BMP

Non-automated TSS Calculation Sheet
must be used if Proprietary BMP Proposed
1. From MassDEP Stormwater Handbook Vol. 1

Mass. Dept. of Environmental Protection

Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **G-5** **Subject:** **Stormwater Management Area Design**

Prepared By: **MTA** **Date:** **February 2024**

Reviewed By: **BMS** **Date:** **February 2024**

Objective

Analyze the effect of proposed earthwork on existing infiltration features, referred to herein as Stormwater Management Areas (SMAs). Since proposed earthwork will impact the SMAs, analysis will be performed on the revised infiltration feature footprint, receiving drainage area, and associated land cover to document any changes. This analysis will aid in later assessment of existing versus proposed conditions.

References

1. Arcadis U.S. Inc. *Calculation Brief G-1: Design Storm.* February 2024.
2. Arcadis U.S. Inc. *Calculation Brief G-2: Existing Stormwater Conditions.* February 2024.
3. Arcadis U.S. Inc. *Calculation Brief G-7: Proposed Stormwater Conditions.* February 2024.
4. Arcadis U.S. Inc. *Calculation Brief G-4: Stormwater Basin Design.* February 2024.
5. HydroCAD. Software Solutions, LLC. *HydroCAD Version 10.2.* Computer Software, 2022.
6. MassDEP Division of Watershed Management. *Hydrology Handbook for Conservation Commissioners.* March 2002.
7. Autodesk, Inc. Civil 3D. Computer Software. 2023.

Assumptions

1. Assumptions regarding existing conditions will be maintained according to Reference 2.
2. Curve numbers (CNs) within the limits of work are based on the following (Reference 3):
   - Final cover and regraded areas: Pasture, grassland or range (HSG B, CN 61)
   - Roads/Access Drives: Gravel (w/o right-of-way) (HSG B, CN 96)
3. Seven SMAs are evaluated and referenced as SMA-1, SMA-2, SMA-3A, SMA-3B, SMA-4, SMA-5, and SMA-6. Their boundaries are delineated using Reference 7.
4. All SMAs are existing on-site depressions that are affected by the UDF construction and closure and/or are proposed for modification. Because the SMAs are existing, they are not intended to comply with current MassDEP requirements for infiltration features. Instead, the benchmark for their performance under proposed conditions is based on a comparison of water quantity control to existing conditions. This comparison is performed in a separate analysis.

5. Infiltration occurs in all proposed SMAs based on the on-site hydraulic conductivity testing as described in Reference 4. Areas north of the UDF cell divide use the same infiltration rate as the North Basin (0.46 in/hr, Reference 4), while SMAs south of the UDF cell divide use the same infiltration rates as the South Basin (0.39 in/hr, Reference 4).

Calculations

1. Changes to Existing SMA Hydrology

All SMAs evaluated herein will be modified from their existing condition as a result of proposed earthwork or other proposed construction. Each is analyzed to ensure that the overall proposed drainage area complies with MassDEP requirements for peak discharge rate attenuation. The changes to each SMA are described below:

- SMA-1 – The existing depression of SMA-1 is regraded to manage stormwater runoff in a manner which conveys runoff from the eastern property and associated drainage area. SMA-1 is designed, through use of an overflow weir that drains to an on-site area to the north, to manage incoming stormwater runoff and mimic the existing SMA.
- SMA-2 – The footprint of existing SMA-2 is reduced due to off-grading from the proposed south stormwater basin. To mitigate this, SMA-2 is deepened and regraded, and the new drainage area directed toward SMA-2 is analyzed. All runoff entering SMA-2 infiltrates into the ground; there is no outflow.
- SMA-3A & SMA-3B – The proposed access road and associated earthwork modifies existing drainage patterns, blocking drainage toward an existing low point south of SMA-2 and the South Basin. To mitigate flooding of the proposed access road, a channel is proposed to redirect water toward the regraded infiltration areas south of the access road, SMA-3A and SMA-3B. Peak outflow for stormwater requirements is analyzed at the outflow of SMA-3B. SMA-3A acts as the first infiltration area of the two in series. Outflow from SMA-3A occurs via infiltration, piped outflow towards SMA-2, or weir overflow to SMA-3B. A portion of the flow is rerouted to SMA-2 to meet peak discharge rate requirements. SMA-3B also acts as an infiltration feature, with outflow from infiltration and weir overflow.
- SMA-4 – Due to hydrologic changes and an increase in runoff being directed toward the existing extents of SMA-4, a new footprint is proposed to manage the runoff. SMA-4 is regraded to contain stormwater runoff with adequate freeboard and a reduction in off-site runoff compared to existing conditions. Outflow from SMA-4 occurs via infiltration, an overflow weir, and four low-flow orifices to manage smaller storm events.
- SMA-5 – An existing stormwater retention pond is completely regraded in the design condition to accommodate adequate surface runoff from the UDF area. The existing SMA outfalls into an adjacent stormwater pond. To reduce the impact of removing the existing SMA, SMA-5 is proposed to convey surface water from 10 P (Reference 3) to the overflow area toward the adjacent stormwater pond.
- SMA-6 – An existing depression is utilized during existing and proposed routing from drainage areas routed to Design Point 1. This existing infiltration area outfalls by means of a spillway offsite. Proposed grading of access road redefines the upper limits of stage-storage of the infiltration area. To achieve compliance with MassDEP peak discharge rate regulations, the spillway invert elevation is increased.

2. Contributing Drainage Areas and Hydrologic Conditions

A majority of the drainage areas change between existing and proposed conditions. Table 1 summarizes the characteristics of each proposed drainage area that drains to an SMA. Reference 3 has detailed information on proposed drainage areas and CN values.

Table 1 – Proposed Drainage Area for SMAs

Receiving SMA	Drainage Area ID	Drainage Area (ac)	Composite CN
SMA-1	3 P	23.59	58
SMA-2	6 P	1.95	64
SMA-3A	8A P	0.52	57
SMA-3B	8B P	0.44	65
SMA-4	7 P	10.95	43
	Entrance Road Culvert	0.82	61
SMA-5	10 P	5.00	65
SMA-6	1A P	38.00	62
	1B P	2.44	41
	2A P	49.15	62
	2B P	2.82	42
	2C P	2.18	38

3. SMA Routing Calculations

Routing calculations for each of the SMAs are summarized in Tables 2, 3, and 4 below. The SMAs are designed to adequately manage revised drainage patterns, maintain existing infiltration areas, and aid in peak discharge rate attenuation requirements. Peak outflows are analyzed at the surface water outflow point of the SMA (i.e., spillway, storm culvert, etc). All comparisons between existing and proposed conditions can be found in Reference 3. Modeling results for the SMAs can be found in Attachment 2. Full routing results can be found in Reference 3.

Table 2 – Peak Outflow and Peak Water Surface Elevations (2-Yr, 24 Hour Storm)

SMA	2-Year, 24-Hour Conditions		
	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Water Surface El. (ft)
SMA-1	6.47	0.00	996.83
SMA-2	1.72	0.00	1022.82
SMA-3A	0.22	0.20	1028.87
SMA-3B	0.42	0.00	1023.78
SMA-4	0.14	0.00	987.14
SMA-5	4.82	2.72	953.52
SMA-6	19.86	0.00	984.26

Table 3 – Peak Outflow and Peak Water Surface Elevations (10-Yr, 24 Hour Storm)

SMA #	10-Year, 24-Hour Conditions		
	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Water Surface El. (ft)
1	17.65	0.00	999.03
2	4.00	0.00	1023.72
3A	0.67	0.64	1029.02
3B	0.91	0.00	1024.33
4	1.93	0.52	987.84
5	10.38	4.26	954.27
6	78.29	11.04	985.39

Table 4 – Peak Outflow and Peak Water Surface Elevations (100-Yr, 24 Hour Storm)

SMA #	100-Year, 24-Hour Conditions		
	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Water Surface El. (ft)
1	58.30	7.16	1001.80
2	11.50	0.00	1025.82
3A	2.30	2.06	1029.41
3B	2.49	1.26	1024.61
4	29.84	14.12	990.62
5	28.25	24.69	955.00
6	231.44	125.68	988.67

4. SMA Infiltration Rates

Table 5 summarizes the peak infiltration rate calculated for each design storm event.

Table 5 – Peak SMA Infiltration

Design Storm Event	Peak Basin Infiltration Rate (cfs)						
	SMA-1	SMA-2	SMA-3A	SMA-3B	SMA-4	SMA-5	SMA-6
2-Year	0.26	0.06	0.00	0.02	0.07	0.04	0.65
10-Year	0.32	0.08	0.00	0.02	0.08	0.07	0.75
100-Year	0.55	0.13	0.01	0.02	0.12	0.09	0.86

Summary

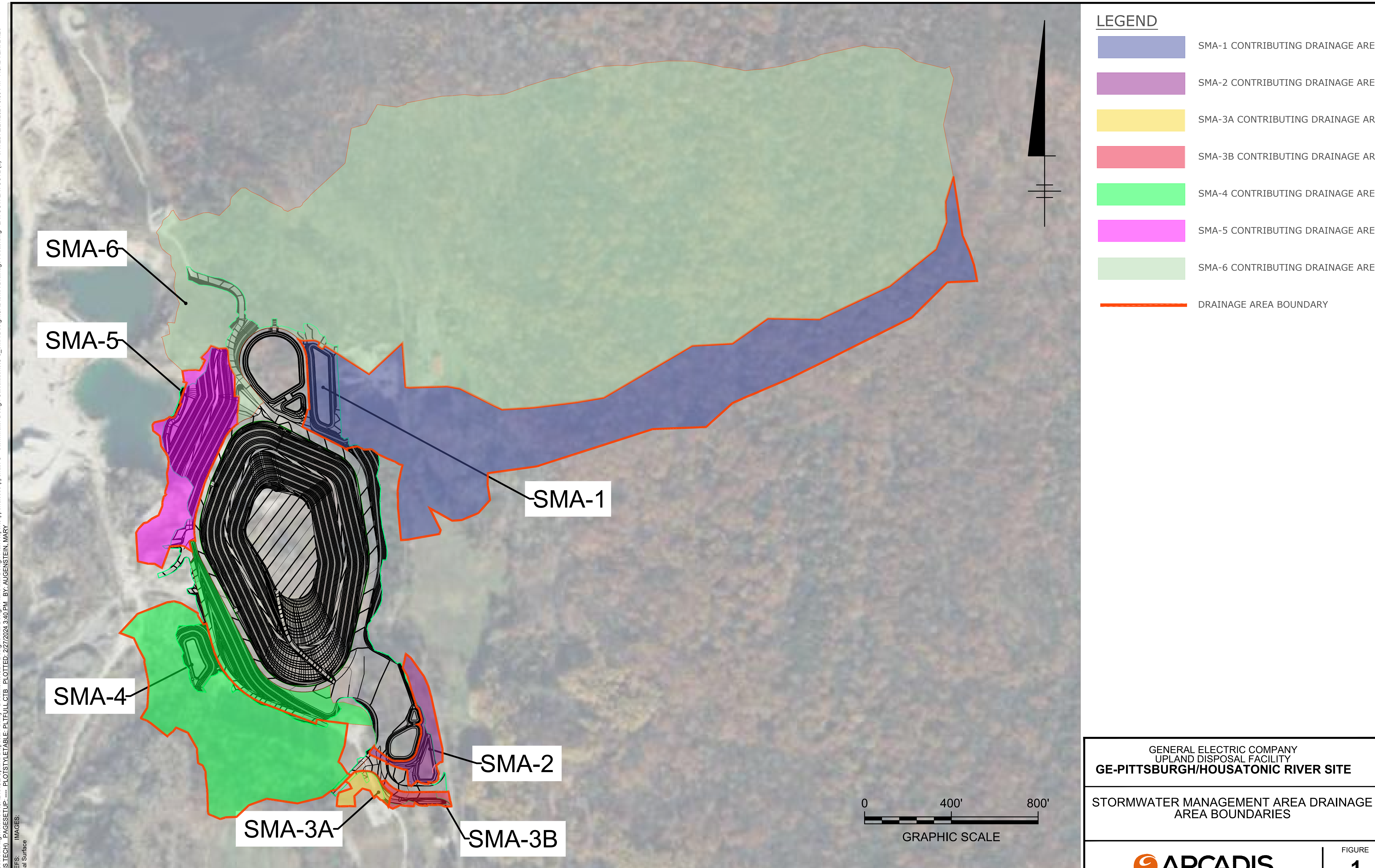
The performance of the seven SMAs is evaluated. The proposed modifications to the seven SMAs adequately manage changes in proposed stormwater conditions associated with UDF construction and closure.

Attachments

1. SMA Drainage Area Boundaries
2. SMA HydroCAD Results

Attachment 1

Stormwater Management Area Drainage Area Boundaries



GENERAL ELECTRIC COMPANY
UPLAND DISPOSAL FACILITY
GE-PITTSBURGH/HOUSATONIC RIVER SITE

STORMWATER MANAGEMENT AREA DRAINAGE AREA BOUNDARIES

ARCADIS

FIGURE
1

Attachment 2

Stormwater Management Area HydroCAD Results

Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	2-YR	Type III 24-hr		Default	24.00	1	3.84	2
2	10-YR	Type III 24-hr		Default	24.00	1	5.28	2
3	100-YR	Type III 24-hr		Default	24.00	1	9.12	2

Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 3P: SMA-1 (Design Point 2) Peak Elev=996.83' Storage=0.914 af Inflow=6.47 cfs 1.167 af
Discarded=0.26 cfs 1.167 af Primary=0.00 cfs 0.000 af Outflow=0.26 cfs 1.167 af

Pond 13P: SMA-5 (Design Point 9) (Culvert Peak Elev=953.52' Storage=0.036 af Inflow=5.15 cfs 0.390 af
Discarded=0.04 cfs 0.008 af Primary=2.74 cfs 0.383 af Secondary=0.00 cfs 0.000 af Outflow=2.78 cfs 0.390 af

Pond 17P: SMA3B (Design Point 6) Peak Elev=1,023.78' Storage=0.021 af Inflow=0.42 cfs 0.034 af
Discarded=0.02 cfs 0.034 af Primary=0.00 cfs 0.000 af Outflow=0.02 cfs 0.034 af

Pond 19P: SMA-4 (Design Point 7) (Culvert 9) Peak Elev=987.14' Storage=0.026 af Inflow=0.14 cfs 0.089 af
Discarded=0.07 cfs 0.089 af Primary=0.00 cfs 0.000 af Secondary=0.00 cfs 0.000 af Outflow=0.07 cfs 0.089 af

Pond 20P: SMA3A (Culvert 15) Peak Elev=1,028.87' Storage=0.001 af Inflow=0.22 cfs 0.024 af
Discarded=0.00 cfs 0.002 af Primary=0.20 cfs 0.022 af Secondary=0.00 cfs 0.000 af Outflow=0.20 cfs 0.024 af

Pond 22P: SMA-6/Proposed Powerline Peak Elev=984.26' Storage=4.455 af Inflow=19.86 cfs 5.066 af
Discarded=0.65 cfs 5.066 af Primary=0.00 cfs 0.000 af Outflow=0.65 cfs 5.066 af

Pond 24P: SMA-2 (Design Point 5) Peak Elev=1,022.82' Storage=0.110 af Inflow=1.72 cfs 0.166 af
Outflow=0.06 cfs 0.166 af

Summary for Pond 3P: SMA-1 (Design Point 2)

Inflow Area = 23.590 ac, 0.00% Impervious, Inflow Depth = 0.59" for 2-YR event
Inflow = 6.47 cfs @ 12.58 hrs, Volume= 1.167 af
Outflow = 0.26 cfs @ 24.34 hrs, Volume= 1.167 af, Atten= 96%, Lag= 706.0 min
Discarded = 0.26 cfs @ 24.34 hrs, Volume= 1.167 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 996.83' @ 24.34 hrs Surf.Area= 0.555 ac Storage= 0.914 af
Flood Elev= 1,001.76' Surf.Area= 1.185 ac Storage= 4.700 af

Plug-Flow detention time= 1,544.8 min calculated for 1.167 af (100% of inflow)
Center-of-Mass det. time= 1,544.8 min (2,477.3 - 932.5)

Volume	Invert	Avail.Storage	Storage Description
#1	995.00'	4.991 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

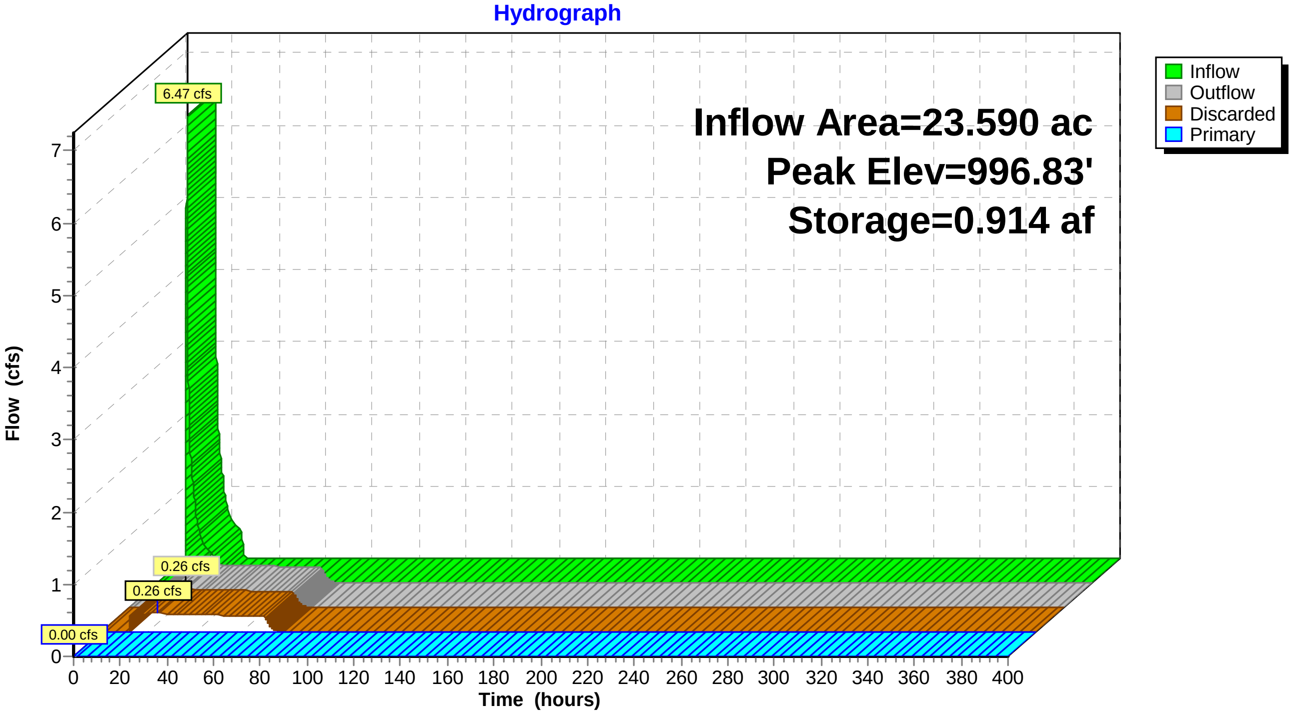
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
995.00	0.448	0.000	0.000
996.00	0.505	0.476	0.476
998.00	0.627	1.132	1.608
1,000.00	0.756	1.383	2.991
1,002.00	1.244	2.000	4.991

Device	Routing	Invert	Outlet Devices
#1	Discarded	995.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,001.55'	**20.0' long + 3.0 '/' SideZ x 15.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.26 cfs @ 24.34 hrs HW=996.83' (Free Discharge)
└**1=Exfiltration** (Exfiltration Controls 0.26 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=995.00' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 3P: SMA-1 (Design Point 2)



Summary for Pond 24P: SMA-2 (Design Point 5)

Inflow Area = 2.470 ac, 0.00% Impervious, Inflow Depth = 0.81" for 2-YR event
Inflow = 1.72 cfs @ 12.15 hrs, Volume= 0.166 af
Outflow = 0.06 cfs @ 20.42 hrs, Volume= 0.166 af, Atten= 97%, Lag= 495.9 min
Discarded = 0.06 cfs @ 20.42 hrs, Volume= 0.166 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,022.82' @ 20.42 hrs Surf.Area= 0.151 ac Storage= 0.110 af

Plug-Flow detention time= 891.6 min calculated for 0.166 af (100% of inflow)
Center-of-Mass det. time= 891.6 min (1,781.1 - 889.5)

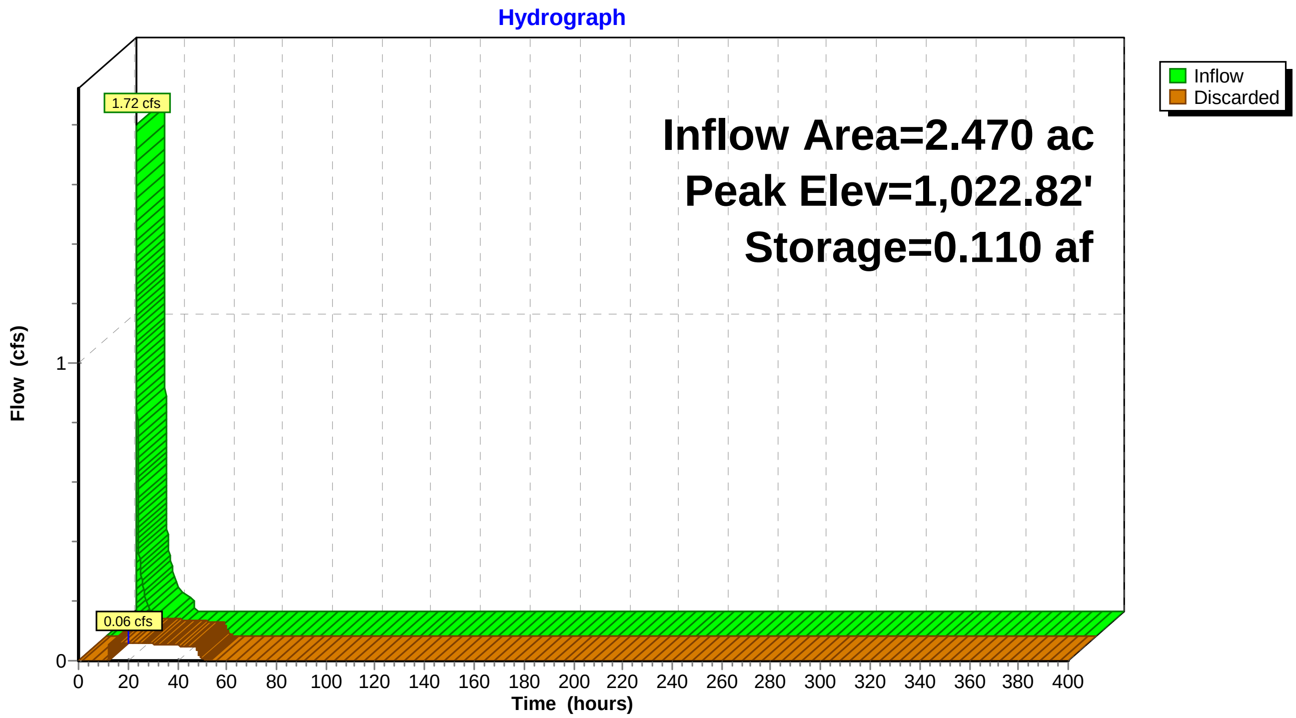
Volume	Invert	Avail.Storage	Storage Description
#1	1,022.00'	0.856 af	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.00	0.116	0.000	0.000	0.116
1,026.00	0.330	0.856	0.856	0.332

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.00'	**0.390 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.06 cfs @ 20.42 hrs HW=1,022.82' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.06 cfs)

Pond 24P: SMA-2 (Design Point 5)



Summary for Pond 20P: SMA3A (Culvert 15)

Inflow Area = 0.520 ac, 0.00% Impervious, Inflow Depth = 0.55" for 2-YR event
Inflow = 0.22 cfs @ 12.12 hrs, Volume= 0.024 af
Outflow = 0.20 cfs @ 12.16 hrs, Volume= 0.024 af, Atten= 7%, Lag= 2.1 min
Discarded = 0.00 cfs @ 12.16 hrs, Volume= 0.002 af
Primary = 0.20 cfs @ 12.16 hrs, Volume= 0.022 af
Routed to Pond 24P : SMA-2 (Design Point 5)
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Reach 13R : SMA3 CHANNEL

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,028.87' @ 12.16 hrs Surf.Area= 0.005 ac Storage= 0.001 af

Plug-Flow detention time= 18.4 min calculated for 0.024 af (100% of inflow)
Center-of-Mass det. time= 18.4 min (931.0 - 912.6)

Volume	Invert	Avail.Storage	Storage Description
#1	1,028.50'	0.019 af	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,028.50	0.001	0.000	0.000	0.001
1,029.00	0.007	0.002	0.002	0.007
1,030.00	0.031	0.018	0.019	0.031

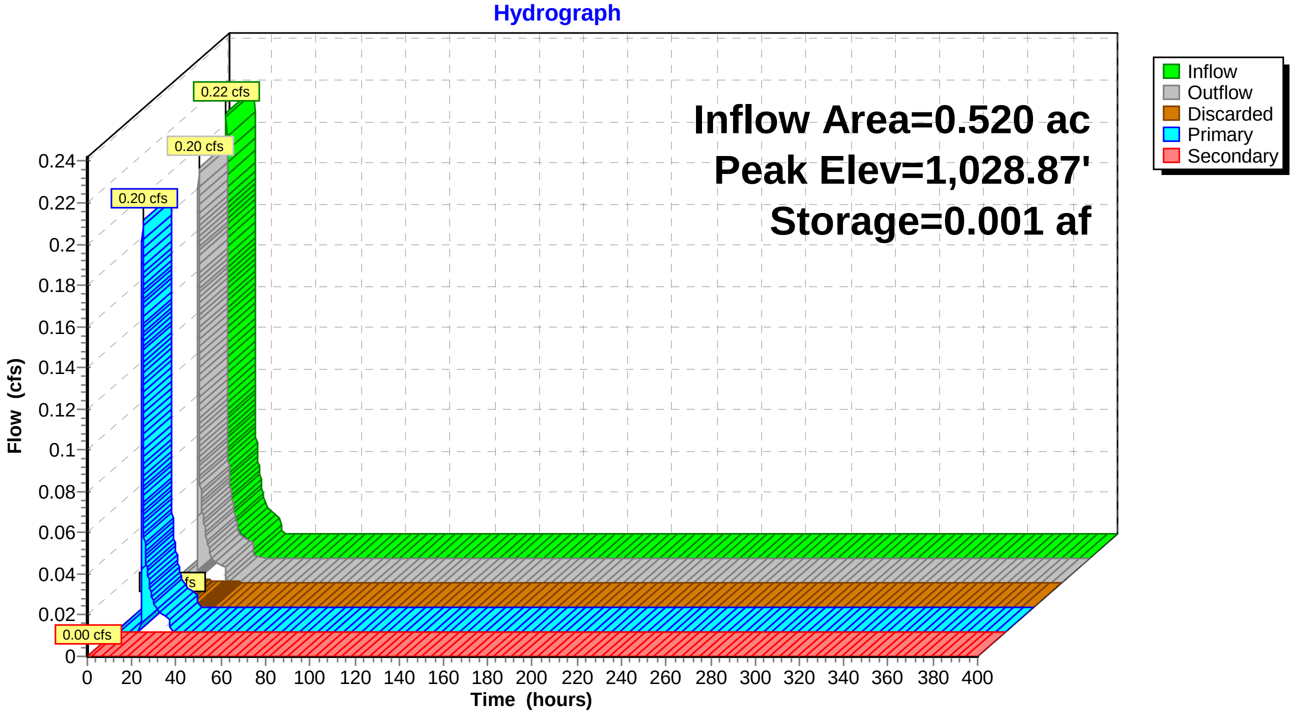
Device	Routing	Invert	Outlet Devices
#1	Discarded	1,028.50'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,028.70'	**8.0" Round Culvert X 2.00** L= 109.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 1,028.70' / 1,026.63' S= 0.0190 '/' Cc= 0.900 n= 0.013, Flow Area= 0.35 sf
#3	Secondary	1,029.80'	**16.0' long + 3.0 '/' SideZ x 2.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 Coef. (English) 2.48 2.60 2.60 2.60 2.64 2.65 2.68 2.75 2.74 2.76 2.89 3.05 3.19 3.32

Discarded OutFlow Max=0.00 cfs @ 12.16 hrs HW=1,028.87' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=0.20 cfs @ 12.16 hrs HW=1,028.87' (Free Discharge)
└─**2=Culvert** (Inlet Controls 0.20 cfs @ 1.41 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,028.50' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 20P: SMA3A (Culvert 15)



Summary for Pond 17P: SMA3B (Design Point 6)

Inflow Area =	0.440 ac,	0.00% Impervious,	Inflow Depth = 0.94"	for 2-YR event
Inflow =	0.42 cfs @	12.10 hrs, Volume=	0.034 af	
Outflow =	0.02 cfs @	17.55 hrs, Volume=	0.034 af,	Atten= 96%, Lag= 327.0 min
Discarded =	0.02 cfs @	17.55 hrs, Volume=	0.034 af	
Primary =	0.00 cfs @	0.00 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,023.78' @ 17.55 hrs Surf.Area= 0.043 ac Storage= 0.021 af

Plug-Flow detention time= 754.7 min calculated for 0.034 af (100% of inflow)
Center-of-Mass det. time= 754.7 min (1,634.0 - 879.3)

Volume	Invert	Avail.Storage	Storage Description
#1	1,022.60'	0.127 af	**Custom Stage Data (Conic)** Listed below (Recalc)

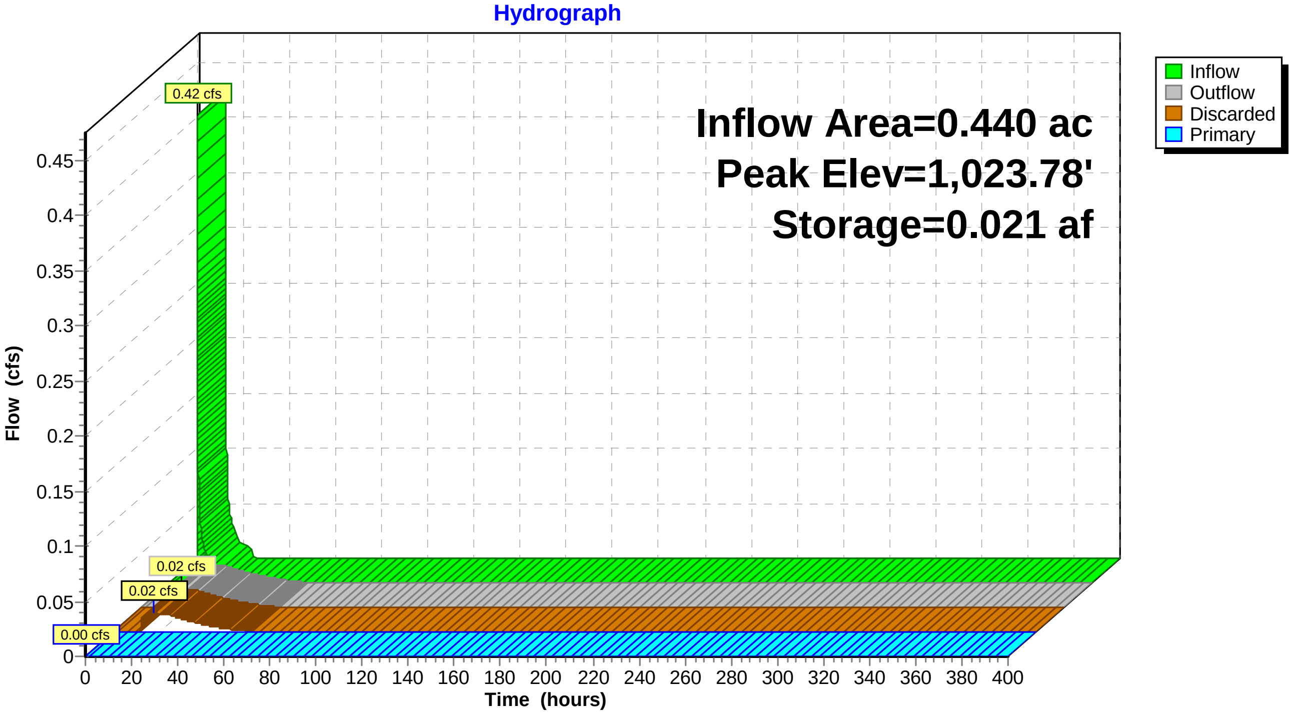
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.60	0.002	0.000	0.000	0.002
1,023.80	0.044	0.022	0.022	0.044
1,025.50	0.081	0.105	0.127	0.082

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.60'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,024.50'	**15.0' long + 3.0 '/' SideZ x 6.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.37 2.51 2.70 2.68 2.68 2.67 2.65 2.65 2.65 2.65 2.66 2.66 2.67 2.69 2.72 2.76 2.83

Discarded OutFlow Max=0.02 cfs @ 17.55 hrs HW=1,023.78' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,022.60' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 17P: SMA3B (Design Point 6)



Summary for Pond 19P: SMA-4 (Design Point 7) (Culvert 9)

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Inflow Area =      17.420 ac,   0.00% Impervious,  Inflow Depth =   0.06"    for  2-YR event
Inflow      =       0.14 cfs @  14.75 hrs,  Volume=          0.089 af
Outflow     =       0.07 cfs @  21.16 hrs,  Volume=          0.089 af,  Atten= 49%,  Lag= 384.5 min
Discarded  =        0.07 cfs @  21.16 hrs,  Volume=          0.089 af
Primary     =       0.00 cfs @   0.00 hrs,  Volume=          0.000 af
Secondary =         0.00 cfs @   0.00 hrs,  Volume=          0.000 af
```

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 987.14' @ 21.16 hrs Surf.Area= 0.185 ac Storage= 0.026 af

Plug-Flow detention time= 193.0 min calculated for 0.089 af (100% of inflow)
Center-of-Mass det. time= 192.9 min (1,248.9 - 1,055.9)

Volume	Invert	Avail.Storage	Storage Description
#1	987.00'	0.976 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
987.00	0.180	0.000	0.000
991.00	0.308	0.976	0.976

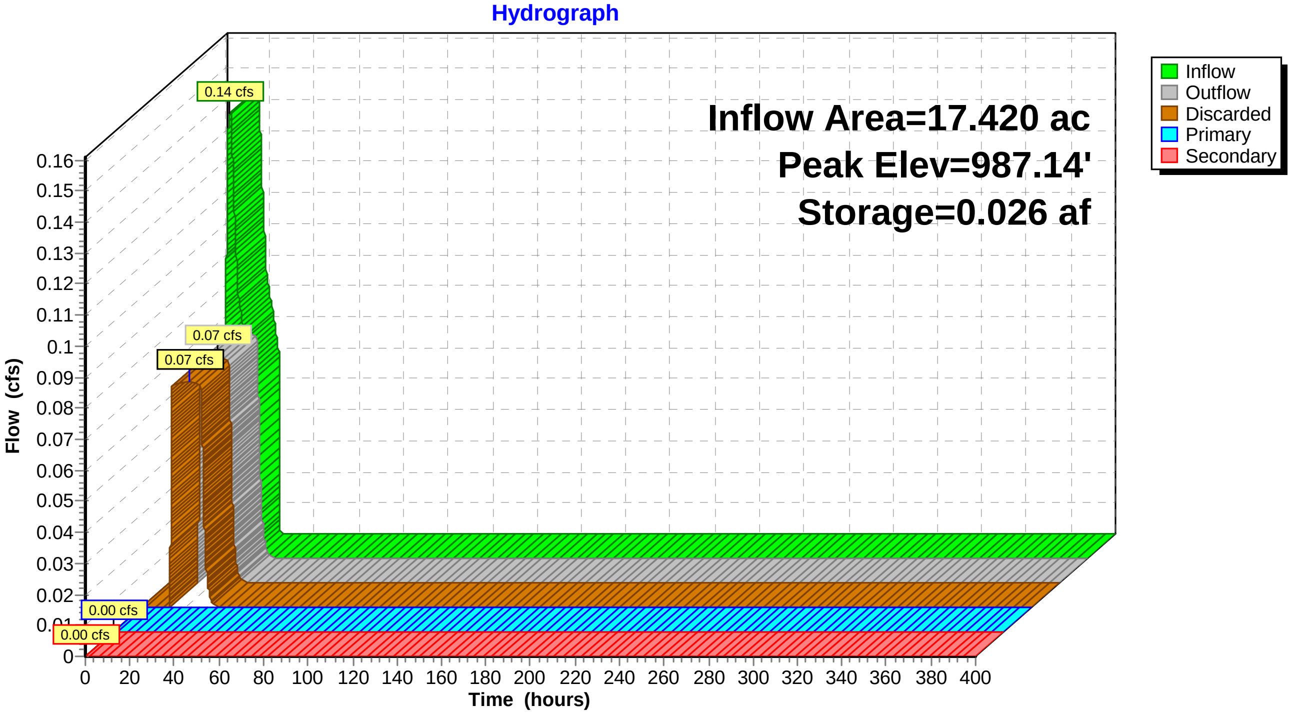
Device	Routing	Invert	Outlet Devices
#1	Discarded	987.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	987.50'	**4.0" Round Culvert X 4.00** L= 30.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 987.50' / 987.10' S= 0.0133 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 0.09 sf
#3	Secondary	990.00'	**8.0' long + 3.0 '/' SideZ x 5.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.34 2.50 2.70 2.68 2.68 2.66 2.65 2.65 2.65 2.65 2.67 2.66 2.68 2.70 2.74 2.79 2.88

Discarded OutFlow Max=0.07 cfs @ 21.16 hrs HW=987.14' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.07 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=987.00' (Free Discharge)
└─**2=Culvert** (Controls 0.00 cfs)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=987.00' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 19P: SMA-4 (Design Point 7) (Culvert 9)



Summary for Pond 13P: SMA-5 (Design Point 9) (Culvert 12)

[44] Hint: Outlet device #2 is below defined storage

Inflow Area =	5.000 ac,	0.00% Impervious,	Inflow Depth = 0.94"	for 2-YR event
Inflow =	4.82 cfs @	12.10 hrs, Volume=	0.390 af	
Outflow =	2.76 cfs @	12.28 hrs, Volume=	0.390 af,	Atten= 43%, Lag= 10.4 min
Discarded =	0.04 cfs @	12.28 hrs, Volume=	0.008 af	
Primary =	2.72 cfs @	12.28 hrs, Volume=	0.383 af	
Secondary =	0.00 cfs @	0.00 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 953.52' @ 12.28 hrs Surf.Area= 0.088 ac Storage= 0.036 af

Plug-Flow detention time= 3.4 min calculated for 0.390 af (100% of inflow)
Center-of-Mass det. time= 3.4 min (882.7 - 879.3)

Volume	Invert	Avail.Storage	Storage Description
#1	953.00'	0.361 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
953.00	0.049	0.000	0.000
955.50	0.240	0.361	0.361

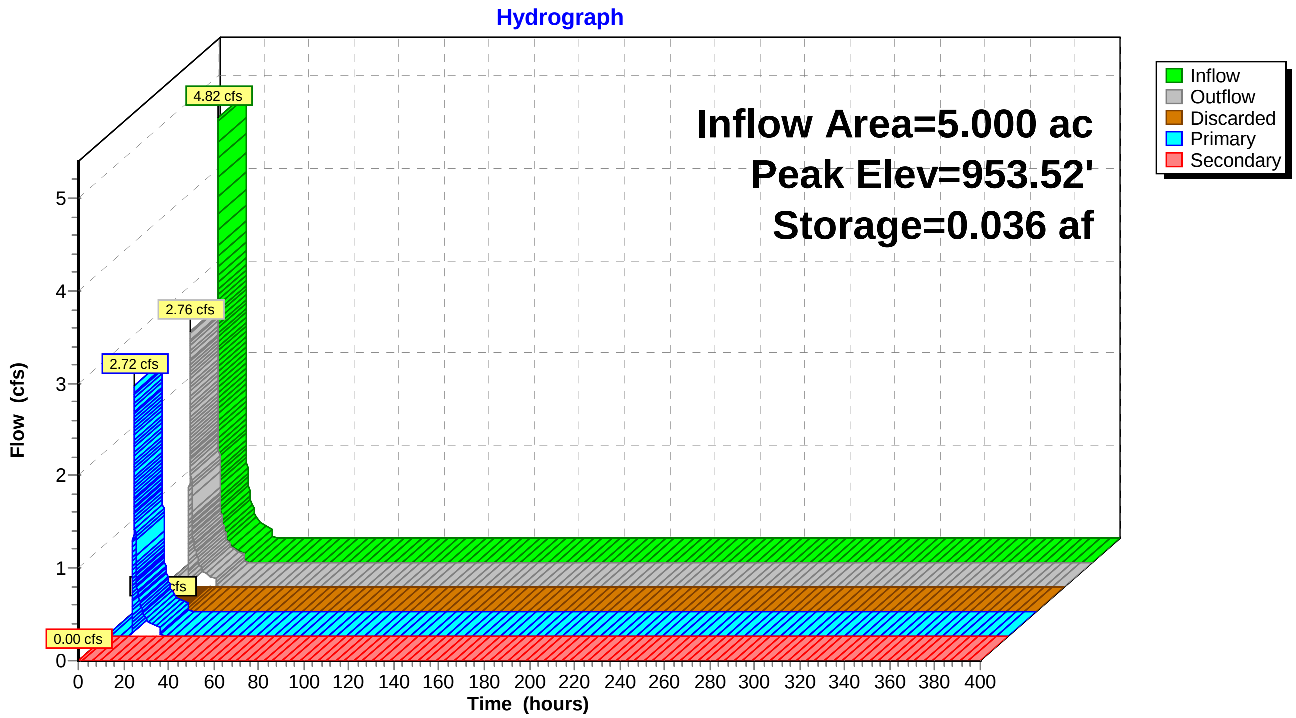
Device	Routing	Invert	Outlet Devices
#1	Discarded	953.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	952.50'	**12.0" Round Culvert #12** L= 40.0' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 952.50' / 949.60' S= 0.0725 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#3	Secondary	954.50'	**16.0' long + 10.0 '/' SideZ x 16.4' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.04 cfs @ 12.28 hrs HW=953.52' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.04 cfs)

Primary OutFlow Max=2.72 cfs @ 12.28 hrs HW=953.52' (Free Discharge)
└─**2=Culvert #12** (Inlet Controls 2.72 cfs @ 3.46 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=953.00' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 13P: SMA-5 (Design Point 9) (Culvert 12)



Summary for Pond 22P: SMA-6/Proposed Powerline Depression (Design Point 1)

[81] Warning: Exceeded Pond 14P by 2.26' @ 24.66 hrs
[79] Warning: Submerged Pond 21P Primary device # 2 OUTLET by 2.09'

Inflow Area = 139.990 ac, 0.00% Impervious, Inflow Depth = 0.43" for 2-YR event
Inflow = 19.86 cfs @ 12.57 hrs, Volume= 5.066 af
Outflow = 0.65 cfs @ 24.66 hrs, Volume= 5.066 af, Atten= 97%, Lag= 724.9 min
Discarded = 0.65 cfs @ 24.66 hrs, Volume= 5.066 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 984.26' @ 24.66 hrs Surf.Area= 1.388 ac Storage= 4.455 af

Plug-Flow detention time= 3,268.6 min calculated for 5.066 af (100% of inflow)
Center-of-Mass det. time= 3,268.8 min (4,213.9 - 945.1)

Volume	Invert	Avail.Storage	Storage Description
#1	978.00'	7.150 af	**Custom Stage Data (Conic)** Listed below

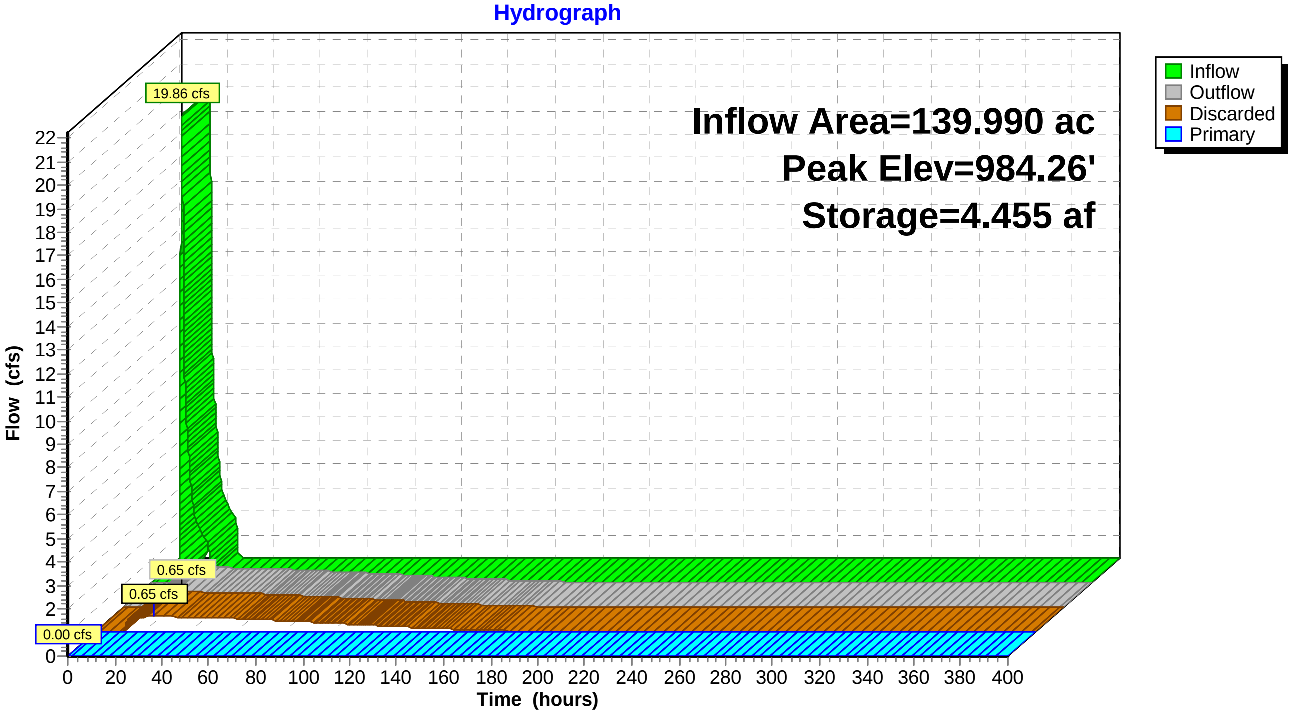
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
978.00	0.030	0.000	0.000	0.030
979.00	0.163	0.088	0.088	0.163
980.00	0.375	0.262	0.349	0.375
981.00	0.687	0.523	0.873	0.688
982.00	0.977	0.828	1.700	0.978
983.00	1.217	1.095	2.795	1.219
984.00	1.360	1.288	4.083	1.363
985.00	1.468	1.414	5.497	1.473
986.00	1.846	1.653	7.150	1.851

Device	Routing	Invert	Outlet Devices
#1	Primary	984.58'	**165.0 deg x 1.42' rise Sharp-Crested Vee/Trap Weir** Cv= 2.47 (C= 3.09)
#2	Discarded	978.00'	**0.460 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.65 cfs @ 24.66 hrs HW=984.26' (Free Discharge)
└─**2=Exfiltration** (Exfiltration Controls 0.65 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=978.00' (Free Discharge)
└─**1=Sharp-Crested Vee/Trap Weir** (Controls 0.00 cfs)

Pond 22P: SMA-6/Proposed Powerline Depression (Design Point 1)



Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 3P: SMA-1 (Design Point 2) Peak Elev=999.03' Storage=2.291 af Inflow=17.65 cfs 2.607 af
Discarded=0.32 cfs 2.607 af Primary=0.00 cfs 0.000 af Outflow=0.32 cfs 2.607 af

Pond 13P: SMA-5 (Design Point 9) (Culvert Peak Elev=954.27' Storage=0.125 af Inflow=11.08 cfs 0.768 af
Discarded=0.07 cfs 0.014 af Primary=4.27 cfs 0.753 af Secondary=0.00 cfs 0.000 af Outflow=4.34 cfs 0.768 af

Pond 17P: SMA3B (Design Point 6) Peak Elev=1,024.33' Storage=0.048 af Inflow=0.91 cfs 0.068 af
Discarded=0.02 cfs 0.068 af Primary=0.00 cfs 0.000 af Outflow=0.02 cfs 0.068 af

Pond 19P: SMA-4 (Design Point 7) (Culvert 9) Peak Elev=987.84' Storage=0.162 af Inflow=1.93 cfs 0.505 af
Discarded=0.08 cfs 0.195 af Primary=0.52 cfs 0.310 af Secondary=0.00 cfs 0.000 af Outflow=0.60 cfs 0.505 af

Pond 20P: SMA3A (Culvert 15) Peak Elev=1,029.02' Storage=0.002 af Inflow=0.67 cfs 0.054 af
Discarded=0.00 cfs 0.002 af Primary=0.64 cfs 0.053 af Secondary=0.00 cfs 0.000 af Outflow=0.64 cfs 0.054 af

Pond 22P: SMA-6/Proposed Powerline Peak Elev=985.39' Storage=6.137 af Inflow=78.29 cfs 11.270 af
Discarded=0.75 cfs 6.008 af Primary=11.04 cfs 5.262 af Outflow=11.79 cfs 11.270 af

Pond 24P: SMA-2 (Design Point 5) Peak Elev=1,023.72' Storage=0.263 af Inflow=4.00 cfs 0.339 af
Outflow=0.08 cfs 0.339 af

Summary for Pond 3P: SMA-1 (Design Point 2)

Inflow Area = 23.590 ac, 0.00% Impervious, Inflow Depth = 1.33" for 10-YR event
Inflow = 17.65 cfs @ 12.51 hrs, Volume= 2.607 af
Outflow = 0.32 cfs @ 24.46 hrs, Volume= 2.607 af, Atten= 98%, Lag= 716.8 min
Discarded = 0.32 cfs @ 24.46 hrs, Volume= 2.607 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 999.03' @ 24.46 hrs Surf.Area= 0.694 ac Storage= 2.291 af
Flood Elev= 1,001.76' Surf.Area= 1.185 ac Storage= 4.700 af

Plug-Flow detention time= 3,109.3 min calculated for 2.606 af (100% of inflow)
Center-of-Mass det. time= 3,109.4 min (4,011.8 - 902.4)

Volume	Invert	Avail.Storage	Storage Description
#1	995.00'	4.991 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

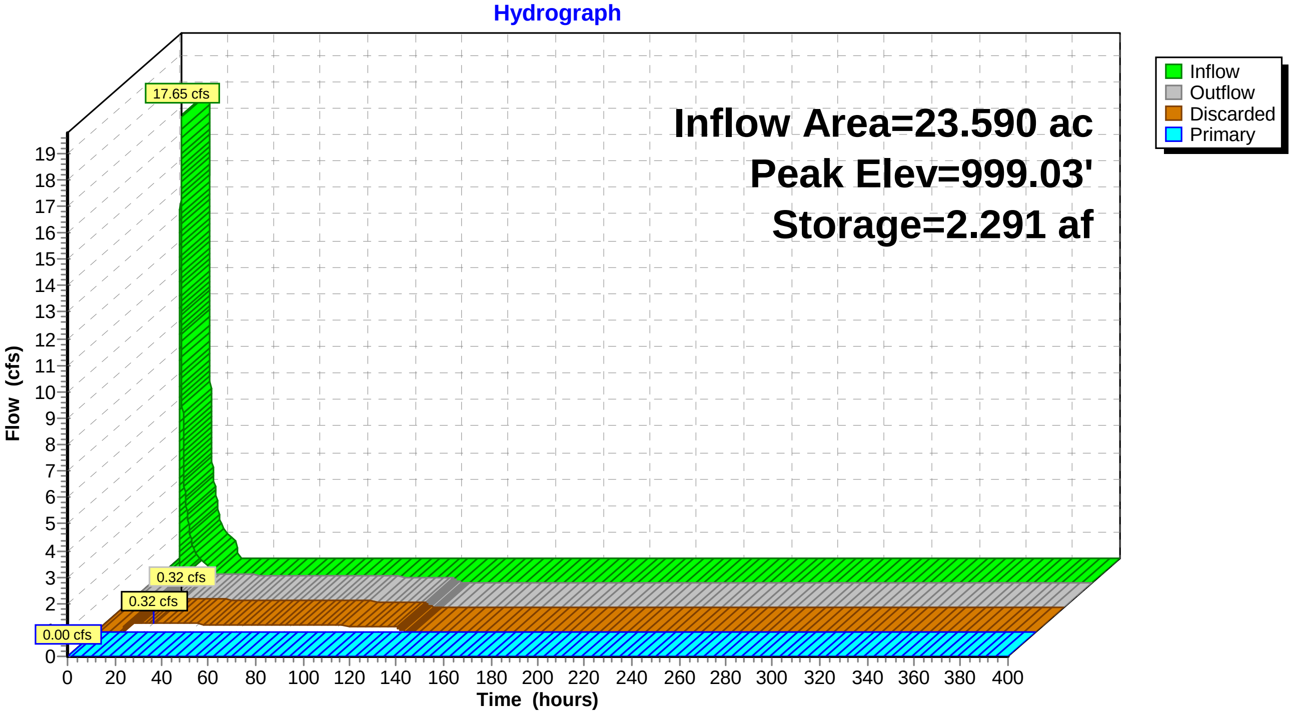
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
995.00	0.448	0.000	0.000
996.00	0.505	0.476	0.476
998.00	0.627	1.132	1.608
1,000.00	0.756	1.383	2.991
1,002.00	1.244	2.000	4.991

Device	Routing	Invert	Outlet Devices
#1	Discarded	995.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,001.55'	**20.0' long + 3.0 '/' SideZ x 15.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.32 cfs @ 24.46 hrs HW=999.03' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.32 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=995.00' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 3P: SMA-1 (Design Point 2)



Summary for Pond 24P: SMA-2 (Design Point 5)

Inflow Area = 2.470 ac, 0.00% Impervious, Inflow Depth = 1.65" for 10-YR event
Inflow = 4.00 cfs @ 12.14 hrs, Volume= 0.339 af
Outflow = 0.08 cfs @ 23.50 hrs, Volume= 0.339 af, Atten= 98%, Lag= 681.7 min
Discarded = 0.08 cfs @ 23.50 hrs, Volume= 0.339 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,023.72' @ 23.50 hrs Surf.Area= 0.194 ac Storage= 0.263 af

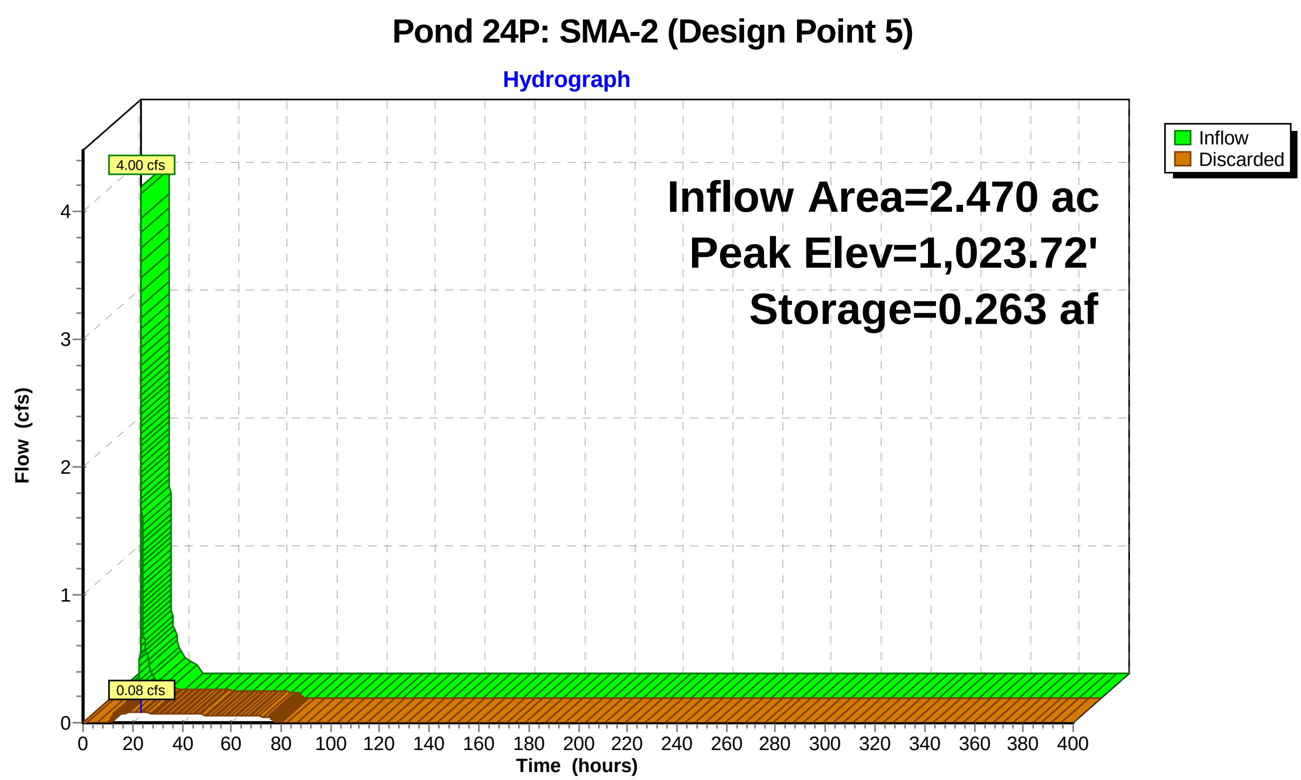
Plug-Flow detention time= 1,620.9 min calculated for 0.339 af (100% of inflow)
Center-of-Mass det. time= 1,621.0 min (2,487.2 - 866.2)

Volume	Invert	Avail.Storage	Storage Description
#1	1,022.00'	0.856 af	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.00	0.116	0.000	0.000	0.116
1,026.00	0.330	0.856	0.856	0.332

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.00'	**0.390 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.08 cfs @ 23.50 hrs HW=1,023.72' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.08 cfs)



Summary for Pond 20P: SMA3A (Culvert 15)

Inflow Area = 0.520 ac, 0.00% Impervious, Inflow Depth = 1.26" for 10-YR event
Inflow = 0.67 cfs @ 12.10 hrs, Volume= 0.054 af
Outflow = 0.64 cfs @ 12.13 hrs, Volume= 0.054 af, Atten= 4%, Lag= 1.5 min
Discarded = 0.00 cfs @ 12.13 hrs, Volume= 0.002 af
Primary = 0.64 cfs @ 12.13 hrs, Volume= 0.053 af
Routed to Pond 24P : SMA-2 (Design Point 5)
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Reach 13R : SMA3 CHANNEL

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,029.02' @ 12.13 hrs Surf.Area= 0.007 ac Storage= 0.002 af

Plug-Flow detention time= 9.5 min calculated for 0.054 af (100% of inflow)
Center-of-Mass det. time= 9.5 min (890.3 - 880.8)

Volume	Invert	Avail.Storage	Storage Description
#1	1,028.50'	0.019 af	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,028.50	0.001	0.000	0.000	0.001
1,029.00	0.007	0.002	0.002	0.007
1,030.00	0.031	0.018	0.019	0.031

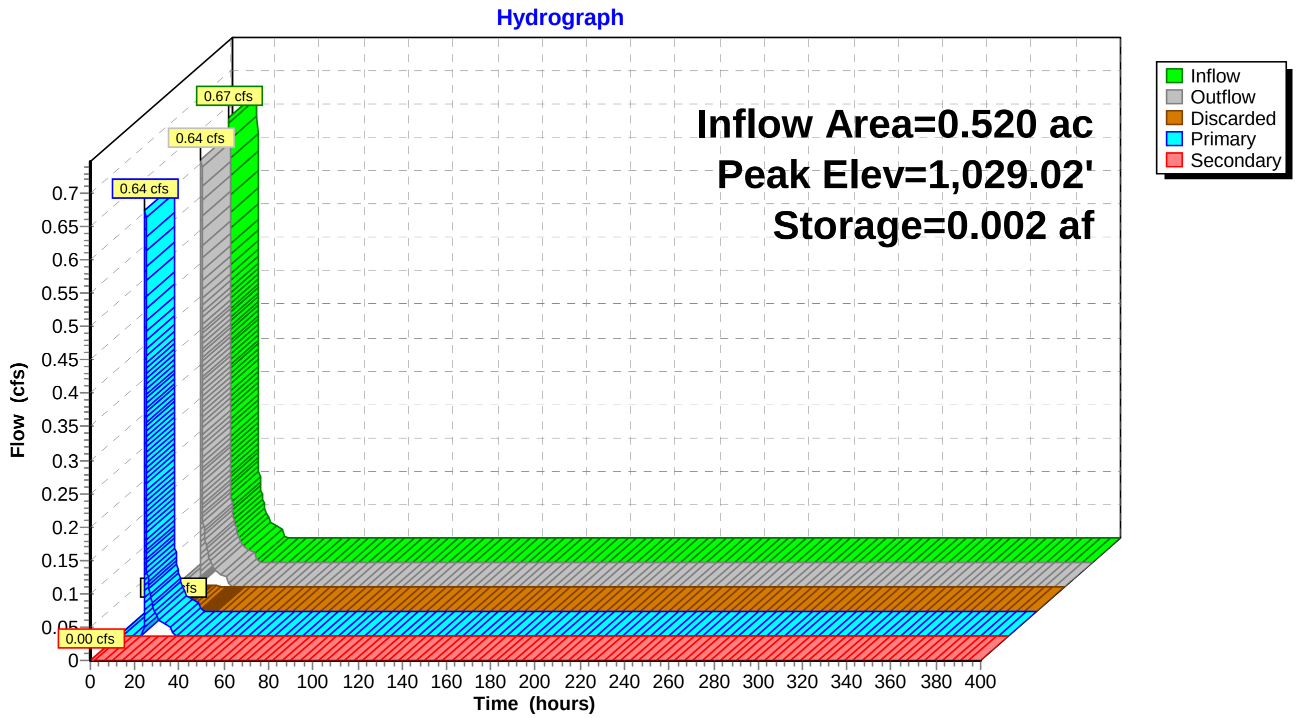
Device	Routing	Invert	Outlet Devices
#1	Discarded	1,028.50'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,028.70'	**8.0" Round Culvert X 2.00** L= 109.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 1,028.70' / 1,026.63' S= 0.0190 '/' Cc= 0.900 n= 0.013, Flow Area= 0.35 sf
#3	Secondary	1,029.80'	**16.0' long + 3.0 '/' SideZ x 2.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 Coef. (English) 2.48 2.60 2.60 2.60 2.64 2.65 2.68 2.75 2.74 2.76 2.89 3.05 3.19 3.32

Discarded OutFlow Max=0.00 cfs @ 12.13 hrs HW=1,029.02' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=0.64 cfs @ 12.13 hrs HW=1,029.02' (Free Discharge)
└─**2=Culvert** (Inlet Controls 0.64 cfs @ 1.92 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,028.50' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 20P: SMA3A (Culvert 15)



Summary for Pond 17P: SMA3B (Design Point 6)

Inflow Area = 0.440 ac, 0.00% Impervious, Inflow Depth = 1.84" for 10-YR event
Inflow = 0.91 cfs @ 12.09 hrs, Volume= 0.068 af
Outflow = 0.02 cfs @ 19.61 hrs, Volume= 0.068 af, Atten= 98%, Lag= 450.8 min
Discarded = 0.02 cfs @ 19.61 hrs, Volume= 0.068 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,024.33' @ 19.61 hrs Surf.Area= 0.054 ac Storage= 0.048 af

Plug-Flow detention time= 1,161.5 min calculated for 0.068 af (100% of inflow)
Center-of-Mass det. time= 1,161.5 min (2,019.0 - 857.5)

Volume	Invert	Avail.Storage	Storage Description
#1	1,022.60'	0.127 af	**Custom Stage Data (Conic)** Listed below (Recalc)

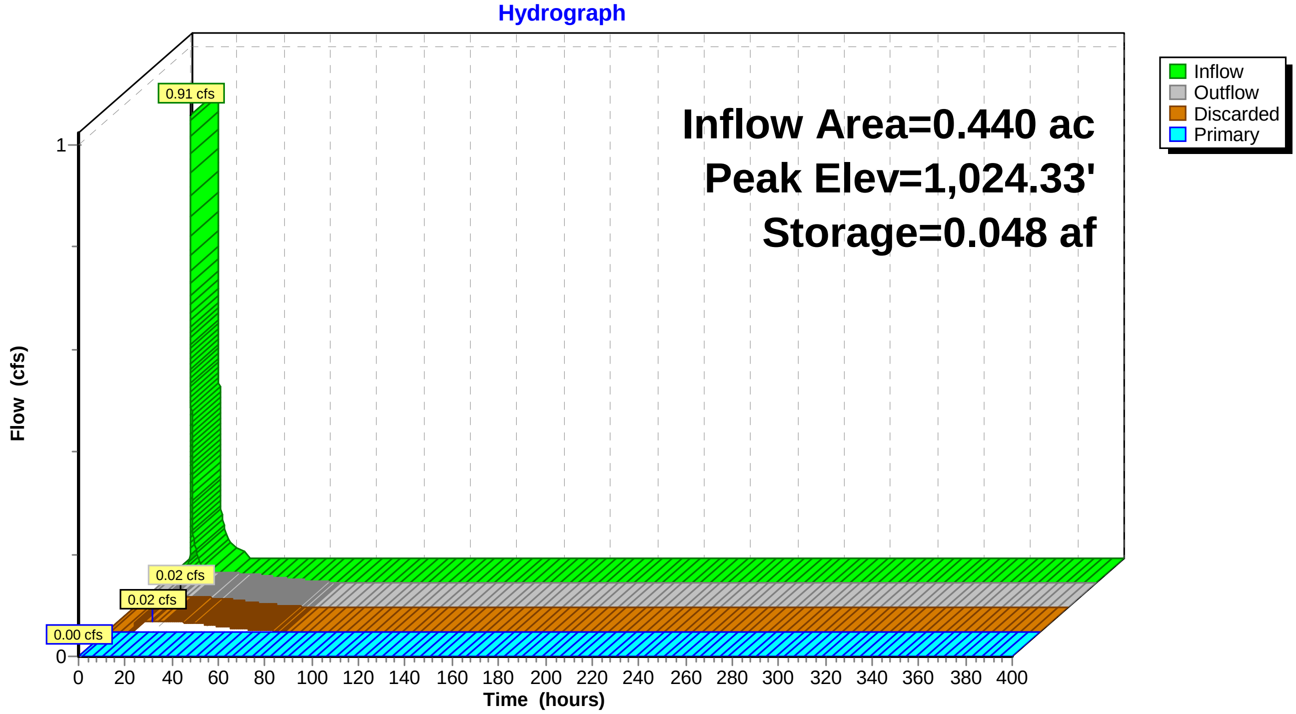
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.60	0.002	0.000	0.000	0.002
1,023.80	0.044	0.022	0.022	0.044
1,025.50	0.081	0.105	0.127	0.082

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.60'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,024.50'	**15.0' long + 3.0 '/' SideZ x 6.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.37 2.51 2.70 2.68 2.68 2.67 2.65 2.65 2.65 2.65 2.66 2.66 2.67 2.69 2.72 2.76 2.83

Discarded OutFlow Max=0.02 cfs @ 19.61 hrs HW=1,024.33' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,022.60' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 17P: SMA3B (Design Point 6)



Summary for Pond 19P: SMA-4 (Design Point 7) (Culvert 9)

Inflow Area =	17.420 ac,	0.00% Impervious,	Inflow Depth = 0.35"	for 10-YR event	
Inflow =	1.93 cfs @	12.42 hrs,	Volume=	0.505 af	
Outflow =	0.60 cfs @	16.79 hrs,	Volume=	0.505 af,	Atten= 69%, Lag= 262.8 min
Discarded =	0.08 cfs @	16.79 hrs,	Volume=	0.195 af	
Primary =	0.52 cfs @	16.79 hrs,	Volume=	0.310 af	
Secondary =	0.00 cfs @	0.00 hrs,	Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 987.84' @ 16.79 hrs Surf.Area= 0.207 ac Storage= 0.162 af

Plug-Flow detention time= 322.1 min calculated for 0.505 af (100% of inflow)
Center-of-Mass det. time= 322.1 min (1,314.1 - 992.0)

Volume	Invert	Avail.Storage	Storage Description
#1	987.00'	0.976 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
987.00	0.180	0.000	0.000
991.00	0.308	0.976	0.976

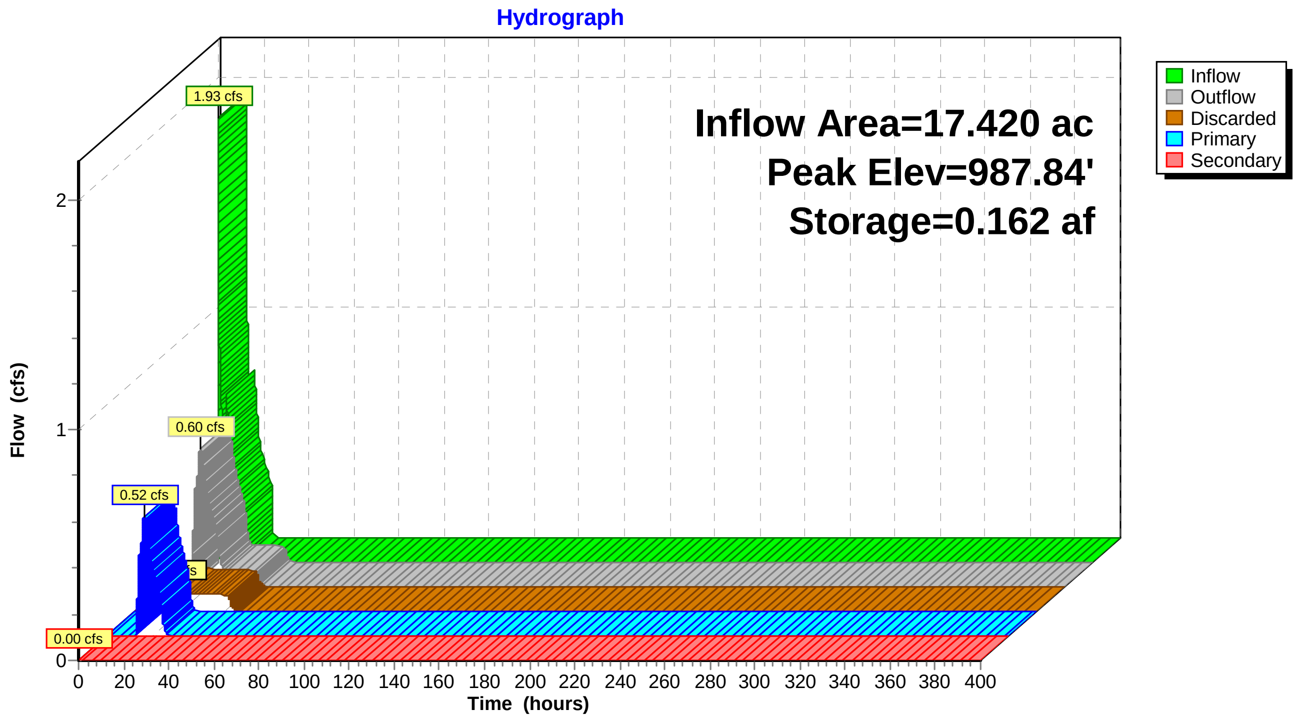
Device	Routing	Invert	Outlet Devices
#1	Discarded	987.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	987.50'	**4.0" Round Culvert X 4.00** L= 30.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 987.50' / 987.10' S= 0.0133 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 0.09 sf
#3	Secondary	990.00'	**8.0' long + 3.0 '/' SideZ x 5.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.34 2.50 2.70 2.68 2.68 2.66 2.65 2.65 2.65 2.65 2.67 2.66 2.68 2.70 2.74 2.79 2.88

Discarded OutFlow Max=0.08 cfs @ 16.79 hrs HW=987.84' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.08 cfs)

Primary OutFlow Max=0.52 cfs @ 16.79 hrs HW=987.84' (Free Discharge)
└─**2=Culvert** (Barrel Controls 0.52 cfs @ 1.82 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=987.00' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 19P: SMA-4 (Design Point 7) (Culvert 9)



Summary for Pond 13P: SMA-5 (Design Point 9) (Culvert 12)

[44] Hint: Outlet device #2 is below defined storage

Inflow Area = 5.000 ac, 0.00% Impervious, Inflow Depth = 1.84" for 10-YR event
Inflow = 10.38 cfs @ 12.09 hrs, Volume= 0.768 af
Outflow = 4.33 cfs @ 12.37 hrs, Volume= 0.768 af, Atten= 58%, Lag= 16.6 min
Discarded = 0.07 cfs @ 12.37 hrs, Volume= 0.014 af
Primary = 4.26 cfs @ 12.37 hrs, Volume= 0.753 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 954.27' @ 12.37 hrs Surf.Area= 0.146 ac Storage= 0.124 af

Plug-Flow detention time= 8.0 min calculated for 0.768 af (100% of inflow)
Center-of-Mass det. time= 8.0 min (865.6 - 857.5)

Volume	Invert	Avail.Storage	Storage Description
#1	953.00'	0.361 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
953.00	0.049	0.000	0.000
955.50	0.240	0.361	0.361

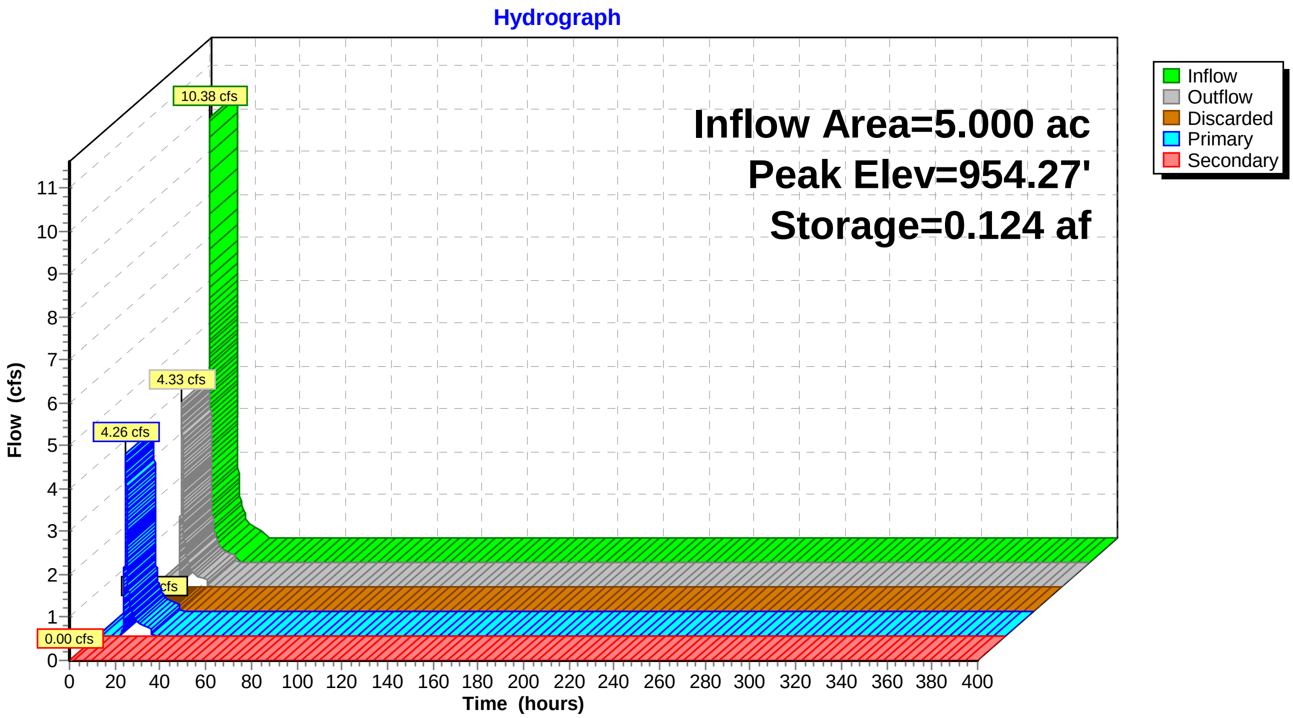
Device	Routing	Invert	Outlet Devices
#1	Discarded	953.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	952.50'	**12.0" Round Culvert #12** L= 40.0' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 952.50' / 949.60' S= 0.0725 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#3	Secondary	954.50'	**16.0' long + 10.0 '/' SideZ x 16.4' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.07 cfs @ 12.37 hrs HW=954.27' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.07 cfs)

Primary OutFlow Max=4.26 cfs @ 12.37 hrs HW=954.27' (Free Discharge)
└─**2=Culvert #12** (Inlet Controls 4.26 cfs @ 5.42 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=953.00' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 13P: SMA-5 (Design Point 9) (Culvert 12)



Summary for Pond 22P: SMA-6/Proposed Powerline Depression (Design Point 1)

[81] Warning: Exceeded Pond 14P by 3.38' @ 15.04 hrs
[81] Warning: Exceeded Pond 21P by 0.29' @ 16.38 hrs

Inflow Area = 139.990 ac, 0.00% Impervious, Inflow Depth = 0.97" for 10-YR event
Inflow = 78.29 cfs @ 12.62 hrs, Volume= 11.270 af
Outflow = 11.79 cfs @ 15.04 hrs, Volume= 11.270 af, Atten= 85%, Lag= 145.0 min
Discarded = 0.75 cfs @ 15.04 hrs, Volume= 6.008 af
Primary = 11.04 cfs @ 15.04 hrs, Volume= 5.262 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 985.39' @ 15.04 hrs Surf.Area= 1.615 ac Storage= 6.137 af

Plug-Flow detention time= 1,999.1 min calculated for 11.270 af (100% of inflow)
Center-of-Mass det. time= 1,999.4 min (2,906.7 - 907.4)

Volume	Invert	Avail.Storage	Storage Description
#1	978.00'	7.150 af	**Custom Stage Data (Conic)** Listed below

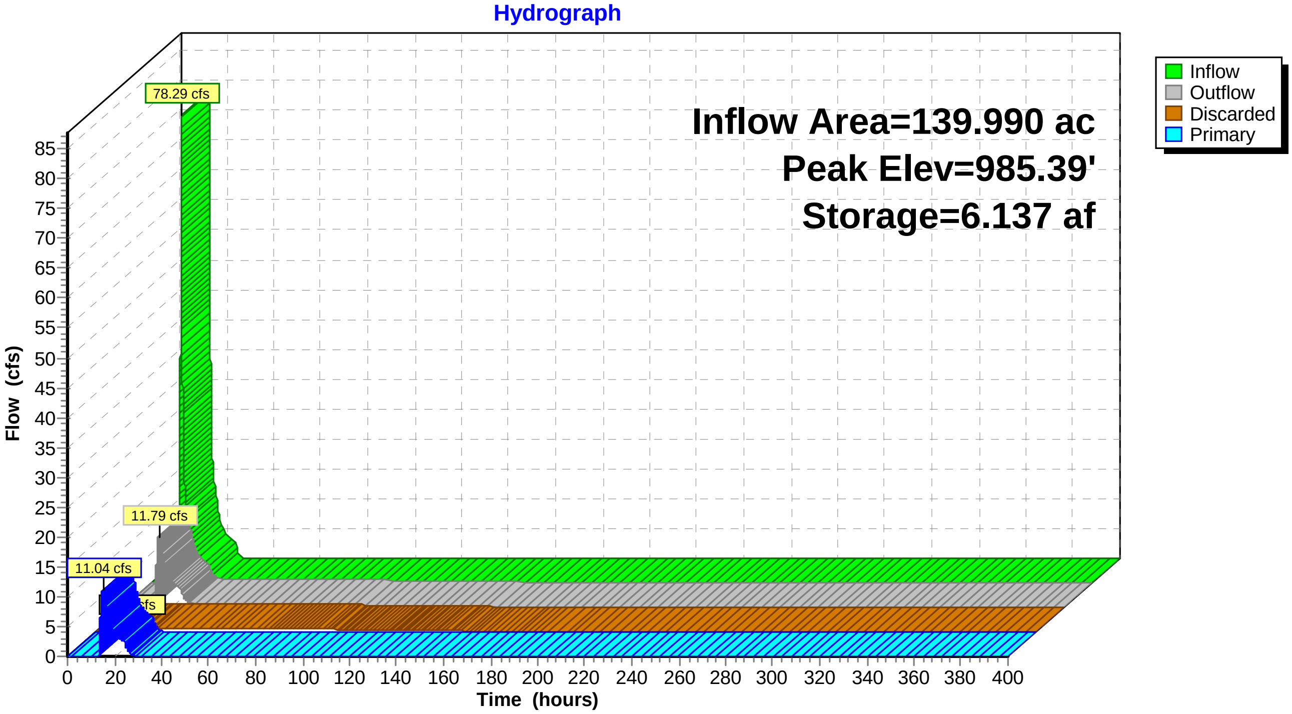
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
978.00	0.030	0.000	0.000	0.030
979.00	0.163	0.088	0.088	0.163
980.00	0.375	0.262	0.349	0.375
981.00	0.687	0.523	0.873	0.688
982.00	0.977	0.828	1.700	0.978
983.00	1.217	1.095	2.795	1.219
984.00	1.360	1.288	4.083	1.363
985.00	1.468	1.414	5.497	1.473
986.00	1.846	1.653	7.150	1.851

Device	Routing	Invert	Outlet Devices
#1	Primary	984.58'	**165.0 deg x 1.42' rise Sharp-Crested Vee/Trap Weir** Cv= 2.47 (C= 3.09)
#2	Discarded	978.00'	**0.460 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.75 cfs @ 15.04 hrs HW=985.39' (Free Discharge)
└─**2=Exfiltration** (Exfiltration Controls 0.75 cfs)

Primary OutFlow Max=11.00 cfs @ 15.04 hrs HW=985.39' (Free Discharge)
└─**1=Sharp-Crested Vee/Trap Weir** (Weir Controls 11.00 cfs @ 2.22 fps)

Pond 22P: SMA-6/Proposed Powerline Depression (Design Point 1)



Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 3P: SMA-1 (Design Point 2) Peak Elev=1,001.80' Storage=4.753 af Inflow=58.30 cfs 7.758 af
Discarded=0.55 cfs 5.072 af Primary=7.16 cfs 2.686 af Outflow=7.72 cfs 7.758 af

Pond 13P: SMA-5 (Design Point 9) (Culvert Peak Elev=955.02' Storage=0.256 af Inflow=30.15 cfs 2.007 af
Discarded=0.09 cfs 0.029 af Primary=5.38 cfs 1.548 af Secondary=20.64 cfs 0.431 af Outflow=26.11 cfs 2.007 af

Pond 17P: SMA3B (Design Point 6) Peak Elev=1,024.61' Storage=0.064 af Inflow=2.49 cfs 0.177 af
Discarded=0.02 cfs 0.082 af Primary=1.26 cfs 0.094 af Outflow=1.28 cfs 0.177 af

Pond 19P: SMA-4 (Design Point 7) (Culvert Peak Elev=990.62' Storage=0.863 af Inflow=29.84 cfs 3.052 af
Discarded=0.12 cfs 0.266 af Primary=1.47 cfs 1.660 af Secondary=12.65 cfs 1.126 af Outflow=14.24 cfs 3.052 af

Pond 20P: SMA3A (Culvert 15) Peak Elev=1,029.41' Storage=0.006 af Inflow=2.30 cfs 0.166 af
Discarded=0.01 cfs 0.002 af Primary=2.06 cfs 0.163 af Secondary=0.00 cfs 0.000 af Outflow=2.07 cfs 0.166 af

Pond 22P: SMA-6/Proposed Powerline Peak Elev=988.67' Storage=7.150 af Inflow=231.44 cfs 36.798 af
Discarded=0.86 cfs 6.186 af Primary=125.68 cfs 24.864 af Outflow=126.53 cfs 31.050 af

Pond 24P: SMA-2 (Design Point 5) Peak Elev=1,025.82' Storage=0.797 af Inflow=11.50 cfs 0.926 af
Outflow=0.13 cfs 0.926 af

Summary for Pond 3P: SMA-1 (Design Point 2)

[58] Hint: Peaked 0.04' above defined flood level

Inflow Area = 23.590 ac, 0.00% Impervious, Inflow Depth = 3.95" for 100-YR event
Inflow = 58.30 cfs @ 12.47 hrs, Volume= 7.758 af
Outflow = 7.72 cfs @ 14.46 hrs, Volume= 7.758 af, Atten= 87%, Lag= 119.1 min
Discarded = 0.55 cfs @ 14.46 hrs, Volume= 5.072 af
Primary = 7.16 cfs @ 14.46 hrs, Volume= 2.686 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,001.80' @ 14.46 hrs Surf.Area= 1.196 ac Storage= 4.753 af
Flood Elev= 1,001.76' Surf.Area= 1.185 ac Storage= 4.700 af

Plug-Flow detention time= 2,992.2 min calculated for 7.758 af (100% of inflow)
Center-of-Mass det. time= 2,992.1 min (3,860.6 - 868.5)

Volume	Invert	Avail.Storage	Storage Description
#1	995.00'	4.991 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

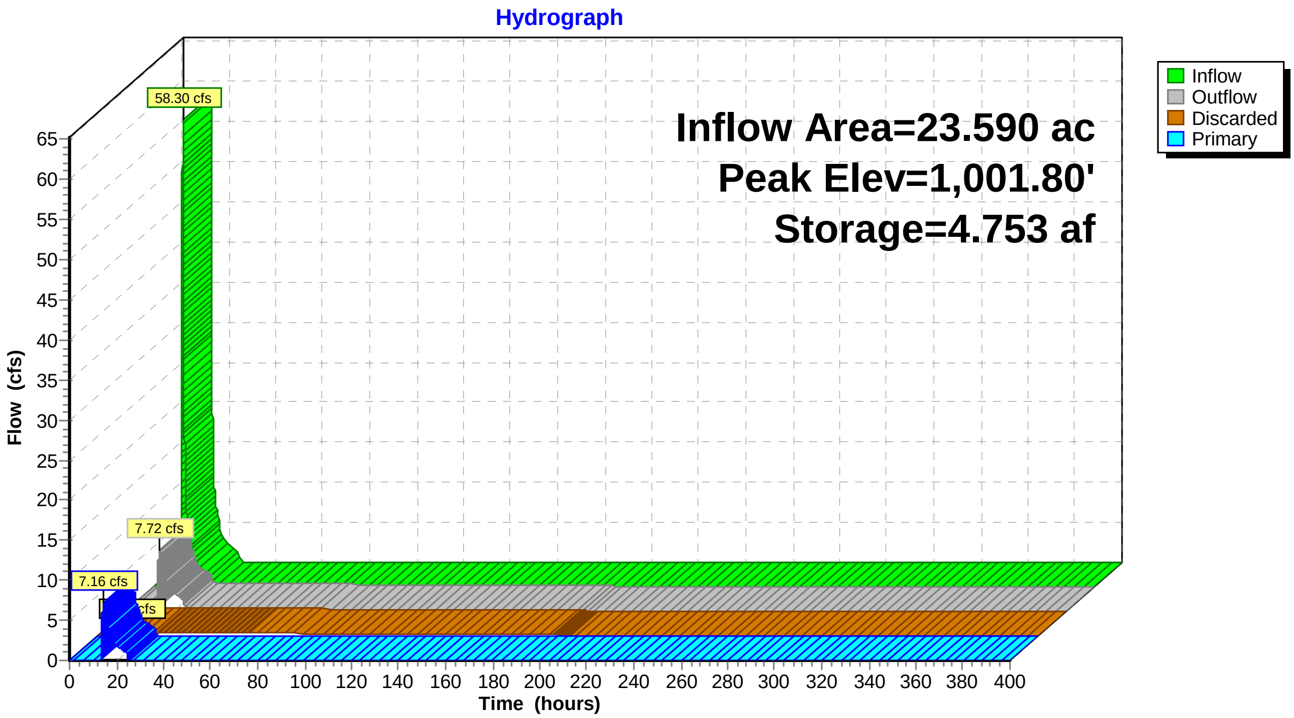
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
995.00	0.448	0.000	0.000
996.00	0.505	0.476	0.476
998.00	0.627	1.132	1.608
1,000.00	0.756	1.383	2.991
1,002.00	1.244	2.000	4.991

Device	Routing	Invert	Outlet Devices
#1	Discarded	995.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,001.55'	**20.0' long + 3.0 '/' SideZ x 15.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.55 cfs @ 14.46 hrs HW=1,001.80' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.55 cfs)

Primary OutFlow Max=7.12 cfs @ 14.46 hrs HW=1,001.80' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Weir Controls 7.12 cfs @ 1.35 fps)

Pond 3P: SMA-1 (Design Point 2)



Summary for Pond 24P: SMA-2 (Design Point 5)

Inflow Area = 2.470 ac, 0.00% Impervious, Inflow Depth = 4.50" for 100-YR event
Inflow = 11.50 cfs @ 12.14 hrs, Volume= 0.926 af
Outflow = 0.13 cfs @ 24.09 hrs, Volume= 0.926 af, Atten= 99%, Lag= 717.2 min
Discarded = 0.13 cfs @ 24.09 hrs, Volume= 0.926 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,025.82' @ 24.09 hrs Surf.Area= 0.318 ac Storage= 0.797 af

Plug-Flow detention time= 3,091.1 min calculated for 0.926 af (100% of inflow)
Center-of-Mass det. time= 3,091.1 min (3,927.9 - 836.8)

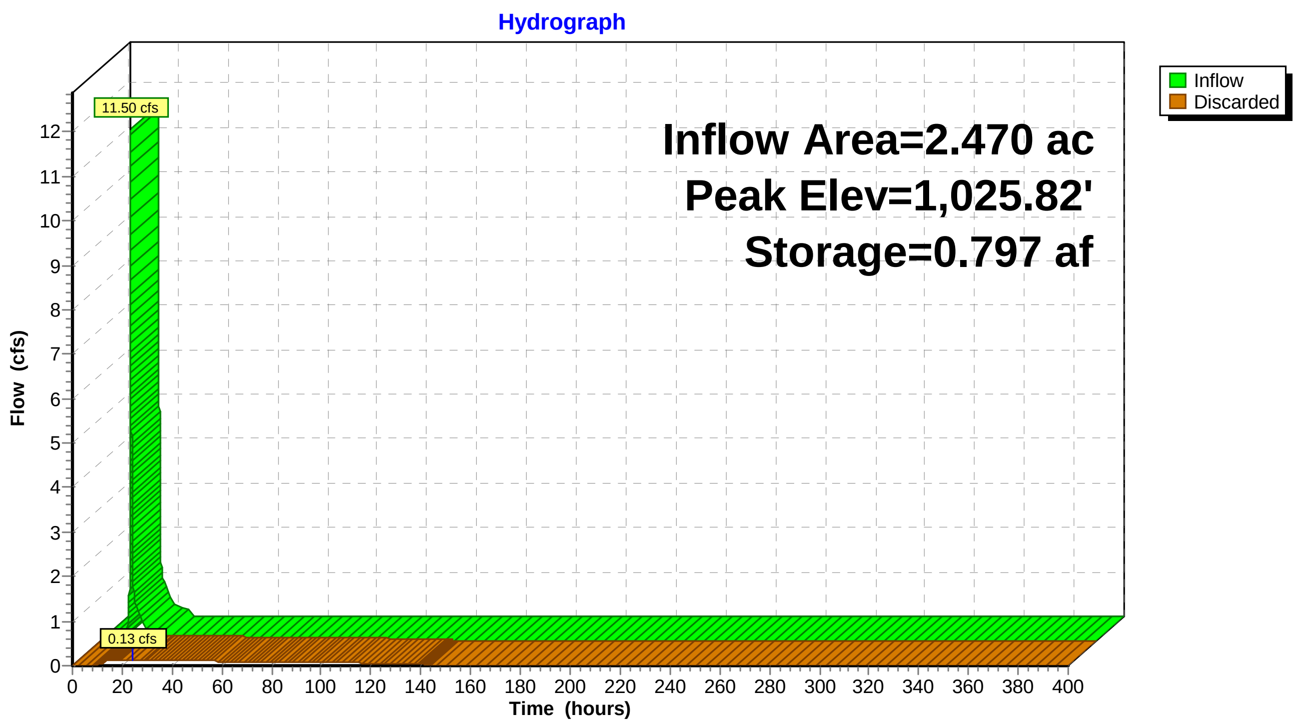
Volume	Invert	Avail.Storage	Storage Description
#1	1,022.00'	0.856 af	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.00	0.116	0.000	0.000	0.116
1,026.00	0.330	0.856	0.856	0.332

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.00'	**0.390 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.13 cfs @ 24.09 hrs HW=1,025.82' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.13 cfs)

Pond 24P: SMA-2 (Design Point 5)



Summary for Pond 20P: SMA3A (Culvert 15)

Inflow Area = 0.520 ac, 0.00% Impervious, Inflow Depth = 3.82" for 100-YR event
Inflow = 2.30 cfs @ 12.09 hrs, Volume= 0.166 af
Outflow = 2.07 cfs @ 12.13 hrs, Volume= 0.166 af, Atten= 10%, Lag= 2.4 min
Discarded = 0.01 cfs @ 12.13 hrs, Volume= 0.002 af
Primary = 2.06 cfs @ 12.13 hrs, Volume= 0.163 af
Routed to Pond 24P : SMA-2 (Design Point 5)
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Reach 13R : SMA3 CHANNEL

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,029.41' @ 12.13 hrs Surf.Area= 0.015 ac Storage= 0.006 af

Plug-Flow detention time= 4.7 min calculated for 0.166 af (100% of inflow)
Center-of-Mass det. time= 4.7 min (850.5 - 845.7)

Volume	Invert	Avail.Storage	Storage Description
#1	1,028.50'	0.019 af	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,028.50	0.001	0.000	0.000	0.001
1,029.00	0.007	0.002	0.002	0.007
1,030.00	0.031	0.018	0.019	0.031

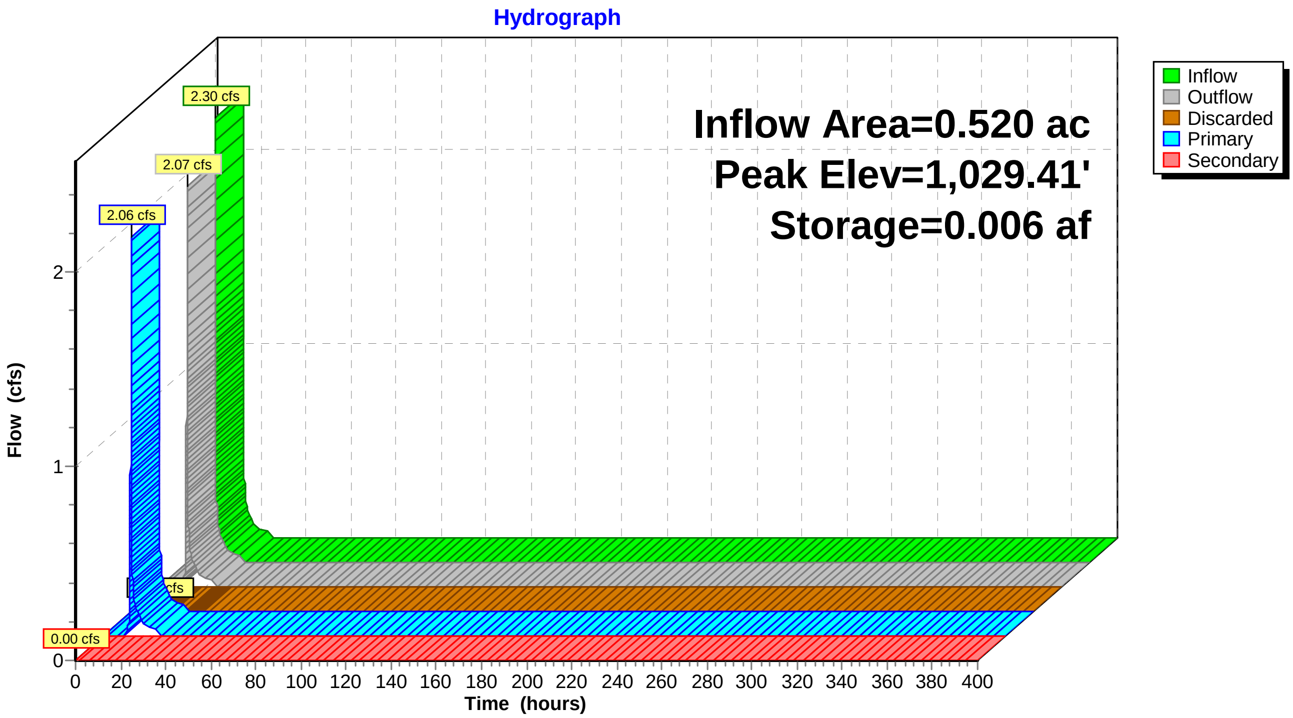
Device	Routing	Invert	Outlet Devices
#1	Discarded	1,028.50'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,028.70'	**8.0" Round Culvert X 2.00** L= 109.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 1,028.70' / 1,026.63' S= 0.0190 '/' Cc= 0.900 n= 0.013, Flow Area= 0.35 sf
#3	Secondary	1,029.80'	**16.0' long + 3.0 '/' SideZ x 2.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 Coef. (English) 2.48 2.60 2.60 2.60 2.64 2.65 2.68 2.75 2.74 2.76 2.89 3.05 3.19 3.32

Discarded OutFlow Max=0.01 cfs @ 12.13 hrs HW=1,029.41' (Free Discharge)
└—**1=Exfiltration** (Exfiltration Controls 0.01 cfs)

Primary OutFlow Max=2.06 cfs @ 12.13 hrs HW=1,029.41' (Free Discharge)
└—**2=Culvert** (Inlet Controls 2.06 cfs @ 2.95 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,028.50' (Free Discharge)
└—**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 20P: SMA3A (Culvert 15)



Summary for Pond 17P: SMA3B (Design Point 6)

Inflow Area = 0.440 ac, 0.00% Impervious, Inflow Depth = 4.82" for 100-YR event
Inflow = 2.49 cfs @ 12.09 hrs, Volume= 0.177 af
Outflow = 1.28 cfs @ 12.24 hrs, Volume= 0.177 af, Atten= 49%, Lag= 9.2 min
Discarded = 0.02 cfs @ 12.24 hrs, Volume= 0.082 af
Primary = 1.26 cfs @ 12.24 hrs, Volume= 0.094 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,024.61' @ 12.24 hrs Surf.Area= 0.060 ac Storage= 0.064 af

Plug-Flow detention time= 618.1 min calculated for 0.177 af (100% of inflow)
Center-of-Mass det. time= 618.1 min (1,447.3 - 829.2)

Volume	Invert	Avail.Storage	Storage Description
#1	1,022.60'	0.127 af	**Custom Stage Data (Conic)** Listed below (Recalc)

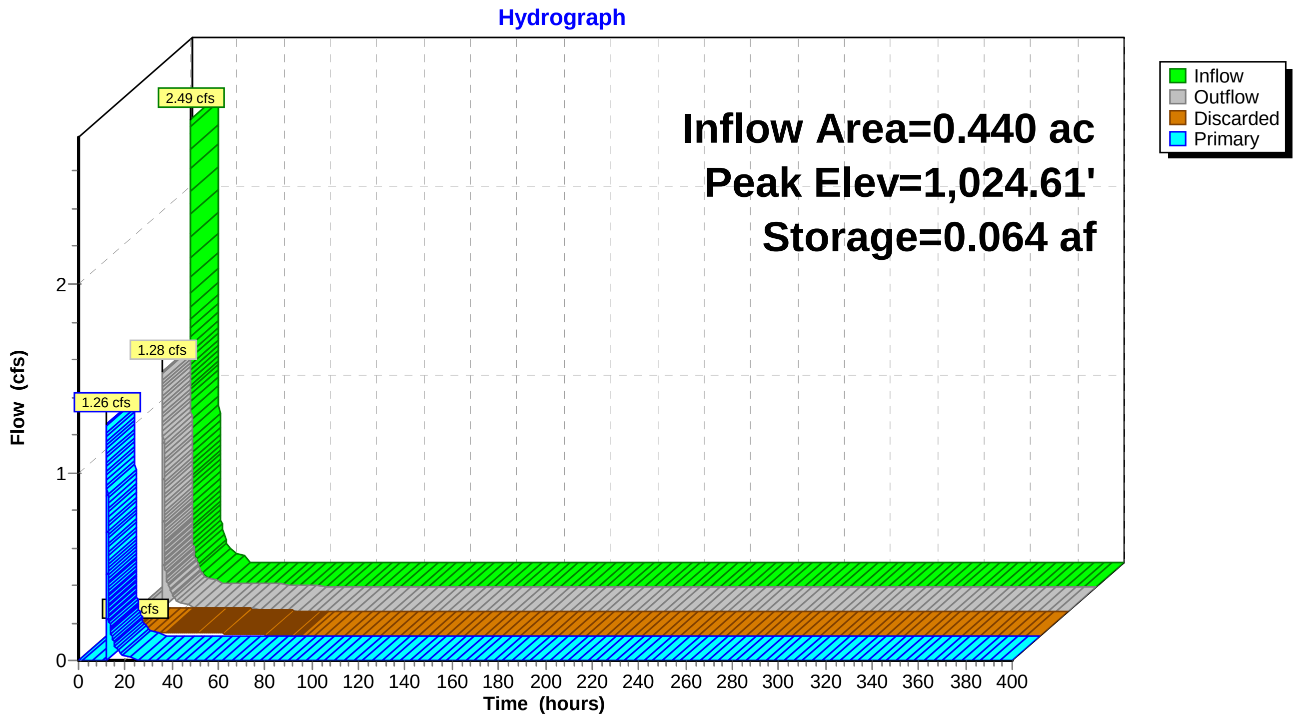
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.60	0.002	0.000	0.000	0.002
1,023.80	0.044	0.022	0.022	0.044
1,025.50	0.081	0.105	0.127	0.082

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.60'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,024.50'	**15.0' long + 3.0 '/' SideZ x 6.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.37 2.51 2.70 2.68 2.68 2.67 2.65 2.65 2.65 2.65 2.66 2.66 2.67 2.69 2.72 2.76 2.83

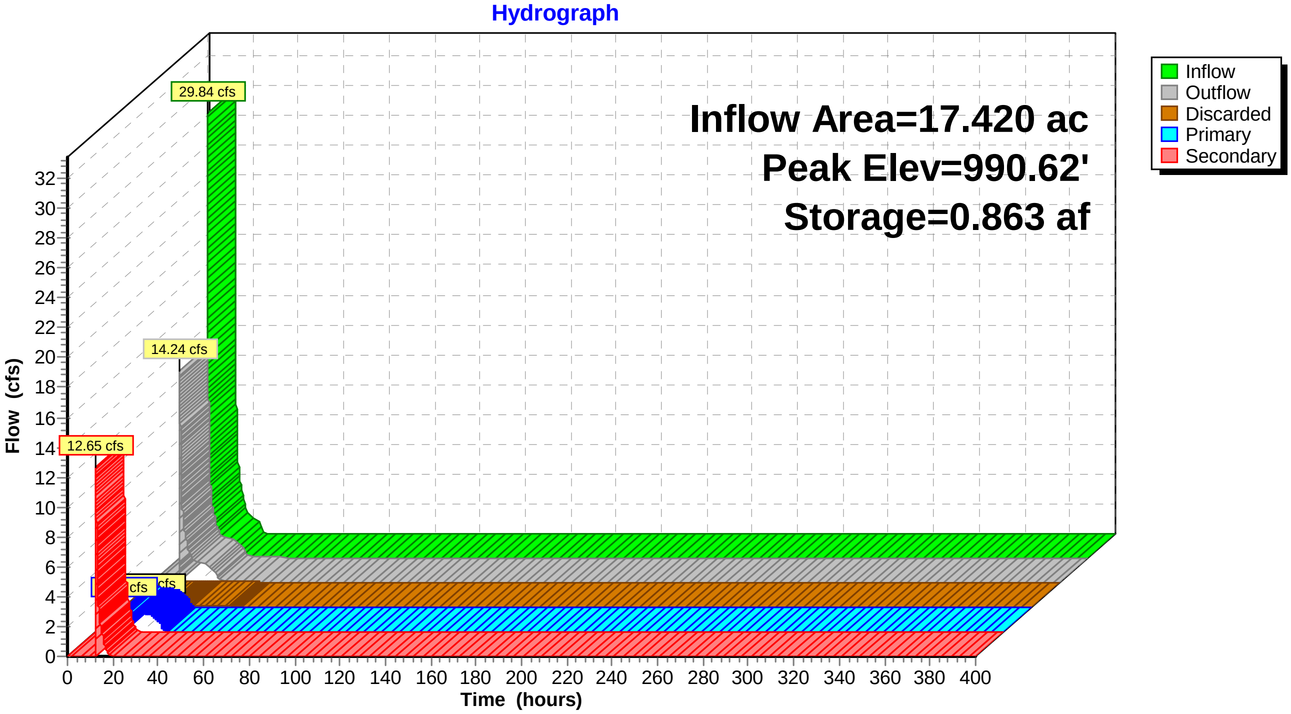
Discarded OutFlow Max=0.02 cfs @ 12.24 hrs HW=1,024.61' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=1.25 cfs @ 12.24 hrs HW=1,024.61' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Weir Controls 1.25 cfs @ 0.77 fps)

Pond 17P: SMA3B (Design Point 6)



Pond 19P: SMA-4 (Design Point 7) (Culvert 9)



Summary for Pond 19P: SMA-4 (Design Point 7) (Culvert 9)

Inflow Area = 17.420 ac, 0.00% Impervious, Inflow Depth = 2.10" for 100-YR event
Inflow = 29.84 cfs @ 12.24 hrs, Volume= 3.052 af
Outflow = 14.24 cfs @ 12.59 hrs, Volume= 3.052 af, Atten= 52%, Lag= 20.9 min
Discarded = 0.12 cfs @ 12.59 hrs, Volume= 0.266 af
Primary = 1.47 cfs @ 12.59 hrs, Volume= 1.660 af
Secondary = 12.65 cfs @ 12.59 hrs, Volume= 1.126 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 990.62' @ 12.59 hrs Surf.Area= 0.296 ac Storage= 0.863 af

Plug-Flow detention time= 212.0 min calculated for 3.052 af (100% of inflow)
Center-of-Mass det. time= 212.1 min (1,100.8 - 888.7)

Volume	Invert	Avail.Storage	Storage Description
#1	987.00'	0.976 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
987.00	0.180	0.000	0.000
991.00	0.308	0.976	0.976

Device	Routing	Invert	Outlet Devices
#1	Discarded	987.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	987.50'	**4.0" Round Culvert X 4.00** L= 30.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 987.50' / 987.10' S= 0.0133 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 0.09 sf
#3	Secondary	990.00'	**8.0' long + 3.0 '/' SideZ x 5.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.34 2.50 2.70 2.68 2.68 2.66 2.65 2.65 2.65 2.65 2.67 2.66 2.68 2.70 2.74 2.79 2.88

Discarded OutFlow Max=0.12 cfs @ 12.59 hrs HW=990.62' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.12 cfs)

Primary OutFlow Max=1.47 cfs @ 12.59 hrs HW=990.62' (Free Discharge)
└─**2=Culvert** (Barrel Controls 1.47 cfs @ 4.22 fps)

Secondary OutFlow Max=12.64 cfs @ 12.59 hrs HW=990.62' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Weir Controls 12.64 cfs @ 2.05 fps)

Summary for Pond 13P: SMA-5 (Design Point 9) (Culvert 12)

[44] Hint: Outlet device #2 is below defined storage

Inflow Area = 5.000 ac, 0.00% Impervious, Inflow Depth = 4.82" for 100-YR event
Inflow = 28.25 cfs @ 12.09 hrs, Volume= 2.007 af
Outflow = 24.81 cfs @ 12.13 hrs, Volume= 2.007 af, Atten= 12%, Lag= 2.7 min
Discarded = 0.09 cfs @ 12.13 hrs, Volume= 0.029 af
Primary = 5.35 cfs @ 12.13 hrs, Volume= 1.549 af
Secondary = 19.36 cfs @ 12.13 hrs, Volume= 0.429 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 955.00' @ 12.13 hrs Surf.Area= 0.202 ac Storage= 0.252 af

Plug-Flow detention time= 9.3 min calculated for 2.007 af (100% of inflow)
Center-of-Mass det. time= 9.3 min (838.5 - 829.2)

Volume	Invert	Avail.Storage	Storage Description
#1	953.00'	0.361 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
953.00	0.049	0.000	0.000
955.50	0.240	0.361	0.361

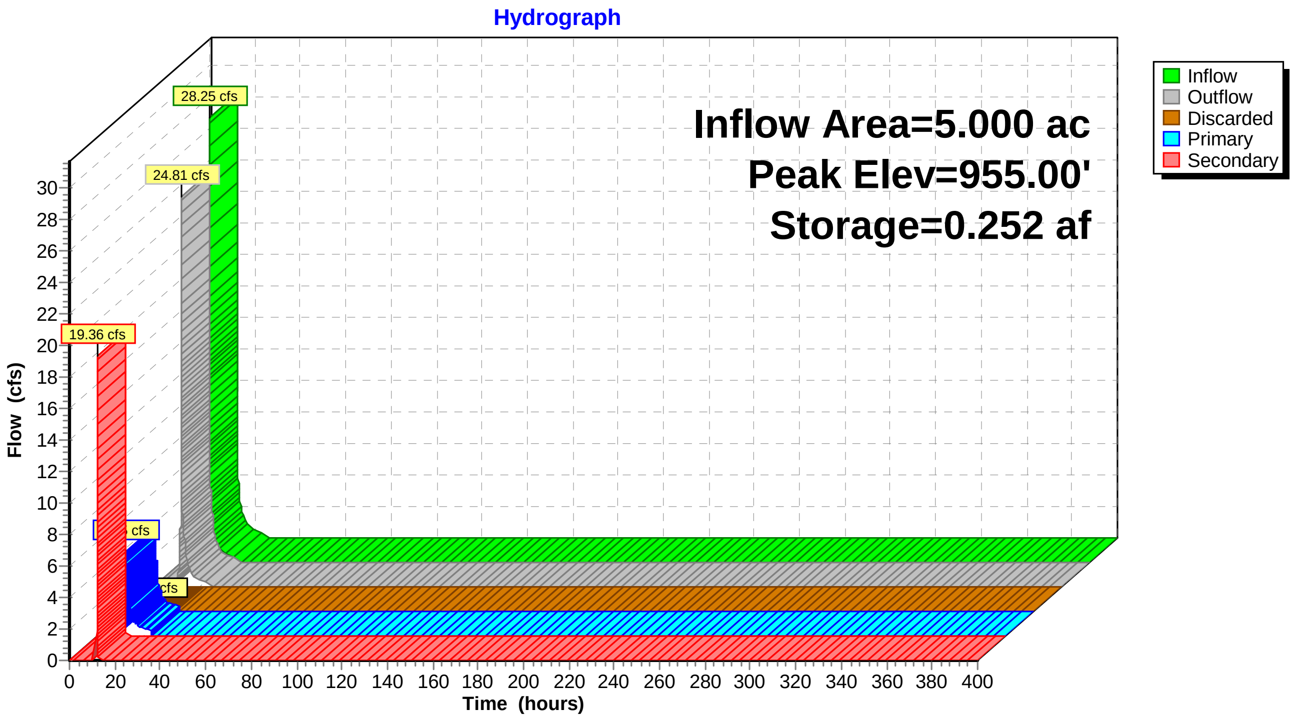
Device	Routing	Invert	Outlet Devices
#1	Discarded	953.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	952.50'	**12.0" Round Culvert #12** L= 40.0' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 952.50' / 949.60' S= 0.0725 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#3	Secondary	954.50'	**16.0' long + 10.0 '/' SideZ x 16.4' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.09 cfs @ 12.13 hrs HW=955.00' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.09 cfs)

Primary OutFlow Max=5.35 cfs @ 12.13 hrs HW=955.00' (Free Discharge)
└─**2=Culvert #12** (Inlet Controls 5.35 cfs @ 6.82 fps)

Secondary OutFlow Max=19.31 cfs @ 12.13 hrs HW=955.00' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Weir Controls 19.31 cfs @ 1.82 fps)

Pond 13P: SMA-5 (Design Point 9) (Culvert 12)



Summary for Pond 22P: SMA-6/Proposed Powerline Depression (Design Point 1)

[93] Warning: Storage range exceeded by 2.67'
[95] Warning: Outlet Device #1 rise exceeded
[81] Warning: Exceeded Pond 14P by 6.06' @ 12.55 hrs
[81] Warning: Exceeded Pond 21P by 0.46' @ 16.38 hrs

Inflow Area = 139.990 ac, 0.00% Impervious, Inflow Depth = 3.15" for 100-YR event
Inflow = 231.44 cfs @ 12.55 hrs, Volume= 36.798 af
Outflow = 126.53 cfs @ 12.55 hrs, Volume= 31.050 af, Atten= 45%, Lag= 0.0 min
Discarded = 0.86 cfs @ 12.51 hrs, Volume= 6.186 af
Primary = 125.68 cfs @ 12.55 hrs, Volume= 24.864 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 988.67' @ 12.55 hrs Surf.Area= 1.846 ac Storage= 7.150 af

Plug-Flow detention time= 852.1 min calculated for 31.050 af (84% of inflow)
Center-of-Mass det. time= 782.9 min (1,677.0 - 894.2)

Volume	Invert	Avail.Storage	Storage Description
#1	978.00'	7.150 af	**Custom Stage Data (Conic)** Listed below

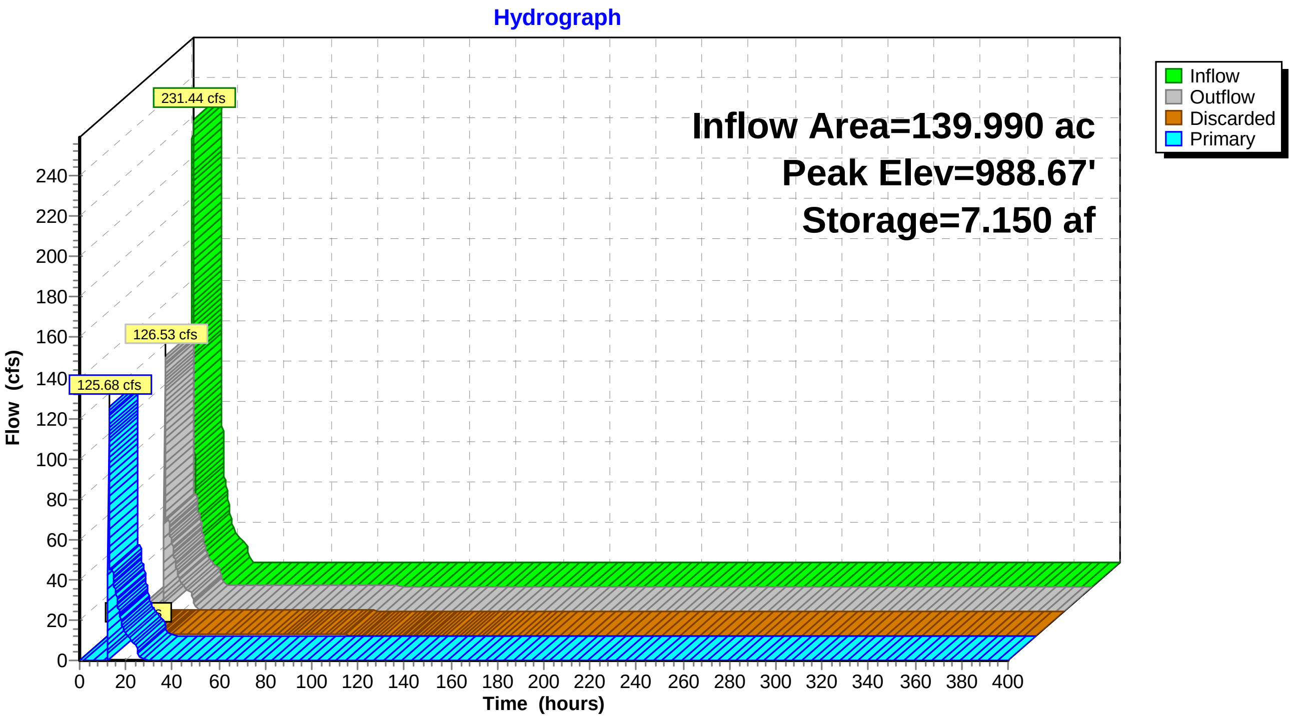
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
978.00	0.030	0.000	0.000	0.030
979.00	0.163	0.088	0.088	0.163
980.00	0.375	0.262	0.349	0.375
981.00	0.687	0.523	0.873	0.688
982.00	0.977	0.828	1.700	0.978
983.00	1.217	1.095	2.795	1.219
984.00	1.360	1.288	4.083	1.363
985.00	1.468	1.414	5.497	1.473
986.00	1.846	1.653	7.150	1.851

Device	Routing	Invert	Outlet Devices
#1	Primary	984.58'	**165.0 deg x 1.42' rise Sharp-Crested Vee/Trap Weir** Cv= 2.47 (C= 3.09)
#2	Discarded	978.00'	**0.460 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.86 cfs @ 12.51 hrs HW=988.37' (Free Discharge)
↑—**2=Exfiltration** (Exfiltration Controls 0.86 cfs)

Primary OutFlow Max=125.30 cfs @ 12.55 hrs HW=988.66' (Free Discharge)
↑—**1=Sharp-Crested Vee/Trap Weir** (Orifice Controls 125.30 cfs @ 8.18 fps)

Pond 22P: SMA-6/Proposed Powerline Depression (Design Point 1)



Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **G-6** **Subject:** **Culvert Design**

Prepared By: **CSH** **Date:** **February 2024**

Reviewed By: **BMS** **Date:** **February 2024**

Objective

Determine the required culvert configuration for all UDF stormwater conveyance piping based on the estimated peak discharge from the specified design storm.

References

1. Arcadis U.S., Inc. *Calculation Brief G-1: Design Storm*. February 2024.
2. Arcadis U.S., Inc. *Calculation Brief G-3: Channel Design*. February 2024.
3. Massachusetts Department of Environmental Protection (MassDEP). *Massachusetts Stormwater Handbook and Stormwater Standards Volume 3, Chapter 1*. 2008.
4. HydroCAD Software Solutions, LLC. *HydroCAD Version 10.2*. Computer Software, 2022.
5. Autodesk, Inc. *Civil3D*. Computer Software. 2023.
6. Advanced Drainage Systems, Inc. *ADS, Inc. Drainage Handbook.* Hydraulics. March 2020.
7. Natural Resource Conservation Service. *Urban Hydrology for Small Watersheds.* Technical Release 55 (TR-55). June 1986.
8. MassDEP Division of Watershed Management. *Hydrology Handbook for Conservation Commissioners.* March 2002.
9. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 8: Final Grading Plan.* February 2024.
10. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 29: Stormwater Management Details - 1.* February 2024.
11. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 30: Stormwater Management Details - 2.* February 2024.
12. Massachusetts Department of Fish and Game; Division of Ecological Restoration. *Massachusetts Stream Crossings Handbook.* May 2018.

Assumptions

1. Modeled precipitation events can be found in Reference 1.
2. Calculations of peak runoff flow rates within the channels tributary to culvert within the UDF are detailed in Reference 2.
3. Culvert drainage areas and time of concentration (Tc) paths are delineated using Autodesk Civil3D software (Reference 5) based on the final design grades (Reference 9).
4. The maximum distance for an assumed sheet flow segment of a Tc path is 50 feet before transitioning to shallow concentrated flow (Reference 3, Reference 8).
5. Acceleration due to gravity (i.e., gravitational constant) is 32.2 ft/s^2 (9.8 m/s^2). Specific weight of water is 62.4 lb/ft^3 (1000 kg/m^3).
6. Kinematic viscosity of water is 1.131×10^{-6} m^2/s at 15.5 degrees Celsius and 1.217x10-5 ft^2/s at 60 degrees Fahrenheit.
7. The flow capacity of the culvert is modeled using Reference 4, which accounts for both pipe friction losses and energy losses at the culvert entrance and exit.
8. All standard culverts with a specified slope less than 5% are modeled as a smooth-interior corrugated HDPE pipe having a Manning's "n" value of 0.012. All other culverts, which contain pipe segments having a slope greater than 5%, are modeled as corrugated interior HDPE pipe with a Manning's "n" value of 0.020 (Reference 6).
9. The localized depression in the topography at each of the culvert inlets is modeled as a pond using Reference 4. The low point provides a small amount of storage at each culvert inlet point during more severe precipitation events where incoming flow is greater than culvert capacity. Elevation data surrounding the culvert inlets is taken from the final design grades (Reference 9).
10. Culvert 7 conveys stormwater runoff overflow from the South Stormwater Basin to the Southwest Exterior Ditch (Channel 8) during more severe precipitation events. As such, Culvert 9 is designed to convey the estimated overflow from the South Stormwater Basin during the 100-year, 24-hour storm event.
11. A minimum cover of 12 inches is provided for stormwater downchutes within the UDF final cover system. Profiles of the storm culverts within the UDF area can be found in References 10 and 11.
12. An open-arch culvert will be utilized for channel crossing and conveyance under the North Access Road. This culvert has an open bottom and spans the existing channel width in an effort to maintain existing drainage patterns underneath the proposed access road. The open-arch culvert is modeled with a Manning's n of 0.035 to mimic the natural channel bottom (Reference 7).
13. Open-arch culvert sizing is assumed to take place during the 2-year storm event, as specified by the Massachusetts Department of Fish and Game (Reference 12).
14. The required culvert configuration is based on the tributary peak flow resulting from the design storm event as specified below in Table 1. The culvert configuration is deemed acceptable if the design can convey the estimated design peak flow without overtopping at the inlet location of the specified culvert. Estimated peak flows to each culvert are as follows:

Table 1: Standard Storm Culvert Hydrologic Evaluation

Culvert Number	Inlet Location	Outlet Location	Tributary Channel Number	Design Precipitation Event	Contributing Drainage Area (ac)	Tributary Peak Flow Rate (cfs)
1	Perimeter Ditch (West)	North Stormwater Basin Forebay	1	100-Year, 24-Hour	5.22	26.70
2	Final Cover Diversion Berm (West)	North Stormwater Basin Forebay	2	25-Year, 24-Hour	2.10	4.59
3	Final Cover Plateau Ditch	North Stormwater Basin Forebay	3		3.05	6.87
4	Final Cover Diversion Berm (East)	North Stormwater Basin Forebay	4		3.46	7.57
5	Perimeter Ditch (East)	North Stormwater Basin Forebay	5	100-Year, 24-Hour	4.65	29.39
6	East Exterior Ditch	Perimeter Ditch (East)	6	25-Year, 24-Hour	0.90	2.03
7	South Stormwater Basin Overflow Structure	Southwest Exterior Ditch (South)	-	100-Year, 24-Hour	3.55	2.83
8	Southwest Exterior Ditch	SMA-4	7&8	25-Year, 24-Hour	2.92	10.74
9	SMA-4	Offsite (Southwest)	-	100-Year, 24-Hour	16.60	23.38
10	West of Southern Access Road	South Stormwater Basin Overflow Structure	-	25-Year, 24-Hour	0.82	2.17
11	North Slope Diversion Berm	SMA-5	10&11		1.88	4.69
12	SMA-5	Offsite (Northwest)	-		5.00	16.68
13	Perimeter Ditch (West)	Perimeter Ditch (West)	1 (Partial, South)	100-Year, 24-Hour	1.93	11.73
14	Perimeter Ditch (West)	Perimeter Ditch (West)	1 (Partial, North)		3.76	22.86
15	SMA3A-P	SMA2	-		0.52	2.30
16	North of North Access Road	South of North Access Road	-		2.18	2.10
1A	East of North Access Road	West of North Access Road	-	100-Year, 24-Hour	89.59	238.98

Calculations

1. Required Culvert Configuration

HydroCAD (Reference 4) is used to model the proposed culvert configurations for each storm pipe based on the previously specified design storm events. Based on input parameters, HydroCAD evaluates a culvert by checking multiple flow conditions and determining the prevailing control (i.e., outlet or inlet) for the flow conduit. The required culvert configurations are summarized in Table 2 below.

Table 2: Standard Storm Culvert Configuration Details

Culvert Number	Tributary Peak Flow Rate (cfs)	Culvert Diameter (inches)	Number of Pipes	Pipe Length Pipe Slope[1] (ft) / (%)	Pipe Invert Elevations (ft)	Spillover Elevation (ft)	Calculated Headwater Elevation (ft)	Freeboard (ft)
1	26.70	24"	2	70' 3.0%	1008.5 (In) 1006.4 (Out)	1011.4	1010.6	0.7
2	4.59	18"	2	200' 2.0%	1042.2 (In) 1004.1 (Out)	1043.7	1043.1	0.6
3	6.87	15"	2	350' 2.0%	1071.6 (In) 1004.1 (Out)	1074.9	1072.7	2.2
4	7.57	18"	2	200' 2.0%	1042.2 (In) 1004.1 (Out)	1043.7	1043.1	0.6
5	29.39	24"	2	70' 3.0%	1008.5 (In) 1006.4 (Out)	1011.4	1010.6	0.7
6	2.05	18"	1	71' 2.0%	1015.4 (In) 1014.0 (Out)	1018.3	1016.1	2.2
7	14.17	12"	1	590' 0.9%	1030.0 (In) 1024.2 (Out)	1033.0	1031.4	1.6
8	10.44	18"	1	75' 3.2%	999.4 (In) 997.0 (Out)	1006.5	1005.1	1.4
9	23.38	4"	4	30' 1.3%	987.5 (In) 987.1 (Out)	991.0	990.5	0.5
10	2.17	12"	1	165' 1.0%	1032.1 (In) 1030.4(Out)	1034.0	1032.9	1.1
11	4.69	18"	2	112' 25.0%	982.0 (In) 954.0 (Out)	983.5	982.8	0.7
12	16.68	12"	1	40' 7.3%	952.5 (In) 949.6 (Out)	955.5	954.7	0.8
13	11.73	18"	1	20' 2.0%	1028.0 (In) 1027.6 (Out)	1031.0	1030.6	0.4
14	22.86	18"	2	20' 2.0%	1017.0 (In) 1016.6 (Out)	1020.0	1019.7	0.3
15	2.30	8"	2	109' 1.9%	1028.7 (In) 1026.6 (Out)	1029.8	1029.4	0.4
16	2.10	12"	1	50' 1.8%	981.8 (In) 980.9 (Out)	984.8	982.8	2.0

Notes:
1. Pipe slopes may vary for several of the UDF culverts. The pipe slope shown is the minimum (flattest) slope present within the culvert profile.
2. Manning's "n" value for each pipe is based on Assumption 8.

As indicated above, a minimum freeboard of 0.3 ft is provided against overtopping at the culvert inlet for each culvert location. Supporting output from HydroCAD is included as Attachment 1.

2. Open Arch Channel Sizing and Analysis

Culvert Width

Requirements state that the bottom of the culvert spans the channel width with a minimum span of 1.2 times the bank full width of the stream during the 2-Year Storm Event (Assumption 13). Results of the 2-Year Storm Event in the existing channel can be found in Attachment 2 of this document.

The bank full depth during the 2-Year Storm Event is 8.82 ft in the Existing Channel. The following calculation is performed to ensure compliance with channel crossing regulations:

$$1.2 * 8.82\ ft = 10.8\ ft$$

The open-arch culvert selected is 12 ft wide and is therefore compliant.

Openness Ratio

Additionally, the openness ratio (cross-sectional area/crossing length) must be at least 0.82' (Reference 12). The openness ratio of the selected open-arch culvert is calculated as follows:

$$Cross\ sectional\ area = \frac{1}{2} * \pi * r^2 = \frac{1}{2} * \pi * (\frac{12\ ft}{2})^2 = 56.55\ ft$$

$$Crossing\ Length = 50\ ft$$

$$Openness\ Ratio = \frac{56.55\ ft^2}{50\ ft} = 1.31\ ft$$

The selected open-arch culvert's openness ratio is greater than the minimum of 0.82 ft and is therefore compliant.

Open-Arch Culvert Configuration

HydroCAD (Reference 4) is used to model the proposed culvert configurations for the open-arch culvert based on the previously specified design storm events. The required open-arch culvert configuration is summarized in Table 3 below.

Table 3: Open-Arch Culvert Configuration Details

Culvert Number	Tributary Peak Flow Rate (cfs)	Culvert Width & Height (inches)	Number of Pipes	Pipe Length Pipe Slope[1] (ft) / (%)	Pipe Invert Elevations (ft)	Spillover Elevation (ft)	Calculated Headwater Elevation (ft)	Freeboard (ft)
1A	238.98	144"x43.2"	1	83' 4.7%	984.6 (In) 982.2 (Out)	989.50	988.98	0.52

Notes:
1. Manning's "n" value for Open-arch culvert is based on Assumption 12.

As indicated above, a minimum freeboard of 0.3 ft is provided against overtopping at the culvert inlet for each culvert location. Supporting output from HydroCAD is included as Attachment 1.

Summary

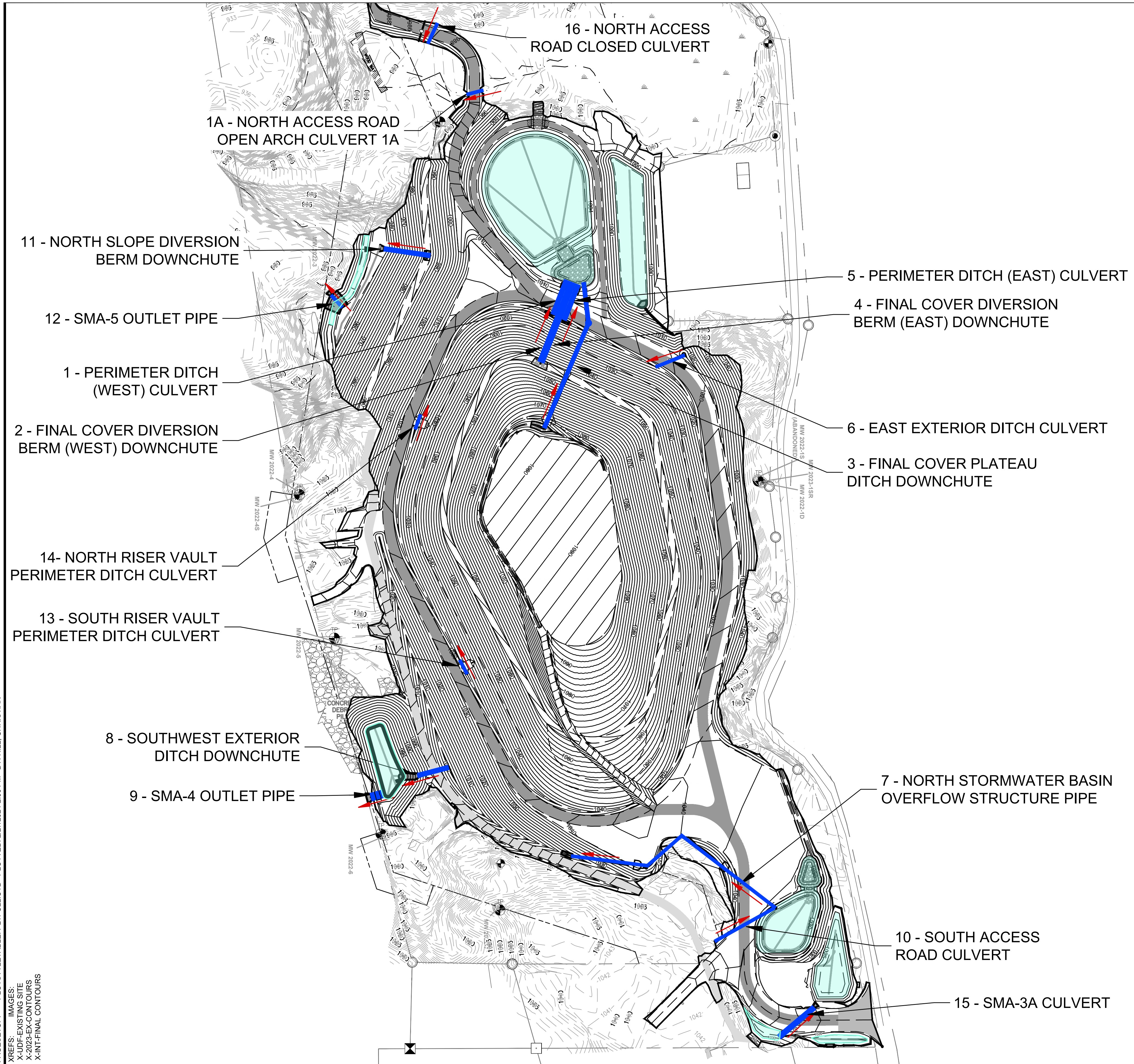
Based on the assumptions and calculations presented above, the specified pipe size for each culvert is sufficient to convey the estimated peak discharge from the corresponding design storm.

Figures

1. Stormwater Conveyance Culvert Location Map

Attachments

1. HydroCAD Culvert Modelling Input and Results
2. HydroCAD Existing Channel Analysis for Open-Arch Culvert Crossing



LEGEND

- STORMWATER BASINS
- 1650 — INDEX ELEVATION CONTOUR (10-FT INTERVAL)
- INTERMEDIATE ELEVATION CONTOUR (2-FT INTERVAL)
- STORMWATER CULVERT
- PIPE FLOW DIRECTION

NOTES:
1. PROPOSED GRADING REPRESENTS THE TOP OF FINAL COVER FOR THE UDF.

GENERAL ELECTRIC COMPANY
UPLAND DISPOSAL FACILITY
GE-PITTSBURGH/HOUSATONIC RIVER SITE

STORMWATER CONVEYANCE
CULVERT LOCATION MAP

ARCADIS

FIGURE
1

C:\Users\CSHill\ARCADIS\GE Upland Disposal Facility - Documents\UDF Design\Final Design Plan\Final Design Plan Report\Appendices\Appendix G - Stormwater Design Calculations\G-6_Culvert Design\03_CAD\Culvert Locations.dwg LAYOUT: 1 SAVED: 2/27/2024 2:05 PM ACADVER: 24.2S (LMS TECH)
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XREFS: IMAGES:
X-UDF-EXISTING SITE
X-2023-EX-CONTOURS
X-INT-FINAL CONTOURS

Attachment 1:

HydroCAD Culvert Modeling Input and Results

Summary for Pond 11P: Perimeter Low Point (Culvert 1&5)

Inflow Area = 10.770 ac, 0.00% Impervious, Inflow Depth = 5.28" for 100-YR event
Inflow = 55.53 cfs @ 12.21 hrs, Volume= 4.739 af
Outflow = 54.83 cfs @ 12.23 hrs, Volume= 4.739 af, Atten= 1%, Lag= 1.0 min
Primary = 54.83 cfs @ 12.23 hrs, Volume= 4.739 af

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Peak Elev= 1,010.56' @ 12.23 hrs Surf.Area= 1,592 sf Storage= 1,158 cf
Flood Elev= 1,011.37' Surf.Area= 2,740 sf Storage= 2,747 cf

Plug-Flow detention time= 0.2 min calculated for 4.739 af (100% of inflow)
Center-of-Mass det. time= 0.2 min (833.7 - 833.6)

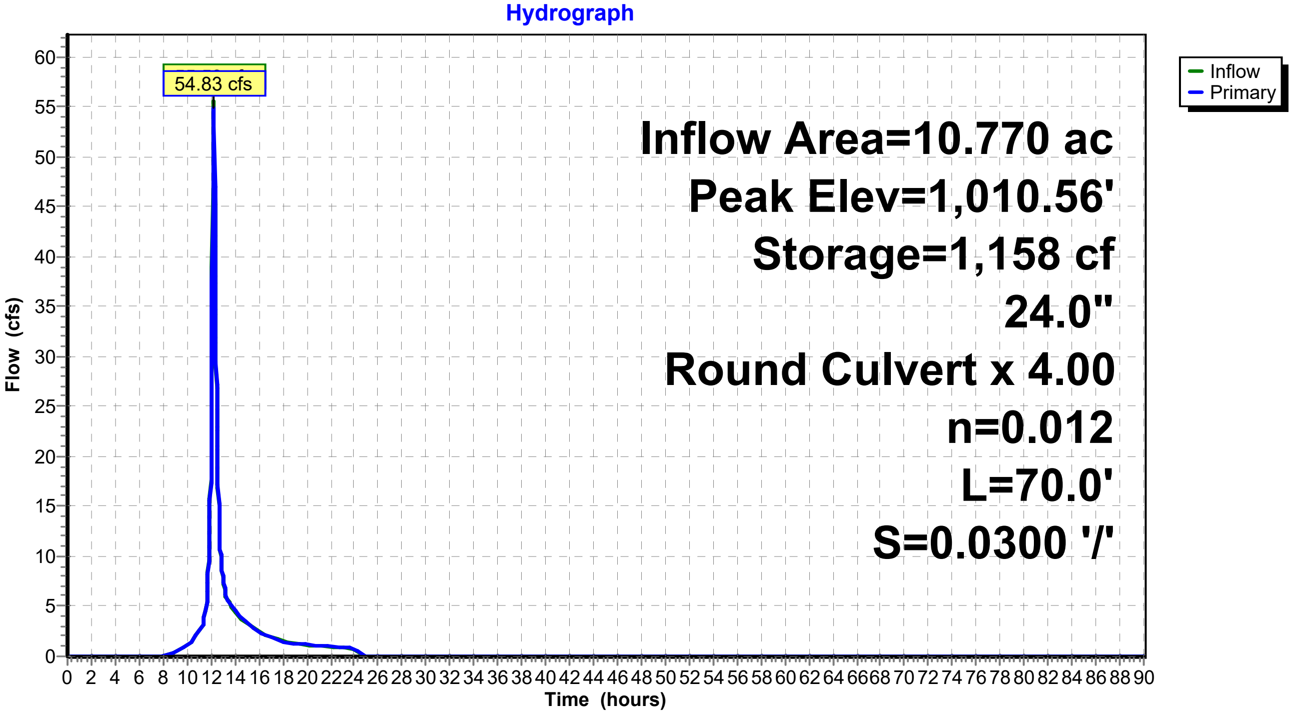
Volume	Invert	Avail.Storage	Storage Description
#1	1,008.50'	2,747 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,008.50	10	0	0
1,009.00	110	30	30
1,010.00	810	460	490
1,011.00	2,217	1,514	2,004
1,011.30	2,740	744	2,747

Device	Routing	Invert	Outlet Devices
#1	Primary	1,008.50'	**24.0" Round Culvert X 4.00** L= 70.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 1,008.50' / 1,006.40' S= 0.0300 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf

Primary OutFlow Max=54.47 cfs @ 12.23 hrs HW=1,010.54' (Free Discharge)
↑—**1=Culvert** (Inlet Controls 54.47 cfs @ 4.33 fps)

Pond 11P: Perimeter Low Point (Culvert 1&5)



Summary for Pond 10P: Bench Low Point (Culvert 2&4)

Inflow Area = 5.560 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-YR event
Inflow = 12.16 cfs @ 12.24 hrs, Volume= 1.081 af
Outflow = 12.16 cfs @ 12.24 hrs, Volume= 1.081 af, Atten= 0%, Lag= 0.3 min
Primary = 12.16 cfs @ 12.24 hrs, Volume= 1.081 af

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Peak Elev= 1,043.08' @ 12.24 hrs Surf.Area= 493 sf Storage= 154 cf
Flood Elev= 1,043.70' Surf.Area= 1,330 sf Storage= 719 cf

Plug-Flow detention time= 0.1 min calculated for 1.081 af (100% of inflow)
Center-of-Mass det. time= 0.1 min (869.4 - 869.3)

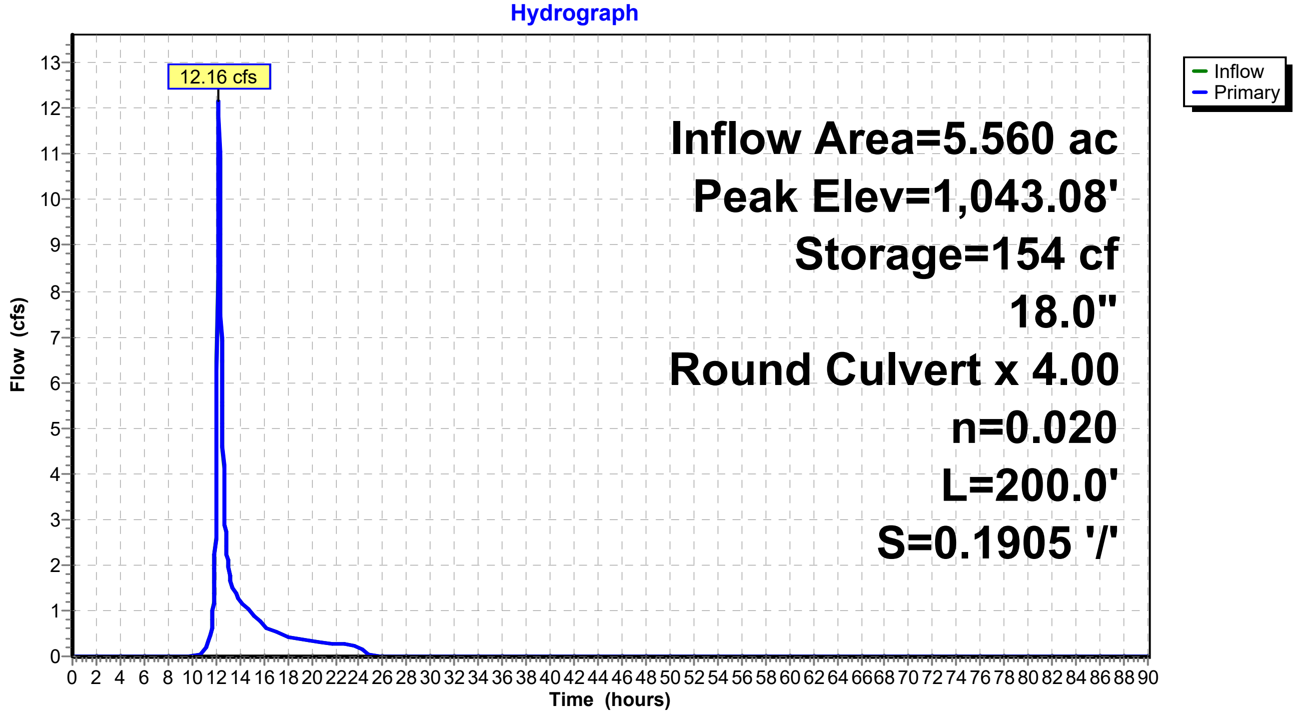
Volume	Invert	Avail.Storage	Storage Description
#1	1,042.20'	719 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,042.20	0	0	0
1,042.50	57	9	9
1,043.00	384	110	119
1,043.70	1,330	600	719

Device	Routing	Invert	Outlet Devices
#1	Primary	1,042.20'	**18.0" Round Culvert X 4.00** L= 200.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 1,042.20' / 1,004.10' S= 0.1905 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 1.77 sf

Primary OutFlow Max=12.10 cfs @ 12.24 hrs HW=1,043.08' (Free Discharge)
└─**1=Culvert** (Inlet Controls 12.10 cfs @ 2.81 fps)

Pond 10P: Bench Low Point (Culvert 2&4)



Summary for Pond 9P: Plateau Low Point (Culvert 3)

Inflow Area = 3.050 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-YR event
Inflow = 6.87 cfs @ 12.20 hrs, Volume= 0.593 af
Outflow = 6.83 cfs @ 12.21 hrs, Volume= 0.593 af, Atten= 1%, Lag= 0.9 min
Primary = 6.83 cfs @ 12.21 hrs, Volume= 0.593 af
Routed to nonexistent node 16P

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Peak Elev= 1,072.66' @ 12.21 hrs Surf.Area= 460 sf Storage= 223 cf
Flood Elev= 1,074.90' Surf.Area= 2,513 sf Storage= 3,247 cf

Plug-Flow detention time= 0.4 min calculated for 0.593 af (100% of inflow)
Center-of-Mass det. time= 0.4 min (864.4 - 864.0)

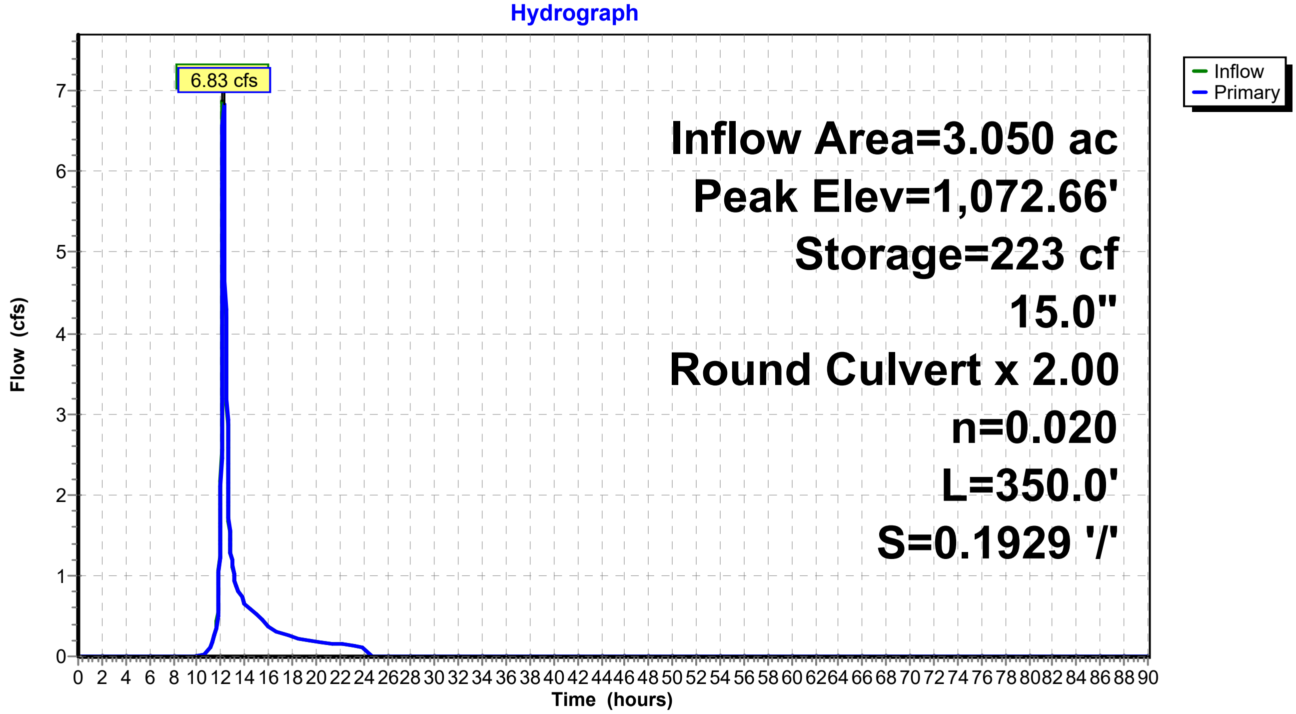
Volume	Invert	Avail.Storage	Storage Description
#1	1,071.60'	3,504 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,071.60	0	0	0
1,072.00	137	27	27
1,073.00	630	384	411
1,074.00	1,463	1,047	1,457
1,075.00	2,630	2,047	3,504

Device	Routing	Invert	Outlet Devices
#1	Primary	1,071.60'	**15.0" Round Culvert X 2.00** L= 350.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 1,071.60' / 1,004.10' S= 0.1929 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 1.23 sf

Primary OutFlow Max=6.82 cfs @ 12.21 hrs HW=1,072.65' (Free Discharge)
└─**1=Culvert** (Inlet Controls 6.82 cfs @ 3.09 fps)

Pond 9P: Plateau Low Point (Culvert 3)



Summary for Pond 14P: Culvert 6 Inlet

Inflow Area = 0.900 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-YR event
Inflow = 2.03 cfs @ 12.22 hrs, Volume= 0.175 af
Outflow = 2.03 cfs @ 12.22 hrs, Volume= 0.175 af, Atten= 0%, Lag= 0.3 min
Primary = 2.03 cfs @ 12.22 hrs, Volume= 0.175 af
Routed to Reach 5R : Perimeter Ditch East

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Peak Elev= 1,016.10' @ 12.22 hrs Surf.Area= 102 sf Storage= 31 cf
Flood Elev= 1,016.40' Surf.Area= 183 sf Storage= 74 cf

Plug-Flow detention time= 0.2 min calculated for 0.175 af (100% of inflow)
Center-of-Mass det. time= 0.2 min (867.4 - 867.1)

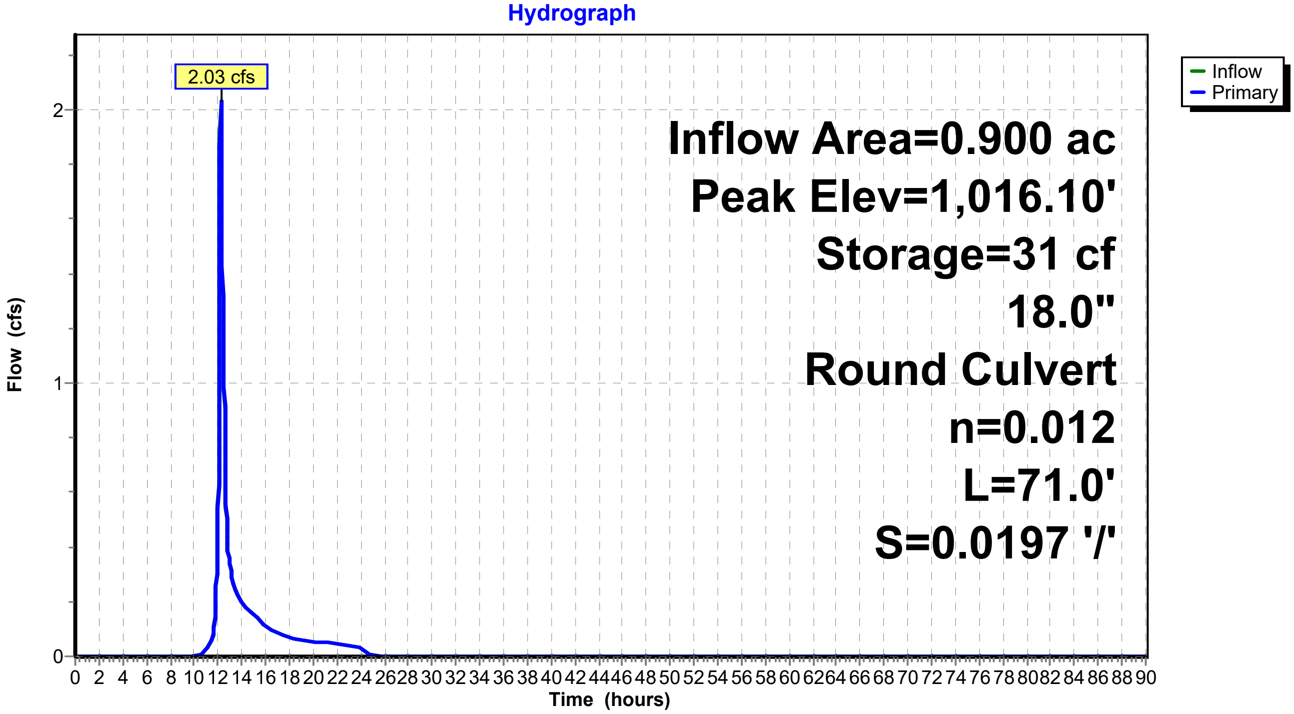
Volume	Invert	Avail.Storage	Storage Description
#1	1,015.40'	1,001 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,015.40	0	0	0
1,016.00	75	23	23
1,018.00	615	690	713
1,018.40	828	289	1,001

Device	Routing	Invert	Outlet Devices
#1	Primary	1,015.40'	**18.0" Round Culvert** L= 71.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 1,015.40' / 1,014.00' S= 0.0197 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 1.77 sf

Primary OutFlow Max=2.01 cfs @ 12.22 hrs HW=1,016.10' (Free Discharge)
└─**1=Culvert** (Inlet Controls 2.01 cfs @ 2.50 fps)

Pond 14P: Culvert 6 Inlet



Summary for Pond 16P: Culvert 7

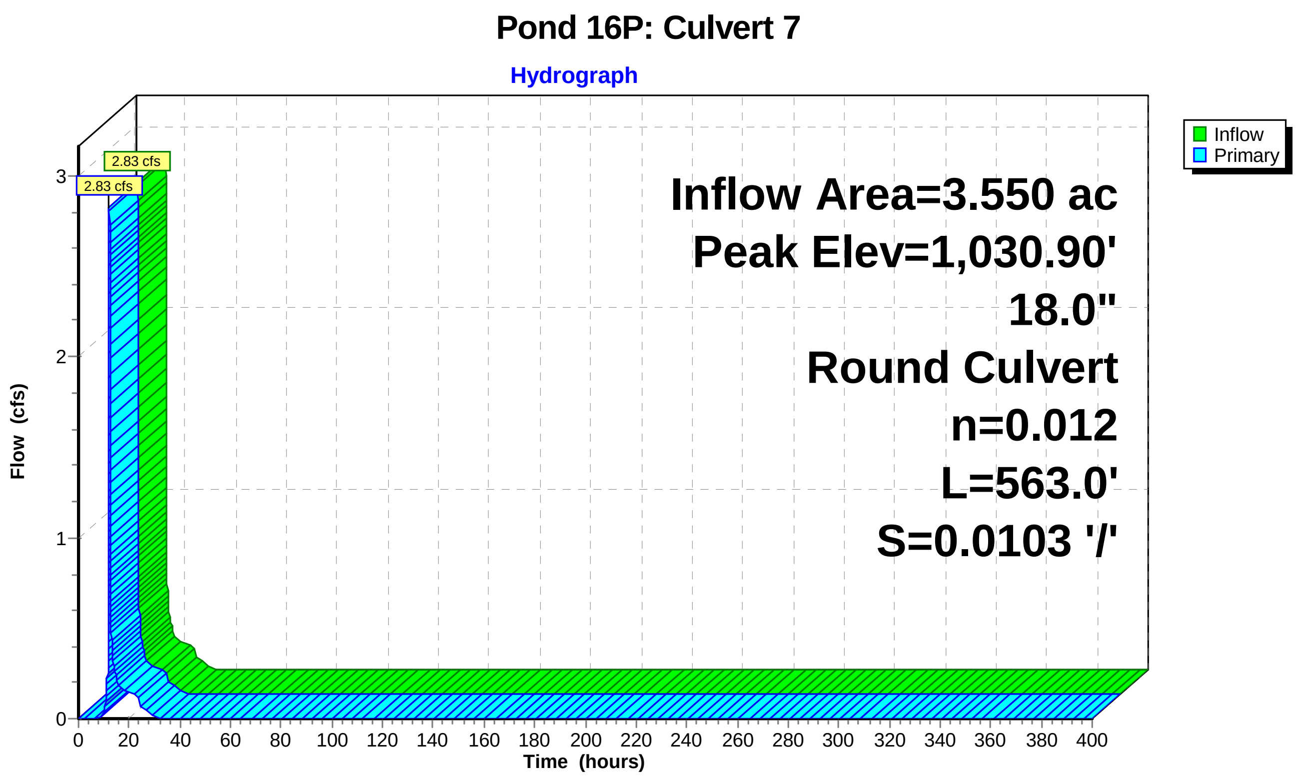
[57] Hint: Peaked at 1,030.90' (Flood elevation advised)
[79] Warning: Submerged Pond 15P Primary device # 1 OUTLET by 0.50'

Inflow Area = 3.550 ac, 0.00% Impervious, Inflow Depth = 1.21" for 100-YR event
Inflow = 2.83 cfs @ 12.18 hrs, Volume= 0.358 af
Outflow = 2.83 cfs @ 12.18 hrs, Volume= 0.358 af, Atten= 0%, Lag= 0.0 min
Primary = 2.83 cfs @ 12.18 hrs, Volume= 0.358 af
Routed to Pond 11P : SW Diversion Low Point

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,030.90' @ 12.18 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	1,030.00'	**18.0" Round Culvert** L= 563.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 1,030.00' / 1,024.20' S= 0.0103 '/' Cc= 0.900 n= 0.012, Flow Area= 1.77 sf

Primary OutFlow Max=2.83 cfs @ 12.18 hrs HW=1,030.90' (Free Discharge)
└─**1=Culvert** (Inlet Controls 2.83 cfs @ 2.55 fps)



Summary for Pond 15P: SW Diversion Low Point (Culvert #8)

Inflow Area = 2.920 ac, 0.00% Impervious, Inflow Depth = 3.30" for 25-YR event
Inflow = 10.78 cfs @ 12.14 hrs, Volume= 0.802 af
Outflow = 0.79 cfs @ 13.96 hrs, Volume= 0.787 af, Atten= 93%, Lag= 109.2 min
Discarded = 0.15 cfs @ 13.96 hrs, Volume= 0.629 af
Primary = 0.64 cfs @ 13.96 hrs, Volume= 0.158 af
Routed to nonexistent node 19P

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Peak Elev= 1,005.07' @ 13.96 hrs Surf.Area= 8,339 sf Storage= 21,866 cf
Flood Elev= 1,006.50' Surf.Area= 8,762 sf Storage= 27,957 cf

Plug-Flow detention time= 1,360.0 min calculated for 0.787 af (98% of inflow)
Center-of-Mass det. time= 1,349.0 min (2,184.9 - 836.0)

Volume	Invert	Avail.Storage	Storage Description
#1	999.50'	27,957 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

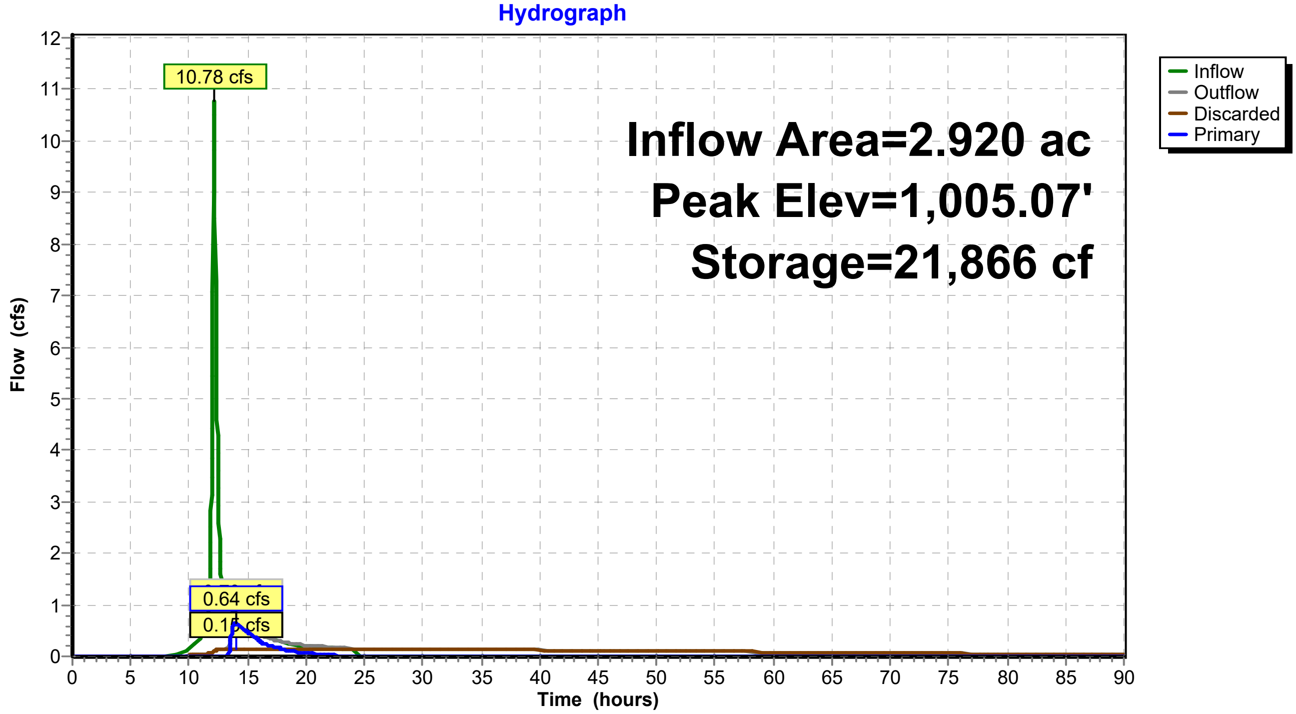
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
999.50	0	0	0
1,000.00	202	51	51
1,005.00	8,299	21,253	21,303
1,005.78	8,762	6,654	27,957

Device	Routing	Invert	Outlet Devices
#1	Discarded	999.50'	**0.775 in/hr Exfiltration over Surface area**
#2	Primary	999.40'	**18.0" Round Culvert** L= 75.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 999.40' / 997.00' S= 0.0320 '/' Cc= 0.900 n= 0.013, Flow Area= 1.77 sf
#3	Device 2	1,004.30'	**6.0" Vert. Orifice/Grate X 0.00** C= 0.600 Limited to weir flow at low heads
#4	Device 2	1,005.00'	**30.0" x 30.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.15 cfs @ 13.96 hrs HW=1,005.07' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.15 cfs)

Primary OutFlow Max=0.58 cfs @ 13.96 hrs HW=1,005.07' (Free Discharge)
└─**2=Culvert** (Passes 0.58 cfs of 14.90 cfs potential flow)
  ├─**3=Orifice/Grate** (Controls 0.00 cfs)
  └─**4=Orifice/Grate** (Weir Controls 0.58 cfs @ 0.85 fps)

Pond 15P: SW Diversion Low Point (Culvert #8)



Summary for Pond 19P: SMA-4 (Design Point 7) (Culvert 9)

Inflow Area = 16.600 ac, 0.00% Impervious, Inflow Depth = 1.99" for 100-YR event
Inflow = 23.38 cfs @ 12.28 hrs, Volume= 2.757 af
Outflow = 9.94 cfs @ 12.66 hrs, Volume= 2.757 af, Atten= 57%, Lag= 23.1 min
Discarded = 0.11 cfs @ 12.66 hrs, Volume= 0.263 af
Primary = 1.44 cfs @ 12.66 hrs, Volume= 1.617 af
Secondary = 8.38 cfs @ 12.66 hrs, Volume= 0.877 af

Routing by Stor-Ind method, Time Span= 0.00-300.00 hrs, dt= 0.01 hrs
Peak Elev= 990.50' @ 12.66 hrs Surf.Area= 0.292 ac Storage= 0.825 af

Plug-Flow detention time= 227.5 min calculated for 2.757 af (100% of inflow)
Center-of-Mass det. time= 227.5 min (1,119.9 - 892.4)

Volume	Invert	Avail.Storage	Storage Description
#1	987.00'	0.976 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
987.00	0.180	0.000	0.000
991.00	0.308	0.976	0.976

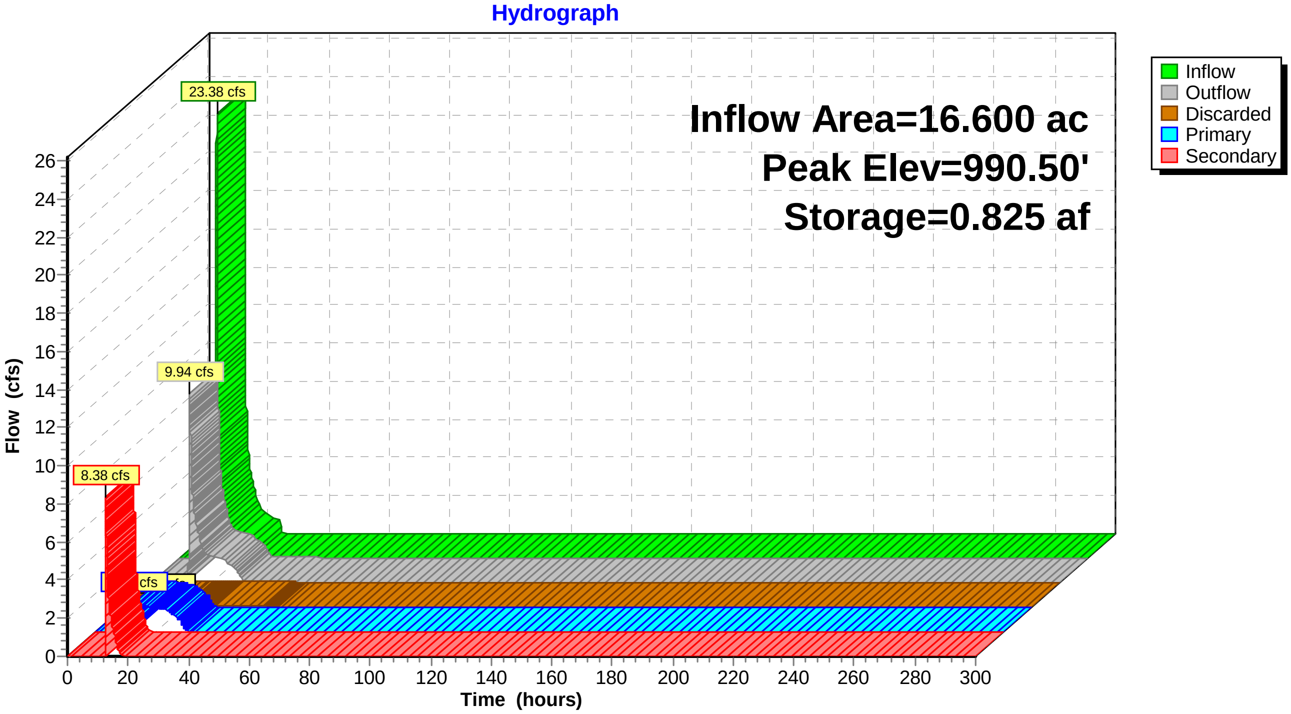
Device	Routing	Invert	Outlet Devices
#1	Discarded	987.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	987.50'	**4.0" Round Culvert X 4.00** L= 30.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 987.50' / 987.10' S= 0.0133 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 0.09 sf
#3	Secondary	990.00'	**8.0' long + 3.0 '/' SideZ x 5.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.34 2.50 2.70 2.68 2.68 2.66 2.65 2.65 2.65 2.65 2.67 2.66 2.68 2.70 2.74 2.79 2.88

Discarded OutFlow Max=0.11 cfs @ 12.66 hrs HW=990.50' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.11 cfs)

Primary OutFlow Max=1.44 cfs @ 12.66 hrs HW=990.50' (Free Discharge)
└─**2=Culvert** (Barrel Controls 1.44 cfs @ 4.13 fps)

Secondary OutFlow Max=8.37 cfs @ 12.66 hrs HW=990.50' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Weir Controls 8.37 cfs @ 1.77 fps)

Pond 19P: SMA-4 (Design Point 7) (Culvert 9)



Summary for Pond 15P: Culvert #10

Inflow Area = 0.820 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-YR event
Inflow = 2.17 cfs @ 12.09 hrs, Volume= 0.159 af
Outflow = 1.87 cfs @ 12.14 hrs, Volume= 0.159 af, Atten= 14%, Lag= 2.9 min
Primary = 1.87 cfs @ 12.14 hrs, Volume= 0.159 af
Routed to Pond 16P : Culvert 7

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,032.92' @ 12.14 hrs Surf.Area= 0.019 ac Storage= 0.008 af

Plug-Flow detention time= 2.4 min calculated for 0.159 af (100% of inflow)
Center-of-Mass det. time= 2.4 min (858.0 - 855.6)

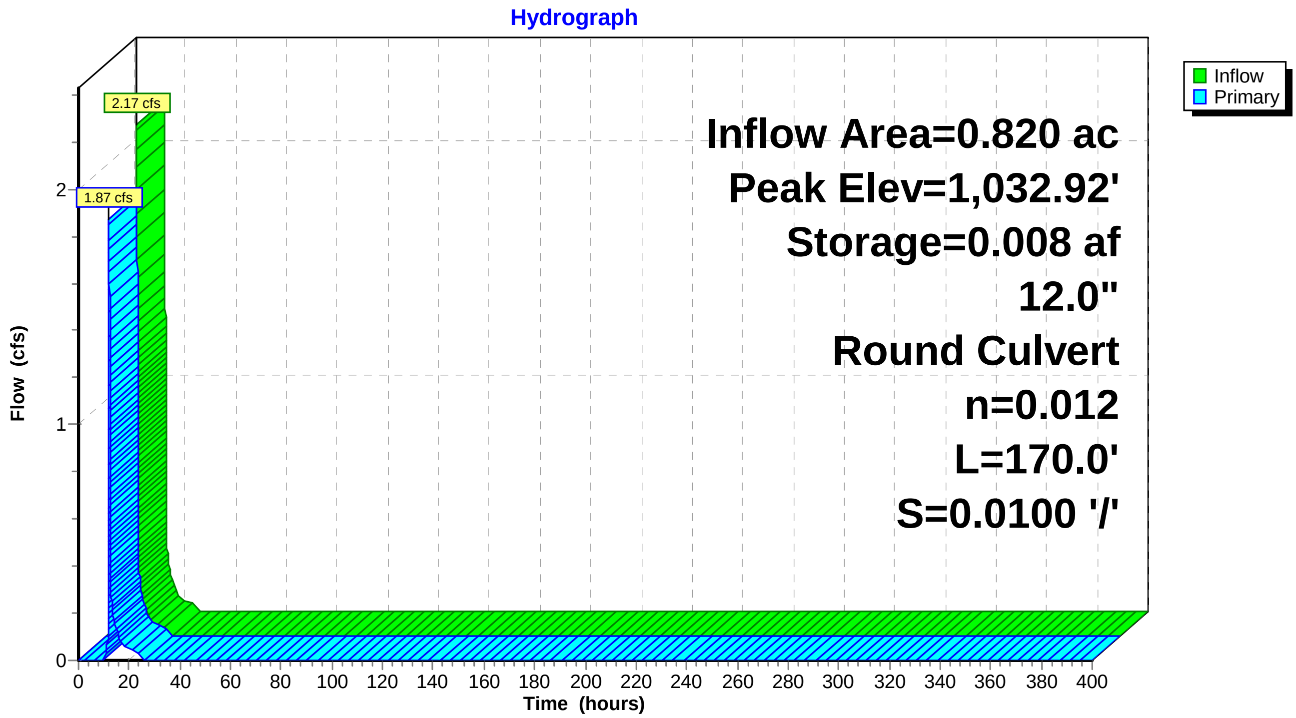
Volume	Invert	Avail.Storage	Storage Description
#1	1,032.10'	0.136 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,032.10	0.000	0.000	0.000
1,033.00	0.021	0.009	0.009
1,034.00	0.136	0.078	0.088
1,034.30	0.187	0.048	0.136

Device	Routing	Invert	Outlet Devices
#1	Primary	1,032.10'	**12.0" Round Culvert** L= 170.0' RCP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 1,032.10' / 1,030.40' S= 0.0100 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Primary OutFlow Max=1.87 cfs @ 12.14 hrs HW=1,032.92' (Free Discharge)
└—**1=Culvert** (Inlet Controls 1.87 cfs @ 2.72 fps)

Pond 15P: Culvert #10



Summary for Pond 12P: NW Diversion Low Point (Culvert #11)

Inflow Area = 1.880 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-YR event
Inflow = 4.65 cfs @ 12.16 hrs, Volume= 0.366 af
Outflow = 4.55 cfs @ 12.18 hrs, Volume= 0.365 af, Atten= 2%, Lag= 1.2 min
Primary = 4.55 cfs @ 12.18 hrs, Volume= 0.365 af

Routing by Stor-Ind method, Time Span= 0.00-90.00 hrs, dt= 0.03 hrs
Peak Elev= 982.75' @ 12.18 hrs Surf.Area= 714 sf Storage= 279 cf
Flood Elev= 983.50' Surf.Area= 2,250 sf Storage= 1,156 cf

Plug-Flow detention time= 2.0 min calculated for 0.365 af (100% of inflow)
Center-of-Mass det. time= 1.6 min (862.7 - 861.1)

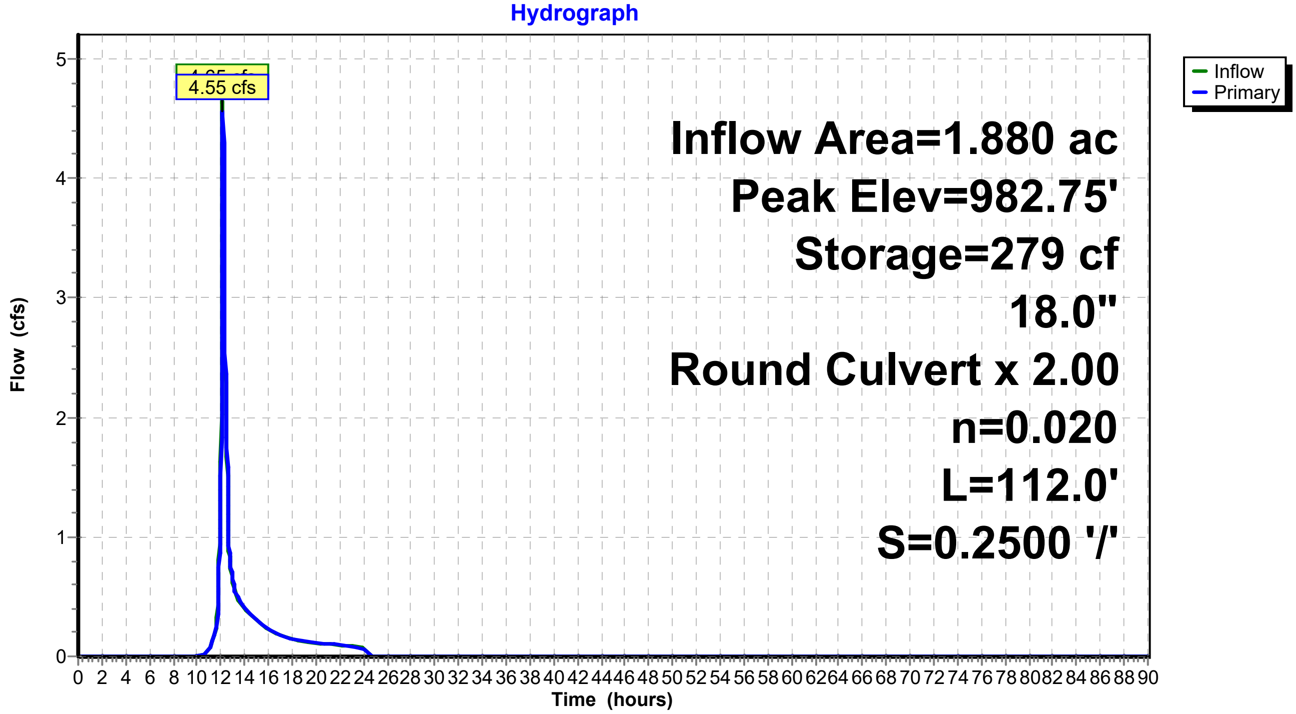
Volume	Invert	Avail.Storage	Storage Description
#1	981.90'	1,156 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
981.90	0	0	0
982.00	125	6	6
982.50	413	135	141
983.00	1,026	360	501
983.40	2,250	655	1,156

Device	Routing	Invert	Outlet Devices
#1	Primary	982.00'	**18.0" Round Culvert #11 X 2.00** L= 112.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 982.00' / 954.00' S= 0.2500 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 1.77 sf

Primary OutFlow Max=4.53 cfs @ 12.18 hrs HW=982.74' (Free Discharge)
↑—**1=Culvert #11** (Inlet Controls 4.53 cfs @ 2.59 fps)

Pond 12P: NW Diversion Low Point (Culvert #11)



Summary for Pond 13P: SMA-5 (Design Point 10) (Culvert 12)

[44] Hint: Outlet device #2 is below defined storage

Inflow Area = 5.000 ac, 0.00% Impervious, Inflow Depth = 2.71" for 25-YR event
Inflow = 16.68 cfs @ 12.07 hrs, Volume= 1.128 af
Outflow = 8.44 cfs @ 12.20 hrs, Volume= 1.128 af, Atten= 49%, Lag= 8.2 min
Discarded = 0.08 cfs @ 12.20 hrs, Volume= 0.020 af
Primary = 4.90 cfs @ 12.20 hrs, Volume= 1.038 af
Routed to nonexistent node 4R
Secondary = 3.46 cfs @ 12.20 hrs, Volume= 0.070 af

Routing by Stor-Ind method, Time Span= 0.00-300.00 hrs, dt= 0.01 hrs
Peak Elev= 954.68' @ 12.20 hrs Surf.Area= 0.177 ac Storage= 0.190 af

Plug-Flow detention time= 9.9 min calculated for 1.128 af (100% of inflow)
Center-of-Mass det. time= 9.9 min (854.3 - 844.3)

Volume	Invert	Avail.Storage	Storage Description
#1	953.00'	0.361 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
953.00	0.049	0.000	0.000
955.50	0.240	0.361	0.361

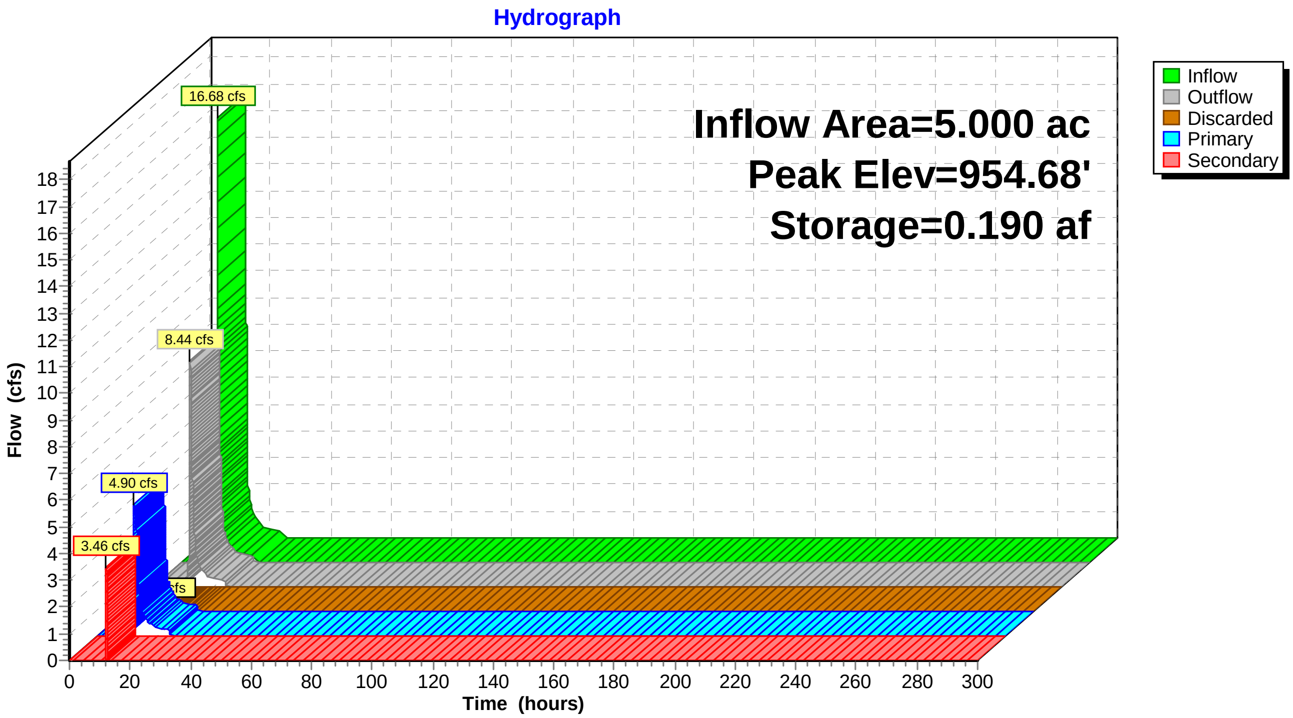
Device	Routing	Invert	Outlet Devices
#1	Discarded	953.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	952.50'	**12.0" Round Culvert #12** L= 40.0' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 952.50' / 949.60' S= 0.0725 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#3	Secondary	954.50'	**16.0' long + 10.0 '/' SideZ x 16.4' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.08 cfs @ 12.20 hrs HW=954.68' (Free Discharge)
└—**1=Exfiltration** (Exfiltration Controls 0.08 cfs)

Primary OutFlow Max=4.90 cfs @ 12.20 hrs HW=954.68' (Free Discharge)
└—**2=Culvert #12** (Inlet Controls 4.90 cfs @ 6.23 fps)

Secondary OutFlow Max=3.45 cfs @ 12.20 hrs HW=954.68' (Free Discharge)
└—**3=Broad-Crested Rectangular Weir** (Weir Controls 3.45 cfs @ 1.10 fps)

Pond 13P: SMA-5 (Design Point 10) (Culvert 12)



Summary for Pond 20P: Vault Culvert South (Culvert #13)

Inflow Area = 1.930 ac, 0.00% Impervious, Inflow Depth > 5.19" for 100-YR event
Inflow = 11.73 cfs @ 12.09 hrs, Volume= 0.834 af
Outflow = 10.08 cfs @ 12.14 hrs, Volume= 0.834 af, Atten= 14%, Lag= 2.9 min
Primary = 10.08 cfs @ 12.14 hrs, Volume= 0.834 af

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.02 hrs
Peak Elev= 1,030.55' @ 12.14 hrs Surf.Area= 1,127 sf Storage= 994 cf
Flood Elev= 1,031.00' Surf.Area= 1,498 sf Storage= 1,580 cf

Plug-Flow detention time= 0.5 min calculated for 0.833 af (100% of inflow)
Center-of-Mass det. time= 0.5 min (823.0 - 822.5)

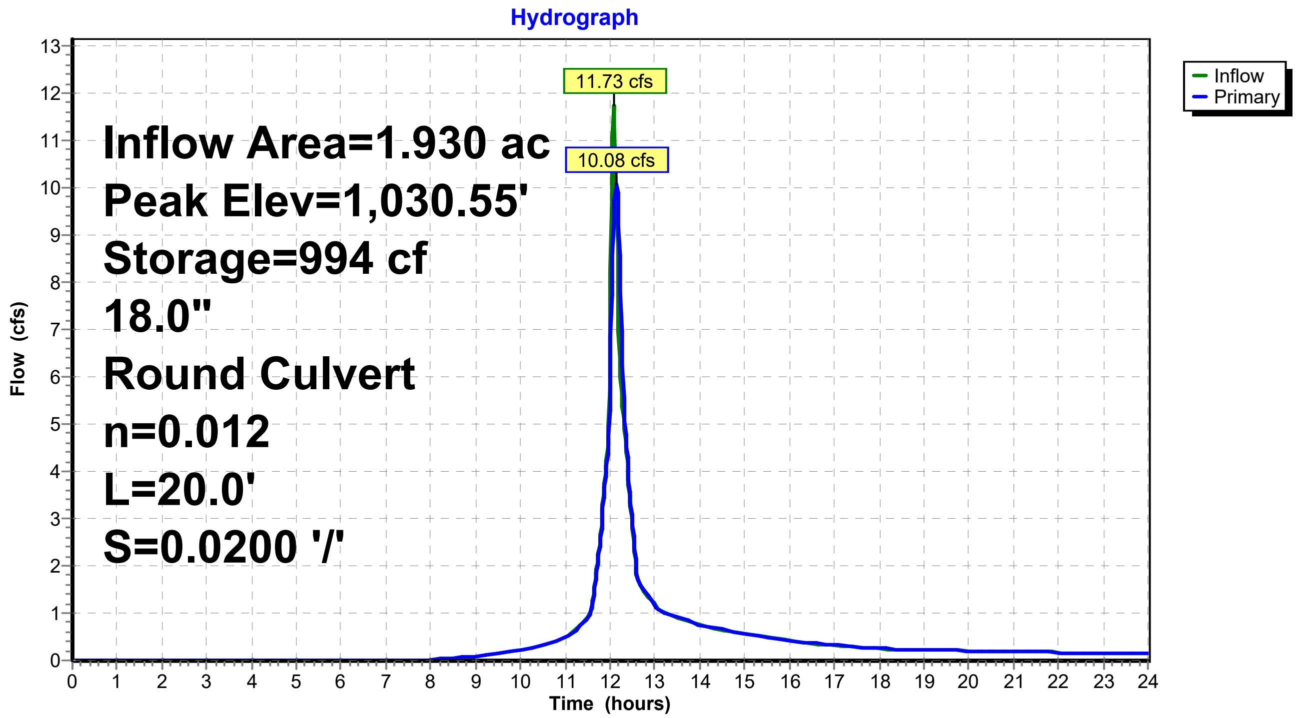
Volume	Invert	Avail.Storage	Storage Description
#1	1,028.00'	1,580 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,028.00	0	0	0
1,029.00	163	82	82
1,030.00	668	416	497
1,031.00	1,498	1,083	1,580

Device	Routing	Invert	Outlet Devices
#1	Primary	1,028.00'	**18.0" Round Culvert** L= 20.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 1,028.00' / 1,027.60' S= 0.0200 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 1.77 sf

Primary OutFlow Max=10.07 cfs @ 12.14 hrs HW=1,030.55' (Free Discharge)
└─**1=Culvert** (Inlet Controls 10.07 cfs @ 5.70 fps)

Pond 20P: Vault Culvert South (Culvert #13)



Summary for Pond 21P: Vault Culvert North (Culvert #14)

Inflow Area = 3.760 ac, 0.00% Impervious, Inflow Depth > 5.19" for 100-YR event
Inflow = 22.86 cfs @ 12.09 hrs, Volume= 1.625 af
Outflow = 20.96 cfs @ 12.12 hrs, Volume= 1.625 af, Atten= 8%, Lag= 2.1 min
Primary = 20.96 cfs @ 12.12 hrs, Volume= 1.625 af

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.02 hrs
Peak Elev= 1,019.70' @ 12.12 hrs Surf.Area= 1,248 sf Storage= 1,166 cf
Flood Elev= 1,020.00' Surf.Area= 1,498 sf Storage= 1,580 cf

Plug-Flow detention time= 0.3 min calculated for 1.625 af (100% of inflow)
Center-of-Mass det. time= 0.2 min (822.7 - 822.5)

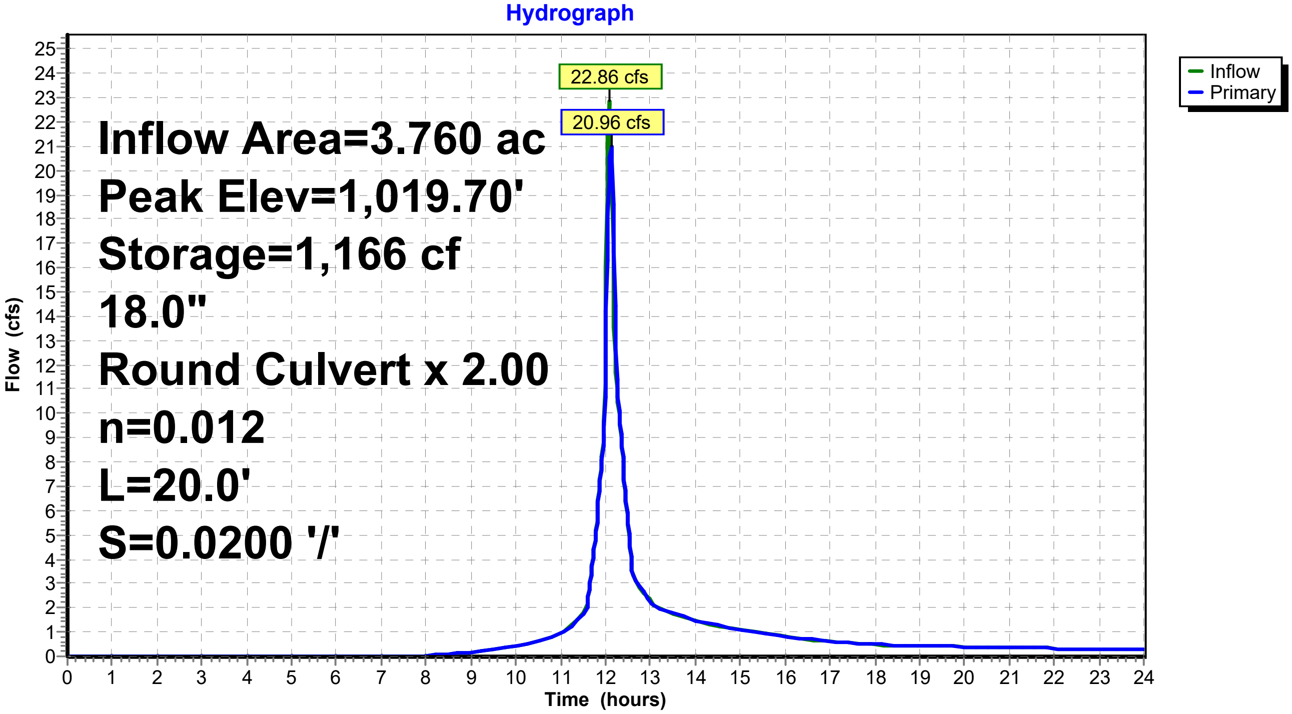
Volume	Invert	Avail.Storage	Storage Description
#1	1,017.00'	1,580 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,017.00	0	0	0
1,018.00	163	82	82
1,019.00	668	416	497
1,020.00	1,498	1,083	1,580

Device	Routing	Invert	Outlet Devices
#1	Primary	1,017.00'	**18.0" Round Culvert X 2.00** L= 20.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 1,017.00' / 1,016.60' S= 0.0200 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 1.77 sf

Primary OutFlow Max=20.92 cfs @ 12.12 hrs HW=1,019.69' (Free Discharge)
↑—**1=Culvert** (Inlet Controls 20.92 cfs @ 5.92 fps)

Pond 21P: Vault Culvert North (Culvert #14)



Summary for Pond 17P: SMA3B (Design Point SMA3)

Inflow Area =	0.490 ac,	0.00% Impervious, Inflow Depth = 5.32" for 100-YR event		
Inflow =	3.05 cfs @	12.09 hrs, Volume=	0.217 af	
Outflow =	2.41 cfs @	12.15 hrs, Volume=	0.217 af,	Atten= 21%, Lag= 3.7 min
Discarded =	0.02 cfs @	12.15 hrs, Volume=	0.083 af	
Primary =	2.39 cfs @	12.15 hrs, Volume=	0.134 af	

Routing by Stor-Ind method, Time Span= 0.00-300.00 hrs, dt= 0.01 hrs
Peak Elev= 1,024.66' @ 12.15 hrs Surf.Area= 0.061 ac Storage= 0.067 af

Plug-Flow detention time= 507.9 min calculated for 0.217 af (100% of inflow)
Center-of-Mass det. time= 507.9 min (1,329.0 - 821.1)

Volume	Invert	Avail.Storage	Storage Description
#1	1,022.60'	0.127 af	**Custom Stage Data (Conic)** Listed below (Recalc)

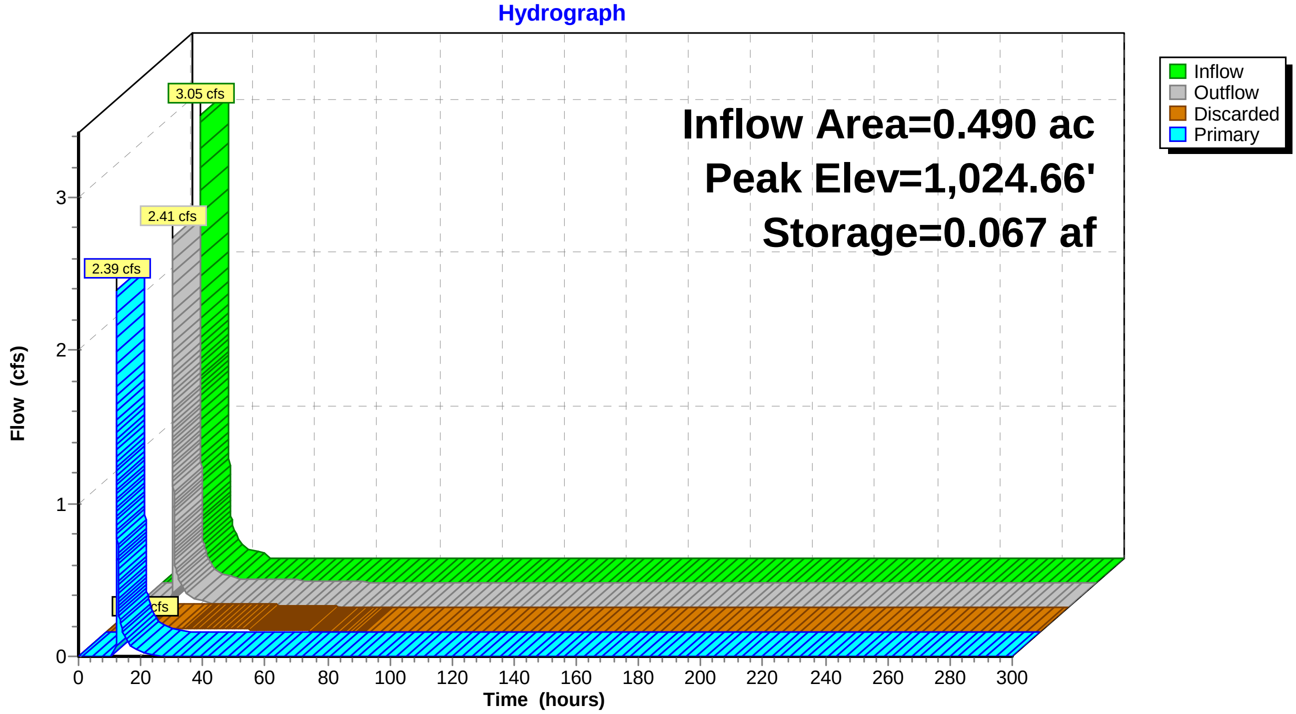
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.60	0.002	0.000	0.000	0.002
1,023.80	0.044	0.022	0.022	0.044
1,025.50	0.081	0.105	0.127	0.082

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.60'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,024.50'	**15.0' long + 3.0 '/' SideZ x 6.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.37 2.51 2.70 2.68 2.68 2.67 2.65 2.65 2.65 2.65 2.66 2.66 2.67 2.69 2.72 2.76 2.83

Discarded OutFlow Max=0.02 cfs @ 12.15 hrs HW=1,024.66' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=2.38 cfs @ 12.15 hrs HW=1,024.66' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Weir Controls 2.38 cfs @ 0.95 fps)

Pond 17P: SMA3B (Design Point SMA3)



Summary for Pond 14P: North Access Road Culvert #16

[44] Hint: Outlet device #2 is below defined storage

Inflow Area = 2.180 ac, 0.00% Impervious, Inflow Depth = 1.55" for 100-YR event
Inflow = 2.10 cfs @ 12.30 hrs, Volume= 0.281 af
Outflow = 2.05 cfs @ 12.34 hrs, Volume= 0.281 af, Atten= 2%, Lag= 2.8 min
Discarded = 0.00 cfs @ 12.34 hrs, Volume= 0.001 af
Primary = 2.05 cfs @ 12.34 hrs, Volume= 0.280 af
Routed to Pond 22P : Proposed Powerline Depression (Design Point 2)

Routing by Stor-Ind method, Time Span= 0.00-300.00 hrs, dt= 0.01 hrs
Peak Elev= 982.76' @ 12.34 hrs Surf.Area= 0.009 ac Storage= 0.004 af

Plug-Flow detention time= 0.7 min calculated for 0.281 af (100% of inflow)
Center-of-Mass det. time= 0.7 min (912.2 - 911.5)

Volume	Invert	Avail.Storage	Storage Description
#1	982.00'	0.004 af	**Custom Stage Data (Conic)** Listed below (Recalc)

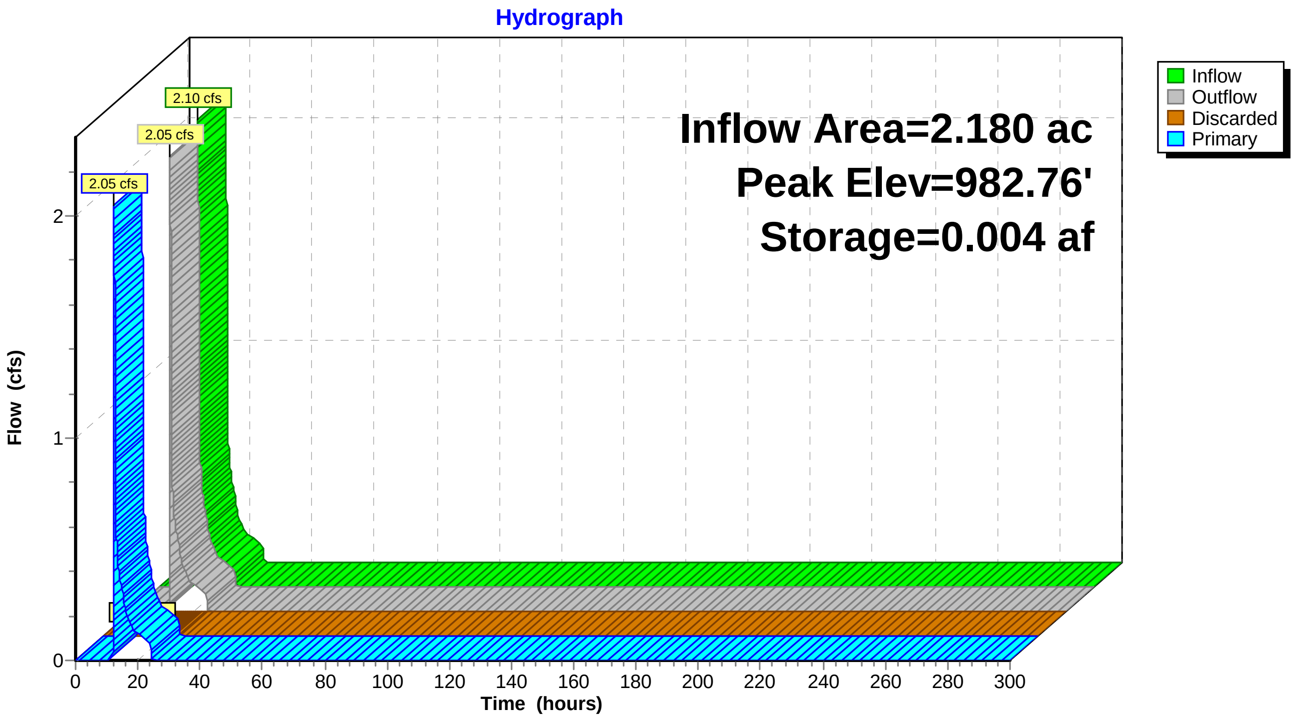
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
982.00	0.002	0.000	0.000	0.002
982.80	0.010	0.004	0.004	0.010

Device	Routing	Invert	Outlet Devices
#1	Discarded	982.00'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	981.80'	**12.0" Round Culvert** L= 50.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 981.80' / 980.92' S= 0.0176 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Discarded OutFlow Max=0.00 cfs @ 12.34 hrs HW=982.76' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=2.04 cfs @ 12.34 hrs HW=982.76' (Free Discharge)
└─**2=Culvert** (Inlet Controls 2.04 cfs @ 2.64 fps)

Pond 14P: North Access Road Culvert #16



Attachment 2:

HydroCAD Existing Channel Analysis for Open-Arch Culvert Crossing

Summary for Pond 21P: North Access Road Open Arch Culvert #1

[93] Warning: Storage range exceeded by 0.08'
[62] Hint: Exceeded Reach 22R OUTLET depth by 0.77' @ 12.55 hrs
[64] Warning: Exceeded Reach 22R outlet bank by 0.53' @ 12.55 hrs

Inflow Area = 89.590 ac, 0.00% Impervious, Inflow Depth = 4.26" for 100-YR event
Inflow = 238.98 cfs @ 12.50 hrs, Volume= 31.800 af
Outflow = 228.55 cfs @ 12.55 hrs, Volume= 31.781 af, Atten= 4%, Lag= 3.3 min
Discarded = 0.25 cfs @ 12.55 hrs, Volume= 0.019 af
Primary = 228.30 cfs @ 12.55 hrs, Volume= 31.762 af
Routed to Pond 22P : Proposed Powerline Depression (Design Point 2)

Routing by Stor-Ind method, Time Span= 0.00-300.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 988.98' @ 12.55 hrs Surf.Area= 23,514 sf Storage= 33,751 cf

Plug-Flow detention time= 1.6 min calculated for 31.781 af (100% of inflow)
Center-of-Mass det. time= 0.9 min (870.6 - 869.7)

Volume	Invert	Avail.Storage	Storage Description
#1	984.65'	33,751 cf	**Custom Stage Data (Conic)** Listed below (Recalc)

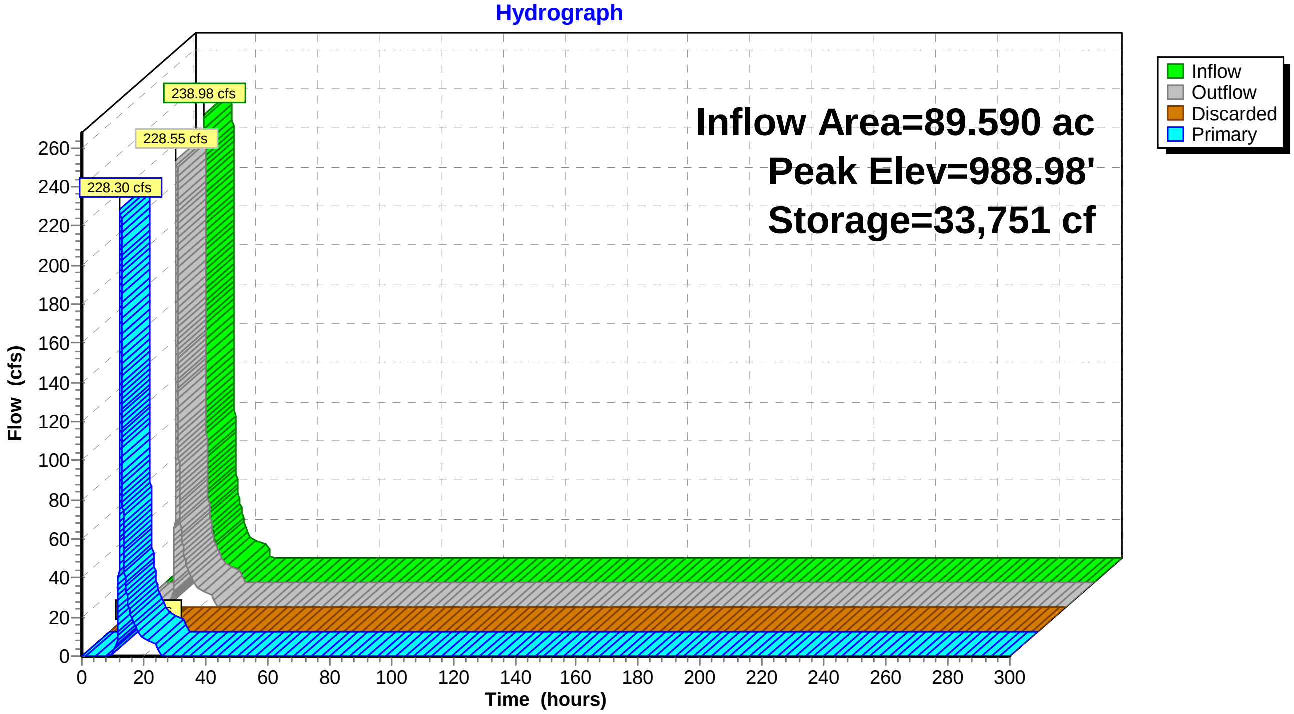
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
984.65	1	0	0	1
985.00	154	20	20	154
985.50	845	227	246	846
986.00	2,215	738	984	2,218
986.50	4,569	1,661	2,645	4,574
987.00	7,470	2,980	5,625	7,478
987.40	10,205	3,521	9,146	10,216
988.90	23,514	24,605	33,751	23,543

Device	Routing	Invert	Outlet Devices
#1	Discarded	984.65'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	984.65'	**144.0" W x 43.2" H, R=90.0" Arch Culvert** L= 49.0' CMP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 984.65' / 982.17' S= 0.0506 '/' Cc= 0.900 n= 0.035, Flow Area= 32.36 sf

Discarded OutFlow Max=0.25 cfs @ 12.55 hrs HW=988.98' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.25 cfs)

Primary OutFlow Max=227.88 cfs @ 12.55 hrs HW=988.97' (Free Discharge)
└─**2=Culvert** (Inlet Controls 227.88 cfs @ 7.04 fps)

Pond 21P: North Access Road Open Arch Culvert #1



Calculation Brief

Client: **General Electric Company**

Project Location: **Pittsfield/Housatonic River Site - Town of Lee, Massachusetts**

Project: **Upland Disposal Facility Area** **Arcadis Project No.:** **30197838**

Calc No.: **G-7** **Subject:** **Proposed Stormwater Conditions**

Prepared By: **MTA** **Date:** **February 2024**

Reviewed By: **BMS** **Date:** **February 2024**

Objective

Analyze proposed stormwater conditions to identified design points surrounding the Upland Disposal Facility (UDF) following construction and closure of the UDF. Demonstrate that existing versus proposed conditions are compliant with Massachusetts Department of Environmental Protection (MassDEP) regulations and requirements.

References

1. Arcadis U.S., Inc. *Calculation Brief G-1: Design Storm*. February 2024.
2. Arcadis U.S., Inc. *Calculation Brief G-2: Existing Stormwater Conditions*. February 2024.
3. Arcadis U.S., Inc. *Calculation Brief G-3: Channel Design*. February 2024.
4. Arcadis U.S., Inc. *Calculation Brief G-4: Stormwater Basin Design*. February 2024.
5. Arcadis U.S., Inc. *Calculation Brief G-5: Stormwater Management Area Design.* February 2024.
6. Arcadis U.S., Inc. *Calculation Brief G-6: Culvert Design*. February 2024.
7. Autodesk, Inc. *Civil3D*. Computer Software. 2023.
8. MassDEP. *Massachusetts Stormwater Handbook and Stormwater Standards Volume 3, Chapter 1*. 2008.
9. National Resources Conservation Service - United States Department of Agriculture (NRCS-USDA). *Web Soil Survey.* http://websoilsurvey.sc.egov.usda.gov/. Accessed April 2023.
10. HydroCAD Software Solutions, LLC. *HydroCAD Version 10.2*. Computer Software, 2022.
11. Northeast Regional Climate Center (NRCC). *Extreme Precipitation in New York & New England, Extreme Precipitation Estimate Tables*, Town of Lee, MA.
12. NOAA's National Weather Service (NOAA). *NOAA Atlas 14-Point Precipitation Frequency Estimates*, Town of Lee, MA.
13. Natural Resource Conservation Service. *Urban Hydrology for Small Watersheds.* Technical Release 55 (TR-55). June 1986.
14. MassDEP Division of Watershed Management. *Hydrology Handbook for Conservation Commissioners.* March 2002

15. MassDEP. *Massachusetts Stormwater Handbook and Stormwater Standards Volume 2, Chapter 2*. 2008.

16. Natural Resource Conservation Service. *Urban Hydrology for Small Watersheds.* Technical Release 55 (TR-55). June 1986.

17. Arcadis U.S., Inc. Upland Disposal Facility Final Design Plan, Appendix A. *Design Drawing 8: Final Grading Plan.* February 2024.

Assumptions

1. The terms "existing" and "proposed" as used herein refer to pre- and post-construction conditions of the UDF, respectively. Existing stormwater conditions are analyzed separately in Reference 2 and presented herein for comparison purposes. Proposed conditions are based on the UDF following final closure.

2. The limits of study and specific design points at which proposed stormwater conditions will be computed are defined in Reference 2.

3. Assumptions regarding existing conditions are based on Reference 2. Assumptions regarding proposed earthwork, ground cover types, and stormwater features are based on References 3, 4, 5, and 6.

4. The 24-hour duration design storms have a Type III NRCS (formerly SCS) rainfall distribution (Reference 16). Modeled precipitation amounts are as follows (Reference 1):

   - 2-year, 24-hour: 3.84 inches
   - 10-year, 24-hour: 5.28 inches
   - 100-year, 24-hour: 9.12 inches

   The modeled precipitation amounts are adjusted for climate change predictions based on assumptions made in Reference 1.

5. Proposed drainage areas and time of concentration (Tc) paths are delineated using Autodesk Civil3D software (Reference 7) based on UDF design grading and existing survey information (Reference 17).

6. The maximum distance for an assumed sheet flow segment of a Tc path is 50 feet before transitioning to shallow concentrated flow (Reference 14).

7. Consistent with stormwater modeling for existing conditions (Reference 2), proposed stormwater conditions to each design point are determined using Reference 10, which utilizes the NRCS curve number (CN) method to convert rainfall to runoff. CNs are selected from Reference 13 based on hydrologic soil groups (HSGs) determined in Reference 2 and ground cover types that either exist (per Reference 2) or are anticipated to exist following closure of the UDF and full establishment of vegetation.

8. Under proposed conditions, six existing depressions that detain stormwater and allow infiltration will be modified in configuration as part of UDF development. These are referred to as Stormwater Management Areas (SMAs). These six SMAs and two proposed stormwater basins will reduce the rate and volume of stormwater runoff reaching the design points. This effect is determined using hydrologic routing and is performed in References 4 and 5.

9. Hydrologic routing through existing infiltration areas is only performed when the proposed UDF development is anticipated to increase the rate and volume of stormwater runoff into a stormwater management area and/or affects the configuration of the infiltration area.
10. Per MassDEP regulations (Reference 8), peak flow attenuation must be achieved on-site so that flows are no greater than existing conditions during the 2- and 10-year storm events. Additionally, if off-site flooding from the peak discharge associated with the 100-year storm event is shown to occur under proposed conditions, BMPs must be implemented to attenuate those discharges.

Calculations

1. Design Points and Contributing Drainage Areas

The nine design points defined in Reference 2 form the basis for comparison to proposed stormwater conditions. Contributing drainage areas to each design point for proposed conditions are defined based on a combination of existing and proposed topography. The design points and the contributing drainage area ID(s) are summarized in Table 1.

Table 1: Design Points

Design Point	Design Point Description	Contributing Drainage Areas	Hydrologic Routing Performed for Flow to Design Point (Y/N)?
1	Point of discharge to jointly owned quarry pond on western property line	1A P, 1B P, 2A P, 2B P, 2C P, 3 P, UDF	Y
2	Point of overflow to on-site area to the north and potentially to abutter along eastern property line (SMA-1)	3 P	Y
3	Point of overflow to Woodland Road along eastern property line	4 P	N
4	Point of overflow to Woodland Road along eastern property line	5 P	N
5	Point of overflow to Woodland Road along eastern property line (SMA-2)	6 P, 8 A P	Y
6	Point of overflow to abutter along southern property line (SMA-3A and SMA-3B)	8B P, 8A P	Y
7	Point of overflow to abutter along western property line (SMA-4)	7 P, South Basin, Entrance Road Culvert	Y
8	Point of overflow to abutter along western property line	9 P	N
9	Quarry pond within property limits that overflows to jointly owned quarry pond on western property line (SMA-5)	10 P	Y

The design point locations and drainage area boundaries are shown in the attached Drainage Area Map (Figure 1). It is noted that all design points are downstream of features that reduce offsite stormwater flow rates and volumes. However, the rate and volume of stormwater runoff reaching Design Points 3, 4, and

8 are reduced as a result of UDF construction and closure; therefore, the effect of their associated infiltration areas is not analyzed herein (Assumption 9). The degree of attenuation provided by upstream features to the flow and volume to Design Points 1, 2, 5, 6, 7, and 9 is evaluated in References 4 and 5.

2. Proposed Drainage Area Hydrologic Conditions

The drainage areas presented above in Table 1 are modeled using HydroCAD (Reference 10) to generate stormwater runoff hydrographs. Table 2 summarizes the hydrologic input parameters and the associated peak flow rates and total runoff volumes for each drainage area based on post-construction conditions:

Table 2: Proposed Hydrologic Conditions

Drainage Area	Area (acres)	Composite CN	Tc (min)	2-yr, 24-hr		10-yr, 24-hr		100-yr, 24-hr	
				Volume (ac-ft)	Rate (cfs)	Volume (ac-ft)	Rate (cfs)	Volume (ac-ft)	Rate (cfs)
1A-P	38.00	62	34.2	2.475	15.29	5.111	35.71	14.072	104.84
1B-P	2.44	41	15.1	0.012	0.02	0.070	0.27	0.384	3.30
2A-P	49.15	62	33.8	3.201	19.86	6.611	46.50	18.202	136.10
2B-P	2.82	41	6.8	0.014	0.02	0.081	0.34	0.444	4.97
2C-P	2.18	38	16.6	0.004	0.01	0.040	0.08	0.281	2.10
3-P	23.59	58	32.8	1.167	6.47	2.607	17.65	7.758	58.30
4-P	0.76	32	6.6	0.00	0.00	0.003	0.00	0.058	0.33
5-P	1.33	58	6.7	0.066	0.62	0.147	1.79	0.437	5.94
6-P	1.95	64	9.7	0.144	1.52	0.287	3.38	0.763	9.45
Entrance Road Culvert	0.82	61	6.0	0.050	0.56	0.105	1.37	0.295	4.14
7-P	10.95	43	11.8	0.089	0.14	0.397	1.93	1.936	19.19
8A P	0.52	57	6.0	0.024	0.22	0.054	0.67	0.166	2.30
8B P	0.44	65	6.0	0.034	0.42	0.068	0.91	0.177	2.49
9-P	0.83	71	6.0	0.089	1.19	0.161	2.25	0.385	5.41
10-P	5.00	65	6.0	0.390	4.82	0.768	10.38	2.007	28.25
UDF	21.81	65	8.9	1.703	18.90	3.349	40.85	8.756	111.48
South Basin	2.73	85	7.4	0.527	7.05	0.825	10.93	1.660	21.29

The individual acreages for each CN value and the composite CN for each drainage area are provided in Attachment 1. The HydroCAD model schematic, modeling inputs, and results are provided in Attachment 2.

3. Hydrologic Routing and Design Point Analysis of Stormwater Management Areas

HydroCAD (Reference 10) is used to route the stormwater runoff hydrographs from the drainage areas presented in Table 2 through their respective stormwater management facilities or directly to their respective design points. See References 4 and 5 for details pertaining to the stormwater basins and SMAs, respectively.

Table 3 below summarizes the peak flow rates at the nine design points under both existing (from Reference 2) and proposed conditions to demonstrate compliance with MassDEP regulations regarding peak flow rates (Assumption 10).

Table 3: Comparison of Existing and Proposed Peak Flow Rates at Design Points

Design Point	2-yr, 24-hr (cfs)		10-yr, 24-hr (cfs)		100-yr, 24-hr (cfs)	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
1	0.00	0.00	11.07	11.04	159.64	125.68
2	0.00	0.00	0.00	0.00	7.86	7.16
3	0.03	0.00	0.35	0.00	3.59	0.33
4	0.63	0.62	2.12	1.79	7.60	5.94
5	0.00	0.00	0.43	0.00	9.25	0.00
6	0.02	0.00	0.33	0.00	5.43	1.26
7	0.11	0.00	1.48	0.52	18.26	14.12
8	1.56	1.19	2.83	2.25	6.58	5.41
9	5.51	2.72	14.88	4.26	17.43	24.71

As demonstrated in the above table, the proposed peak flow rates at each design point for the 2- and 10-year storms are less than or equal to existing conditions. The same is true for the 100-year storm, with the exception of Design Point 9. However, the receiver of flow from Design Point 9 is a quarry pond that is water-filled under ordinary conditions. Although the 100-year peak flow at Design Point 9 increases under proposed conditions, the flow volume for the same event is reduced. Because the flow volume is reduced and the receptor is a pond and not a conveyance feature, the proposed conditions at this design point do not create off-site flooding. Attachment 1 contains routing information and modelling results.

Summary

Proposed stormwater conditions to identified design points are evaluated. The proposed values are compared to those calculated separately for existing conditions. The comparison demonstrates that, under proposed conditions, the peak flow rates are equal to or less than the peak flow rates that currently exist for the 2- and 10-year storms. The analysis demonstrates that no off-site flooding will result due to proposed conditions.

Figures

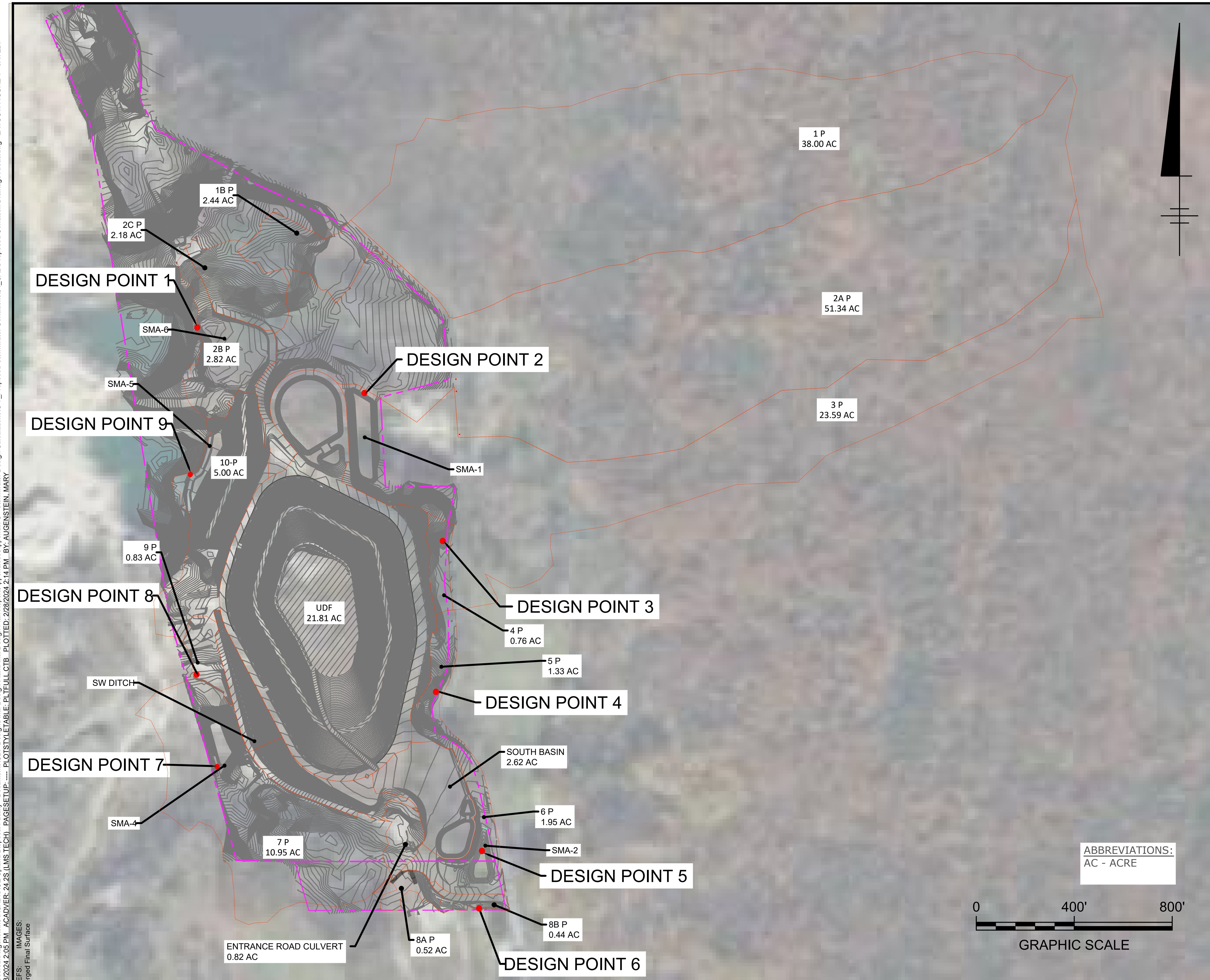
1. Proposed Drainage Areas
2. Proposed Hydrologic Conditions

Attachments

1. Proposed Curve Number Calculations
2. HydroCAD Proposed Condition Modelling Input and Results

Figure 1

Proposed Drainage Areas



LEGEND

- DESIGN POINT
- SUBCATCHMENT BOUNDARY
- PROPERTY LINE
- PROPOSED CONTOURS

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UPLAND DISPOSAL FACILITY
GE-PITTSBURGH/HOUSATONIC RIVER SITE

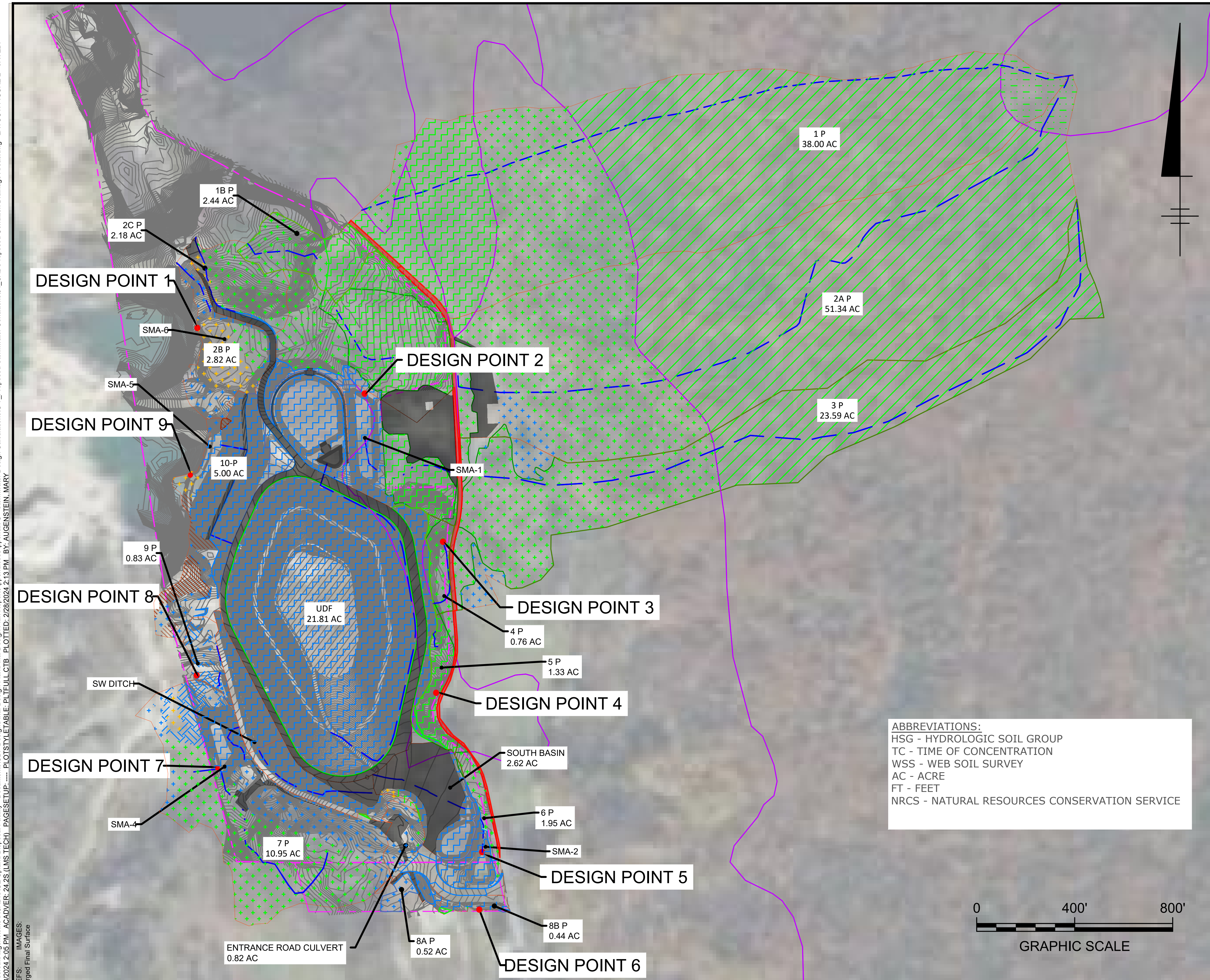
PROPOSED DRAINAGE AREAS

ARCADIS

FIGURE
1

Figure 2

Proposed Hydrologic Conditions



LEGEND

- WOODS, HSG A (GOOD CONDITION)
- WOODS, HSG B (GOOD CONDITION)
- WOODS, HSG C (GOOD CONDITION)
- WOODS, HSG D (GOOD CONDITION)
- PASTURE, HSG B (GOOD CONDITION)
- PASTURE, HSG A (FAIR CONDITION)
- PASTURE, HSG A (POOR CONDITION)
- BRUSH, HSG A/B (GOOD CONDITION)
- BARE SOIL, HSG A
- PAVED ROAD WITH DITCHES
- GRAVEL
- ROOFS
- DESIGN POINT
- SUBCATCHMENT BOUNDARY
- OPEN WATER
- TC PATH
- PROPERTY LINE
- NRCS WSS HSG BOUNDARY/LABEL[1]
- HSG LABEL

GENERAL ELECTRIC COMPANY
UPLAND DISPOSAL FACILITY
GE-PITTSBURGH/HOUSATONIC RIVER SITE

PROPOSED HYDROLOGIC CONDITIONS

ARCADIS

FIGURE
1

Attachment 1

Proposed Conditions Curve Number Calculations

Drainage Area	Area (sf)	Soil Type	Cover Type	Curve Number	Weighted CN	Total Area (ac)
1A-P	47371.12	C	Woods - Good Condition	70		
	952077.33	D	Woods - Good Condition	77		
	384265.73	A	Woods - Good Condition	30		
	272645.19	B	Woods - Good Condition	55	62	38.0
1B-P	4565.16	B	Streets and roads: Paved; open ditches (including right-of-way)	89		
	38101.04	B	Woods - Good Condition	55		
	63759.04	A	Woods - Good Condition	30		
					41	2.44
2A-P	23468.80	C	Woods - Good Condition	70		
	1195606.29	D	Woods - Good Condition	77		
	473577.88	A	Woods - Good Condition	30		
	4679.09	B	Woods - Good Condition	55		
	11103.07	B	Streets and roads: Paved; open ditches (including right-of-way)	89		
	32717.18	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	3604.42	A	Impervious areas: Paved parking lots, roofs, driveways (excluding right-of-way)	98		
	27209.83	A	Gravel w/o right of way	96		
	25695.99	A	Woods - Good Condition	30		
	621.98	B	Streets and roads: Paved; open ditches (including right-of-way)	89		
	20823.61	B	Gravel w/o right of way	96		
	970.34	B	Impervious areas: Paved parking lots, roofs, driveways (excluding right-of-way)	98		
	193719.59	B	Woods - Good Condition	55		
	35197.69	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	81293.34	A	Woods - Good Condition	30		
	10569.28	B	Gravel w/o right of way	96	62	49.15
2B-P	6490.82	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	20842.21	A	Woods - Good Condition	30		
	51527.28	A	Brush - Brush-weed-grass mixture with brush the major element - Good Condition	30		
	37002.87	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	2878.86	A	Gravel w/o right of way	96		
	3885.05	B	Gravel w/o right of way	96	41	2.82
2C-P	76854.70	A	Woods - Good Condition	30		
	6424.79	B	Gravel w/o right of way	96		
	4695.40	A	Gravel w/o right of way	96		
	5418.18	A	Brush - Brush-weed-grass mixture with brush the major element - Good Condition	30		
	1442.97	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61	38	2.18
3-P	417571.92	D	Woods - Good Condition	77		
	332372.05	A	Woods - Good Condition	30		

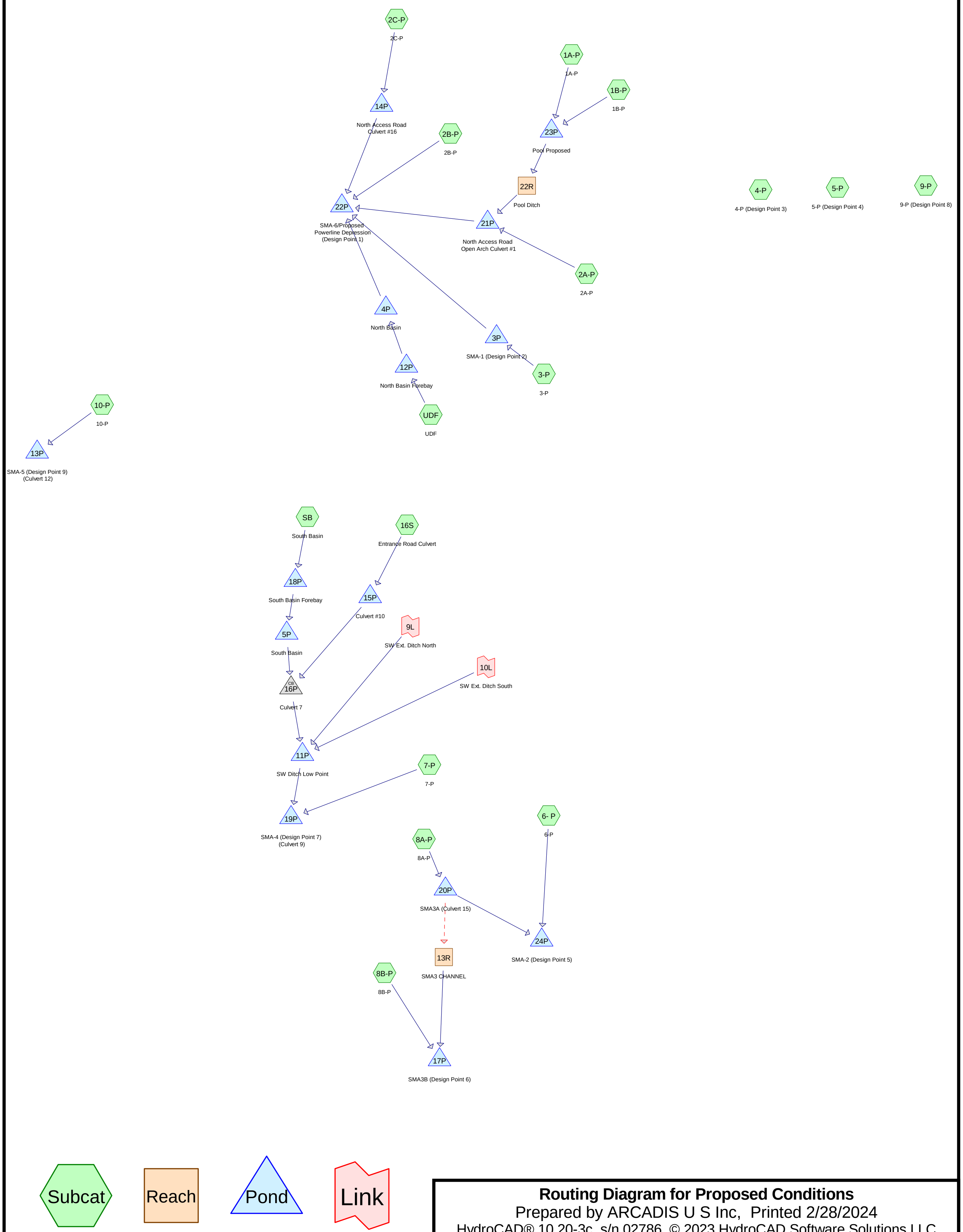
	1092.71	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	6475.34	A	Gravel w/o right of way	96		
	19178.36	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	21950.87	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	20417.87	A	Woods - Good Condition	30		
	5724.13	A	Woods - Good Condition	30		
	3502.90	B	Streets and roads: Paved; open ditches (including right-of-way)	89		
	10194.24	A	Streets and roads: Paved; open ditches (including right-of-way)	83		
	2526.54	A	Woods - Good Condition	30		
	54206.70	B	Gravel w/o right of way	96		
	59.61	B	Impervious areas: Paved parking lots, roofs, driveways (excluding right-of-way)	98		
	66477.90	B	Woods - Good Condition	55		
	65178.56	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61	58	23.59
	807.25	B	Gravel w/o right of way	96		
4-P	30311.31	A	Woods - Good Condition	30		
	2148.88	B	Woods - Good Condition	55		
	464.05	B	Woods - Good Condition	55	32	0.76
5-P	4723.92	A	Woods - Good Condition	30		
	3722.89	B	Streets and roads: Paved; open ditches (including right-of-way)	89		
	1528.85	A	Streets and roads: Paved; open ditches (including right-of-way)	83		
	41839.07	B	Woods - Good Condition	55		
	3778.62	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	2558.63	B	Gravel w/o right of way	96	58	1.33
6-P	1281.25	B	Woods - Good Condition	55		
	418.70	B	Streets and roads: Paved; open ditches (including right-of-way)	89		
	3185.50	A	Streets and roads: Paved; open ditches (including right-of-way)	83		
	24548.77	A	Woods - Good Condition	30		
	37678.29	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	17196.98	B	Gravel w/o right of way	96	64	1.95
	797.22	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	3483.13	B	Impervious areas: Paved parking lots, roofs, driveways (excluding right-of-way)	98		
7-P	192.00	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	1259.86	B	Gravel w/o right of way	96		
	0.00	A	Woods - Good Condition	30		
	0.00	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	10840.21	A	Gravel w/o right of way	96		
	1808.24	B	Gravel w/o right of way	96		
	91239.57	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	262205.16	A	Woods - Good Condition	30		
	4415.61	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	7158.15	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	40611.68	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	33152.41	A	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	68		

	11125.46	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	7758.52	A	Brush - Brush-weed-grass mixture with brush the major element - Good Condition	30		
	5209.44	A	Gravel w/o right of way	96	43	10.95
8A P	15964.09	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	2072.29	B	Gravel w/o right of way	96		
	1082.01	A	Gravel w/o right of way	96		
	3397.87	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61	57	0.52
8B P	2765.11	B	Impervious areas: Paved parking lots, roofs, driveways (excluding right-of-way)	98		
	6144.64	B	Gravel w/o right of way	96		
	8160.87	A	Pasture, grassland, or range - continous forage for grazing - Good Condition	39		
	1676.09	A	Woods - Good Condition	30		
	320.84	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	87.74	A	Gravel w/o right of way	96	65	0.44
9-P	4815.34	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	2075.89	B	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	79		
	1015.63	B	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	79		
	3975.48	A	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	68		
	6058.75	B	Gravel w/o right of way	96		
	6462.99	A	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	68		
	8019.93	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	3599.80	A	Gravel w/o right of way	96	71	0.83
10-P	686.38	A	Pasture, grassland, or range - continuous forage for grazing - Poor Condition	68		
	3024.03	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	2978.34	A	Fallow: Bare Soil	77		
	13343.11	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	4158.75	A	Gravel w/o right of way	96		
	20397.84	A	Fallow: Bare Soil	77		
	7523.25	B	Gravel w/o right of way	96		
	6910.75	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	3631.71	A	Gravel w/o right of way	96		
	7773.75	A	Fallow: Bare Soil	77		
	124481.01	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	9604.78	B	Gravel w/o right of way	96		
	7553.94	A	Brush - Brush-weed-grass mixture with brush the major element - Good Condition	30		
	5930.07	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49	65	5.00
South Basin	34544.11	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	574.52	A	Woods - Good Condition	30		
	80946.22	B	Gravel w/o right of way	96		
	1459.45	B	Woods - Good Condition	55		
	1331.36	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61	85	2.73

Southwest Exterior Ditch (South)	1157.91	B	Woods - Good Condition	55		
	1131.29	A	Brush - Brush-weed-grass mixture with brush the major element - Good Condition	30		
	3089.95	B	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	69		
	1305.72	A	Gravel w/o right of way	96		
	10331.13	B	Gravel w/o right of way	96		
	40867.13	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	14959.62	B	Gravel w/o right of way	96	74	1.67
Southwest Exterior Ditch (North)	44547.03	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61		
	10019.13	B	Gravel w/o right of way	96	67	1.25
UDF	107030.65	B	Gravel w/o right of way	96		
	842851.36	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61	65	21.81
Entrance Road Culvert	7987.25	A	Gravel w/o right of way	96		
	2196.65	B	Gravel w/o right of way	96		
	2812.78	A	Woods - Good Condition	30		
	22114.49	A	Pasture, grassland, or range - continuous forage for grazing - Fair Condition	49		
	732.16	B	Pasture, grassland, or range - continous forage for grazing - Good Condition	61	61	0.82

Attachment 2

HydroCAD Proposed Conditions Modelling Input and Results



Routing Diagram for Proposed Conditions

Prepared by ARCADIS U S Inc, Printed 2/28/2024

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Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	2-YR	Type III 24-hr		Default	24.00	1	3.84	2
2	100-YR	Type III 24-hr		Default	24.00	1	9.12	2

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
38.000	62	(1A-P)
2.820	41	(2B-P)
2.180	38	(2C-P)
0.520	57	(8A-P)
0.440	65	(8B-P)
0.820	61	(16S)
49.150	62	From CN Calc Spreadsheet (2A-P)
24.920	58	From CN Calc Spreadsheet (3-P, 5-P)
0.760	32	From CN Calc Spreadsheet (4-P)
1.950	64	From CN Calc Spreadsheet (6- P)
10.950	43	From CN Calc Spreadsheet (7-P)
0.830	71	From CN Calc Spreadsheet (9-P)
26.810	65	From CN Calc Spreadsheet (10-P, UDF)
2.730	85	From CN Calc Spreadsheet (SB)
2.440	41	From CN Spreadsheet (1B-P)
165.320	**60**	**TOTAL AREA**

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Width (inches)	Diam/Height (inches)	Inside-Fill (inches)	Node Name
1	UDF	0.00	0.00	91.0	0.0100	0.013	0.0	24.0	0.0	
2	11P	1,000.00	997.00	131.0	0.0229	0.013	0.0	18.0	0.0	
3	13P	952.50	949.60	40.0	0.0725	0.013	0.0	12.0	0.0	
4	14P	981.80	980.92	50.0	0.0176	0.012	0.0	12.0	0.0	
5	15P	1,032.10	1,030.40	170.0	0.0100	0.012	0.0	12.0	0.0	
6	16P	1,030.00	1,024.20	563.0	0.0103	0.012	0.0	12.0	0.0	
7	19P	987.50	987.10	30.0	0.0133	0.020	0.0	4.0	0.0	
8	20P	1,028.70	1,026.63	109.0	0.0190	0.013	0.0	8.0	0.0	
9	21P	984.65	982.17	49.0	0.0506	0.035	144.0	43.2	0.0	

Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1A-P: 1A-P Runoff Area=38.000 ac 0.00% Impervious Runoff Depth=0.78"
Flow Length=3,236' Tc=34.2 min CN=62 Runoff=15.29 cfs 2.475 af

Subcatchment 1B-P: 1B-P Runoff Area=2.440 ac 0.00% Impervious Runoff Depth=0.06"
Flow Length=329' Tc=15.1 min CN=41 Runoff=0.02 cfs 0.012 af

Subcatchment 2A-P: 2A-P Runoff Area=49.150 ac 0.00% Impervious Runoff Depth=0.78"
Flow Length=3,993' Tc=33.8 min CN=62 Runoff=19.86 cfs 3.201 af

Subcatchment 2B-P: 2B-P Runoff Area=2.820 ac 0.00% Impervious Runoff Depth=0.06"
Flow Length=248' Tc=6.8 min CN=41 Runoff=0.02 cfs 0.014 af

Subcatchment 2C-P: 2C-P Runoff Area=2.180 ac 0.00% Impervious Runoff Depth=0.02"
Flow Length=373' Tc=16.6 min CN=38 Runoff=0.01 cfs 0.004 af

Subcatchment 3-P: 3-P Runoff Area=23.590 ac 0.00% Impervious Runoff Depth=0.59"
Flow Length=3,460' Tc=32.8 min CN=58 Runoff=6.47 cfs 1.167 af

Subcatchment 4-P: 4-P (Design Point 3) Runoff Area=0.760 ac 0.00% Impervious Runoff Depth=0.00"
Flow Length=362' Tc=6.6 min CN=32 Runoff=0.00 cfs 0.000 af

Subcatchment 5-P: 5-P (Design Point 4) Runoff Area=1.330 ac 0.00% Impervious Runoff Depth=0.59"
Tc=6.7 min CN=58 Runoff=0.62 cfs 0.066 af

Subcatchment 6- P: 6-P Runoff Area=1.950 ac 0.00% Impervious Runoff Depth=0.88"
Flow Length=139' Tc=9.7 min CN=64 Runoff=1.52 cfs 0.144 af

Subcatchment 7-P: 7-P Runoff Area=10.950 ac 0.00% Impervious Runoff Depth=0.10"
Tc=11.8 min CN=43 Runoff=0.14 cfs 0.089 af

Subcatchment 8A-P: 8A-P Runoff Area=0.520 ac 0.00% Impervious Runoff Depth=0.55"
Tc=6.0 min CN=57 Runoff=0.22 cfs 0.024 af

Subcatchment 8B-P: 8B-P Runoff Area=0.440 ac 0.00% Impervious Runoff Depth=0.94"
Tc=6.0 min CN=65 Runoff=0.42 cfs 0.034 af

Subcatchment 9-P: 9-P (Design Point 8) Runoff Area=0.830 ac 0.00% Impervious Runoff Depth=1.29"
Tc=6.0 min CN=71 Runoff=1.19 cfs 0.089 af

Subcatchment 10-P: 10-P Runoff Area=5.000 ac 0.00% Impervious Runoff Depth=0.94"
Tc=6.0 min CN=65 Runoff=4.82 cfs 0.390 af

Subcatchment 16S: Entrance Road Culvert Runoff Area=0.820 ac 0.00% Impervious Runoff Depth=0.73"
Tc=6.0 min CN=61 Runoff=0.56 cfs 0.050 af

Subcatchment SB: South Basin Runoff Area=2.730 ac 0.00% Impervious Runoff Depth=2.32"
Flow Length=410' Tc=7.4 min CN=85 Runoff=7.05 cfs 0.527 af

Subcatchment UDF: UDF Runoff Area=21.810 ac 0.00% Impervious Runoff Depth=0.94"
Flow Length=1,810' Tc=8.9 min CN=65 Runoff=18.90 cfs 1.703 af

Reach 13R: SMA3 CHANNEL Avg. Flow Depth=0.00' Max Vel=0.00 fps Inflow=0.00 cfs 0.000 af
n=0.035 L=62.0' S=0.0605 '/' Capacity=1,271.47 cfs Outflow=0.00 cfs 0.000 af

Reach 22R: Pool Ditch Avg. Flow Depth=0.18' Max Vel=2.04 fps Inflow=8.48 cfs 1.849 af
n=0.035 L=202.1' S=0.0247 '/' Capacity=166.36 cfs Outflow=8.45 cfs 1.849 af

Pond 3P: SMA-1 (Design Point 2) Peak Elev=996.83' Storage=0.914 af Inflow=6.47 cfs 1.167 af
Discarded=0.26 cfs 1.167 af Primary=0.00 cfs 0.000 af Outflow=0.26 cfs 1.167 af

Pond 4P: North Basin Peak Elev=1,001.57' Storage=29,472 cf Inflow=7.92 cfs 1.203 af
Discarded=0.56 cfs 1.203 af Primary=0.00 cfs 0.000 af Outflow=0.56 cfs 1.203 af

Pond 5P: South Basin Peak Elev=1,030.11' Storage=12,757 cf Inflow=6.72 cfs 0.398 af
Discarded=0.11 cfs 0.398 af Primary=0.00 cfs 0.000 af Outflow=0.11 cfs 0.398 af

Pond 11P: SW Ditch Low Point Peak Elev=1,003.95' Storage=13,469 cf Inflow=4.44 cfs 0.365 af
Discarded=0.06 cfs 0.365 af Primary=0.00 cfs 0.000 af Outflow=0.06 cfs 0.365 af

Pond 12P: North Basin Forebay Peak Elev=1,004.81' Storage=23,872 cf Inflow=18.90 cfs 1.703 af
Outflow=7.92 cfs 1.203 af

Pond 13P: SMA-5 (Design Point 9) (Culvert Peak Elev=953.52' Storage=0.036 af Inflow=4.82 cfs 0.390 af
Discarded=0.04 cfs 0.008 af Primary=2.72 cfs 0.383 af Secondary=0.00 cfs 0.000 af Outflow=2.76 cfs 0.390 af

Pond 14P: North Access Road Culvert #16 Peak Elev=982.00' Storage=0.000 af Inflow=0.01 cfs 0.004 af
Discarded=0.00 cfs 0.000 af Primary=0.01 cfs 0.004 af Outflow=0.01 cfs 0.004 af

Pond 15P: Culvert #10 Peak Elev=1,032.48' Storage=0.002 af Inflow=0.56 cfs 0.050 af
12.0" Round Culvert n=0.012 L=170.0' S=0.0100 '/' Outflow=0.50 cfs 0.050 af

Pond 16P: Culvert 7 Peak Elev=1,030.40' Inflow=0.50 cfs 0.050 af
12.0" Round Culvert n=0.012 L=563.0' S=0.0103 '/' Outflow=0.50 cfs 0.050 af

Pond 17P: SMA3B (Design Point 6) Peak Elev=1,023.78' Storage=0.021 af Inflow=0.42 cfs 0.034 af
Discarded=0.02 cfs 0.034 af Primary=0.00 cfs 0.000 af Outflow=0.02 cfs 0.034 af

Pond 18P: South Basin Forebay Peak Elev=1,033.11' Storage=0.146 af Inflow=7.05 cfs 0.527 af
Outflow=6.72 cfs 0.398 af

Pond 19P: SMA-4 (Design Point 7) (Culvert 9) Peak Elev=987.14' Storage=0.026 af Inflow=0.14 cfs 0.089 af
Discarded=0.07 cfs 0.089 af Primary=0.00 cfs 0.000 af Secondary=0.00 cfs 0.000 af Outflow=0.07 cfs 0.089 af

Pond 20P: SMA3A (Culvert 15) Peak Elev=1,028.87' Storage=0.001 af Inflow=0.22 cfs 0.024 af
Discarded=0.00 cfs 0.002 af Primary=0.20 cfs 0.022 af Secondary=0.00 cfs 0.000 af Outflow=0.20 cfs 0.024 af

Pond 21P: North Access Road Open Arch Peak Elev=985.35' Storage=139 cf Inflow=19.86 cfs 5.050 af
Discarded=0.01 cfs 0.001 af Primary=19.86 cfs 5.049 af Outflow=19.86 cfs 5.050 af

Pond 22P: SMA-6/Proposed Powerline Peak Elev=984.26' Storage=4.455 af Inflow=19.86 cfs 5.066 af
Discarded=0.65 cfs 5.066 af Primary=0.00 cfs 0.000 af Outflow=0.65 cfs 5.066 af

Pond 23P: Pool Proposed Peak Elev=992.62' Storage=0.933 af Inflow=15.29 cfs 2.487 af
Outflow=8.48 cfs 1.849 af

Pond 24P: SMA-2 (Design Point 5) Peak Elev=1,022.82' Storage=0.110 af Inflow=1.72 cfs 0.166 af
Outflow=0.06 cfs 0.166 af

Link - Stormwater Design Calculations\G-3_Channel Design\UDF Channels and Culverts~Reach 7R.hce Inflow=1.29 cfs 0.109 af
Area= 1.250 ac Primary=1.29 cfs 0.109 af

Link - Stormwater Design Calculations\G-3_Channel Design\UDF Channels and Culverts~Reach 8R.hce Inflow=2.65 cfs 0.206 af
Area= 1.670 ac Primary=2.65 cfs 0.206 af

Total Runoff Area = 165.320 ac Runoff Volume = 9.990 af Average Runoff Depth = 0.73"
100.00% Pervious = 165.320 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 1A-P: 1A-P

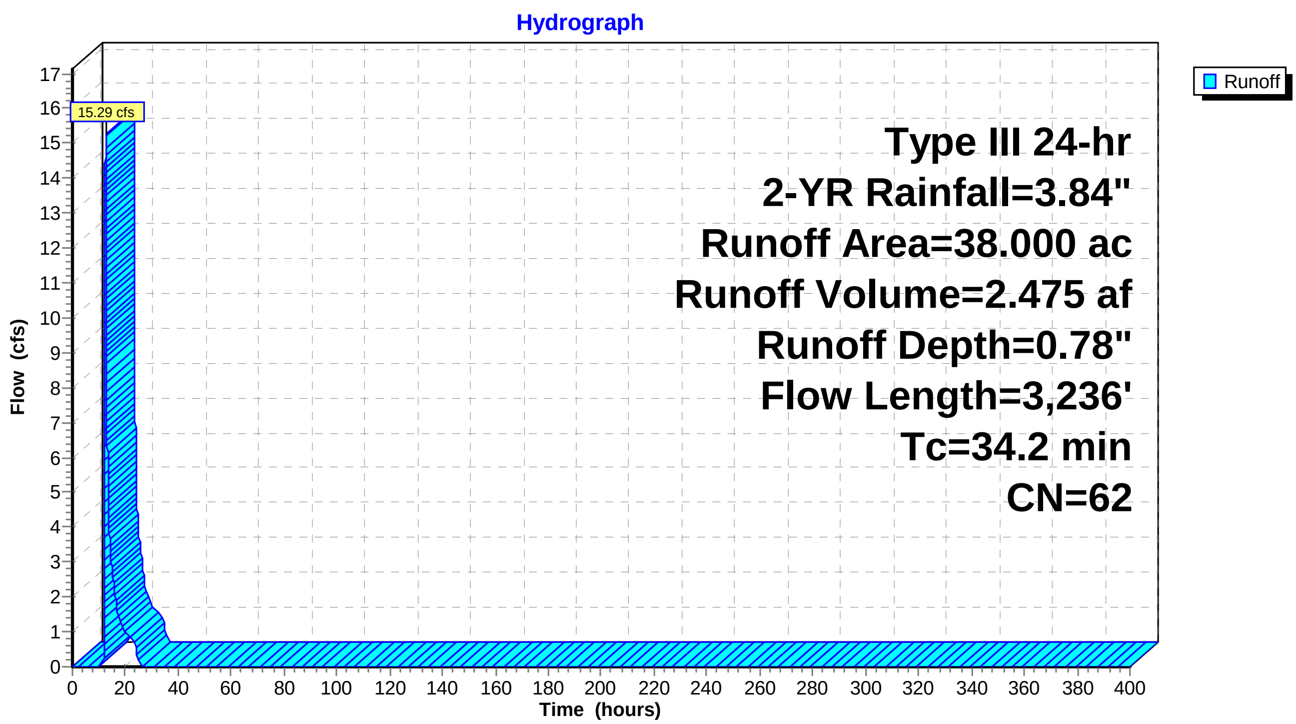
Runoff = 15.29 cfs @ 12.57 hrs, Volume= 2.475 af, Depth= 0.78"
Routed to Pond 23P : Pool Proposed

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	38.000	62	
	38.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	50	0.0400	0.06		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.7	228	0.0790	1.41		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
7.9	1,488	0.3970	3.15		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
8.1	1,050	0.1850	2.15		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.6	420	0.0570	10.83	64.98	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
34.2	3,236	Total			

Subcatchment 1A-P: 1A-P



Summary for Subcatchment 1B-P: 1B-P

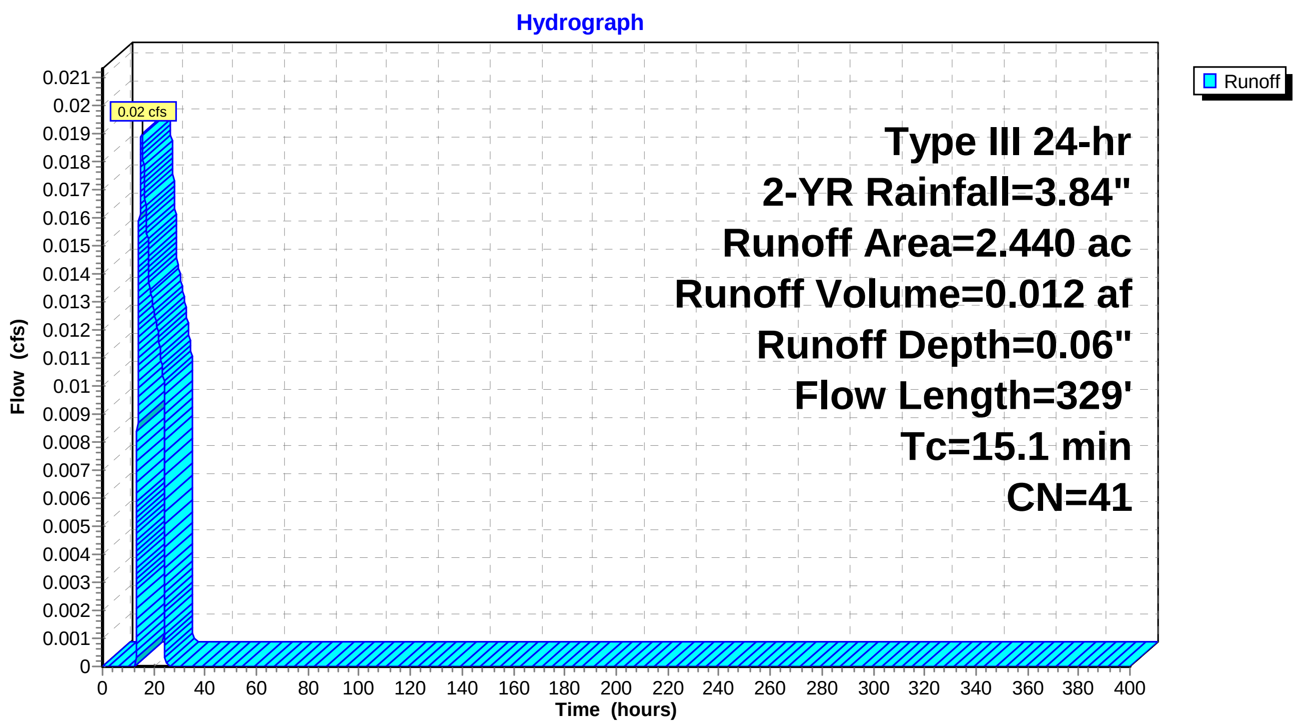
Runoff = 0.02 cfs @ 15.35 hrs, Volume= 0.012 af, Depth= 0.06"
Routed to Pond 23P : Pool Proposed

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	2.440	41	From CN Spreadsheet
	2.440		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.6	50	0.0750	0.07		**Sheet Flow, Sheet** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.9	159	0.0330	0.91		**Shallow Concentrated Flow, SCF-1** Woodland Kv= 5.0 fps
0.1	58	0.1720	18.81	112.88	**Channel Flow, CF-1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.5	62	0.1510	1.94		**Shallow Concentrated Flow, SCF-2** Woodland Kv= 5.0 fps
15.1	329	Total			

Subcatchment 1B-P: 1B-P



Summary for Subcatchment 2A-P: 2A-P

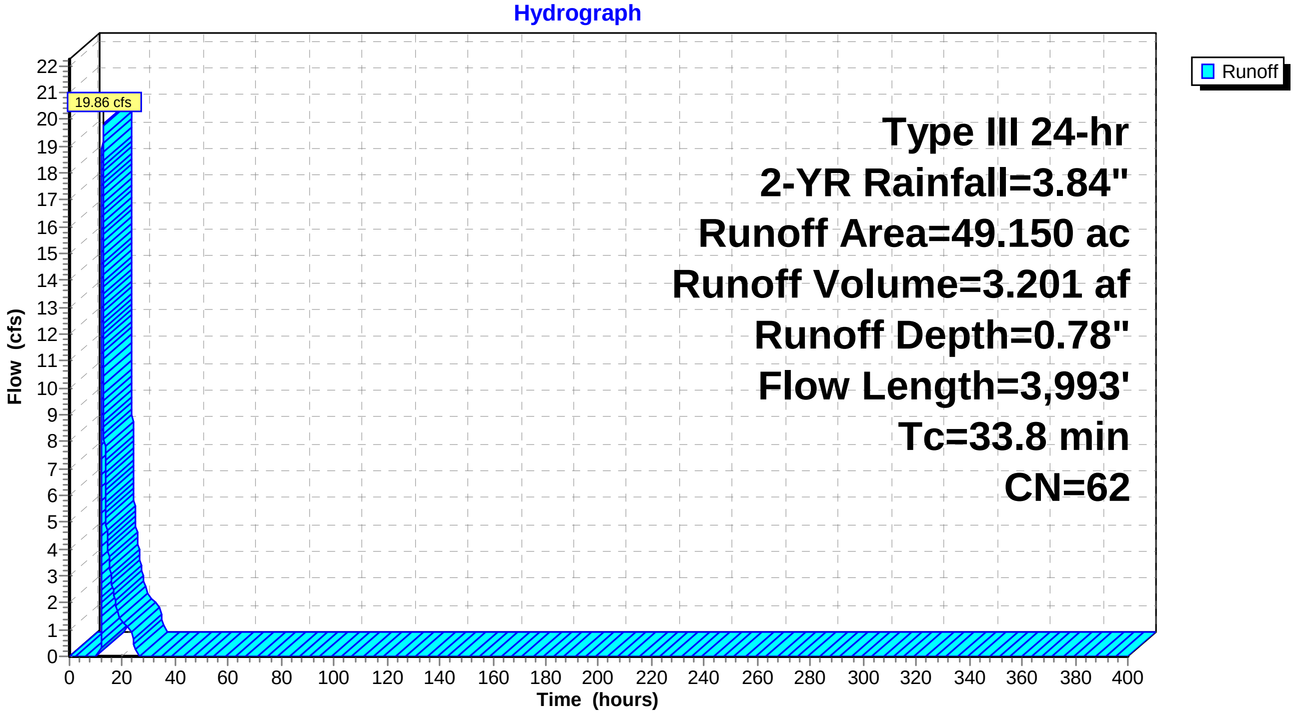
Runoff = 19.86 cfs @ 12.57 hrs, Volume= 3.201 af, Depth= 0.78"
Routed to Pond 21P : North Access Road Open Arch Culvert #1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	49.150	62	From CN Calc Spreadsheet
	49.150		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	50	0.0400	0.06		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.3	207	0.0870	1.47		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
2.4	337	0.2140	2.31		**Shallow Concentrated Flow, SCF2** Woodland Kv= 5.0 fps
2.2	464	0.4830	3.47		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.4	592	0.2570	23.00	137.98	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
1.1	1,448	0.2280	21.66	129.96	**Channel Flow, CF 2** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.1	72	0.0320	8.11	48.69	**Channel Flow, CF 5** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.2	138	0.0480	9.94	59.63	**Channel Flow, CF 3** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.2	148	0.0480	9.94	59.63	**Channel Flow, CF 4** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
10.0	537	0.0320	0.89		**Shallow Concentrated Flow, SCF-4** Woodland Kv= 5.0 fps
33.8	3,993	Total			

Subcatchment 2A-P: 2A-P



Summary for Subcatchment 2B-P: 2B-P

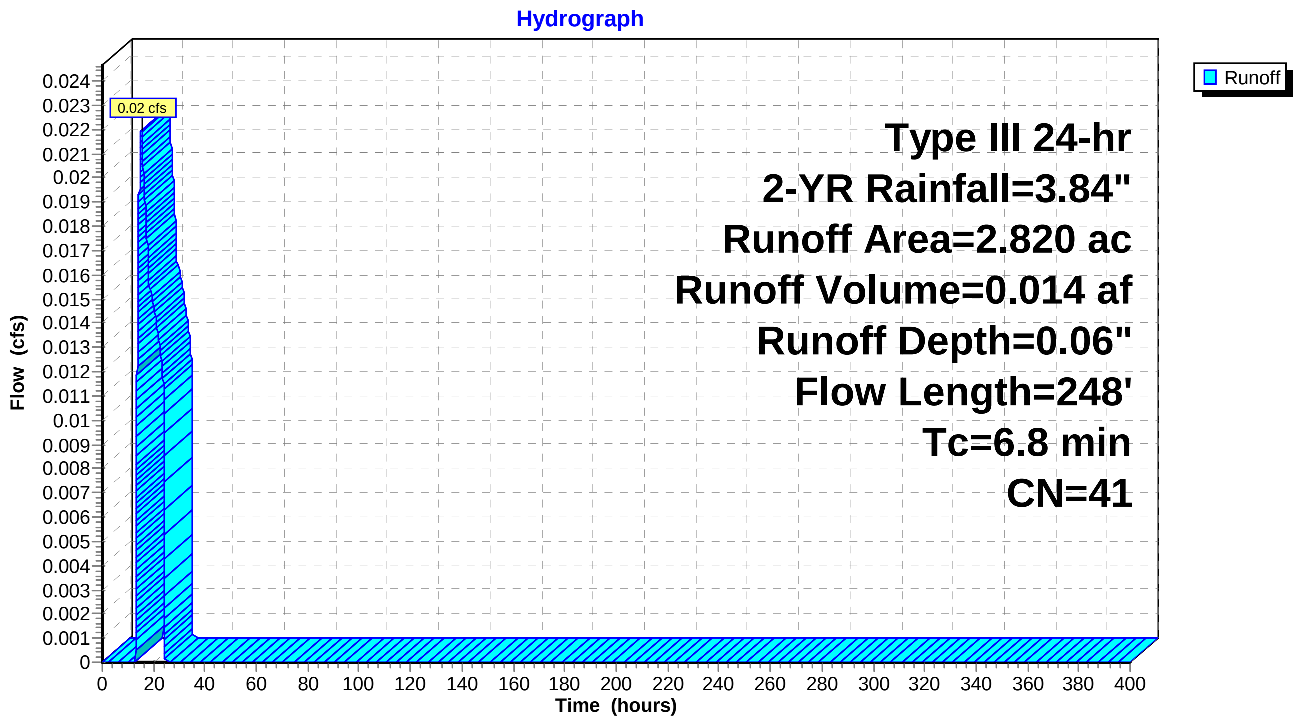
Runoff = 0.02 cfs @ 15.21 hrs, Volume= 0.014 af, Depth= 0.06"
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	2.820	41	
	2.820		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	50	0.1410	0.16		**Sheet Flow, SHEET FLOW** Woods: Light underbrush n= 0.400 P2= 3.84"
1.6	198	0.1720	2.07		**Shallow Concentrated Flow, SCF-1** Woodland Kv= 5.0 fps
6.8	248	Total			

Subcatchment 2B-P: 2B-P



Summary for Subcatchment 2C-P: 2C-P

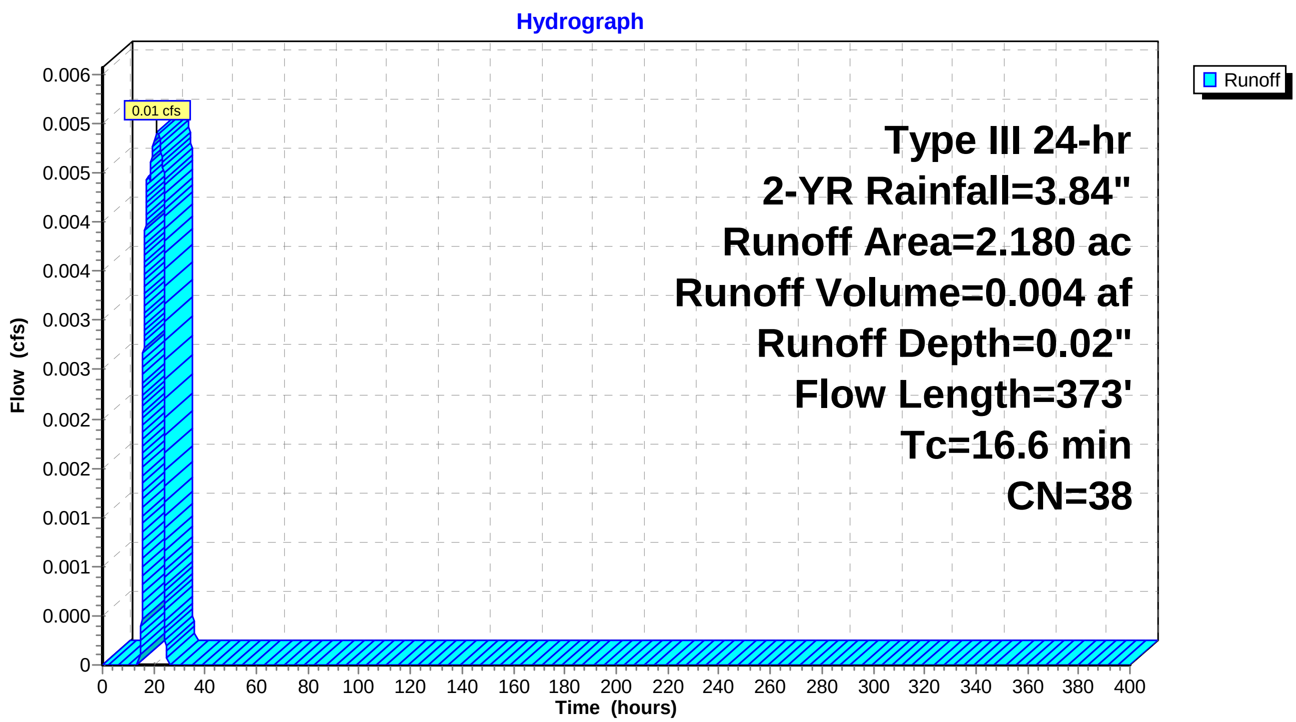
Runoff = 0.01 cfs @ 21.23 hrs, Volume= 0.004 af, Depth= 0.02"
Routed to Pond 14P : North Access Road Culvert #16

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	2.180	38	
	2.180		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.6	50	0.0420	0.06		**Sheet Flow, SHEET FLOW** Woods: Dense underbrush n= 0.800 P2= 3.84"
1.8	225	0.1660	2.04		**Shallow Concentrated Flow, SCF1** Woodland Kv= 5.0 fps
0.2	98	0.0520	10.34	62.06	**Channel Flow, CF1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
16.6	373	Total			

Subcatchment 2C-P: 2C-P



Summary for Subcatchment 3-P: 3-P

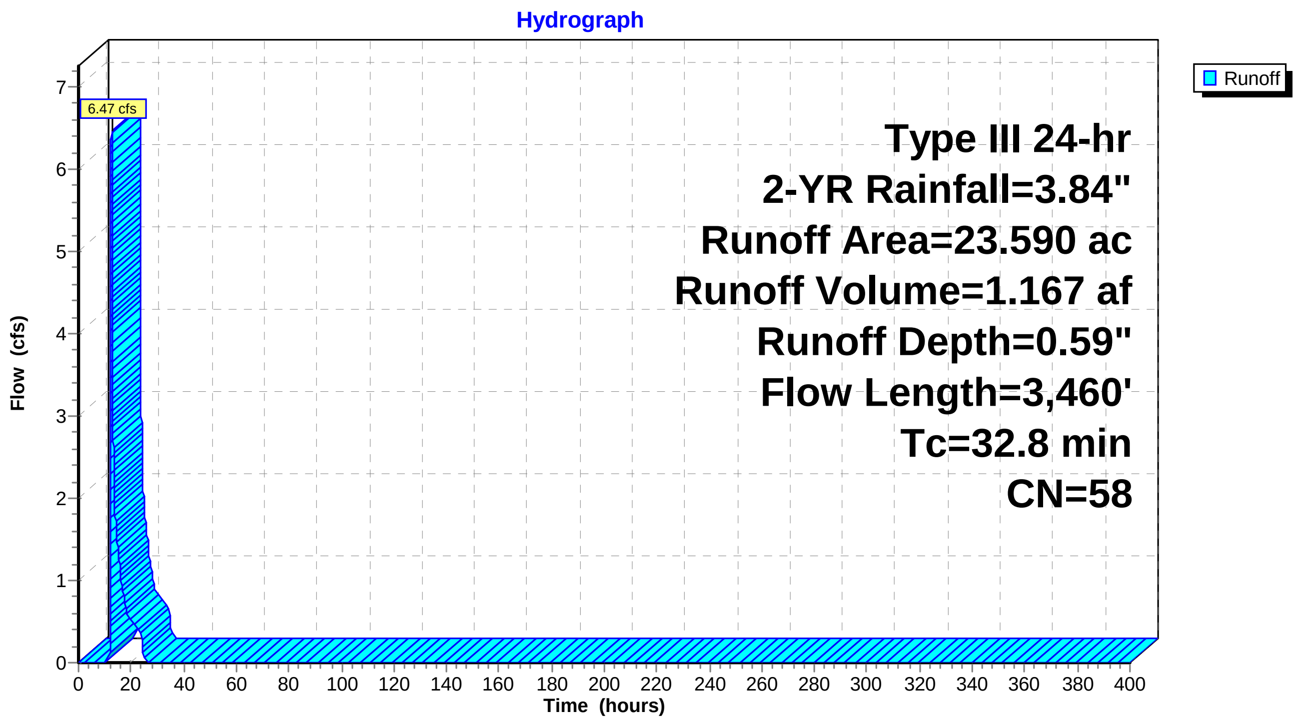
Runoff = 6.47 cfs @ 12.58 hrs, Volume= 1.167 af, Depth= 0.59"
Routed to Pond 3P : SMA-1 (Design Point 2)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	23.590	58	From CN Calc Spreadsheet
	23.590		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.6	50	0.1200	0.09		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.84"
5.9	657	0.1390	1.86		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
6.7	1,207	0.3630	3.01		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
10.1	1,240	0.1690	2.06		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
0.5	306	0.0590	11.02	66.11	**Channel Flow,** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
32.8	3,460	Total			

Subcatchment 3-P: 3-P



Summary for Subcatchment 4-P: 4-P (Design Point 3)

[45] Hint: Runoff=Zero

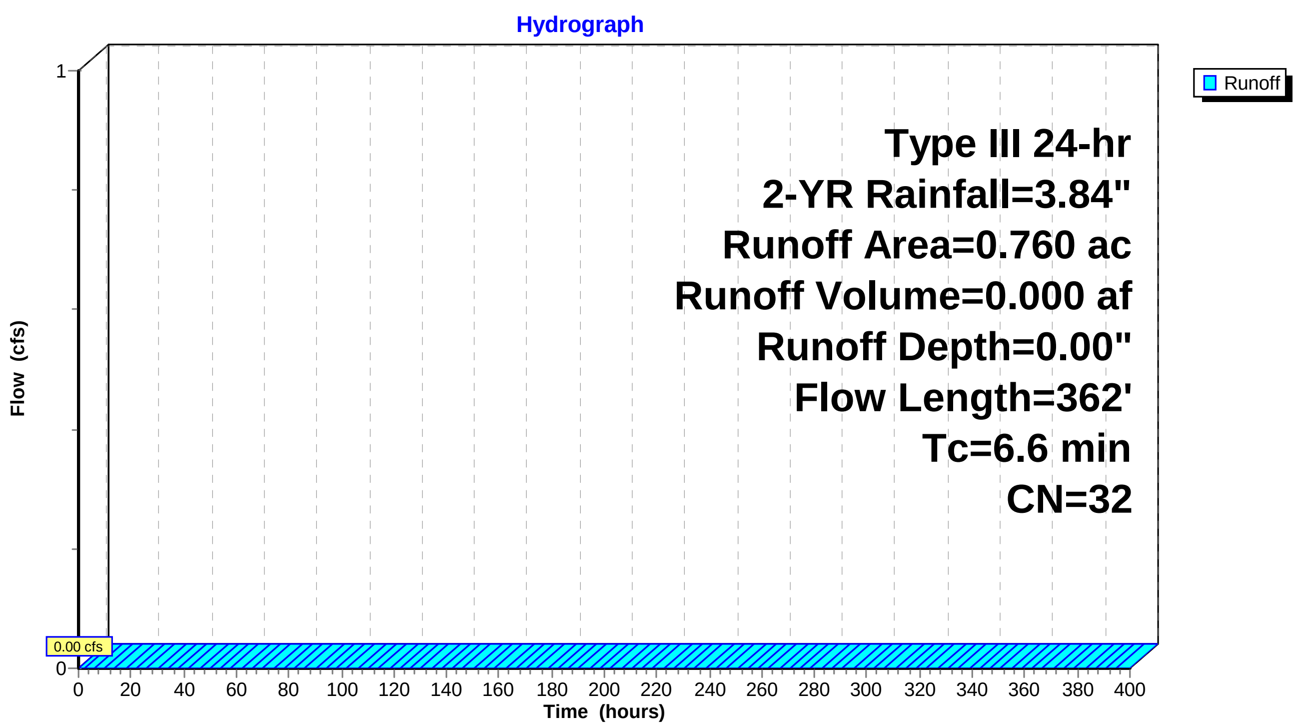
Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	0.760	32	From CN Calc Spreadsheet
	0.760		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.9	50	0.1600	0.17		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.84"
1.3	126	0.1110	1.67		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
0.4	186	0.0320	8.11	48.69	**Channel Flow,** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
6.6	362	Total			

Subcatchment 4-P: 4-P (Design Point 3)



Summary for Subcatchment 5-P: 5-P (Design Point 4)

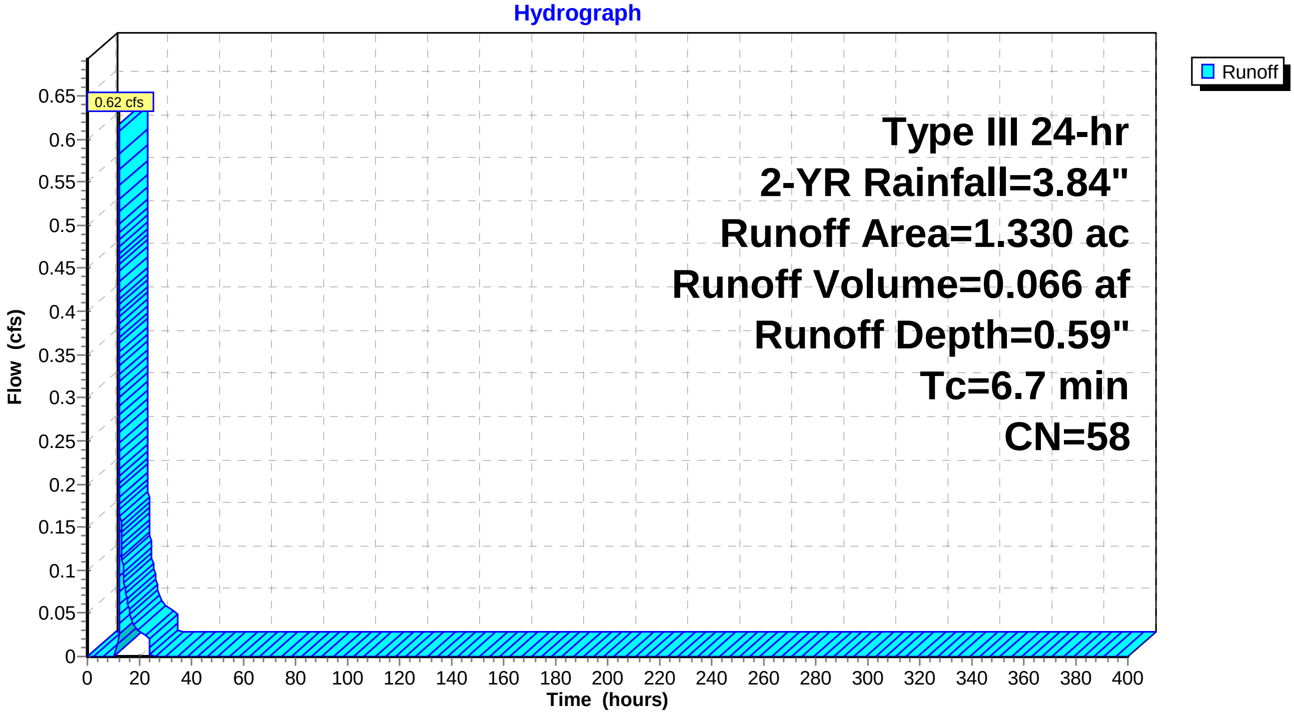
Runoff = 0.62 cfs @ 12.13 hrs, Volume= 0.066 af, Depth= 0.59"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	1.330	58	From CN Calc Spreadsheet
	1.330		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7					**Direct Entry, From Existing Conditions**

Subcatchment 5-P: 5-P (Design Point 4)



Summary for Subcatchment 6- P: 6-P

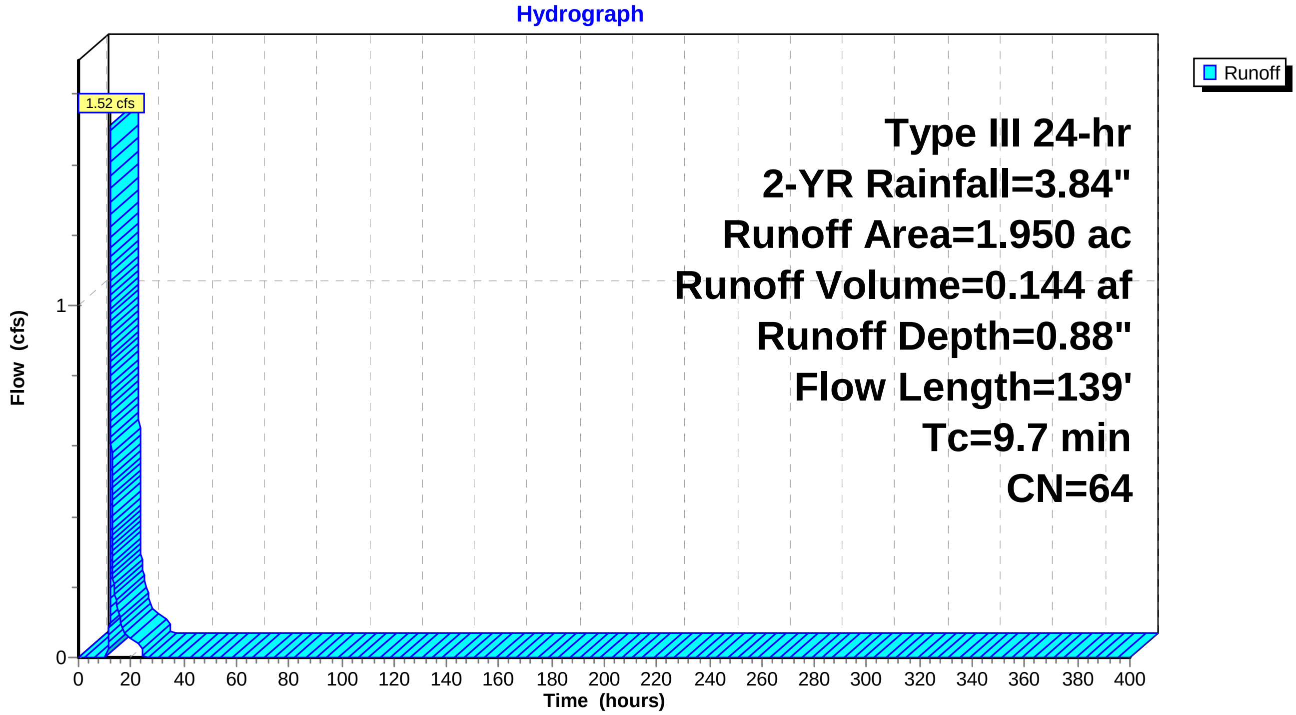
Runoff = 1.52 cfs @ 12.15 hrs, Volume= 0.144 af, Depth= 0.88"
Routed to Pond 24P : SMA-2 (Design Point 5)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	1.950	64	From CN Calc Spreadsheet
	1.950		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.7	50	0.0400	0.15		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.84"
4.0	89	0.0028	0.37		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
9.7	139	Total			

Subcatchment 6- P: 6-P



Summary for Subcatchment 7-P: 7-P

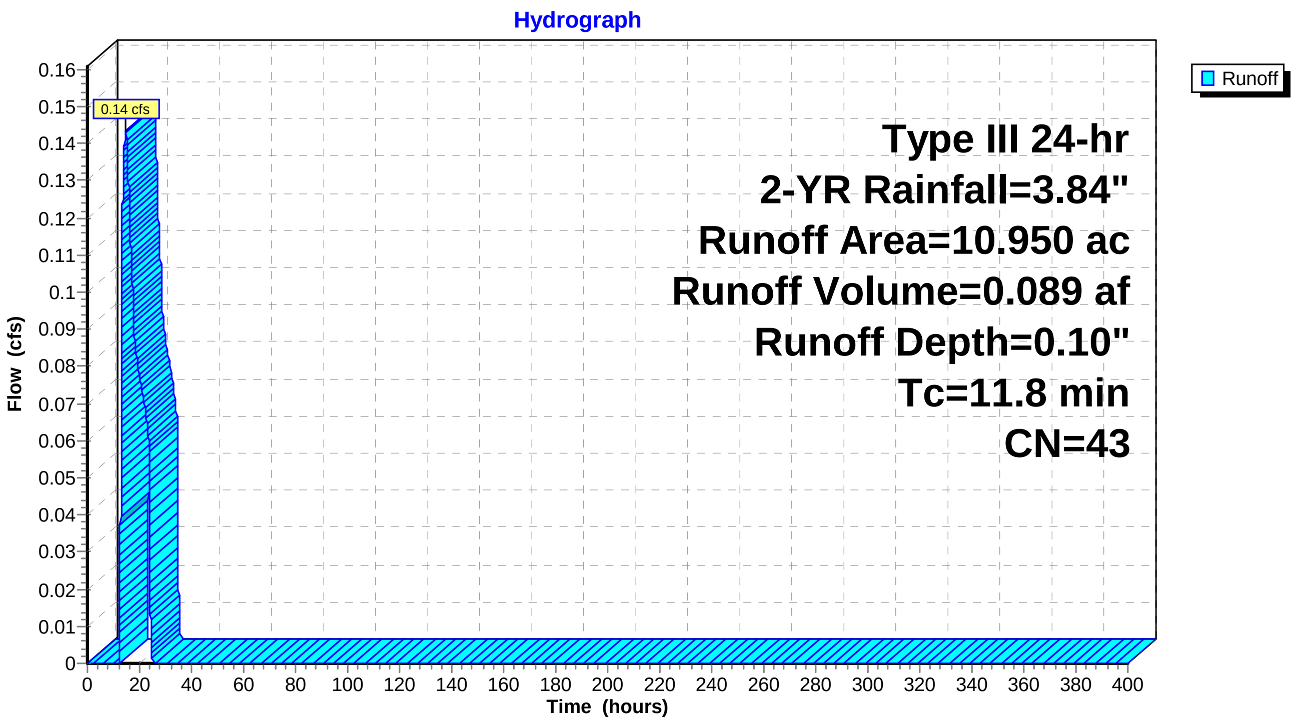
Runoff = 0.14 cfs @ 14.75 hrs, Volume= 0.089 af, Depth= 0.10"
Routed to Pond 19P : SMA-4 (Design Point 7) (Culvert 9)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	10.950	43	From CN Calc Spreadsheet
	10.950		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.8					**Direct Entry, from existing conditions**

Subcatchment 7-P: 7-P



Summary for Subcatchment 8A-P: 8A-P

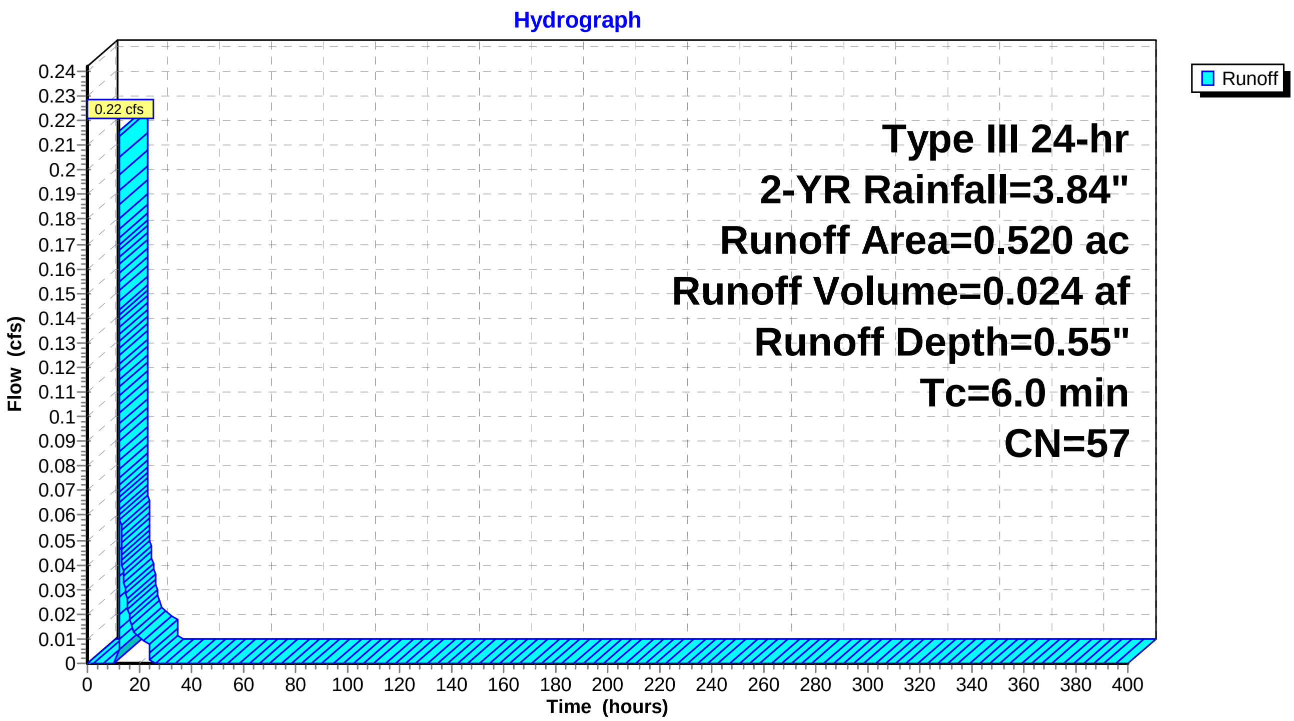
Runoff = 0.22 cfs @ 12.12 hrs, Volume= 0.024 af, Depth= 0.55"
Routed to Pond 20P : SMA3A (Culvert 15)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	0.520	57	
	0.520		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment 8A-P: 8A-P



Summary for Subcatchment 8B-P: 8B-P

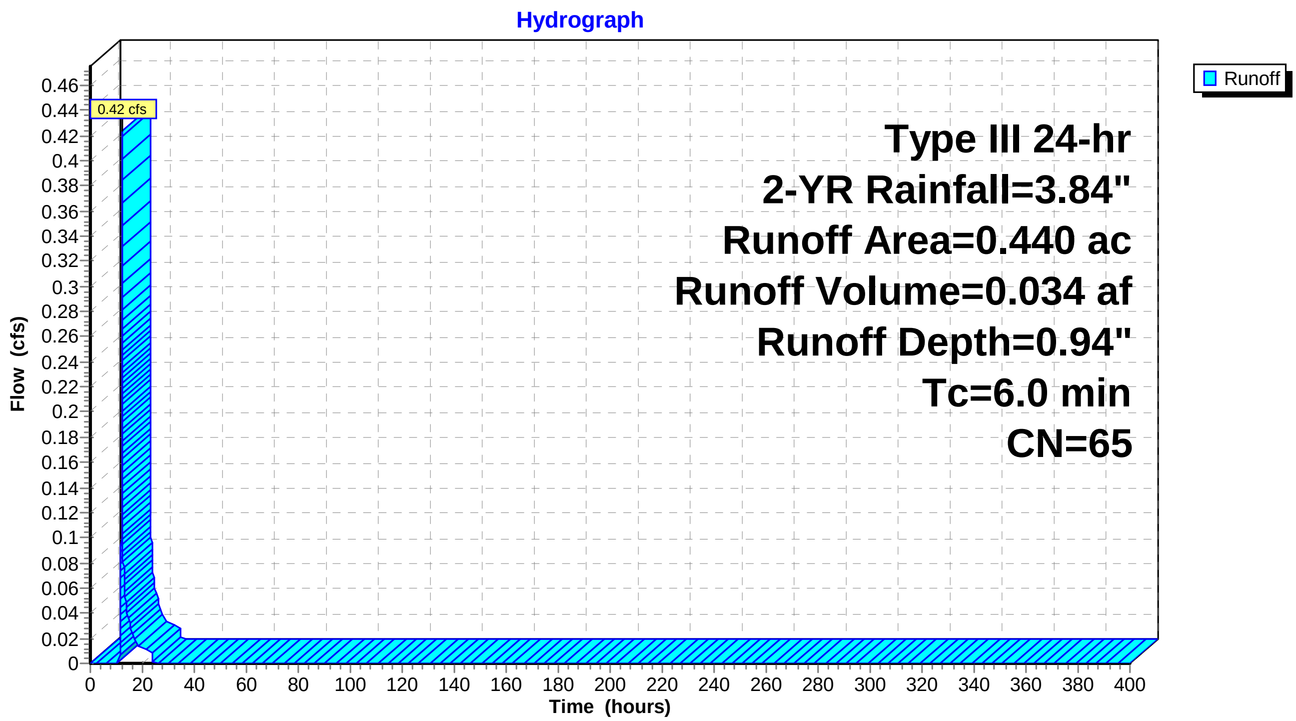
Runoff = 0.42 cfs @ 12.10 hrs, Volume= 0.034 af, Depth= 0.94"
Routed to Pond 17P : SMA3B (Design Point 6)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	0.440	65	
	0.440		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, TR55 MIN**

Subcatchment 8B-P: 8B-P



Summary for Subcatchment 9-P: 9-P (Design Point 8)

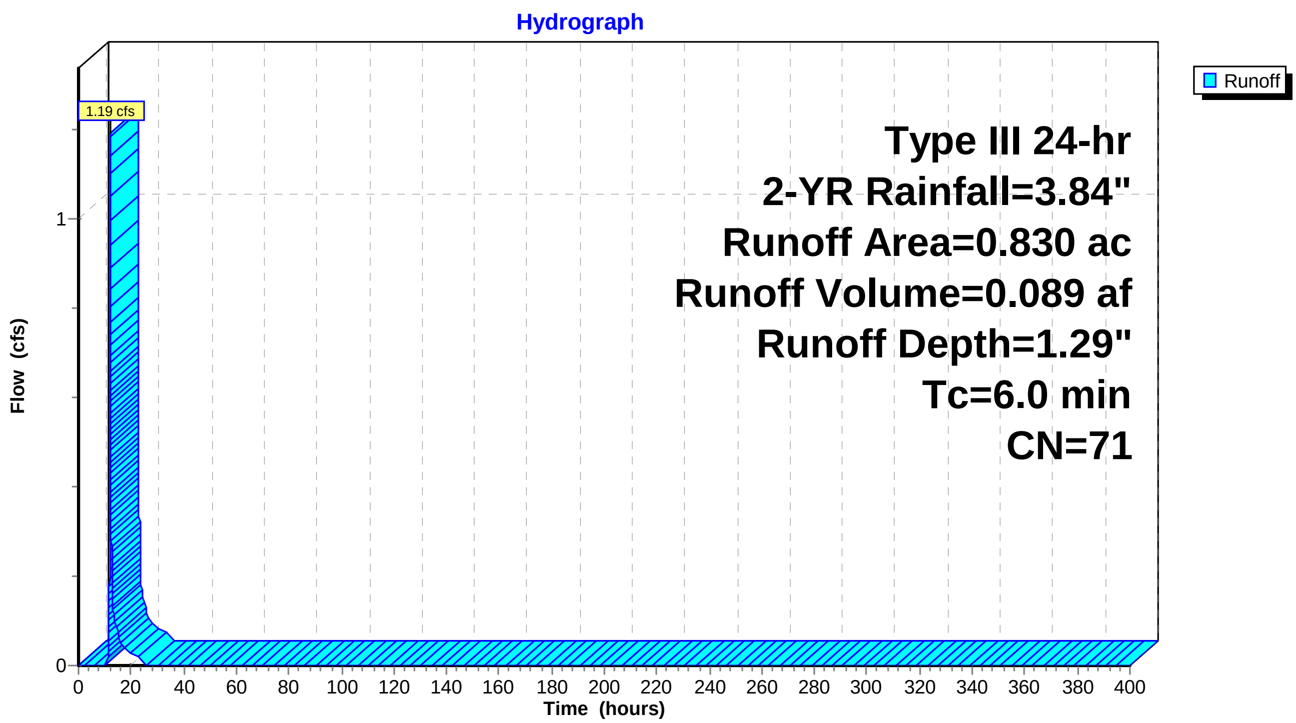
Runoff = 1.19 cfs @ 12.10 hrs, Volume= 0.089 af, Depth= 1.29"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	0.830	71	From CN Calc Spreadsheet
	0.830		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, From Existing Conditions**

Subcatchment 9-P: 9-P (Design Point 8)



Summary for Subcatchment 10-P: 10-P

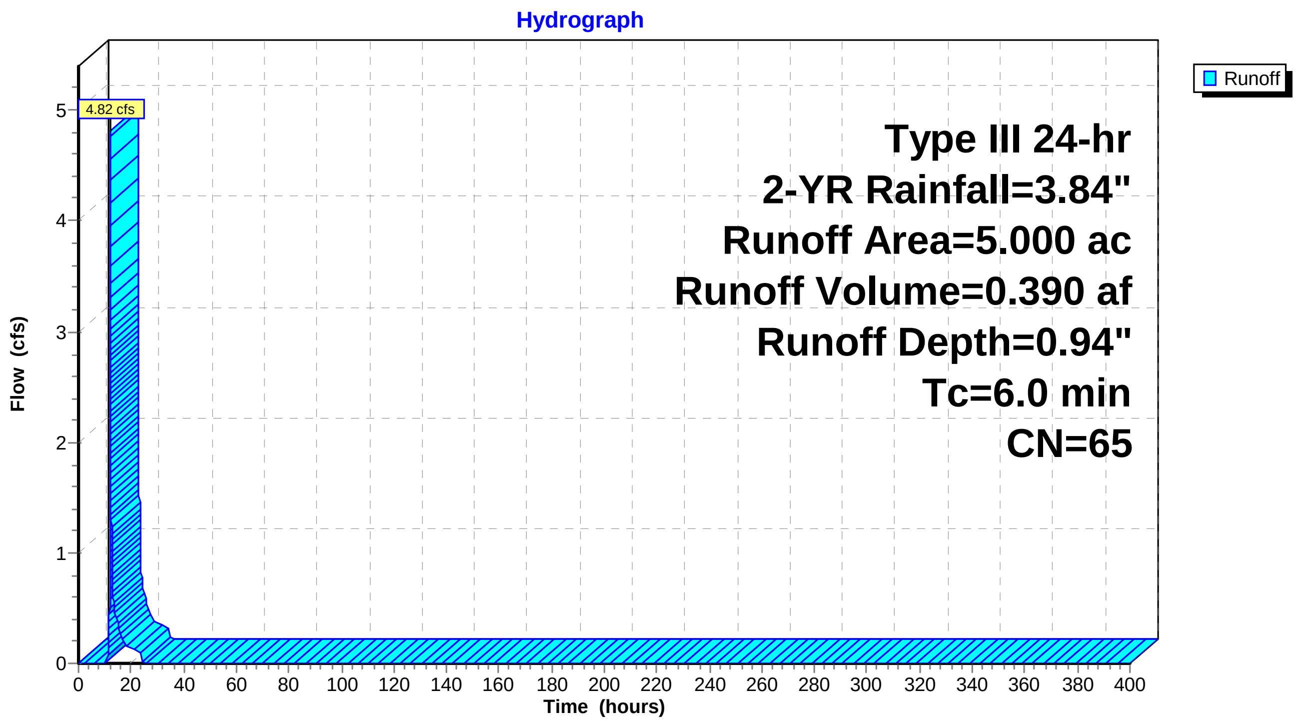
Runoff = 4.82 cfs @ 12.10 hrs, Volume= 0.390 af, Depth= 0.94"
Routed to Pond 13P : SMA-5 (Design Point 9) (Culvert 12)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	5.000	65	From CN Calc Spreadsheet
	5.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, TR55 Min**

Subcatchment 10-P: 10-P



Summary for Subcatchment 16S: Entrance Road Culvert

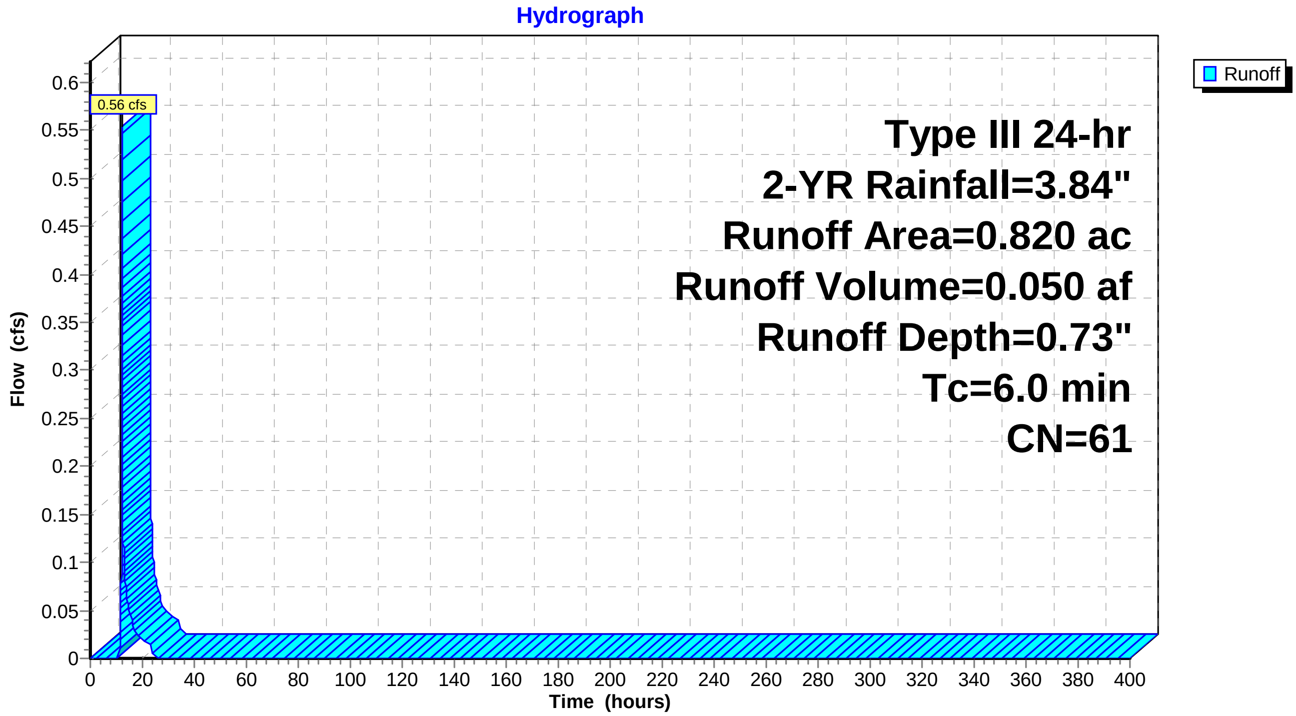
Runoff = 0.56 cfs @ 12.11 hrs, Volume= 0.050 af, Depth= 0.73"
Routed to Pond 15P : Culvert #10

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	0.820	61	
	0.820		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, TR55 MIN**

Subcatchment 16S: Entrance Road Culvert



Summary for Subcatchment SB: South Basin

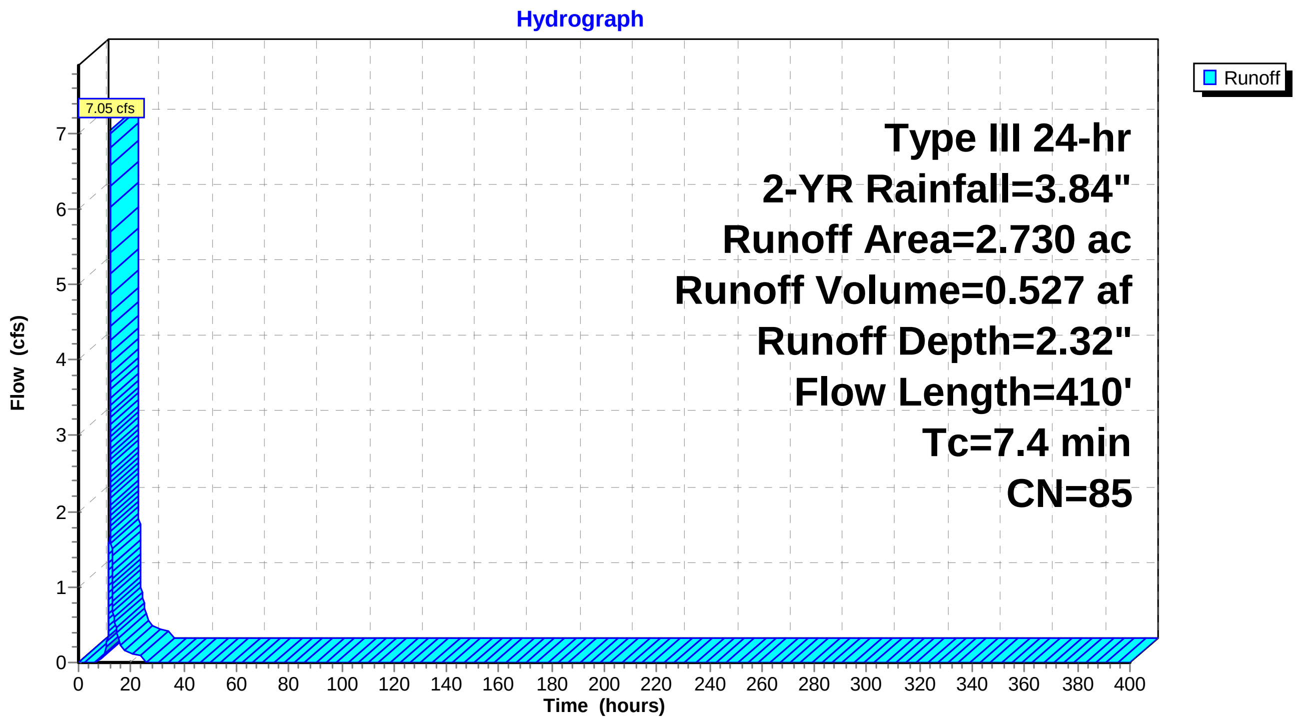
Runoff = 7.05 cfs @ 12.11 hrs, Volume= 0.527 af, Depth= 2.32"
Routed to Pond 18P : South Basin Forebay

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	2.730	85	From CN Calc Spreadsheet
	2.730		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.3	50	0.0310	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.84"
3.1	360	0.0141	1.91		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
7.4	410	Total			

Subcatchment SB: South Basin



Summary for Subcatchment UDF: UDF

A soils

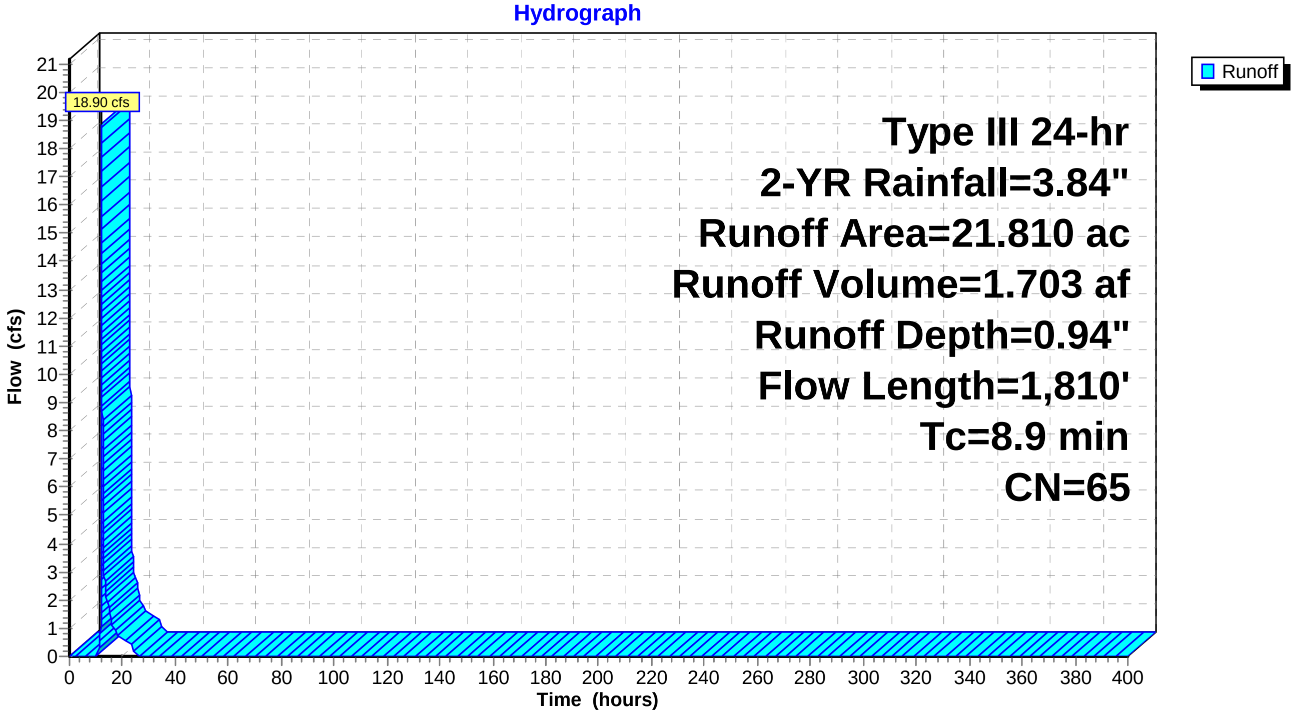
Runoff = 18.90 cfs @ 12.14 hrs, Volume= 1.703 af, Depth= 0.94"
Routed to Pond 12P : North Basin Forebay

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-YR Rainfall=3.84"

	Area (ac)	CN	Description
*	21.810	65	From CN Calc Spreadsheet
	21.810		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.1	50	0.0900	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.84"
0.9	152	0.1500	2.71		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.6	1,365	0.2280	14.39	43.16	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.00' Z= 3.0 '/' Top.W=6.00' n= 0.030 Earth, grassed & winding
2.1	152	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	91	0.0100	7.20	22.62	**Pipe Channel,** 24.0" Round Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Corrugated PE, smooth interior
8.9	1,810	Total			

Subcatchment UDF: UDF



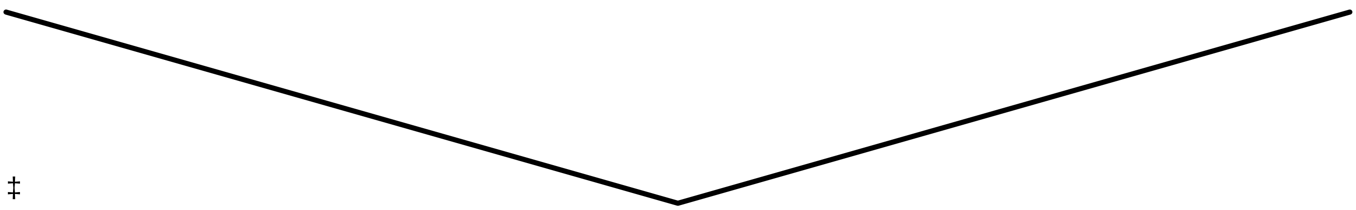
Summary for Reach 13R: SMA3 CHANNEL

Inflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 17P : SMA3B (Design Point 6)

Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Max. Velocity= 0.00 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 0.00 fps, Avg. Travel Time= 0.0 min

Peak Storage= 0 cf @ 0.00 hrs
Average Depth at Peak Storage= 0.00'
Bank-Full Depth= 3.04' Flow Area= 92.4 sf, Capacity= 1,271.47 cfs

0.00' x 3.04' deep channel, n= 0.035 Earth, dense weeds
Side Slope Z-value= 10.0 '/' Top Width= 60.80'
Length= 62.0' Slope= 0.0605 '/'
Inlet Invert= 1,028.55', Outlet Invert= 1,024.80'



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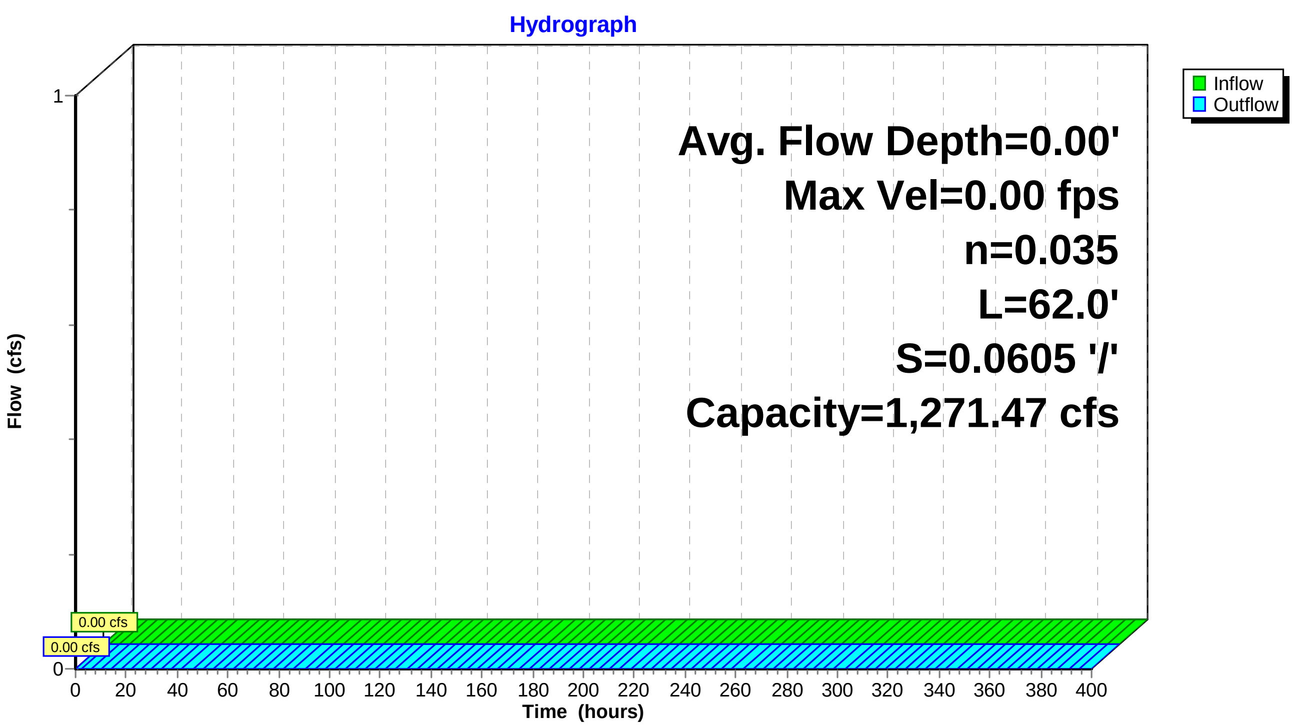
Reach 13R: SMA3 CHANNEL



Summary for Reach 22R: Pool Ditch

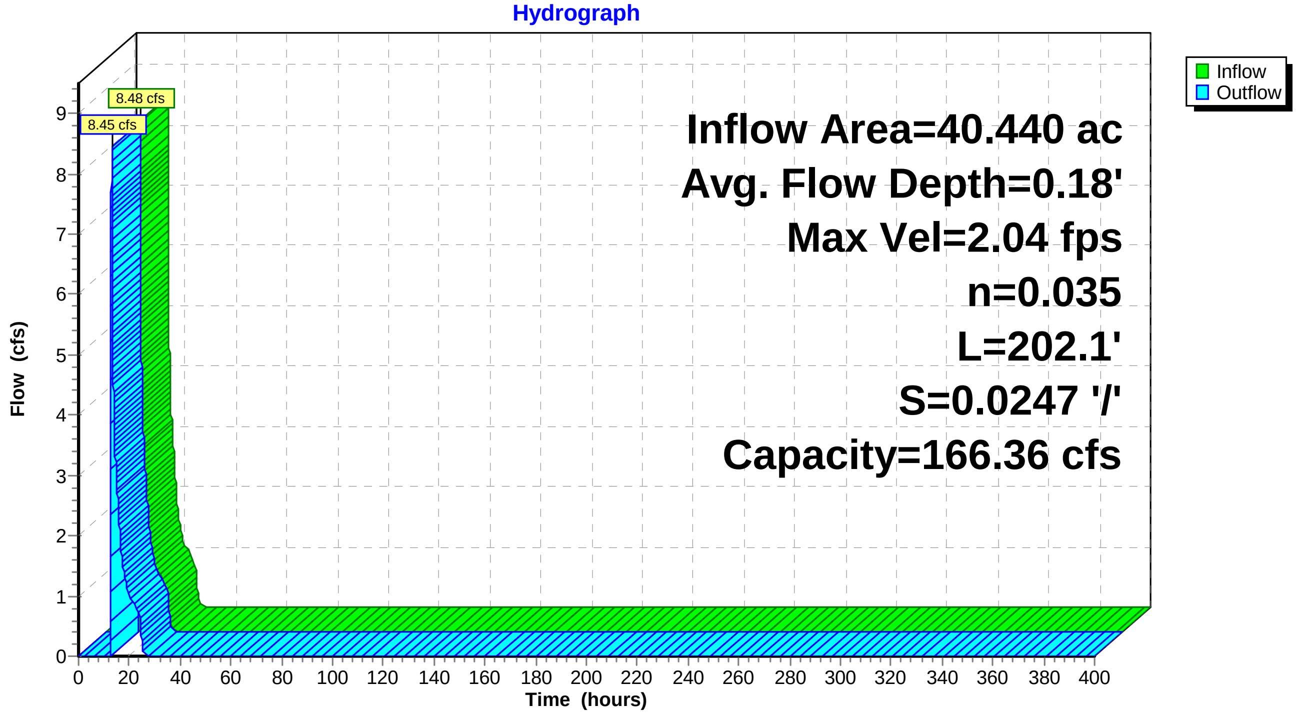
Inflow Area = 40.440 ac, 0.00% Impervious, Inflow Depth = 0.55" for 2-YR event
Inflow = 8.48 cfs @ 13.02 hrs, Volume= 1.849 af
Outflow = 8.45 cfs @ 13.07 hrs, Volume= 1.849 af, Atten= 0%, Lag= 2.9 min
Routed to Pond 21P : North Access Road Open Arch Culvert #1

Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.04 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 0.79 fps, Avg. Travel Time= 4.3 min

Peak Storage= 837 cf @ 13.04 hrs
Average Depth at Peak Storage= 0.18' , Surface Width= 24.43'
Bank-Full Depth= 1.00' Flow Area= 28.8 sf, Capacity= 166.36 cfs

22.00' x 1.00' deep channel, n= 0.035
Side Slope Z-value= 6.8 '/' Top Width= 35.60'
Length= 202.1' Slope= 0.0247 '/'
Inlet Invert= 992.44', Outlet Invert= 987.45'

Reach 22R: Pool Ditch



Summary for Pond 3P: SMA-1 (Design Point 2)

Inflow Area = 23.590 ac, 0.00% Impervious, Inflow Depth = 0.59" for 2-YR event
Inflow = 6.47 cfs @ 12.58 hrs, Volume= 1.167 af
Outflow = 0.26 cfs @ 24.34 hrs, Volume= 1.167 af, Atten= 96%, Lag= 706.0 min
Discarded = 0.26 cfs @ 24.34 hrs, Volume= 1.167 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 996.83' @ 24.34 hrs Surf.Area= 0.555 ac Storage= 0.914 af
Flood Elev= 1,001.76' Surf.Area= 1.185 ac Storage= 4.700 af

Plug-Flow detention time= 1,544.8 min calculated for 1.167 af (100% of inflow)
Center-of-Mass det. time= 1,544.8 min (2,477.3 - 932.5)

Volume	Invert	Avail.Storage	Storage Description
#1	995.00'	4.991 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

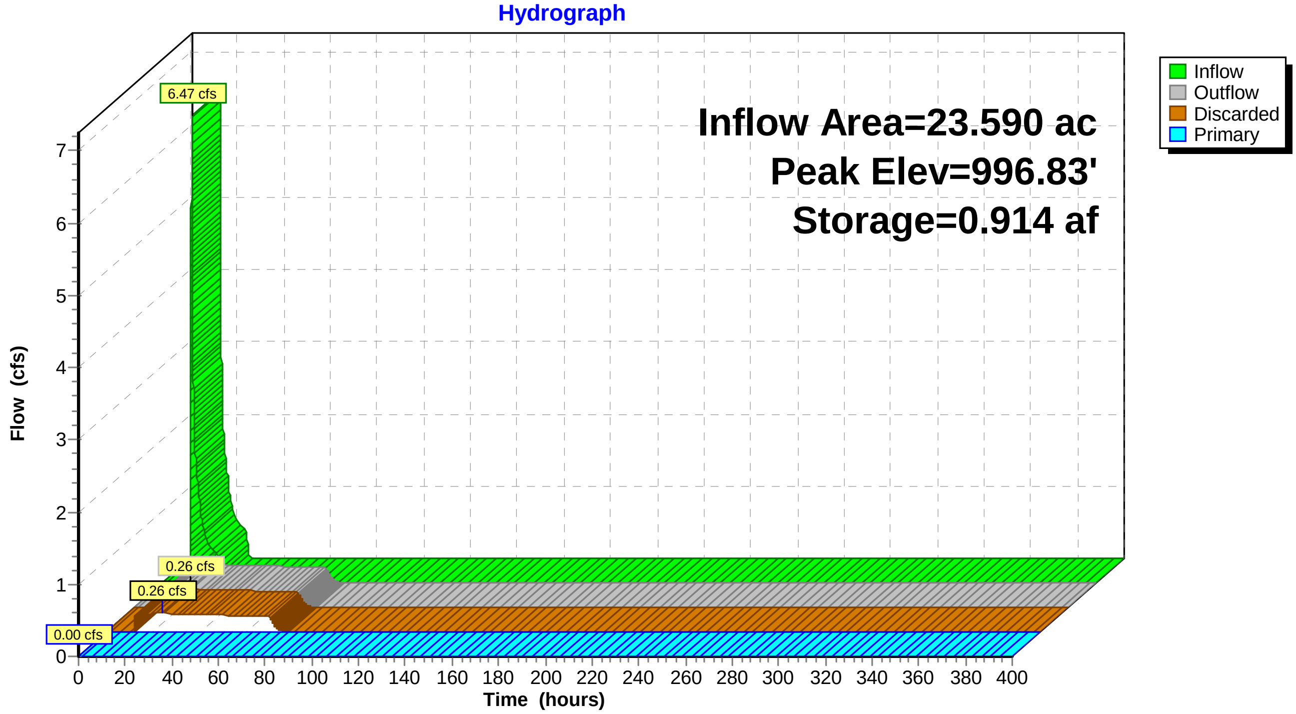
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
995.00	0.448	0.000	0.000
996.00	0.505	0.476	0.476
998.00	0.627	1.132	1.608
1,000.00	0.756	1.383	2.991
1,002.00	1.244	2.000	4.991

Device	Routing	Invert	Outlet Devices
#1	Discarded	995.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,001.55'	**20.0' long + 3.0 '/' SideZ x 15.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.26 cfs @ 24.34 hrs HW=996.83' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.26 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=995.00' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 3P: SMA-1 (Design Point 2)



Summary for Pond 4P: North Basin

Inflow Area = 21.810 ac, 0.00% Impervious, Inflow Depth = 0.66" for 2-YR event
Inflow = 7.92 cfs @ 12.50 hrs, Volume= 1.203 af
Outflow = 0.56 cfs @ 21.02 hrs, Volume= 1.203 af, Atten= 93%, Lag= 511.4 min
Discarded = 0.56 cfs @ 21.02 hrs, Volume= 1.203 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,001.57' @ 21.02 hrs Surf.Area= 52,945 sf Storage= 29,472 cf

Plug-Flow detention time= 579.4 min calculated for 1.203 af (100% of inflow)
Center-of-Mass det. time= 579.4 min (1,532.2 - 952.7)

Volume	Invert	Avail.Storage	Storage Description
#1	1,001.00'	374,394 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

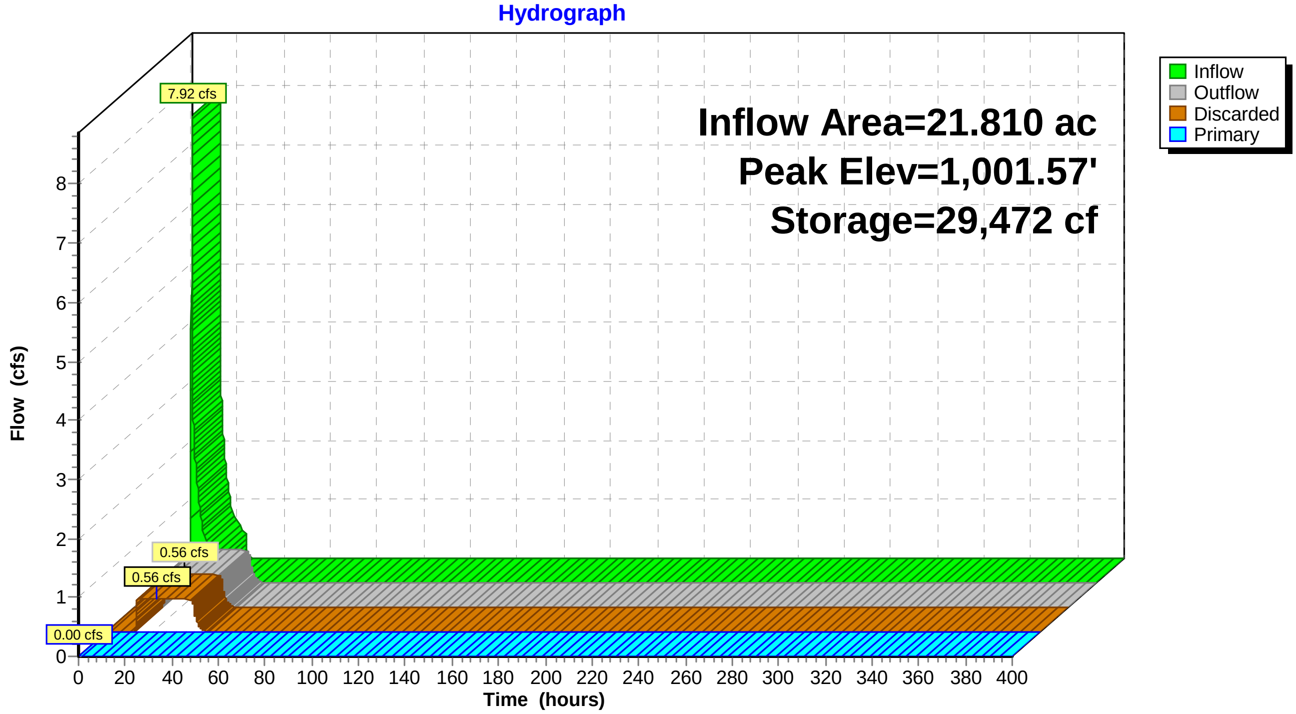
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,001.00	50,734	0	0
1,007.00	74,064	374,394	374,394

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,001.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,005.30'	**30.0' long + 3.0 '/' SideZ x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.56 cfs @ 21.02 hrs HW=1,001.57' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.56 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,001.00' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 4P: North Basin



Summary for Pond 5P: South Basin

Inflow Area = 2.730 ac, 0.00% Impervious, Inflow Depth = 1.75" for 2-YR event
Inflow = 6.72 cfs @ 12.13 hrs, Volume= 0.398 af
Outflow = 0.11 cfs @ 21.28 hrs, Volume= 0.398 af, Atten= 98%, Lag= 549.0 min
Discarded = 0.11 cfs @ 21.28 hrs, Volume= 0.398 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 16P : Culvert 7

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,030.11' @ 21.28 hrs Surf.Area= 12,161 sf Storage= 12,757 cf

Plug-Flow detention time= 1,209.8 min calculated for 0.398 af (100% of inflow)
Center-of-Mass det. time= 1,209.8 min (2,078.4 - 868.6)

Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	79,299 cf	**SE Basin Storage (Prismatic)** Listed below (Recalc)

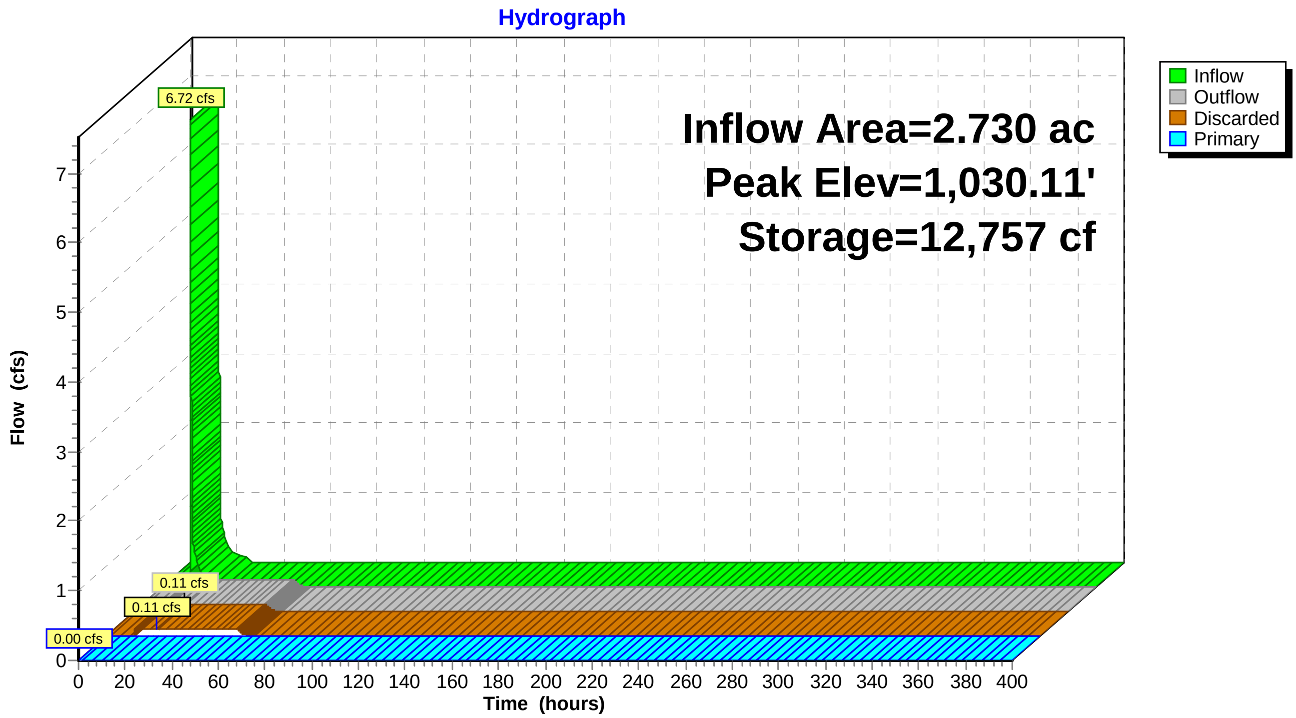
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,029.00	10,755	0	0
1,030.00	12,012	11,384	11,384
1,031.00	13,323	12,668	24,051
1,032.00	14,691	14,007	38,058
1,033.00	16,113	15,402	53,460
1,034.00	17,592	16,853	70,313
1,034.50	18,352	8,986	79,299

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,029.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	1,033.00'	**2.0" x 2.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.11 cfs @ 21.28 hrs HW=1,030.11' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.11 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,029.00' (Free Discharge)
└─**2=Orifice/Grate** (Controls 0.00 cfs)

Pond 5P: South Basin



Summary for Pond 11P: SW Ditch Low Point

Inflow Area = 6.470 ac, 0.00% Impervious, Inflow Depth = 0.68" for 2-YR event
Inflow = 4.44 cfs @ 12.15 hrs, Volume= 0.365 af
Outflow = 0.06 cfs @ 24.13 hrs, Volume= 0.365 af, Atten= 99%, Lag= 718.4 min
Discarded = 0.06 cfs @ 24.13 hrs, Volume= 0.365 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 19P : SMA-4 (Design Point 7) (Culvert 9)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,003.95' @ 24.13 hrs Surf.Area= 6,595 sf Storage= 13,469 cf
Flood Elev= 1,006.50' Surf.Area= 8,762 sf Storage= 27,957 cf

Plug-Flow detention time= 2,667.1 min calculated for 0.365 af (100% of inflow)
Center-of-Mass det. time= 2,667.2 min (3,536.1 - 868.9)

Volume	Invert	Avail.Storage	Storage Description
#1	999.50'	27,957 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

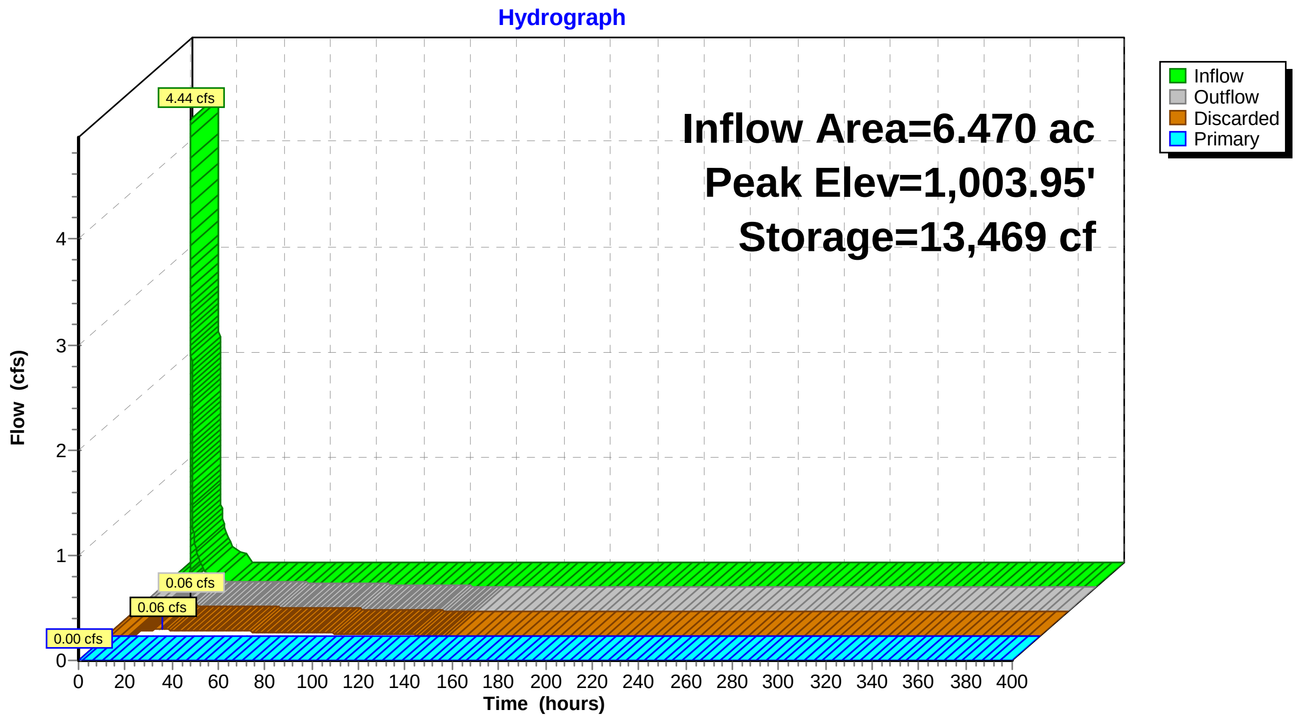
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
999.50	0	0	0
1,000.00	202	51	51
1,005.00	8,299	21,253	21,303
1,005.78	8,762	6,654	27,957

Device	Routing	Invert	Outlet Devices
#1	Discarded	999.50'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	1,000.00'	**18.0" Round Culvert** L= 131.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 1,000.00' / 997.00' S= 0.0229 '/' Cc= 0.900 n= 0.013, Flow Area= 1.77 sf
#3	Device 2	1,004.30'	**6.0" Vert. Orifice/Grate X 0.00** C= 0.600 Limited to weir flow at low heads
#4	Device 2	1,005.00'	**30.0" x 30.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.06 cfs @ 24.13 hrs HW=1,003.95' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.06 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=999.50' (Free Discharge)
└─**2=Culvert** (Controls 0.00 cfs)
  ├─**3=Orifice/Grate** (Controls 0.00 cfs)
  └─**4=Orifice/Grate** (Controls 0.00 cfs)

Pond 11P: SW Ditch Low Point



Summary for Pond 12P: North Basin Forebay

Inflow Area = 21.810 ac, 0.00% Impervious, Inflow Depth = 0.94" for 2-YR event
Inflow = 18.90 cfs @ 12.14 hrs, Volume= 1.703 af
Outflow = 7.92 cfs @ 12.50 hrs, Volume= 1.203 af, Atten= 58%, Lag= 21.5 min
Primary = 7.92 cfs @ 12.50 hrs, Volume= 1.203 af
Routed to Pond 4P : North Basin

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,004.81' @ 12.50 hrs Surf.Area= 10,149 sf Storage= 23,872 cf

Plug-Flow detention time= 177.3 min calculated for 1.203 af (71% of inflow)
Center-of-Mass det. time= 70.8 min (952.7 - 882.0)

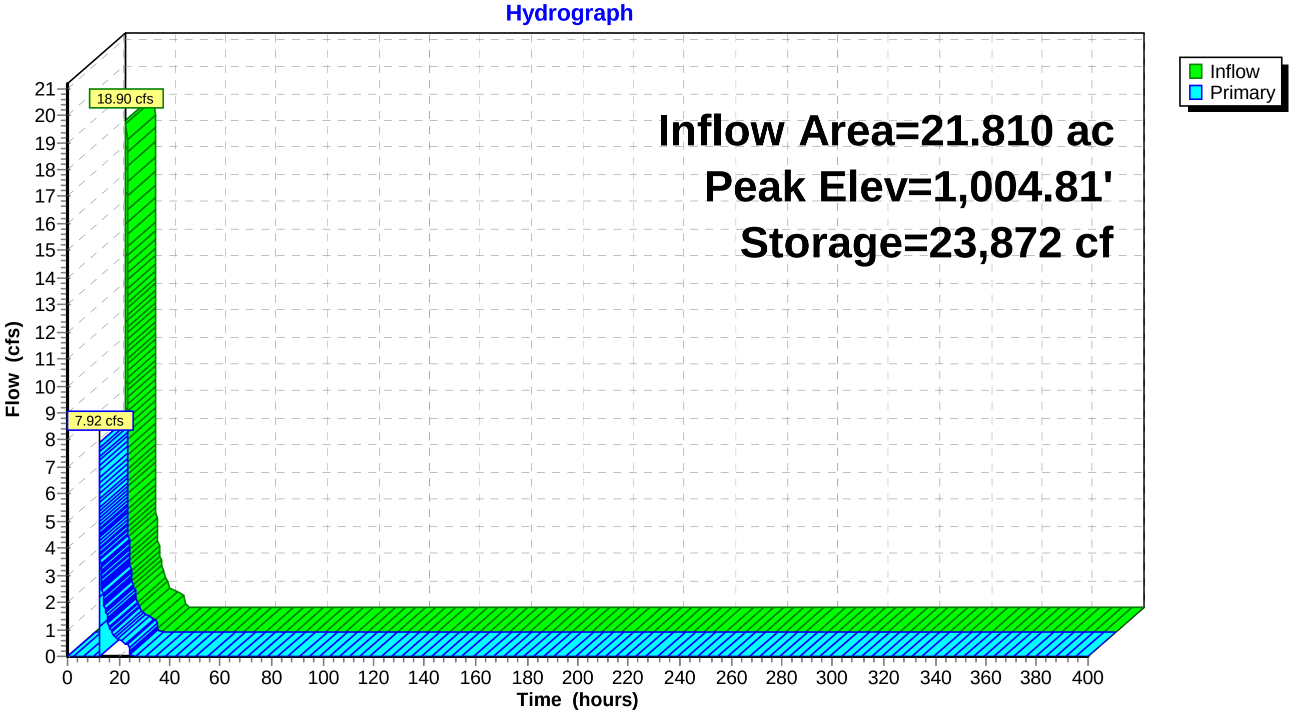
Volume	Invert	Avail.Storage	Storage Description
#1	1,001.00'	50,991 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,001.00	2,383	0	0
1,007.00	14,614	50,991	50,991

Device	Routing	Invert	Outlet Devices
#1	Primary	1,004.60'	**30.0' long + 3.0 '/' SideZ x 30.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=7.85 cfs @ 12.50 hrs HW=1,004.81' (Free Discharge)
↑—**1=Broad-Crested Rectangular Weir** (Weir Controls 7.85 cfs @ 1.22 fps)

Pond 12P: North Basin Forebay



Summary for Pond 13P: SMA-5 (Design Point 9) (Culvert 12)

[44] Hint: Outlet device #2 is below defined storage

```
Inflow Area =      5.000 ac,   0.00% Impervious,  Inflow Depth =   0.94"    for  2-YR event
Inflow      =     4.82 cfs @  12.10 hrs,  Volume=          0.390 af
Outflow     =     2.76 cfs @  12.28 hrs,  Volume=          0.390 af,  Atten= 43%,  Lag= 10.4 min
Discarded  =      0.04 cfs @  12.28 hrs,  Volume=          0.008 af
Primary     =     2.72 cfs @  12.28 hrs,  Volume=          0.383 af
Secondary =       0.00 cfs @   0.00 hrs,  Volume=          0.000 af
```

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 953.52' @ 12.28 hrs Surf.Area= 0.088 ac Storage= 0.036 af

Plug-Flow detention time= 3.4 min calculated for 0.390 af (100% of inflow)
Center-of-Mass det. time= 3.4 min (882.7 - 879.3)

Volume	Invert	Avail.Storage	Storage Description
#1	953.00'	0.361 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
953.00	0.049	0.000	0.000
955.50	0.240	0.361	0.361

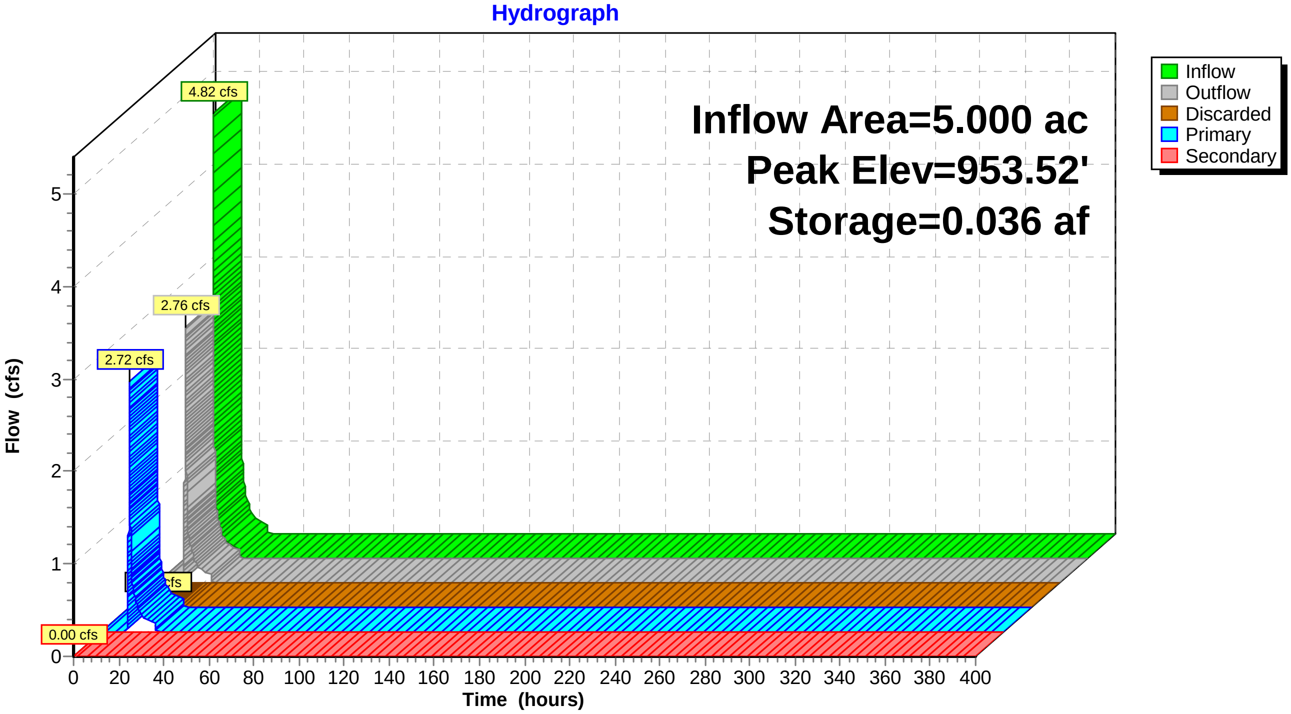
Device	Routing	Invert	Outlet Devices
#1	Discarded	953.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	952.50'	**12.0" Round Culvert #12** L= 40.0' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 952.50' / 949.60' S= 0.0725 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#3	Secondary	954.50'	**16.0' long + 10.0 '/' SideZ x 16.4' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.04 cfs @ 12.28 hrs HW=953.52' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.04 cfs)

Primary OutFlow Max=2.72 cfs @ 12.28 hrs HW=953.52' (Free Discharge)
└─**2=Culvert #12** (Inlet Controls 2.72 cfs @ 3.46 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=953.00' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 13P: SMA-5 (Design Point 9) (Culvert 12)



Summary for Pond 14P: North Access Road Culvert #16

[44] Hint: Outlet device #2 is below defined storage

Inflow Area = 2.180 ac, 0.00% Impervious, Inflow Depth = 0.02" for 2-YR event
Inflow = 0.01 cfs @ 21.23 hrs, Volume= 0.004 af
Outflow = 0.01 cfs @ 21.27 hrs, Volume= 0.004 af, Atten= 0%, Lag= 2.3 min
Discarded = 0.00 cfs @ 21.27 hrs, Volume= 0.000 af
Primary = 0.01 cfs @ 21.27 hrs, Volume= 0.004 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 982.00' @ 21.27 hrs Surf.Area= 0.002 ac Storage= 0.000 af

Plug-Flow detention time= 0.1 min calculated for 0.004 af (100% of inflow)
Center-of-Mass det. time= 0.1 min (1,204.5 - 1,204.4)

Volume	Invert	Avail.Storage	Storage Description
#1	982.00'	0.004 af	**Custom Stage Data (Conic)** Listed below (Recalc)

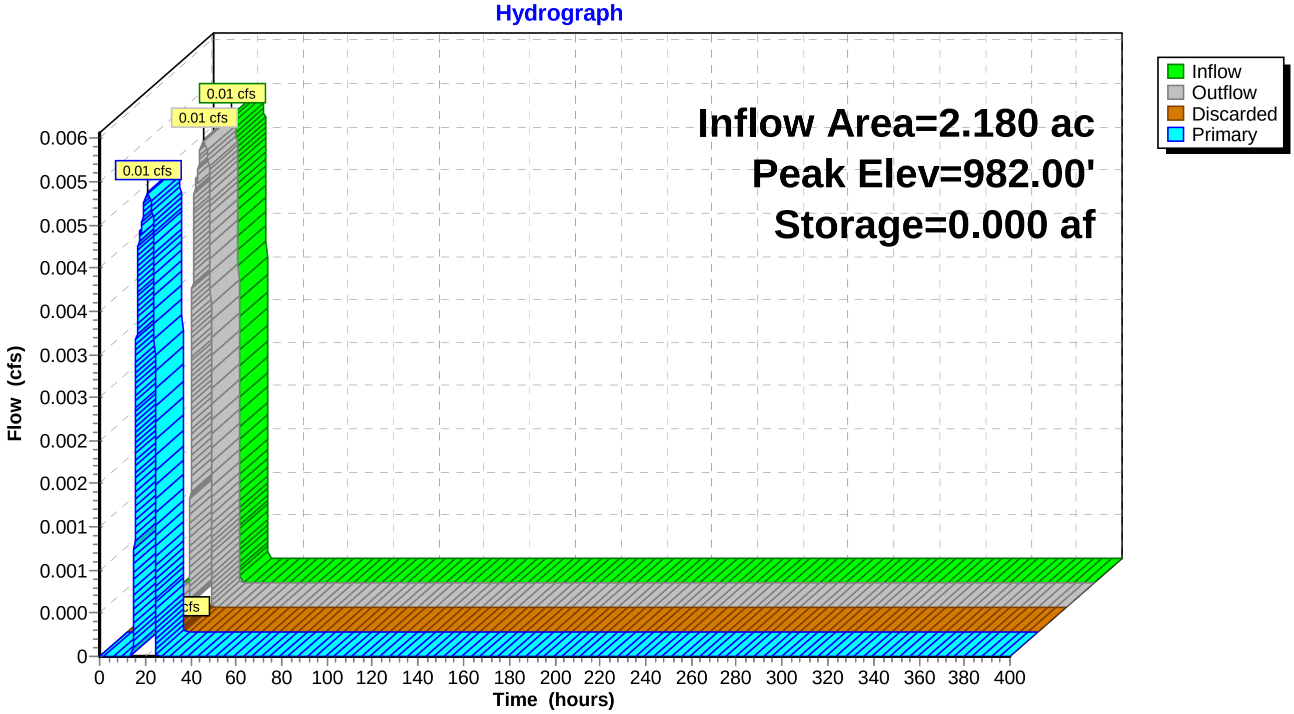
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
982.00	0.002	0.000	0.000	0.002
982.80	0.010	0.004	0.004	0.010

Device	Routing	Invert	Outlet Devices
#1	Discarded	982.00'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	981.80'	**12.0" Round Culvert** L= 50.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 981.80' / 980.92' S= 0.0176 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Discarded OutFlow Max=0.00 cfs @ 21.27 hrs HW=982.00' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=0.13 cfs @ 21.27 hrs HW=982.00' (Free Discharge)
└─**2=Culvert** (Inlet Controls 0.13 cfs @ 1.20 fps)

Pond 14P: North Access Road Culvert #16



Summary for Pond 15P: Culvert #10

Inflow Area = 0.820 ac, 0.00% Impervious, Inflow Depth = 0.73" for 2-YR event
Inflow = 0.56 cfs @ 12.11 hrs, Volume= 0.050 af
Outflow = 0.50 cfs @ 12.15 hrs, Volume= 0.050 af, Atten= 9%, Lag= 2.4 min
Primary = 0.50 cfs @ 12.15 hrs, Volume= 0.050 af
Routed to Pond 16P : Culvert 7

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,032.48' @ 12.15 hrs Surf.Area= 0.009 ac Storage= 0.002 af

Plug-Flow detention time= 2.2 min calculated for 0.050 af (100% of inflow)
Center-of-Mass det. time= 2.2 min (896.6 - 894.3)

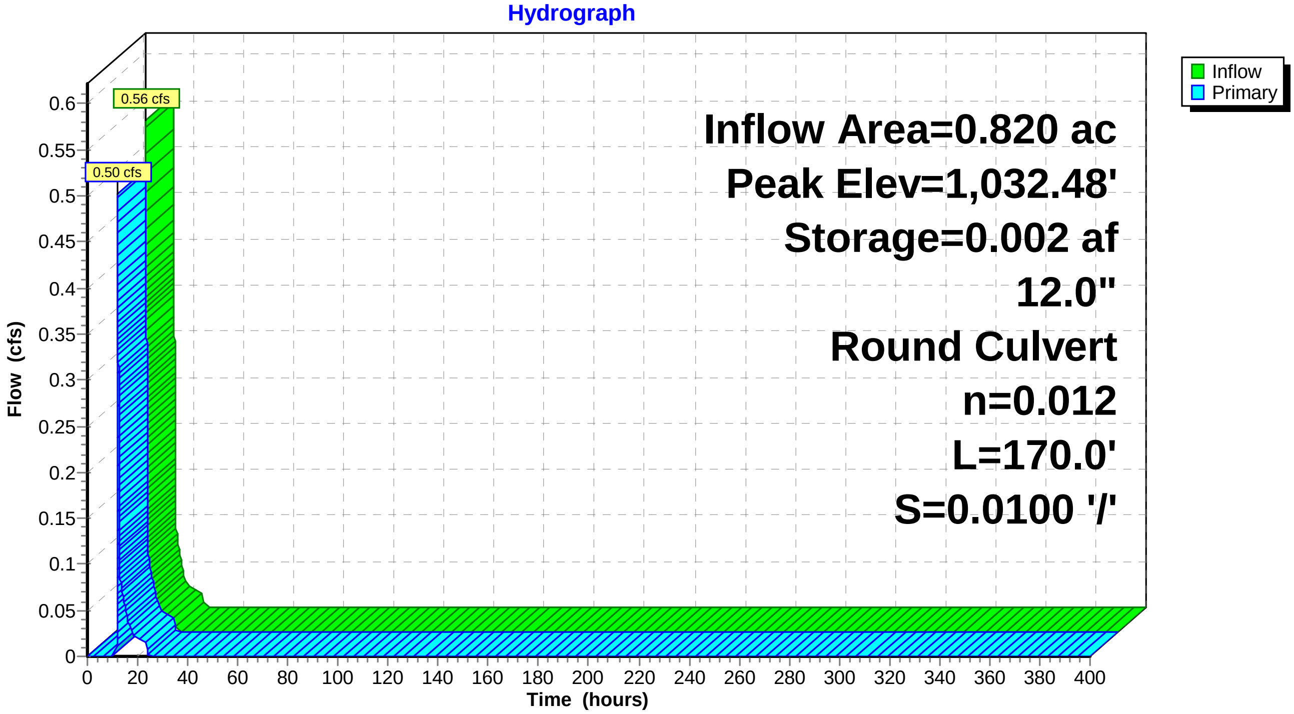
Volume	Invert	Avail.Storage	Storage Description
#1	1,032.10'	0.136 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,032.10	0.000	0.000	0.000
1,033.00	0.021	0.009	0.009
1,034.00	0.136	0.078	0.088
1,034.30	0.187	0.048	0.136

Device	Routing	Invert	Outlet Devices
#1	Primary	1,032.10'	**12.0" Round Culvert** L= 170.0' RCP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 1,032.10' / 1,030.40' S= 0.0100 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Primary OutFlow Max=0.50 cfs @ 12.15 hrs HW=1,032.48' (Free Discharge)
└─**1=Culvert** (Inlet Controls 0.50 cfs @ 1.85 fps)

Pond 15P: Culvert #10



Summary for Pond 16P: Culvert 7

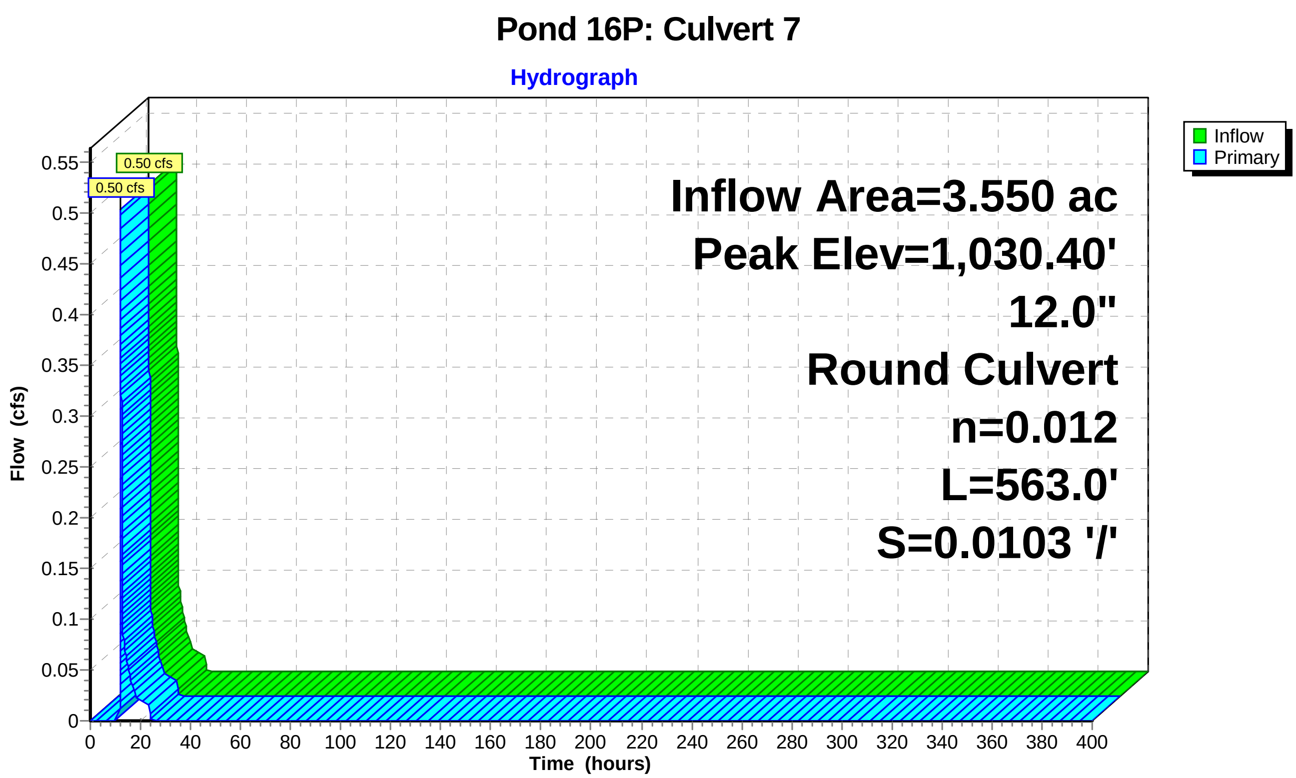
[57] Hint: Peaked at 1,030.40' (Flood elevation advised)

Inflow Area = 3.550 ac, 0.00% Impervious, Inflow Depth = 0.17" for 2-YR event
Inflow = 0.50 cfs @ 12.15 hrs, Volume= 0.050 af
Outflow = 0.50 cfs @ 12.15 hrs, Volume= 0.050 af, Atten= 0%, Lag= 0.0 min
Primary = 0.50 cfs @ 12.15 hrs, Volume= 0.050 af
Routed to Pond 11P : SW Ditch Low Point

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,030.40' @ 12.15 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	1,030.00'	**12.0" Round Culvert** L= 563.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 1,030.00' / 1,024.20' S= 0.0103 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Primary OutFlow Max=0.50 cfs @ 12.15 hrs HW=1,030.40' (Free Discharge)
1=Culvert (Inlet Controls 0.50 cfs @ 1.70 fps)



Summary for Pond 17P: SMA3B (Design Point 6)

Inflow Area = 0.440 ac, 0.00% Impervious, Inflow Depth = 0.94" for 2-YR event
Inflow = 0.42 cfs @ 12.10 hrs, Volume= 0.034 af
Outflow = 0.02 cfs @ 17.55 hrs, Volume= 0.034 af, Atten= 96%, Lag= 327.0 min
Discarded = 0.02 cfs @ 17.55 hrs, Volume= 0.034 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,023.78' @ 17.55 hrs Surf.Area= 0.043 ac Storage= 0.021 af

Plug-Flow detention time= 754.7 min calculated for 0.034 af (100% of inflow)
Center-of-Mass det. time= 754.7 min (1,634.0 - 879.3)

Volume	Invert	Avail.Storage	Storage Description
#1	1,022.60'	0.127 af	**Custom Stage Data (Conic)** Listed below (Recalc)

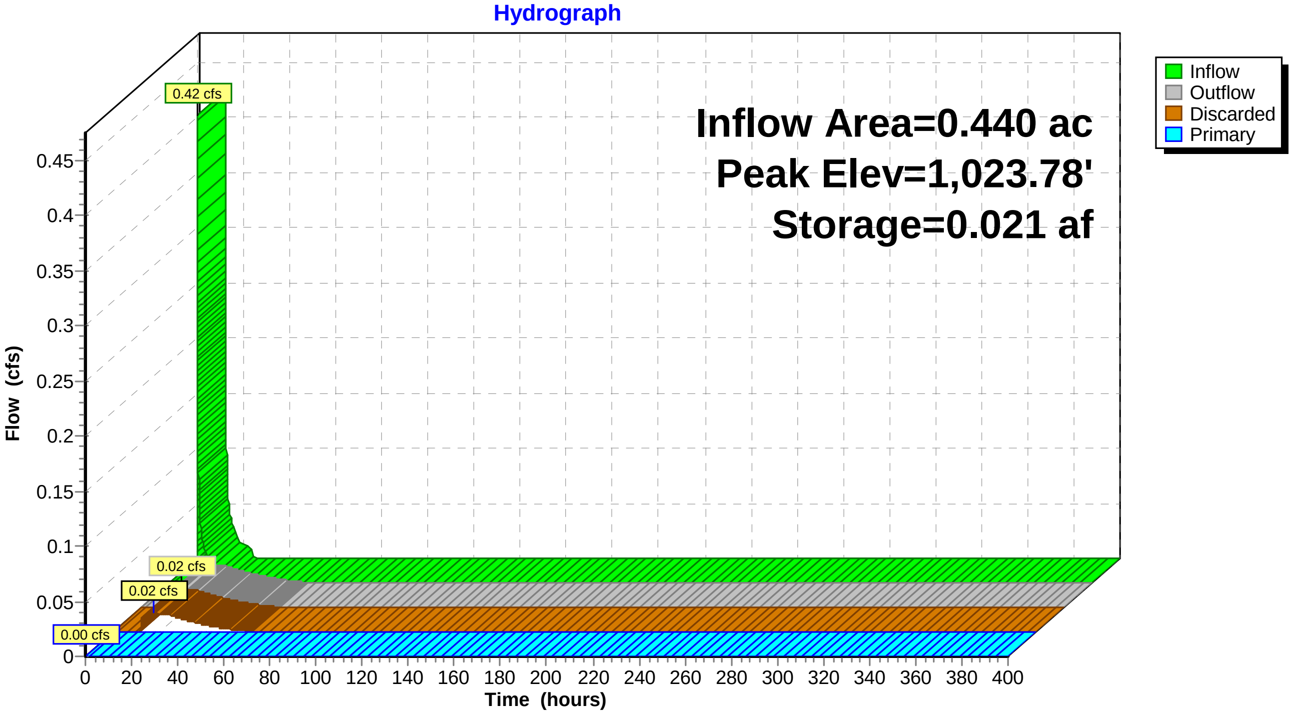
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.60	0.002	0.000	0.000	0.002
1,023.80	0.044	0.022	0.022	0.044
1,025.50	0.081	0.105	0.127	0.082

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.60'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,024.50'	**15.0' long + 3.0 '/' SideZ x 6.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.37 2.51 2.70 2.68 2.68 2.67 2.65 2.65 2.65 2.65 2.66 2.66 2.67 2.69 2.72 2.76 2.83

Discarded OutFlow Max=0.02 cfs @ 17.55 hrs HW=1,023.78' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,022.60' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 17P: SMA3B (Design Point 6)



Summary for Pond 18P: South Basin Forebay

Inflow Area = 2.730 ac, 0.00% Impervious, Inflow Depth = 2.32" for 2-YR event
Inflow = 7.05 cfs @ 12.11 hrs, Volume= 0.527 af
Outflow = 6.72 cfs @ 12.13 hrs, Volume= 0.398 af, Atten= 5%, Lag= 1.7 min
Primary = 6.72 cfs @ 12.13 hrs, Volume= 0.398 af
Routed to Pond 5P : South Basin

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,033.11' @ 12.13 hrs Surf.Area= 0.060 ac Storage= 0.146 af

Plug-Flow detention time= 135.1 min calculated for 0.398 af (76% of inflow)
Center-of-Mass det. time= 49.1 min (868.6 - 819.5)

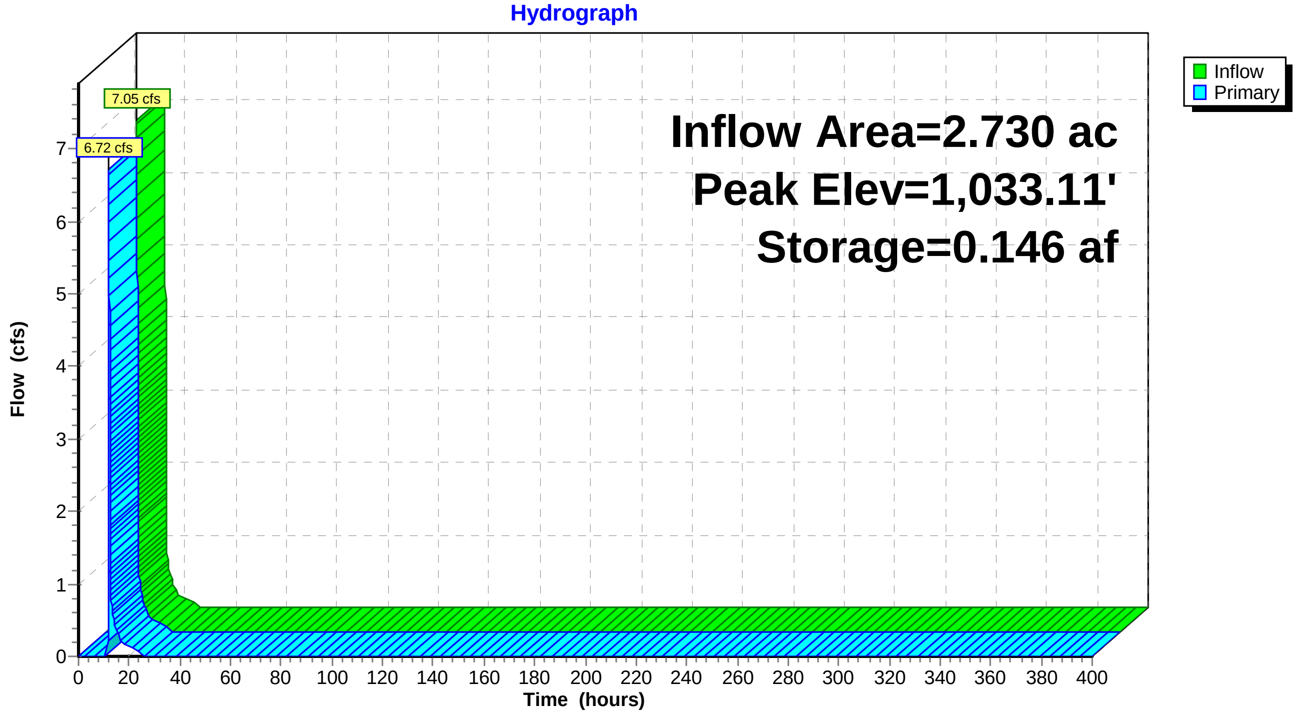
Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	0.208 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,029.00	0.016	0.000	0.000
1,030.00	0.024	0.020	0.020
1,031.00	0.034	0.029	0.049
1,032.00	0.045	0.039	0.088
1,033.00	0.058	0.052	0.140
1,034.00	0.079	0.068	0.208

Device	Routing	Invert	Outlet Devices
#1	Primary	1,032.80'	**14.0' long + 3.0 '/' SideZ x 14.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.64 2.67 2.70 2.65 2.64 2.65 2.65 2.63

Primary OutFlow Max=6.69 cfs @ 12.13 hrs HW=1,033.11' (Free Discharge)
↑—**1=Broad-Crested Rectangular Weir** (Weir Controls 6.69 cfs @ 1.46 fps)

Pond 18P: South Basin Forebay



Summary for Pond 19P: SMA-4 (Design Point 7) (Culvert 9)

Inflow Area = 17.420 ac, 0.00% Impervious, Inflow Depth = 0.06" for 2-YR event
Inflow = 0.14 cfs @ 14.75 hrs, Volume= 0.089 af
Outflow = 0.07 cfs @ 21.16 hrs, Volume= 0.089 af, Atten= 49%, Lag= 384.5 min
Discarded = 0.07 cfs @ 21.16 hrs, Volume= 0.089 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 987.14' @ 21.16 hrs Surf.Area= 0.185 ac Storage= 0.026 af

Plug-Flow detention time= 193.0 min calculated for 0.089 af (100% of inflow)
Center-of-Mass det. time= 192.9 min (1,248.9 - 1,055.9)

Volume	Invert	Avail.Storage	Storage Description
#1	987.00'	0.976 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
987.00	0.180	0.000	0.000
991.00	0.308	0.976	0.976

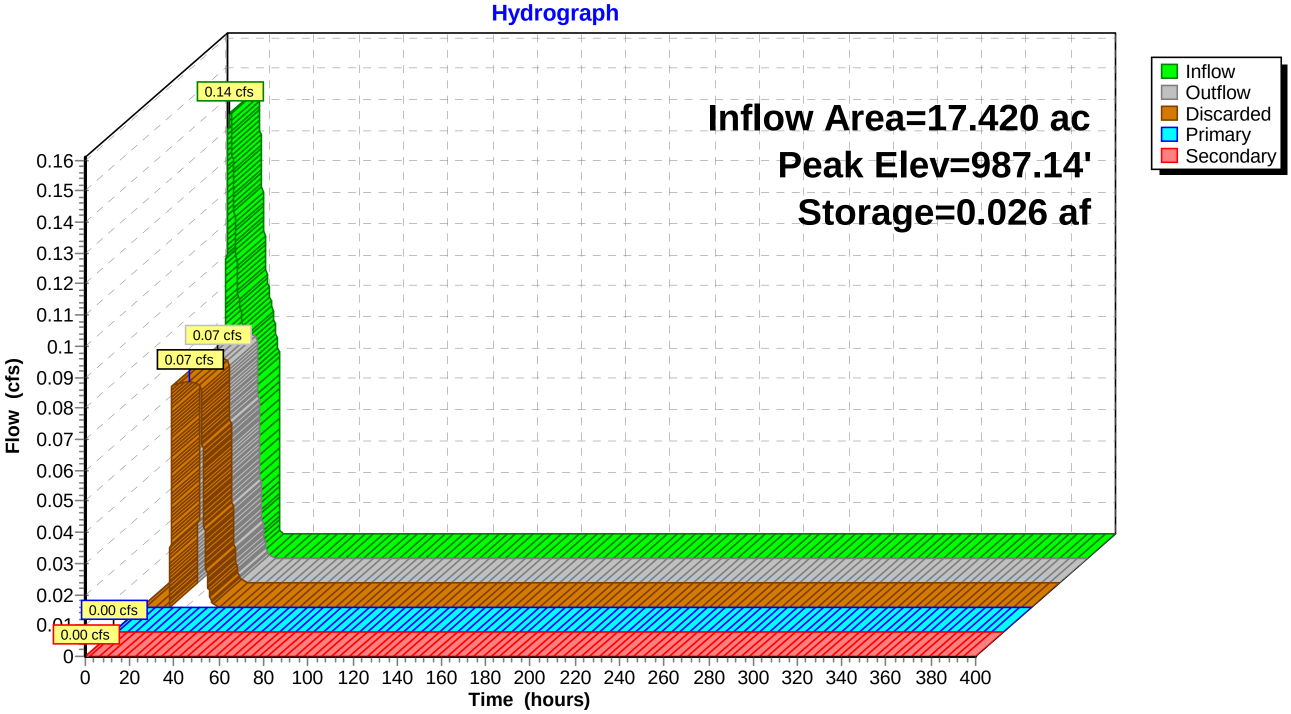
Device	Routing	Invert	Outlet Devices
#1	Discarded	987.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	987.50'	**4.0" Round Culvert X 4.00** L= 30.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 987.50' / 987.10' S= 0.0133 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 0.09 sf
#3	Secondary	990.00'	**8.0' long + 3.0 '/' SideZ x 5.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.34 2.50 2.70 2.68 2.68 2.66 2.65 2.65 2.65 2.65 2.67 2.66 2.68 2.70 2.74 2.79 2.88

Discarded OutFlow Max=0.07 cfs @ 21.16 hrs HW=987.14' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.07 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=987.00' (Free Discharge)
└─**2=Culvert** (Controls 0.00 cfs)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=987.00' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 19P: SMA-4 (Design Point 7) (Culvert 9)



Summary for Pond 20P: SMA3A (Culvert 15)

Inflow Area = 0.520 ac, 0.00% Impervious, Inflow Depth = 0.55" for 2-YR event
Inflow = 0.22 cfs @ 12.12 hrs, Volume= 0.024 af
Outflow = 0.20 cfs @ 12.16 hrs, Volume= 0.024 af, Atten= 7%, Lag= 2.1 min
Discarded = 0.00 cfs @ 12.16 hrs, Volume= 0.002 af
Primary = 0.20 cfs @ 12.16 hrs, Volume= 0.022 af
Routed to Pond 24P : SMA-2 (Design Point 5)
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Reach 13R : SMA3 CHANNEL

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,028.87' @ 12.16 hrs Surf.Area= 0.005 ac Storage= 0.001 af

Plug-Flow detention time= 18.4 min calculated for 0.024 af (100% of inflow)
Center-of-Mass det. time= 18.4 min (931.0 - 912.6)

Volume	Invert	Avail.Storage	Storage Description
#1	1,028.50'	0.019 af	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,028.50	0.001	0.000	0.000	0.001
1,029.00	0.007	0.002	0.002	0.007
1,030.00	0.031	0.018	0.019	0.031

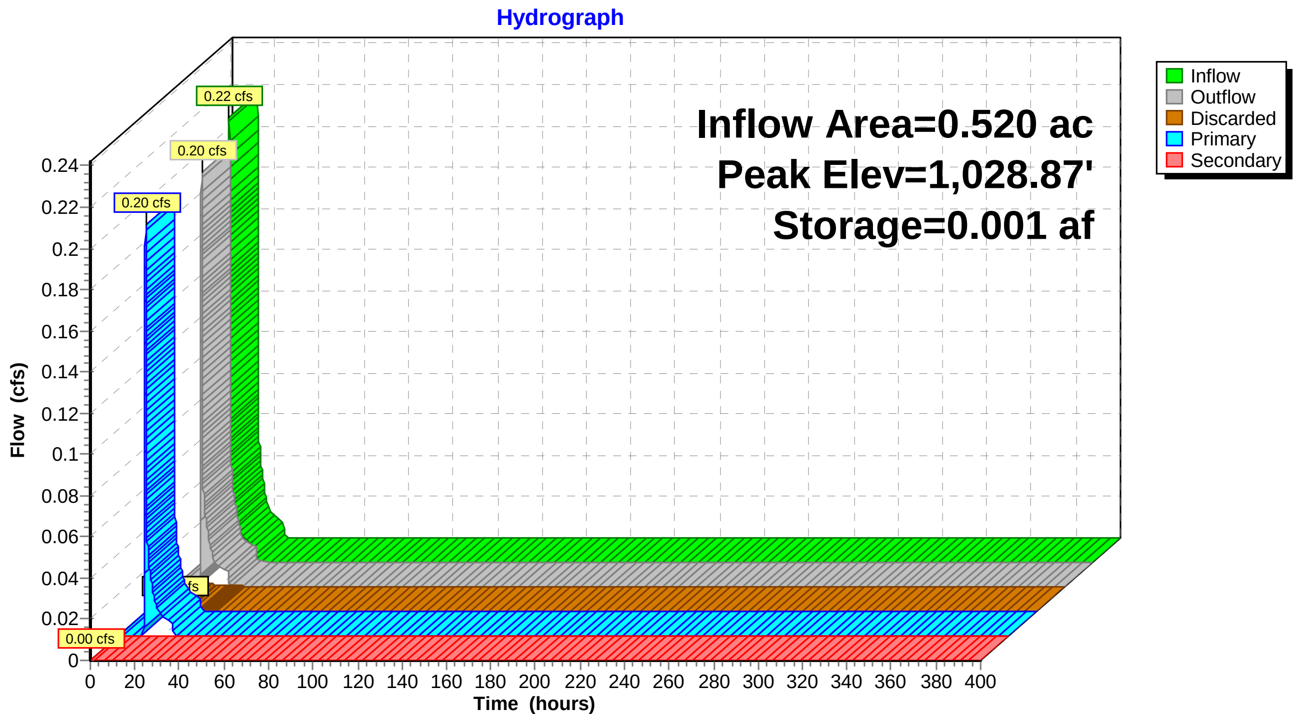
Device	Routing	Invert	Outlet Devices
#1	Discarded	1,028.50'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,028.70'	**8.0" Round Culvert X 2.00** L= 109.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 1,028.70' / 1,026.63' S= 0.0190 '/' Cc= 0.900 n= 0.013, Flow Area= 0.35 sf
#3	Secondary	1,029.80'	**16.0' long + 3.0 '/' SideZ x 2.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 Coef. (English) 2.48 2.60 2.60 2.60 2.64 2.65 2.68 2.75 2.74 2.76 2.89 3.05 3.19 3.32

Discarded OutFlow Max=0.00 cfs @ 12.16 hrs HW=1,028.87' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=0.20 cfs @ 12.16 hrs HW=1,028.87' (Free Discharge)
↑—**2=Culvert** (Inlet Controls 0.20 cfs @ 1.41 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,028.50' (Free Discharge)
↑—**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 20P: SMA3A (Culvert 15)



Summary for Pond 21P: North Access Road Open Arch Culvert #1

Inflow Area = 89.590 ac, 0.00% Impervious, Inflow Depth = 0.68" for 2-YR event
Inflow = 19.86 cfs @ 12.57 hrs, Volume= 5.050 af
Outflow = 19.86 cfs @ 12.57 hrs, Volume= 5.050 af, Atten= 0%, Lag= 0.2 min
Discarded = 0.01 cfs @ 12.57 hrs, Volume= 0.001 af
Primary = 19.86 cfs @ 12.57 hrs, Volume= 5.049 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 985.35' @ 12.57 hrs Surf.Area= 577 sf Storage= 139 cf

Plug-Flow detention time= 0.1 min calculated for 5.050 af (100% of inflow)
Center-of-Mass det. time= 0.1 min (944.5 - 944.4)

Volume	Invert	Avail.Storage	Storage Description
#1	984.65'	33,751 cf	**Custom Stage Data (Conic)** Listed below (Recalc)

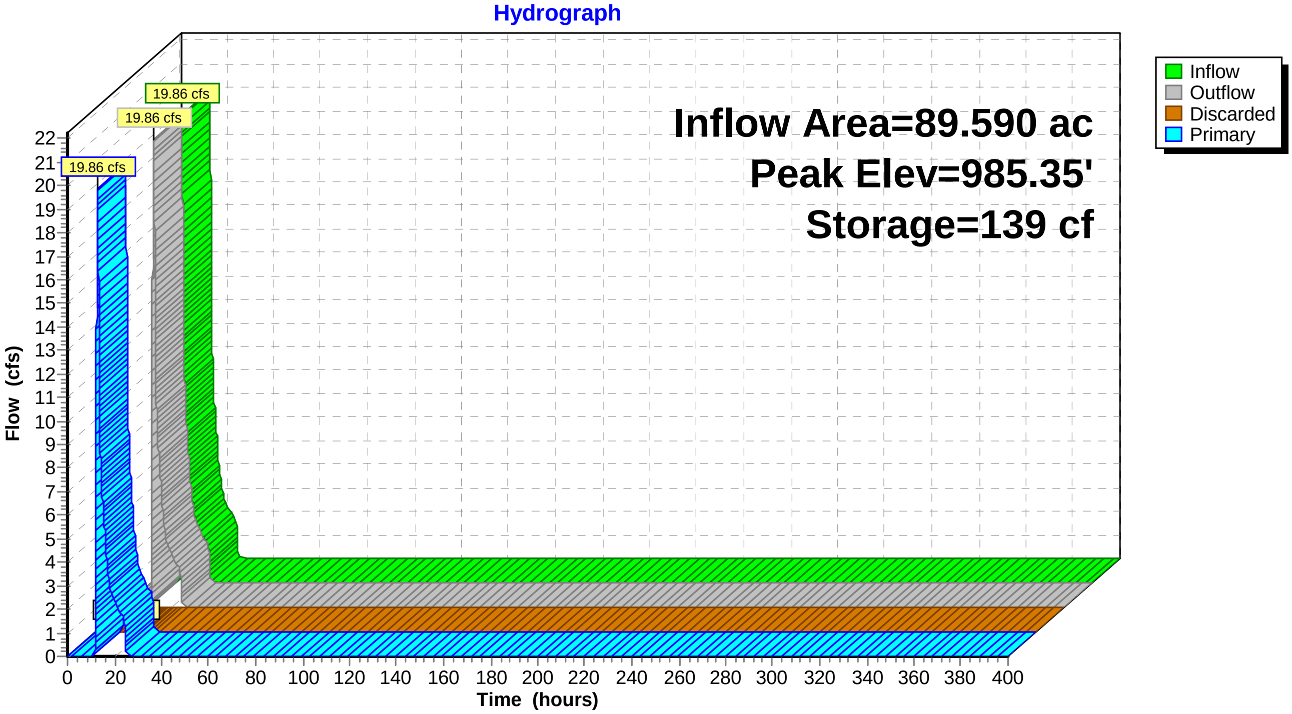
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
984.65	1	0	0	1
985.00	154	20	20	154
985.50	845	227	246	846
986.00	2,215	738	984	2,218
986.50	4,569	1,661	2,645	4,574
987.00	7,470	2,980	5,625	7,478
987.40	10,205	3,521	9,146	10,216
988.90	23,514	24,605	33,751	23,543

Device	Routing	Invert	Outlet Devices
#1	Discarded	984.65'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	984.65'	**144.0" W x 43.2" H, R=90.0" Arch Culvert** L= 49.0' CMP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 984.65' / 982.17' S= 0.0506 '/' Cc= 0.900 n= 0.035, Flow Area= 32.36 sf

Discarded OutFlow Max=0.01 cfs @ 12.57 hrs HW=985.35' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.01 cfs)

Primary OutFlow Max=19.85 cfs @ 12.57 hrs HW=985.35' (Free Discharge)
↑—**2=Culvert** (Inlet Controls 19.85 cfs @ 2.37 fps)

Pond 21P: North Access Road Open Arch Culvert #1



Summary for Pond 22P: SMA-6/Proposed Powerline Depression (Design Point 1)

[81] Warning: Exceeded Pond 14P by 2.26' @ 24.66 hrs
[79] Warning: Submerged Pond 21P Primary device # 2 OUTLET by 2.09'

Inflow Area =	139.990 ac,	0.00% Impervious, Inflow Depth = 0.43"	for 2-YR event
Inflow =	19.86 cfs @ 12.57 hrs,	Volume=	5.066 af
Outflow =	0.65 cfs @ 24.66 hrs,	Volume=	5.066 af, Atten= 97%, Lag= 724.9 min
Discarded =	0.65 cfs @ 24.66 hrs,	Volume=	5.066 af
Primary =	0.00 cfs @ 0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 984.26' @ 24.66 hrs Surf.Area= 1.388 ac Storage= 4.455 af

Plug-Flow detention time= 3,268.6 min calculated for 5.066 af (100% of inflow)
Center-of-Mass det. time= 3,268.8 min (4,213.9 - 945.1)

Volume	Invert	Avail.Storage	Storage Description
#1	978.00'	7.150 af	**Custom Stage Data (Conic)** Listed below

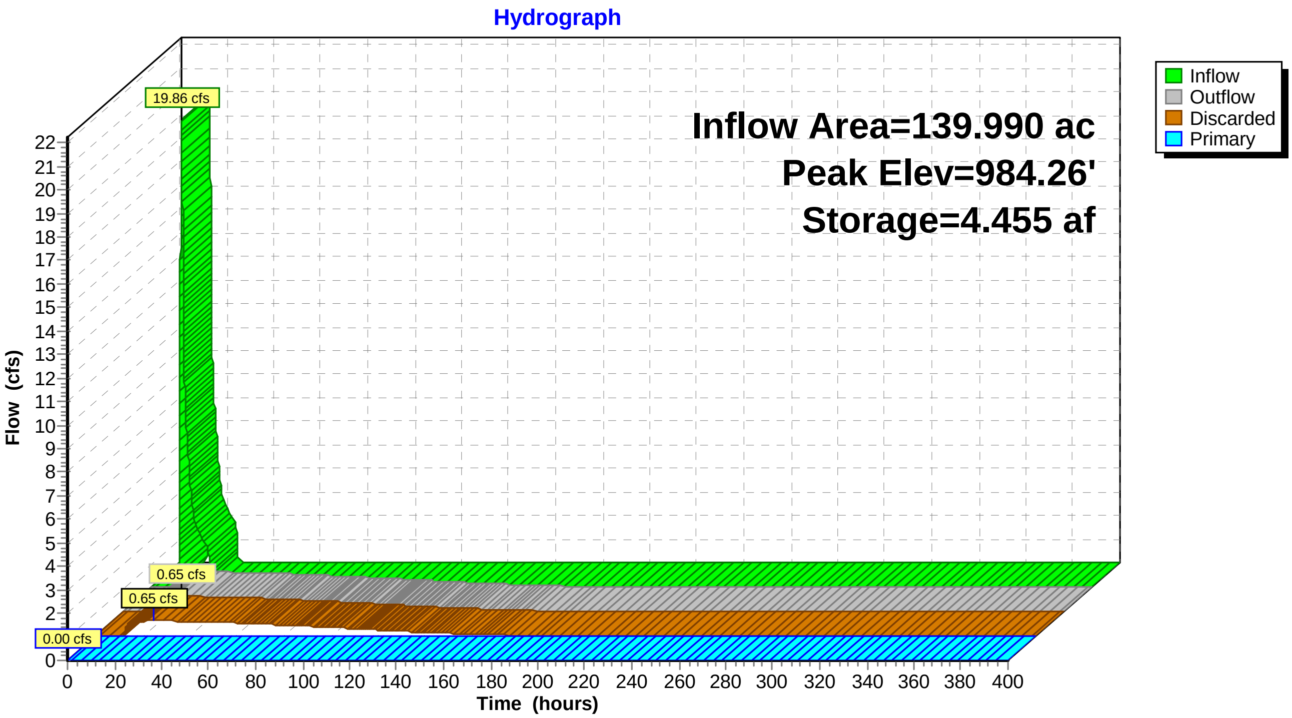
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
978.00	0.030	0.000	0.000	0.030
979.00	0.163	0.088	0.088	0.163
980.00	0.375	0.262	0.349	0.375
981.00	0.687	0.523	0.873	0.688
982.00	0.977	0.828	1.700	0.978
983.00	1.217	1.095	2.795	1.219
984.00	1.360	1.288	4.083	1.363
985.00	1.468	1.414	5.497	1.473
986.00	1.846	1.653	7.150	1.851

Device	Routing	Invert	Outlet Devices
#1	Primary	984.58'	**165.0 deg x 1.42' rise Sharp-Crested Vee/Trap Weir** Cv= 2.47 (C= 3.09)
#2	Discarded	978.00'	**0.460 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.65 cfs @ 24.66 hrs HW=984.26' (Free Discharge)
↑—**2=Exfiltration** (Exfiltration Controls 0.65 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=978.00' (Free Discharge)
↑—**1=Sharp-Crested Vee/Trap Weir** (Controls 0.00 cfs)

Pond 22P: SMA-6/Proposed Powerline Depression (Design Point 1)



Summary for Pond 23P: Pool Proposed

Inflow Area = 40.440 ac, 0.00% Impervious, Inflow Depth = 0.74" for 2-YR event
Inflow = 15.29 cfs @ 12.57 hrs, Volume= 2.487 af
Outflow = 8.48 cfs @ 13.02 hrs, Volume= 1.849 af, Atten= 45%, Lag= 26.6 min
Primary = 8.48 cfs @ 13.02 hrs, Volume= 1.849 af
Routed to Reach 22R : Pool Ditch

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 991.00' Surf.Area= 0.335 ac Storage= 0.199 af
Peak Elev= 992.62' @ 13.02 hrs Surf.Area= 0.544 ac Storage= 0.933 af (0.734 af above start)

Plug-Flow detention time= 215.1 min calculated for 1.650 af (66% of inflow)
Center-of-Mass det. time= 71.6 min (988.9 - 917.4)

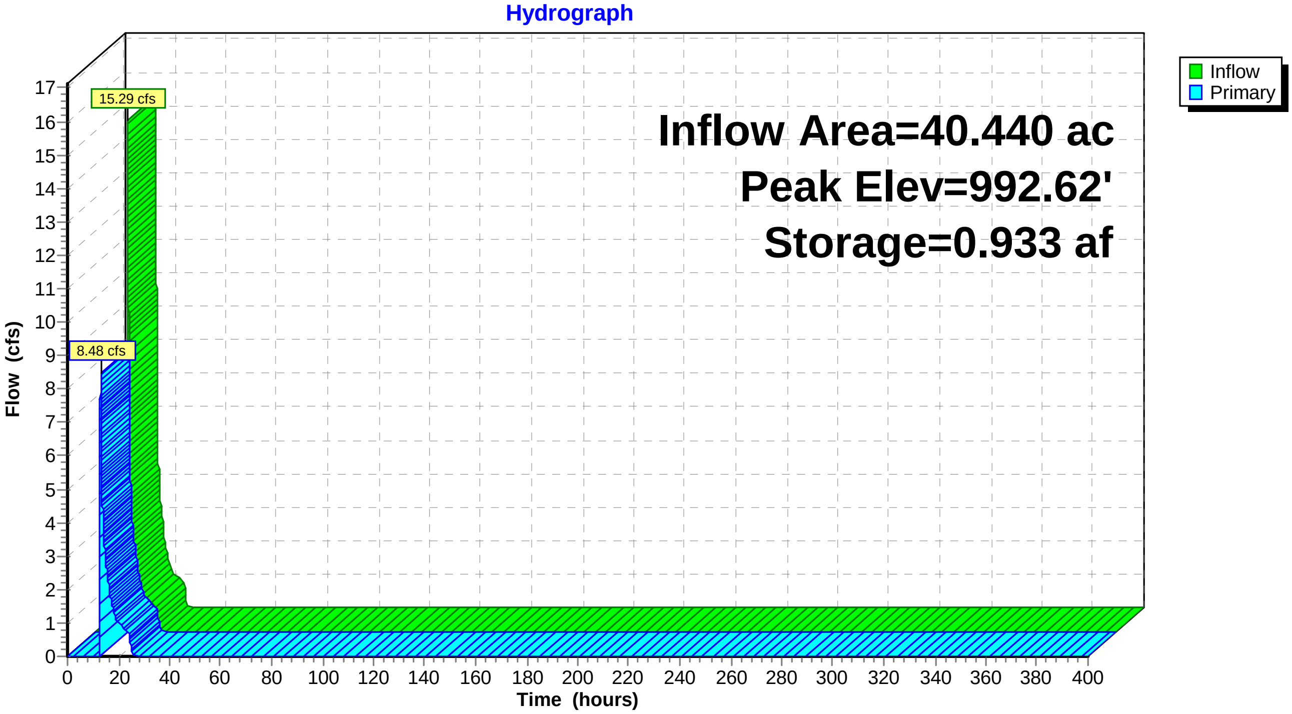
Volume	Invert	Avail.Storage	Storage Description
#1	988.50'	1.147 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
988.50	0.001	0.000	0.000
989.00	0.009	0.003	0.003
989.50	0.026	0.009	0.011
990.00	0.057	0.021	0.032
990.50	0.138	0.049	0.081
991.00	0.335	0.118	0.199
992.00	0.493	0.414	0.613
993.00	0.575	0.534	1.147

Device	Routing	Invert	Outlet Devices
#1	Primary	992.44'	**Channel/Reach** using Reach 22R: Pool Ditch

Primary OutFlow Max=8.39 cfs @ 13.02 hrs HW=992.62' (Free Discharge)
└─**1=Channel/Reach** (Channel Controls 8.39 cfs @ 2.04 fps)

Pond 23P: Pool Proposed



Summary for Pond 24P: SMA-2 (Design Point 5)

Inflow Area = 2.470 ac, 0.00% Impervious, Inflow Depth = 0.81" for 2-YR event
Inflow = 1.72 cfs @ 12.15 hrs, Volume= 0.166 af
Outflow = 0.06 cfs @ 20.42 hrs, Volume= 0.166 af, Atten= 97%, Lag= 495.9 min
Discarded = 0.06 cfs @ 20.42 hrs, Volume= 0.166 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,022.82' @ 20.42 hrs Surf.Area= 0.151 ac Storage= 0.110 af

Plug-Flow detention time= 891.6 min calculated for 0.166 af (100% of inflow)
Center-of-Mass det. time= 891.6 min (1,781.1 - 889.5)

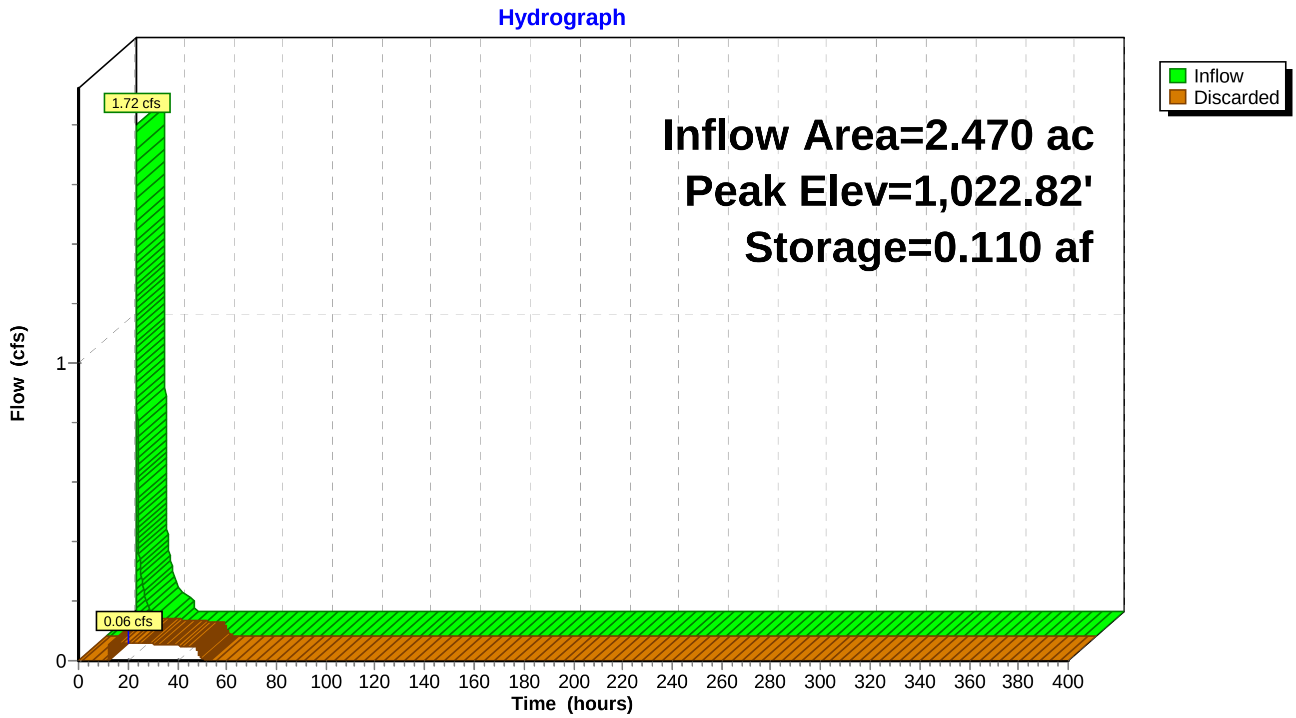
Volume	Invert	Avail.Storage	Storage Description
#1	1,022.00'	0.856 af	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.00	0.116	0.000	0.000	0.116
1,026.00	0.330	0.856	0.856	0.332

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.00'	**0.390 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.06 cfs @ 20.42 hrs HW=1,022.82' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.06 cfs)

Pond 24P: SMA-2 (Design Point 5)



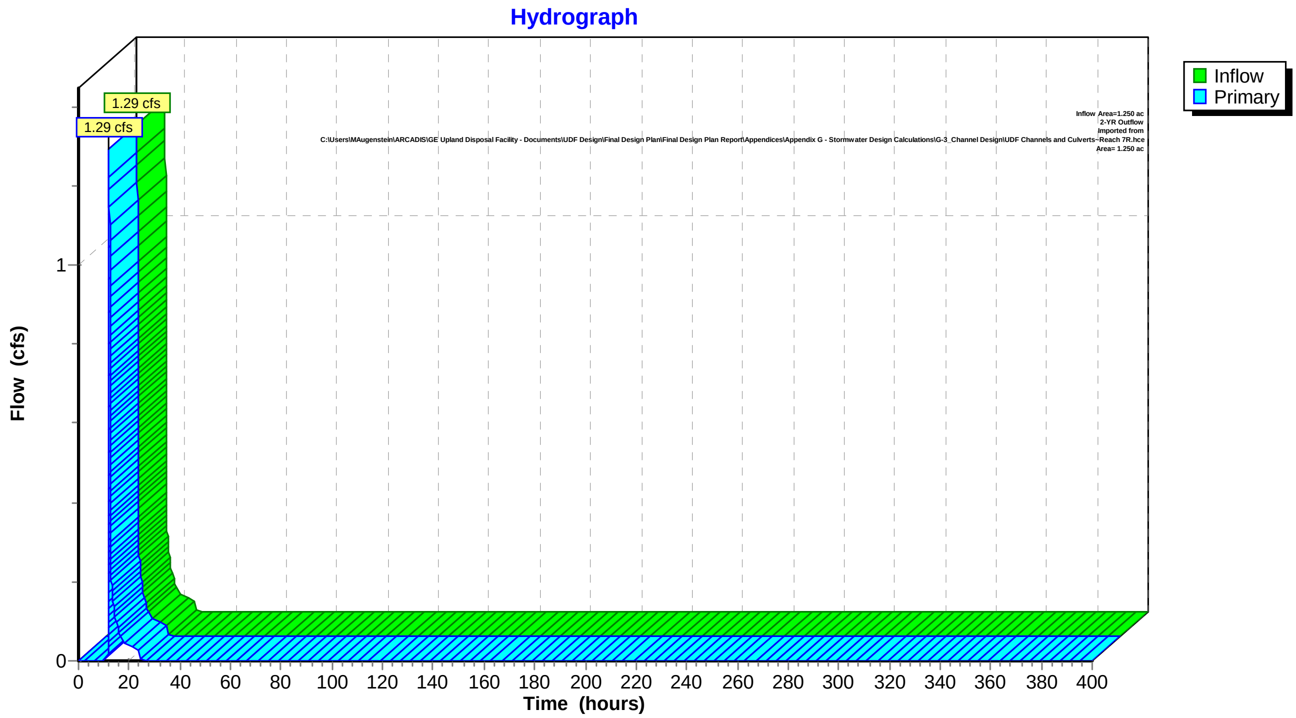
Summary for Link 9L: SW Ext. Ditch North

Inflow Area = 1.250 ac, 0.00% Impervious, Inflow Depth = 1.05" for 2-YR event
Inflow = 1.29 cfs @ 12.18 hrs, Volume= 0.109 af
Primary = 1.29 cfs @ 12.18 hrs, Volume= 0.109 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 11P : SW Ditch Low Point

Primary outflow = Inflow, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs

2-YR Outflow Imported from C:\Users\MAugenstein\ARCADIS\GE Upland Disposal Facility - Documents\UDF Design\F

Link 9L: SW Ext. Ditch North



Summary for Link 10L: SW Ext. Ditch South

Inflow Area = 1.670 ac, 0.00% Impervious, Inflow Depth = 1.48" for 2-YR event
Inflow = 2.65 cfs @ 12.15 hrs, Volume= 0.206 af
Primary = 2.65 cfs @ 12.15 hrs, Volume= 0.206 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 11P : SW Ditch Low Point

Primary outflow = Inflow, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs

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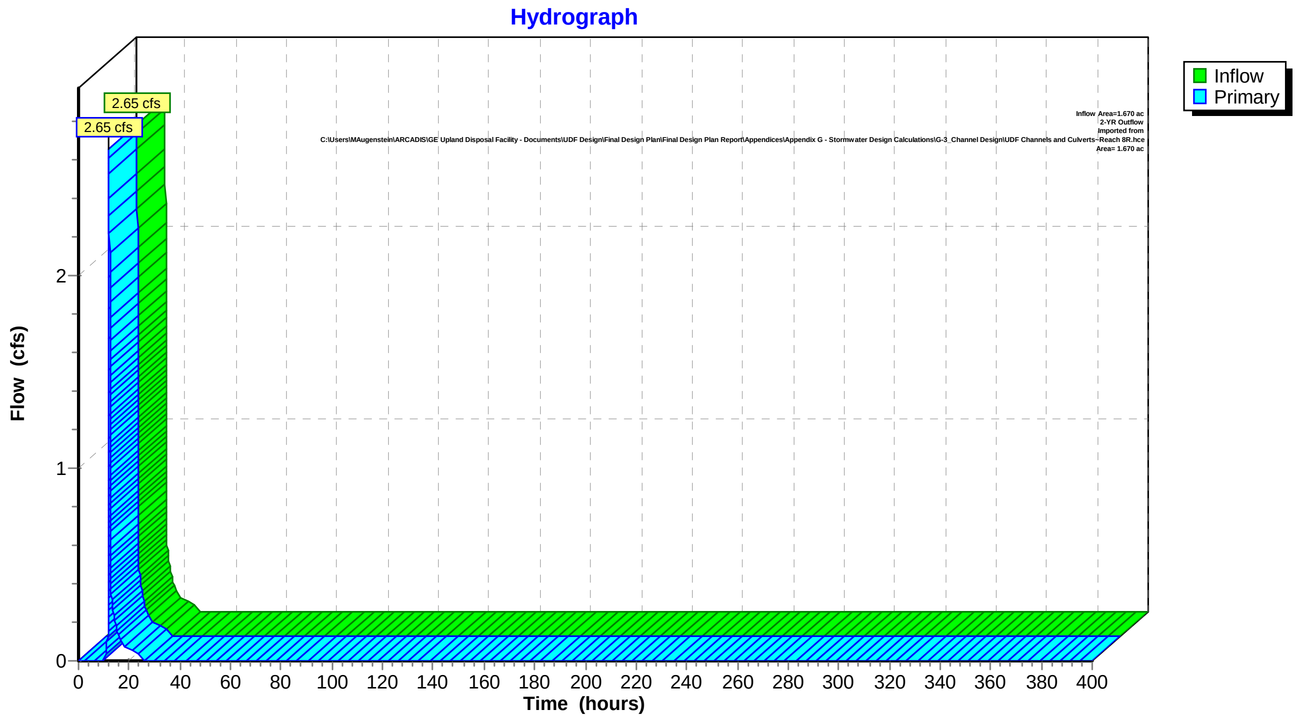
Link 10L: SW Ext. Ditch South



Time span=0.00-400.00 hrs, dt=0.01 hrs, 40001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1A-P: 1A-P Runoff Area=38.000 ac 0.00% Impervious Runoff Depth=4.44"
Flow Length=3,236' Tc=34.2 min CN=62 Runoff=104.84 cfs 14.072 af

Subcatchment 1B-P: 1B-P Runoff Area=2.440 ac 0.00% Impervious Runoff Depth=1.89"
Flow Length=329' Tc=15.1 min CN=41 Runoff=3.30 cfs 0.384 af

Subcatchment 2A-P: 2A-P Runoff Area=49.150 ac 0.00% Impervious Runoff Depth=4.44"
Flow Length=3,993' Tc=33.8 min CN=62 Runoff=136.10 cfs 18.202 af

Subcatchment 2B-P: 2B-P Runoff Area=2.820 ac 0.00% Impervious Runoff Depth=1.89"
Flow Length=248' Tc=6.8 min CN=41 Runoff=4.97 cfs 0.444 af

Subcatchment 2C-P: 2C-P Runoff Area=2.180 ac 0.00% Impervious Runoff Depth=1.55"
Flow Length=373' Tc=16.6 min CN=38 Runoff=2.10 cfs 0.281 af

Subcatchment 3-P: 3-P Runoff Area=23.590 ac 0.00% Impervious Runoff Depth=3.95"
Flow Length=3,460' Tc=32.8 min CN=58 Runoff=58.30 cfs 7.758 af

Subcatchment 4-P: 4-P (Design Point 3) Runoff Area=0.760 ac 0.00% Impervious Runoff Depth=0.91"
Flow Length=362' Tc=6.6 min CN=32 Runoff=0.33 cfs 0.058 af

Subcatchment 5-P: 5-P (Design Point 4) Runoff Area=1.330 ac 0.00% Impervious Runoff Depth=3.95"
Tc=6.7 min CN=58 Runoff=5.94 cfs 0.437 af

Subcatchment 6- P: 6-P Runoff Area=1.950 ac 0.00% Impervious Runoff Depth=4.69"
Flow Length=139' Tc=9.7 min CN=64 Runoff=9.45 cfs 0.763 af

Subcatchment 7-P: 7-P Runoff Area=10.950 ac 0.00% Impervious Runoff Depth=2.12"
Tc=11.8 min CN=43 Runoff=19.19 cfs 1.936 af

Subcatchment 8A-P: 8A-P Runoff Area=0.520 ac 0.00% Impervious Runoff Depth=3.82"
Tc=6.0 min CN=57 Runoff=2.30 cfs 0.166 af

Subcatchment 8B-P: 8B-P Runoff Area=0.440 ac 0.00% Impervious Runoff Depth=4.82"
Tc=6.0 min CN=65 Runoff=2.49 cfs 0.177 af

Subcatchment 9-P: 9-P (Design Point 8) Runoff Area=0.830 ac 0.00% Impervious Runoff Depth=5.57"
Tc=6.0 min CN=71 Runoff=5.41 cfs 0.385 af

Subcatchment 10-P: 10-P Runoff Area=5.000 ac 0.00% Impervious Runoff Depth=4.82"
Tc=6.0 min CN=65 Runoff=28.25 cfs 2.007 af

Subcatchment 16S: Entrance Road Culvert Runoff Area=0.820 ac 0.00% Impervious Runoff Depth=4.32"
Tc=6.0 min CN=61 Runoff=4.14 cfs 0.295 af

Subcatchment SB: South Basin Runoff Area=2.730 ac 0.00% Impervious Runoff Depth=7.30"
Flow Length=410' Tc=7.4 min CN=85 Runoff=21.29 cfs 1.660 af

Subcatchment UDF: UDF Runoff Area=21.810 ac 0.00% Impervious Runoff Depth=4.82"
Flow Length=1,810' Tc=8.9 min CN=65 Runoff=111.48 cfs 8.756 af

Reach 13R: SMA3 CHANNEL Avg. Flow Depth=0.00' Max Vel=0.00 fps Inflow=0.00 cfs 0.000 af
n=0.035 L=62.0' S=0.0605 '/' Capacity=1,271.47 cfs Outflow=0.00 cfs 0.000 af

Reach 22R: Pool Ditch Avg. Flow Depth=0.76' Max Vel=4.95 fps Inflow=103.03 cfs 13.599 af
n=0.035 L=202.1' S=0.0247 '/' Capacity=166.36 cfs Outflow=102.96 cfs 13.599 af

Pond 3P: SMA-1 (Design Point 2) Peak Elev=1,001.80' Storage=4.753 af Inflow=58.30 cfs 7.758 af
Discarded=0.55 cfs 5.072 af Primary=7.16 cfs 2.686 af Outflow=7.72 cfs 7.758 af

Pond 4P: North Basin Peak Elev=1,005.44' Storage=263,450 cf Inflow=108.57 cfs 8.256 af
Discarded=0.72 cfs 6.629 af Primary=4.18 cfs 1.627 af Outflow=4.90 cfs 8.256 af

Pond 5P: South Basin Peak Elev=1,033.27' Storage=57,943 cf Inflow=20.96 cfs 1.532 af
Discarded=0.15 cfs 1.469 af Primary=0.07 cfs 0.063 af Outflow=0.22 cfs 1.532 af

Pond 11P: SW Ditch Low Point Peak Elev=1,005.53' Storage=25,770 cf Inflow=20.79 cfs 1.712 af
Discarded=0.08 cfs 0.596 af Primary=12.56 cfs 1.116 af Outflow=12.64 cfs 1.712 af

Pond 12P: North Basin Forebay Peak Elev=1,005.76' Storage=34,476 cf Inflow=111.48 cfs 8.756 af
Outflow=108.57 cfs 8.256 af

Pond 13P: SMA-5 (Design Point 9) (Culvert Peak Elev=955.00' Storage=0.252 af Inflow=28.25 cfs 2.007 af
Discarded=0.09 cfs 0.029 af Primary=5.35 cfs 1.549 af Secondary=19.36 cfs 0.429 af Outflow=24.81 cfs 2.007 af

Pond 14P: North Access Road Culvert #16 Peak Elev=982.76' Storage=0.004 af Inflow=2.10 cfs 0.281 af
Discarded=0.00 cfs 0.001 af Primary=2.05 cfs 0.280 af Outflow=2.05 cfs 0.281 af

Pond 15P: Culvert #10 Peak Elev=1,033.32' Storage=0.022 af Inflow=4.14 cfs 0.295 af
12.0" Round Culvert n=0.012 L=170.0' S=0.0100 '/' Outflow=2.83 cfs 0.295 af

Pond 16P: Culvert 7 Peak Elev=1,031.40' Inflow=2.83 cfs 0.358 af
12.0" Round Culvert n=0.012 L=563.0' S=0.0103 '/' Outflow=2.83 cfs 0.358 af

Pond 17P: SMA3B (Design Point 6) Peak Elev=1,024.61' Storage=0.064 af Inflow=2.49 cfs 0.177 af
Discarded=0.02 cfs 0.082 af Primary=1.26 cfs 0.094 af Outflow=1.28 cfs 0.177 af

Pond 18P: South Basin Forebay Peak Elev=1,033.43' Storage=0.167 af Inflow=21.29 cfs 1.660 af
Outflow=20.96 cfs 1.532 af

Pond 19P: SMA-4 (Design Point 7) (Culvert Peak Elev=990.62' Storage=0.863 af Inflow=29.84 cfs 3.052 af
Discarded=0.12 cfs 0.266 af Primary=1.47 cfs 1.660 af Secondary=12.65 cfs 1.126 af Outflow=14.24 cfs 3.052 af

Pond 20P: SMA3A (Culvert 15) Peak Elev=1,029.41' Storage=0.006 af Inflow=2.30 cfs 0.166 af
Discarded=0.01 cfs 0.002 af Primary=2.06 cfs 0.163 af Secondary=0.00 cfs 0.000 af Outflow=2.07 cfs 0.166 af

Pond 21P: North Access Road Open Peak Elev=988.98' Storage=33,751 cf Inflow=238.98 cfs 31.800 af
Discarded=0.25 cfs 0.019 af Primary=228.30 cfs 31.762 af Outflow=228.55 cfs 31.781 af

Pond 22P: SMA-6/Proposed Powerline Peak Elev=988.67' Storage=7.150 af Inflow=231.44 cfs 36.798 af
Discarded=0.86 cfs 6.186 af Primary=125.68 cfs 24.864 af Outflow=126.53 cfs 31.050 af

Pond 23P: Pool Proposed Peak Elev=993.20' Storage=1.147 af Inflow=107.14 cfs 14.456 af
Outflow=103.03 cfs 13.599 af

Pond 24P: SMA-2 (Design Point 5) Peak Elev=1,025.82' Storage=0.797 af Inflow=11.50 cfs 0.926 af
Outflow=0.13 cfs 0.926 af

Link - Stormwater Design Calculations\G-3_Channel Design\UDF Channels and Culverts~Reach 7R.hce Inflow=7.09 cfs 0.528 af
Area= 1.250 ac Primary=7.09 cfs 0.528 af

Link Stormwater Design Calculations\G-3_Channel Design\UDF Channels and Culverts~Reach 8R.hce Inflow=11.04 cfs 0.826 af
Area= 1.670 ac Primary=11.04 cfs 0.826 af

Total Runoff Area = 165.320 ac Runoff Volume = 57.781 af Average Runoff Depth = 4.19"
100.00% Pervious = 165.320 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 1A-P: 1A-P

[47] Hint: Peak is 161% of capacity of segment #5

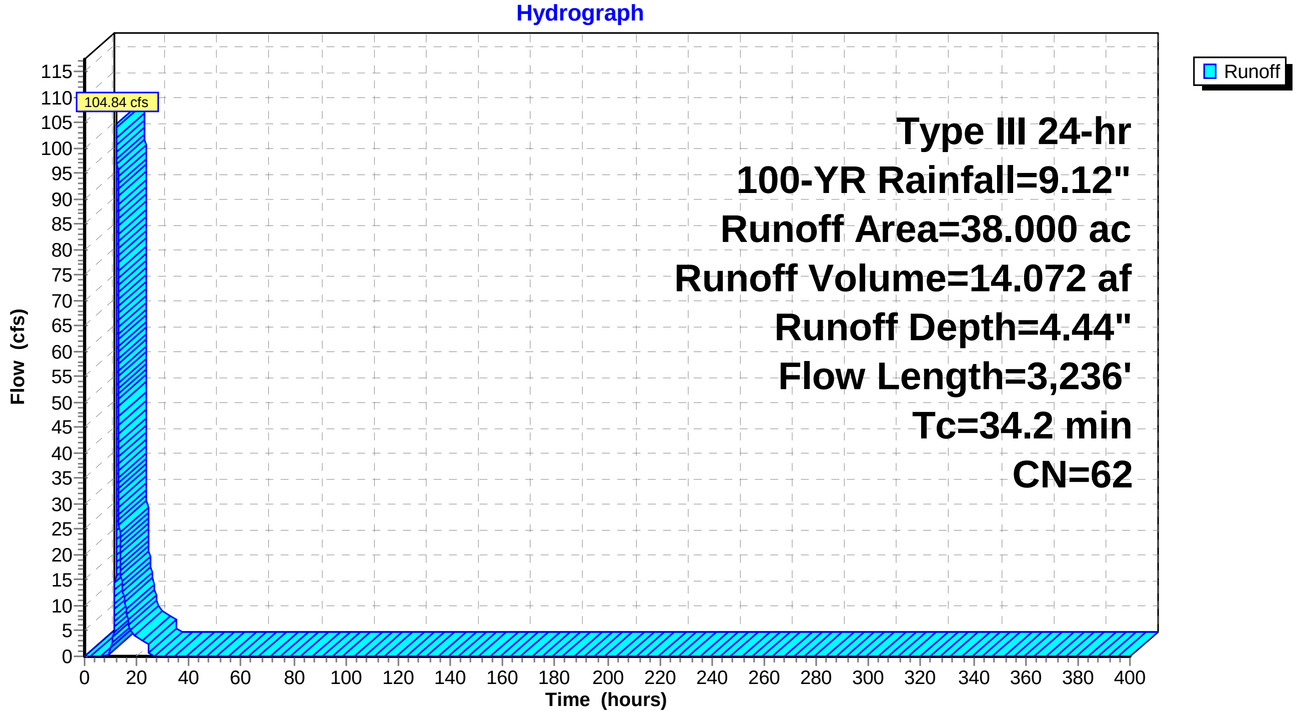
Runoff = 104.84 cfs @ 12.50 hrs, Volume= 14.072 af, Depth= 4.44"
Routed to Pond 23P : Pool Proposed

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	38.000	62	
	38.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	50	0.0400	0.06		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.7	228	0.0790	1.41		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
7.9	1,488	0.3970	3.15		**Shallow Concentrated Flow, SCF 2** Woodland Kv= 5.0 fps
8.1	1,050	0.1850	2.15		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.6	420	0.0570	10.83	64.98	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025 Earth, clean & winding
34.2	3,236	Total			

Subcatchment 1A-P: 1A-P



Summary for Subcatchment 1B-P: 1B-P

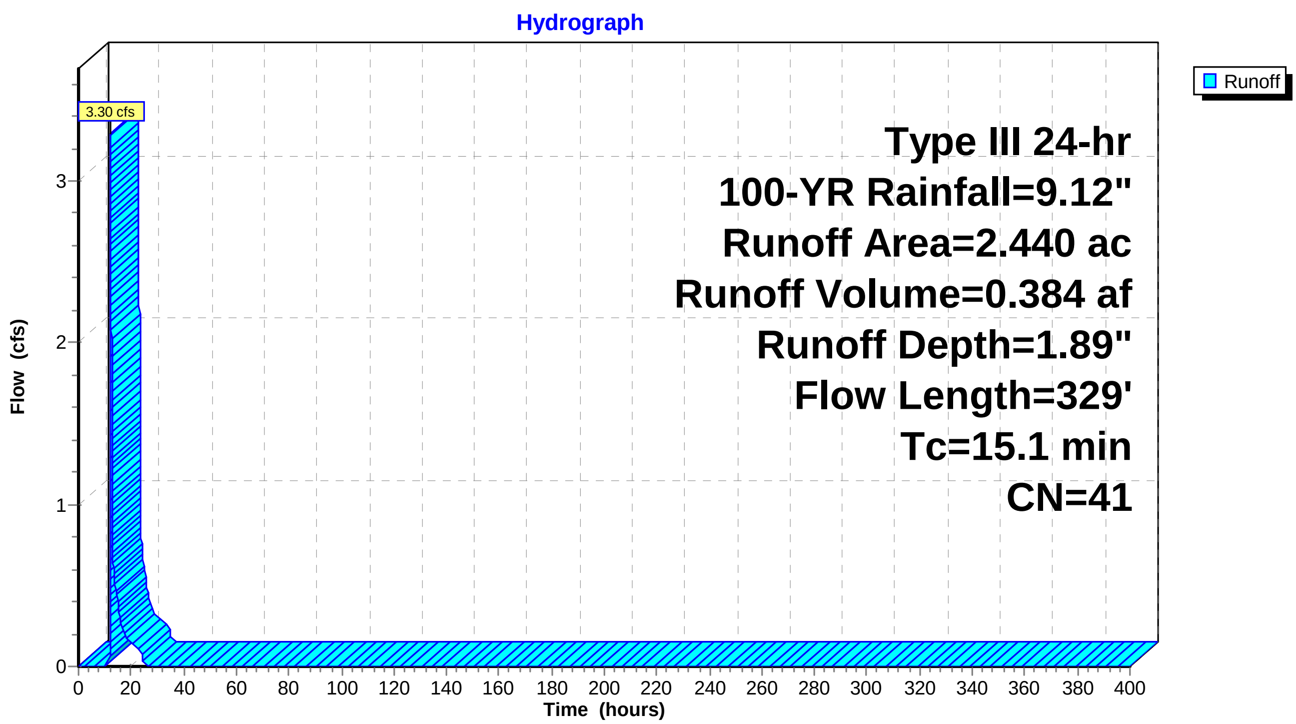
Runoff = 3.30 cfs @ 12.24 hrs, Volume= 0.384 af, Depth= 1.89"
Routed to Pond 23P : Pool Proposed

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	2.440	41	From CN Spreadsheet
	2.440		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.6	50	0.0750	0.07		**Sheet Flow, Sheet** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.9	159	0.0330	0.91		**Shallow Concentrated Flow, SCF-1** Woodland Kv= 5.0 fps
0.1	58	0.1720	18.81	112.88	**Channel Flow, CF-1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.5	62	0.1510	1.94		**Shallow Concentrated Flow, SCF-2** Woodland Kv= 5.0 fps
15.1	329	Total			

Subcatchment 1B-P: 1B-P



Summary for Subcatchment 2A-P: 2A-P

[47] Hint: Peak is 105% of capacity of segment #6
[47] Hint: Peak is 280% of capacity of segment #7
[47] Hint: Peak is 228% of capacity of segment #8
[47] Hint: Peak is 228% of capacity of segment #9

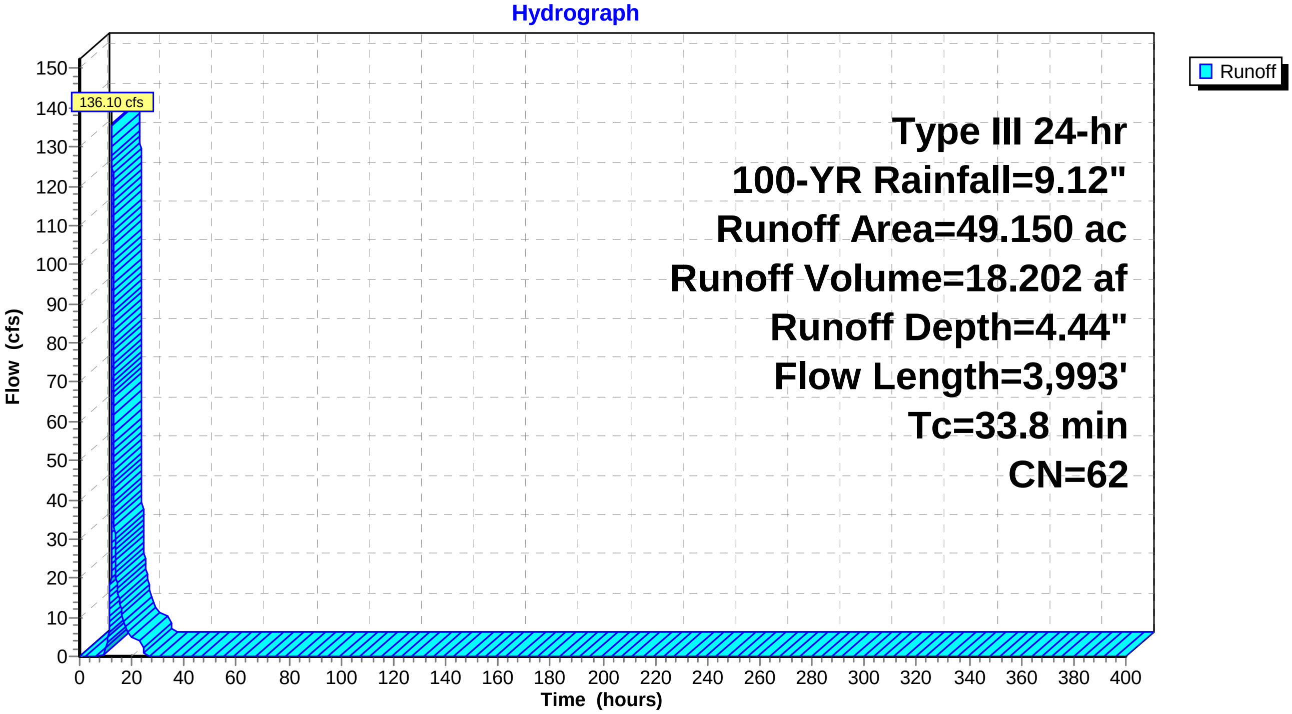
Runoff = 136.10 cfs @ 12.48 hrs, Volume= 18.202 af, Depth= 4.44"
Routed to Pond 21P : North Access Road Open Arch Culvert #1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	49.150	62	From CN Calc Spreadsheet
	49.150		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	50	0.0400	0.06		**Sheet Flow, SF** Woods: Dense underbrush n= 0.800 P2= 3.84"
2.3	207	0.0870	1.47		**Shallow Concentrated Flow, SCF 1** Woodland Kv= 5.0 fps
2.4	337	0.2140	2.31		**Shallow Concentrated Flow, SCF2** Woodland Kv= 5.0 fps
2.2	464	0.4830	3.47		**Shallow Concentrated Flow, SCF 3** Woodland Kv= 5.0 fps
0.4	592	0.2570	23.00	137.98	**Channel Flow, CF 1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
1.1	1,448	0.2280	21.66	129.96	**Channel Flow, CF 2** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.1	72	0.0320	8.11	48.69	**Channel Flow, CF 5** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.2	138	0.0480	9.94	59.63	**Channel Flow, CF 3** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
0.2	148	0.0480	9.94	59.63	**Channel Flow, CF 4** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
10.0	537	0.0320	0.89		**Shallow Concentrated Flow, SCF-4** Woodland Kv= 5.0 fps
33.8	3,993	Total			

Subcatchment 2A-P: 2A-P



Summary for Subcatchment 2B-P: 2B-P

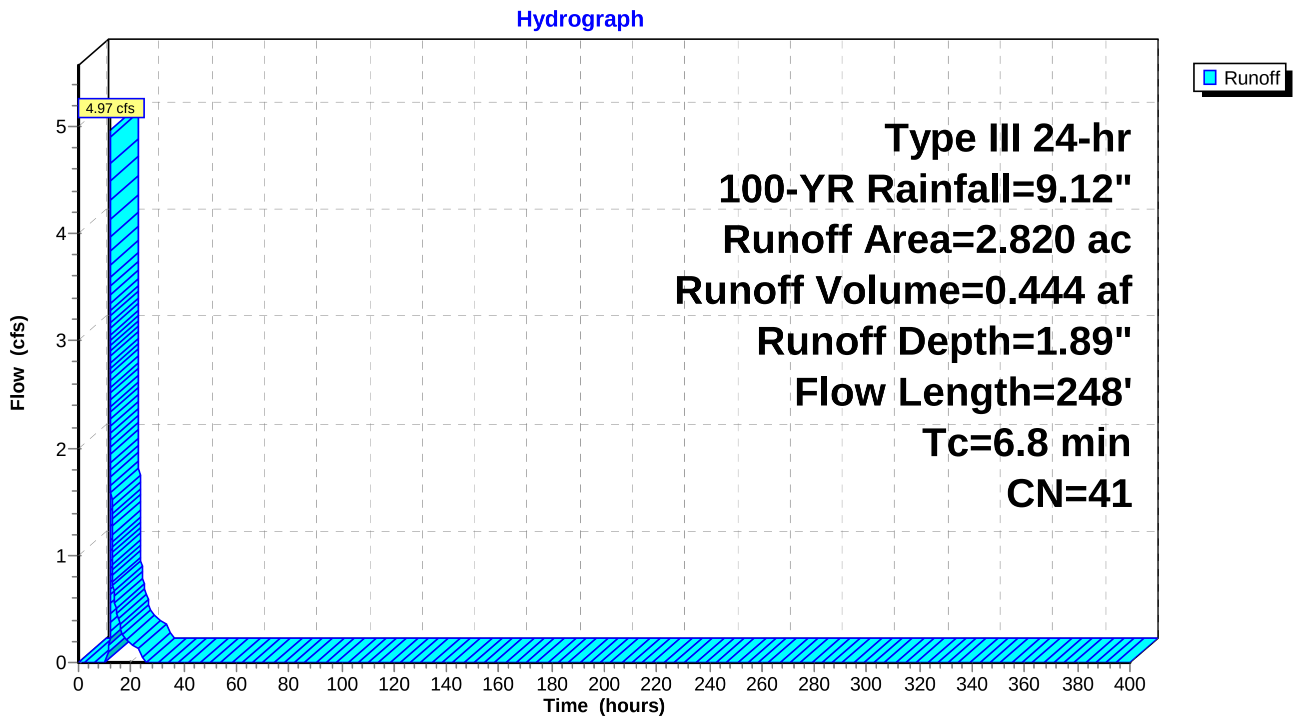
Runoff = 4.97 cfs @ 12.12 hrs, Volume= 0.444 af, Depth= 1.89"
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	2.820	41	
	2.820		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	50	0.1410	0.16		**Sheet Flow, SHEET FLOW** Woods: Light underbrush n= 0.400 P2= 3.84"
1.6	198	0.1720	2.07		**Shallow Concentrated Flow, SCF-1** Woodland Kv= 5.0 fps
6.8	248	Total			

Subcatchment 2B-P: 2B-P



Summary for Subcatchment 2C-P: 2C-P

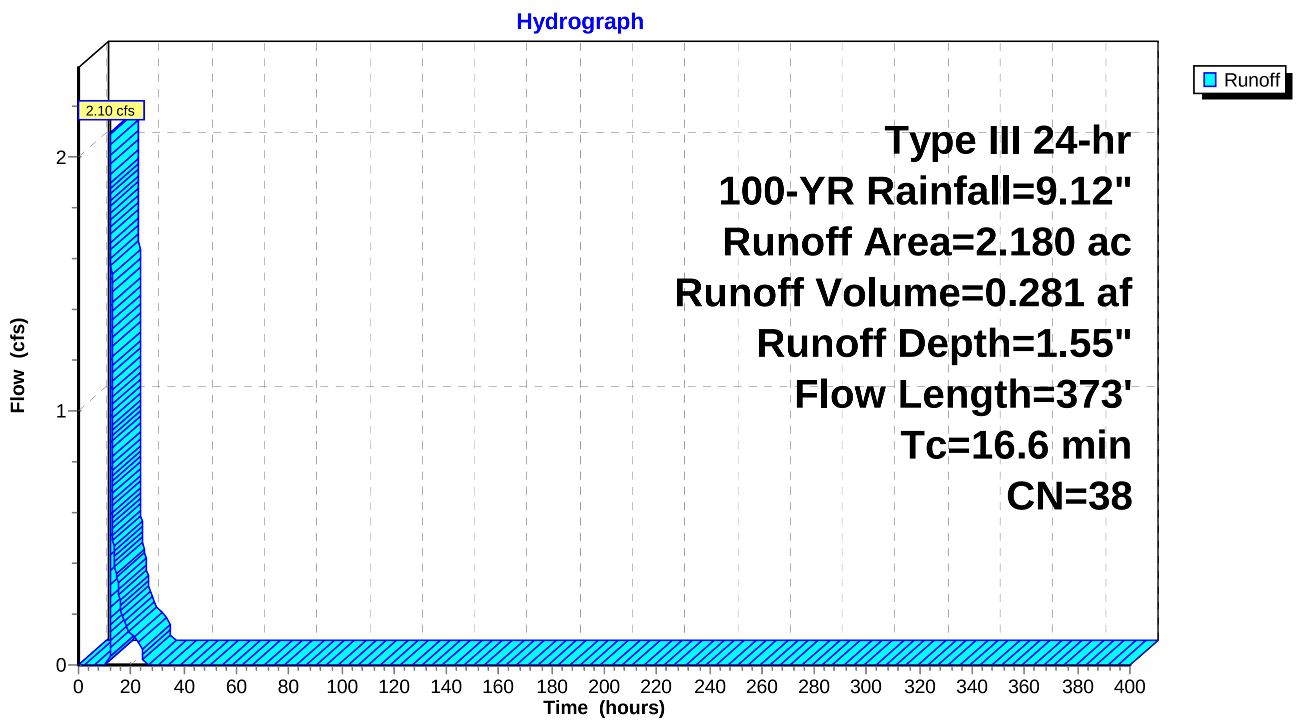
Runoff = 2.10 cfs @ 12.30 hrs, Volume= 0.281 af, Depth= 1.55"
Routed to Pond 14P : North Access Road Culvert #16

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	2.180	38	
	2.180		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.6	50	0.0420	0.06		**Sheet Flow, SHEET FLOW** Woods: Dense underbrush n= 0.800 P2= 3.84"
1.8	225	0.1660	2.04		**Shallow Concentrated Flow, SCF1** Woodland Kv= 5.0 fps
0.2	98	0.0520	10.34	62.06	**Channel Flow, CF1** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
16.6	373	Total			

Subcatchment 2C-P: 2C-P



Summary for Subcatchment 3-P: 3-P

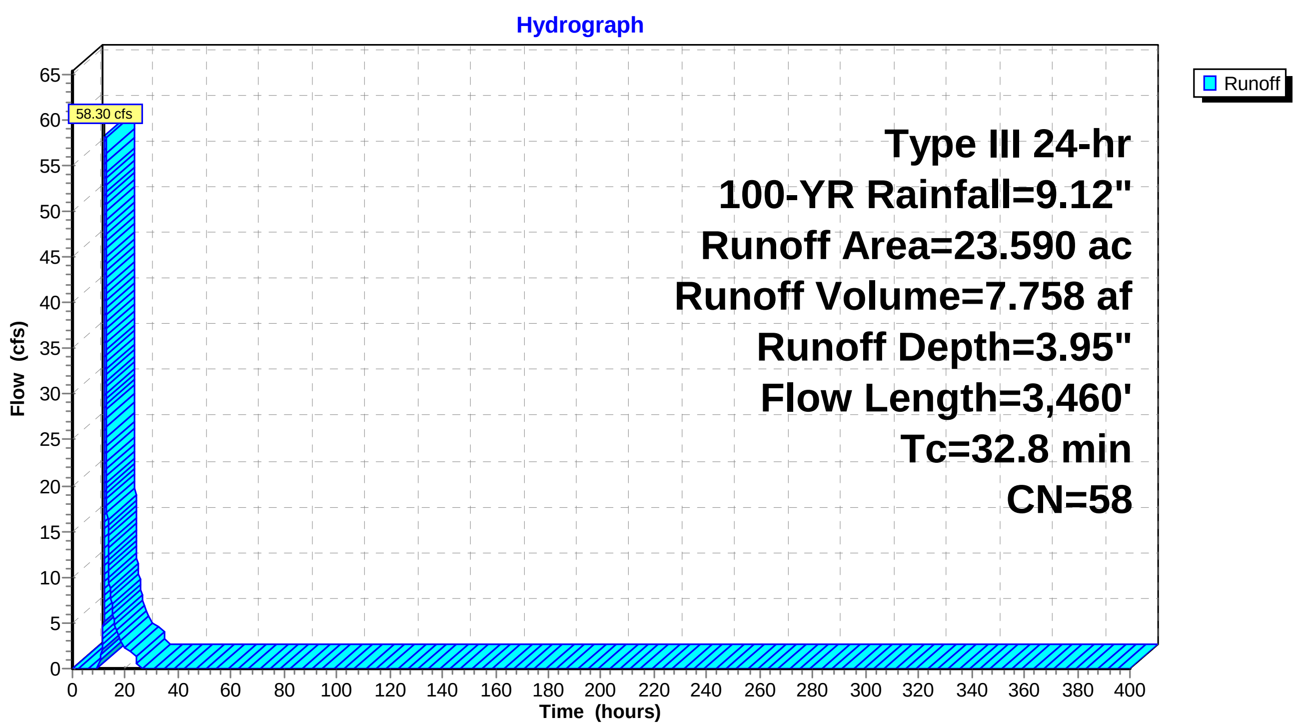
Runoff = 58.30 cfs @ 12.47 hrs, Volume= 7.758 af, Depth= 3.95"
Routed to Pond 3P : SMA-1 (Design Point 2)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	23.590	58	From CN Calc Spreadsheet
	23.590		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.6	50	0.1200	0.09		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.84"
5.9	657	0.1390	1.86		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
6.7	1,207	0.3630	3.01		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
10.1	1,240	0.1690	2.06		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
0.5	306	0.0590	11.02	66.11	**Channel Flow,** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
32.8	3,460	Total			

Subcatchment 3-P: 3-P



Summary for Subcatchment 4-P: 4-P (Design Point 3)

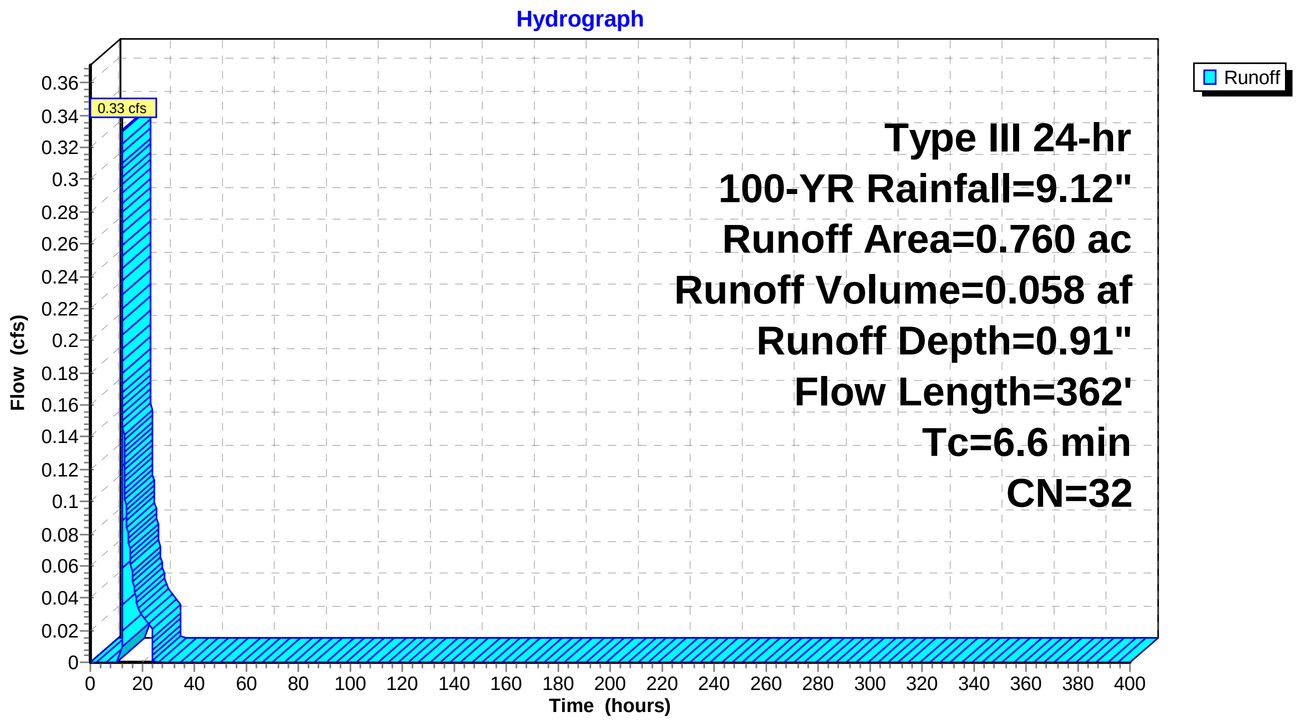
Runoff = 0.33 cfs @ 12.28 hrs, Volume= 0.058 af, Depth= 0.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	0.760	32	From CN Calc Spreadsheet
	0.760		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.9	50	0.1600	0.17		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.84"
1.3	126	0.1110	1.67		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
0.4	186	0.0320	8.11	48.69	**Channel Flow,** Area= 6.0 sf Perim= 9.0' r= 0.67' n= 0.025
6.6	362	Total			

Subcatchment 4-P: 4-P (Design Point 3)



Summary for Subcatchment 5-P: 5-P (Design Point 4)

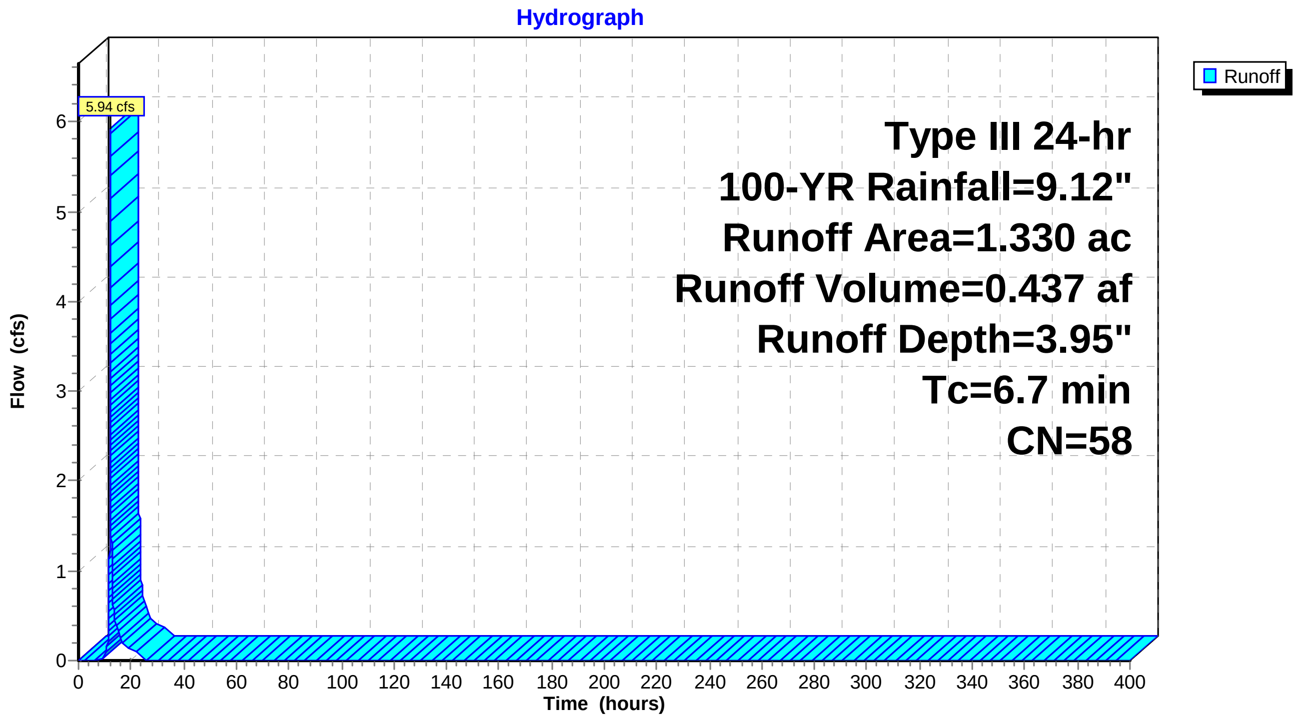
Runoff = 5.94 cfs @ 12.10 hrs, Volume= 0.437 af, Depth= 3.95"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	1.330	58	From CN Calc Spreadsheet
	1.330		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7					**Direct Entry, From Existing Conditions**

Subcatchment 5-P: 5-P (Design Point 4)



Summary for Subcatchment 6- P: 6-P

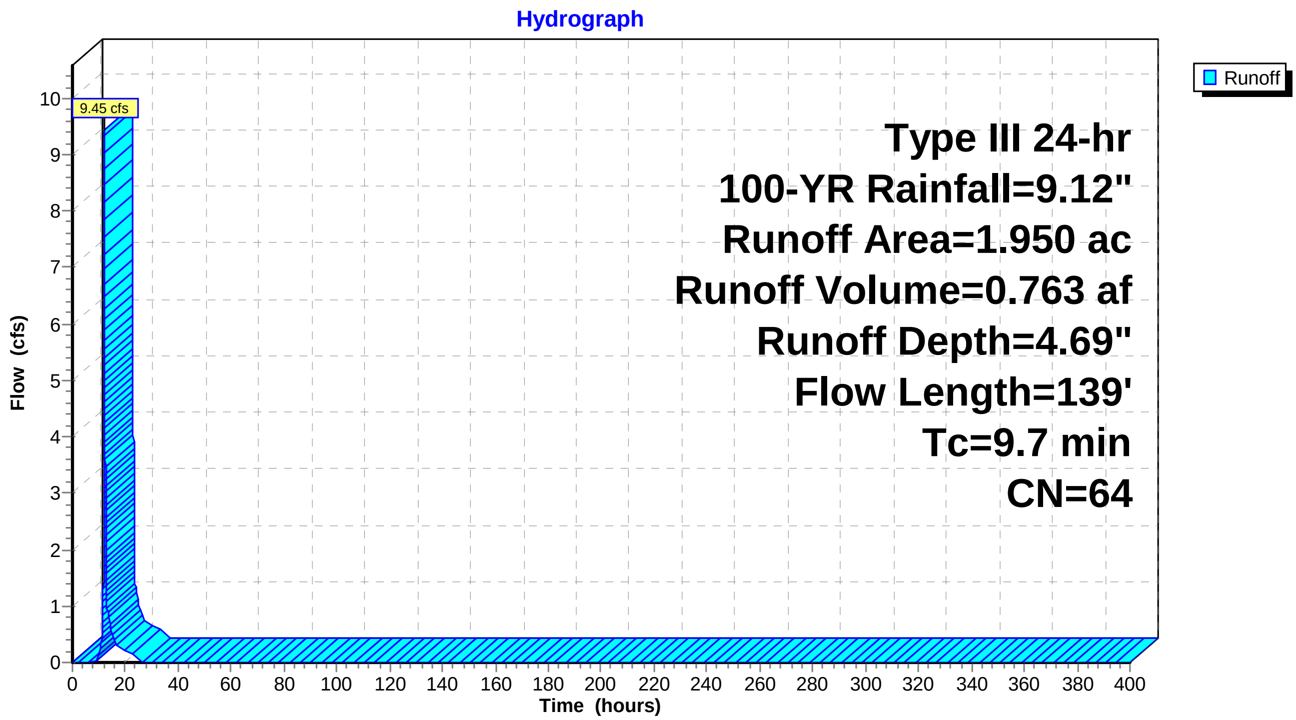
Runoff = 9.45 cfs @ 12.14 hrs, Volume= 0.763 af, Depth= 4.69"
Routed to Pond 24P : SMA-2 (Design Point 5)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	1.950	64	From CN Calc Spreadsheet
	1.950		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.7	50	0.0400	0.15		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.84"
4.0	89	0.0028	0.37		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
9.7	139	Total			

Subcatchment 6- P: 6-P



Summary for Subcatchment 7-P: 7-P

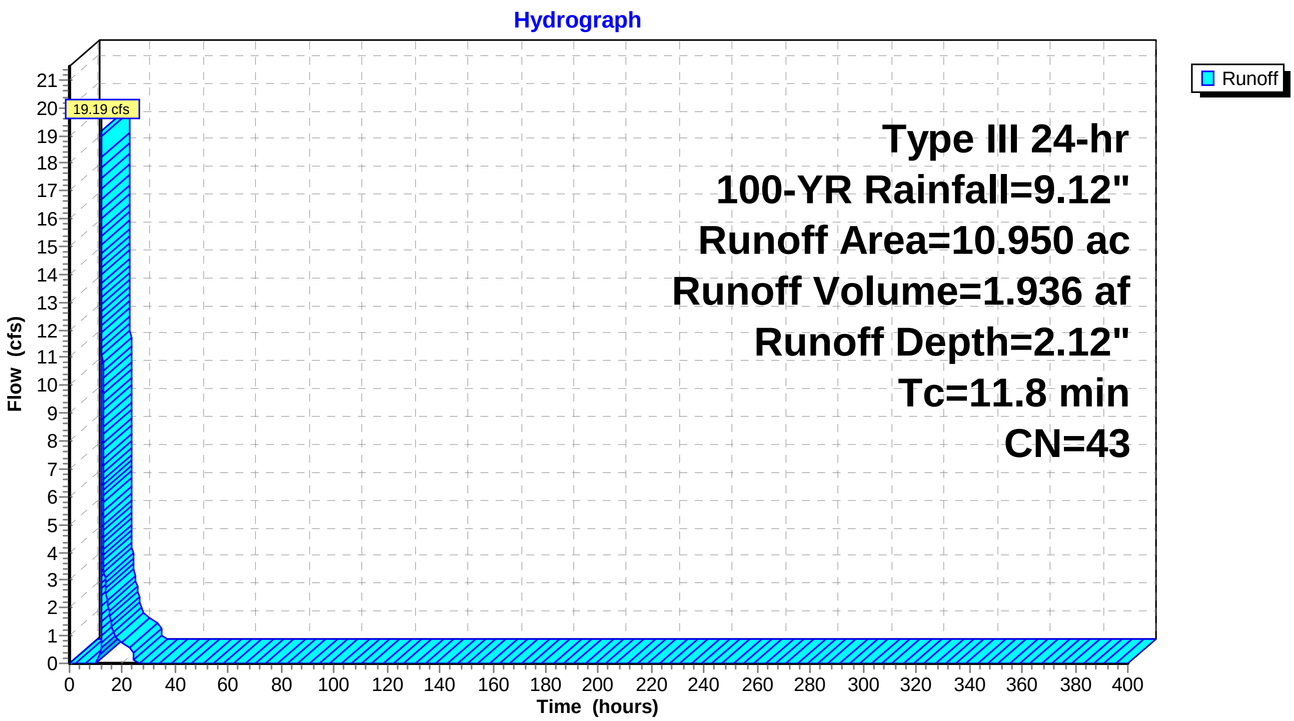
Runoff = 19.19 cfs @ 12.18 hrs, Volume= 1.936 af, Depth= 2.12"
Routed to Pond 19P : SMA-4 (Design Point 7) (Culvert 9)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	10.950	43	From CN Calc Spreadsheet
	10.950		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.8					**Direct Entry, from existing conditions**

Subcatchment 7-P: 7-P



Summary for Subcatchment 8A-P: 8A-P

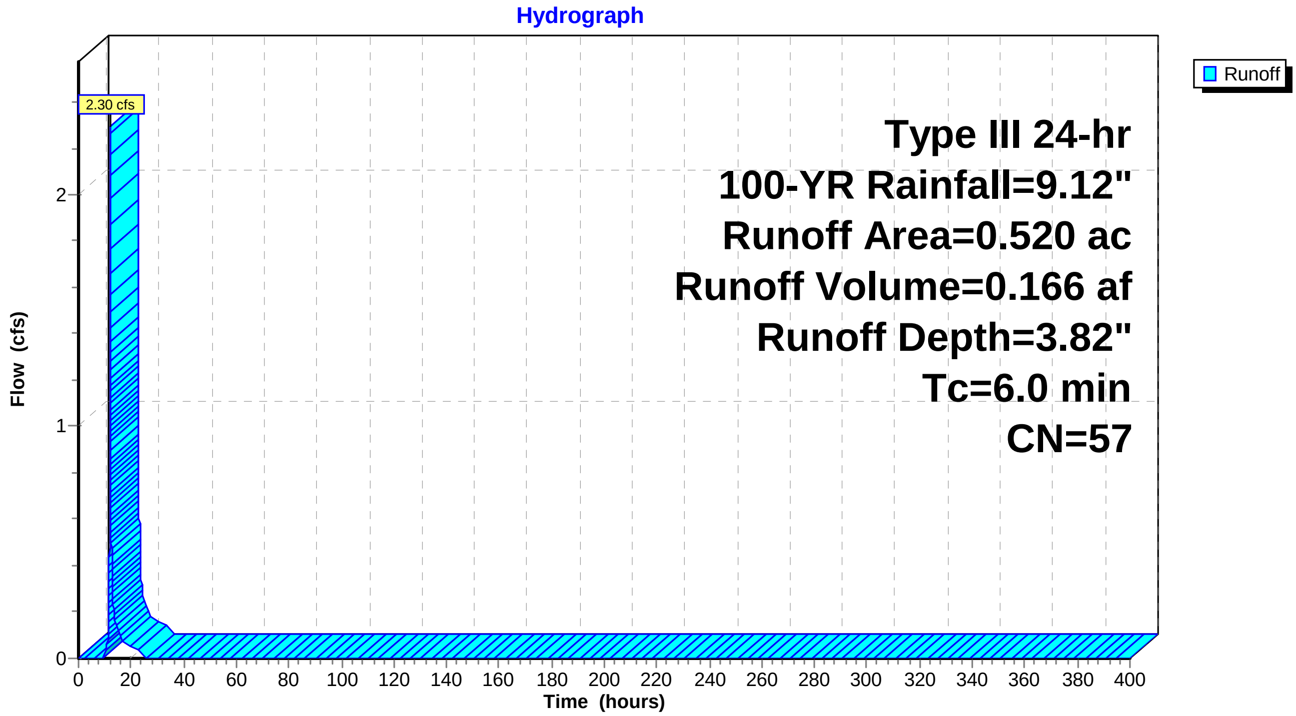
Runoff = 2.30 cfs @ 12.09 hrs, Volume= 0.166 af, Depth= 3.82"
Routed to Pond 20P : SMA3A (Culvert 15)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	0.520	57	
	0.520		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment 8A-P: 8A-P



Summary for Subcatchment 8B-P: 8B-P

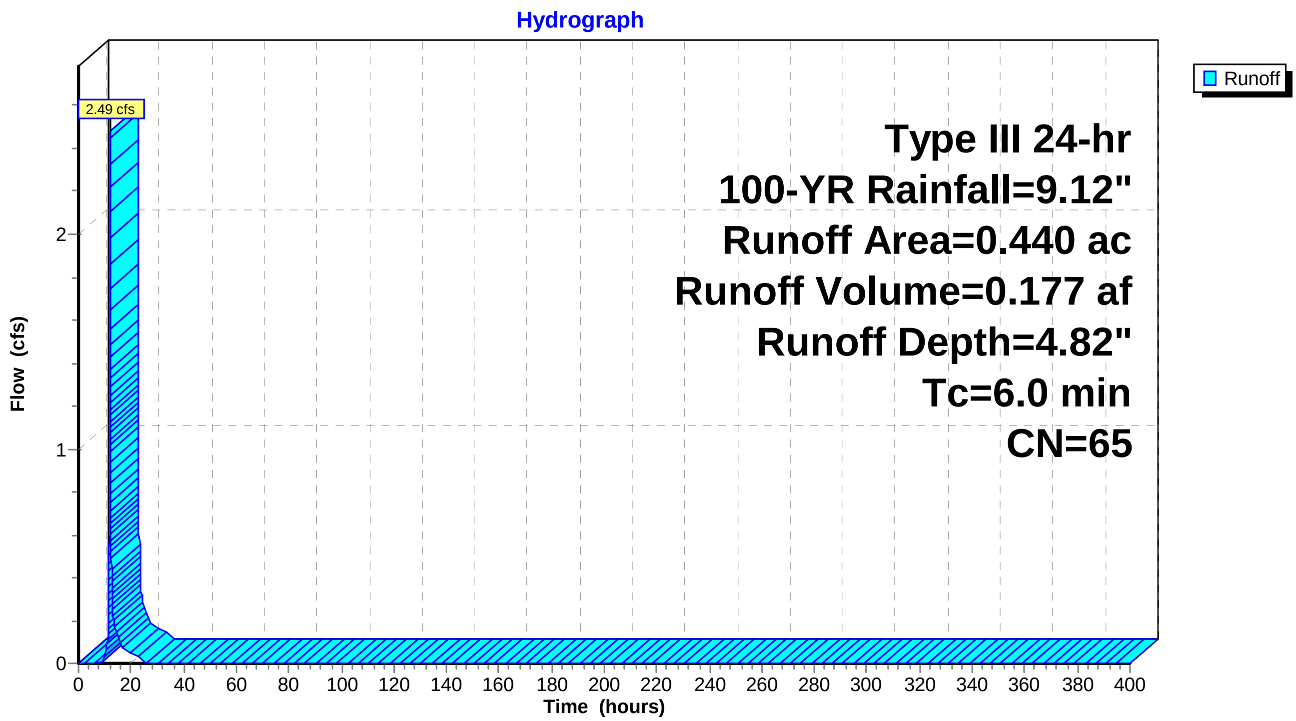
Runoff = 2.49 cfs @ 12.09 hrs, Volume= 0.177 af, Depth= 4.82"
Routed to Pond 17P : SMA3B (Design Point 6)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	0.440	65	
	0.440		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, TR55 MIN**

Subcatchment 8B-P: 8B-P



Summary for Subcatchment 9-P: 9-P (Design Point 8)

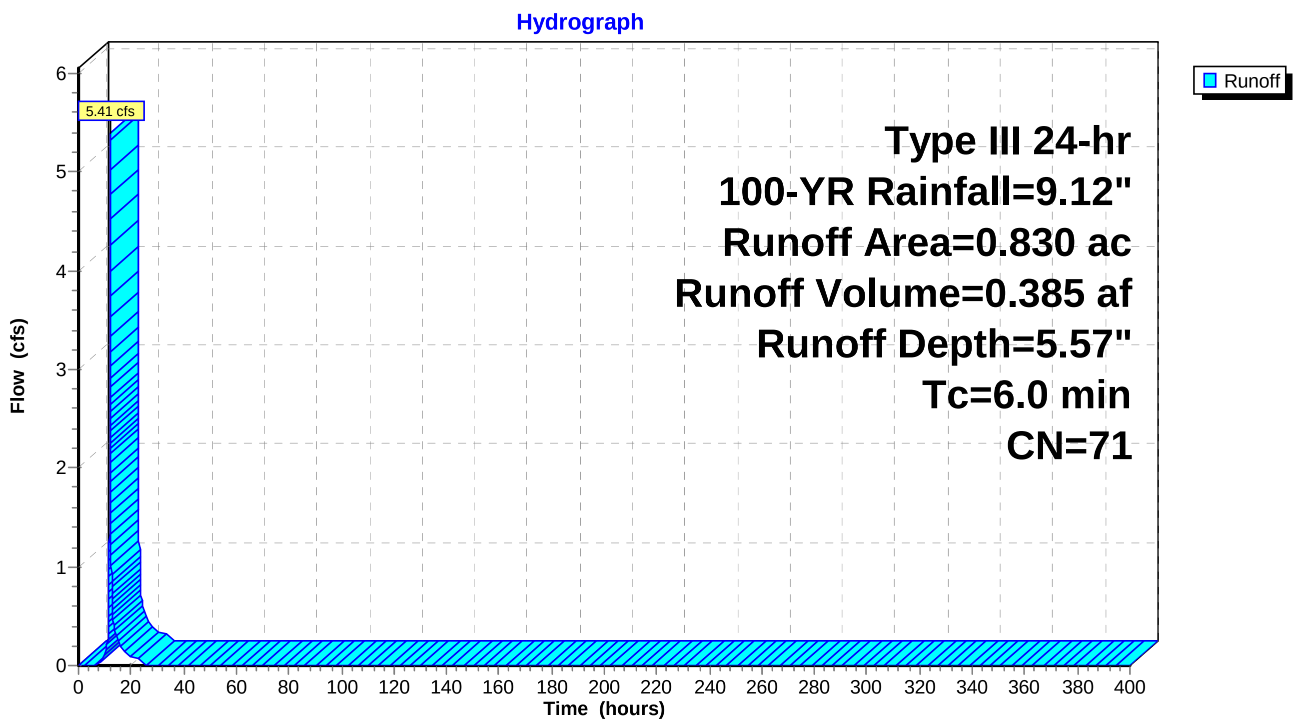
Runoff = 5.41 cfs @ 12.09 hrs, Volume= 0.385 af, Depth= 5.57"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	0.830	71	From CN Calc Spreadsheet
	0.830		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, From Existing Conditions**

Subcatchment 9-P: 9-P (Design Point 8)



Summary for Subcatchment 10-P: 10-P

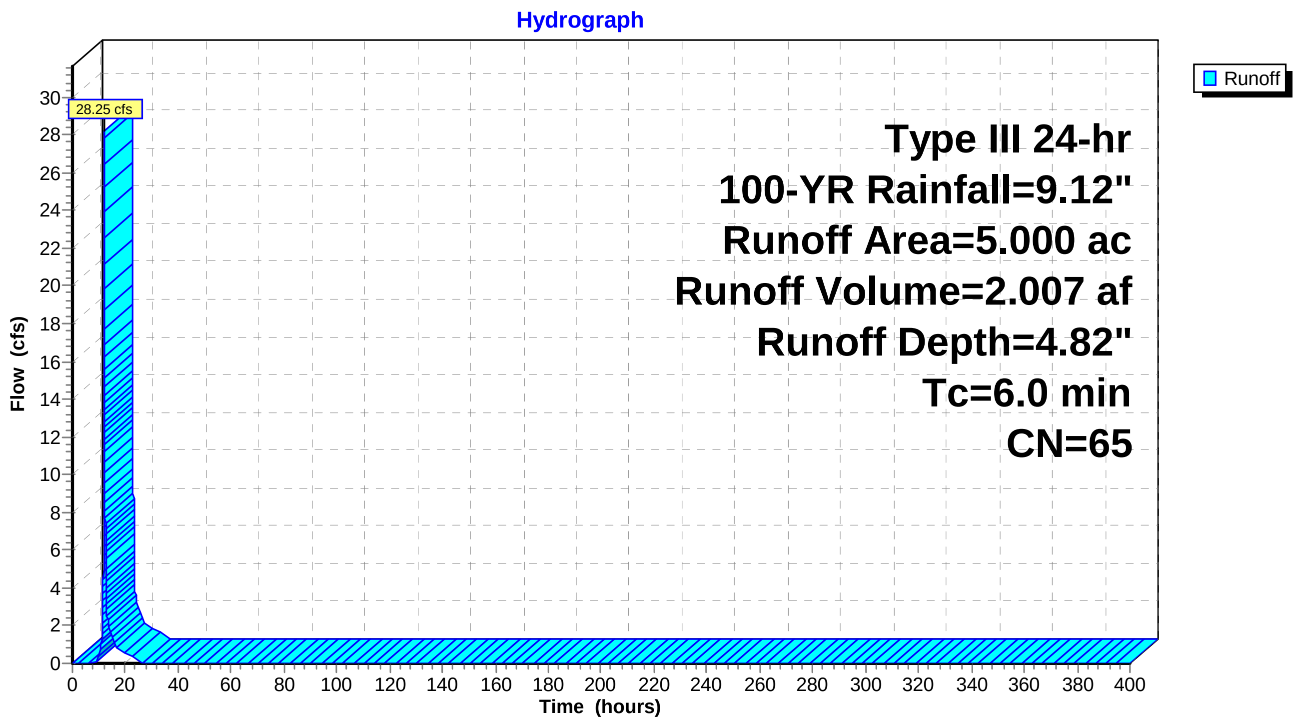
Runoff = 28.25 cfs @ 12.09 hrs, Volume= 2.007 af, Depth= 4.82"
Routed to Pond 13P : SMA-5 (Design Point 9) (Culvert 12)

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	5.000	65	From CN Calc Spreadsheet
	5.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, TR55 Min**

Subcatchment 10-P: 10-P



Summary for Subcatchment 16S: Entrance Road Culvert

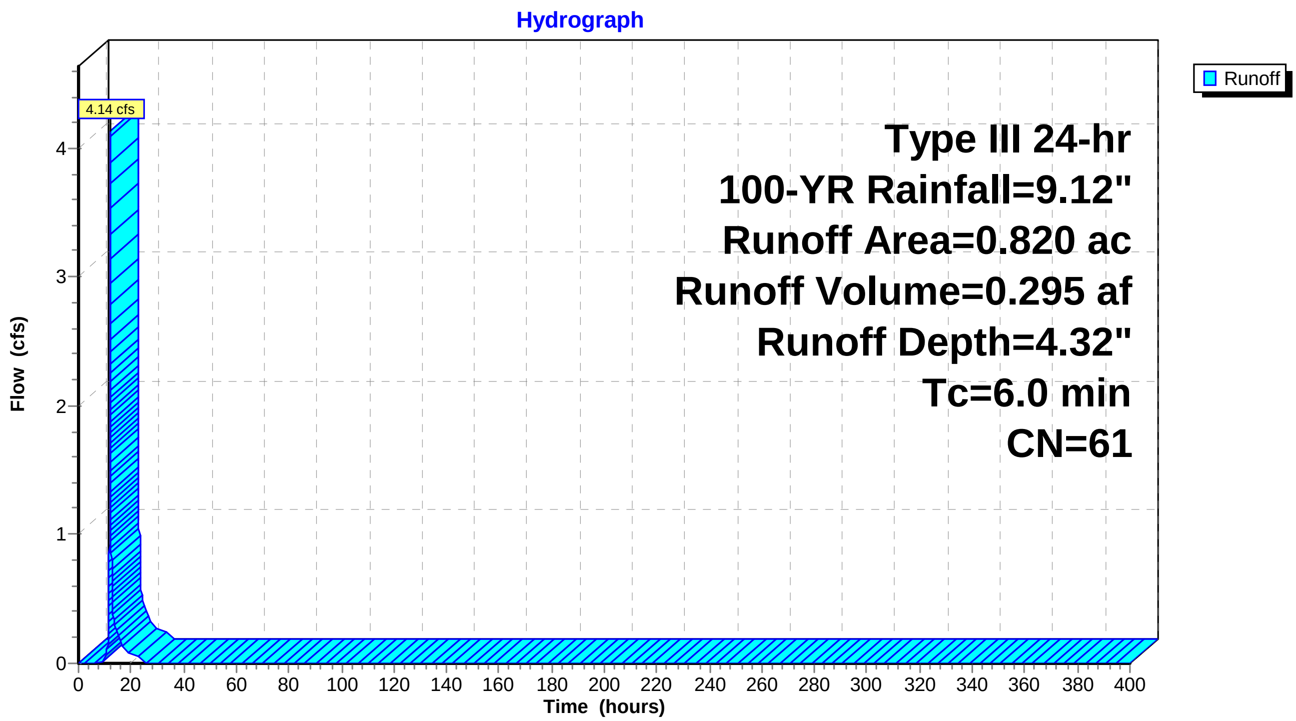
Runoff = 4.14 cfs @ 12.09 hrs, Volume= 0.295 af, Depth= 4.32"
Routed to Pond 15P : Culvert #10

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	0.820	61	
	0.820		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, TR55 MIN**

Subcatchment 16S: Entrance Road Culvert



Summary for Subcatchment SB: South Basin

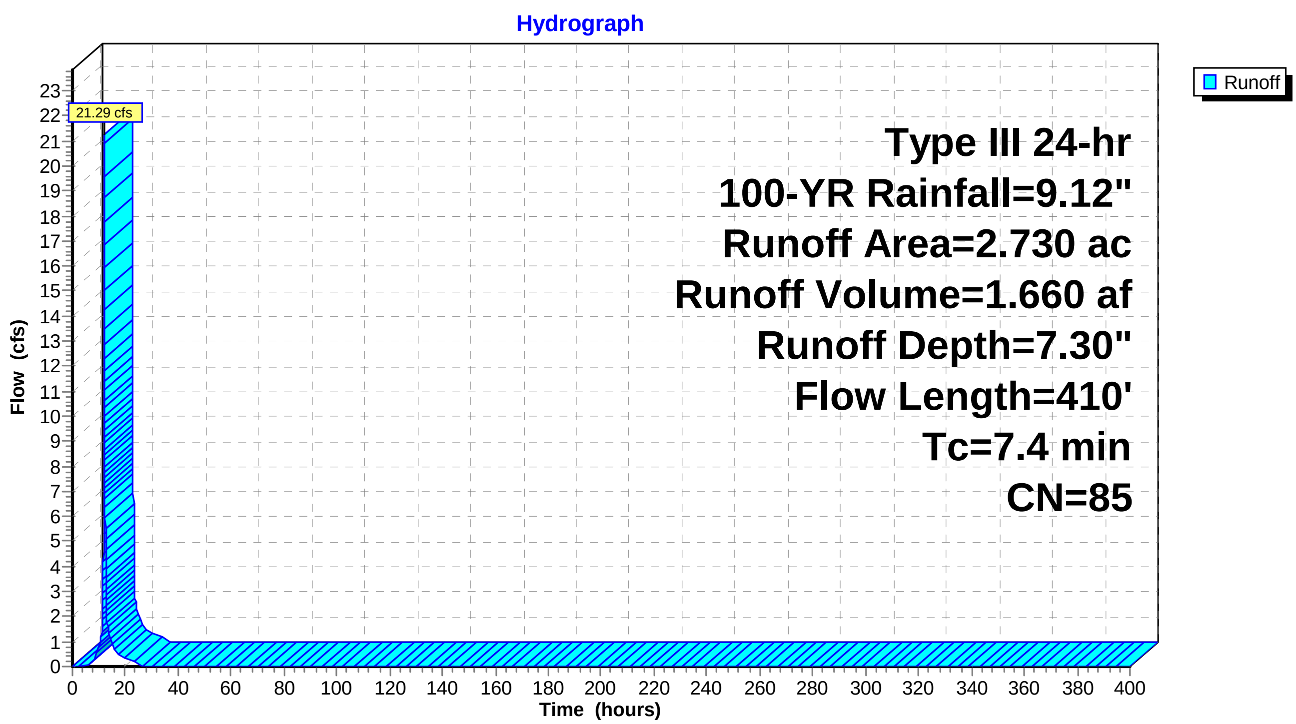
Runoff = 21.29 cfs @ 12.10 hrs, Volume= 1.660 af, Depth= 7.30"
Routed to Pond 18P : South Basin Forebay

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	2.730	85	From CN Calc Spreadsheet
	2.730		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.3	50	0.0310	0.19		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.84"
3.1	360	0.0141	1.91		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
7.4	410	Total			

Subcatchment SB: South Basin



Summary for Subcatchment UDF: UDF

A soils

[47] Hint: Peak is 258% of capacity of segment #3
[47] Hint: Peak is 493% of capacity of segment #5

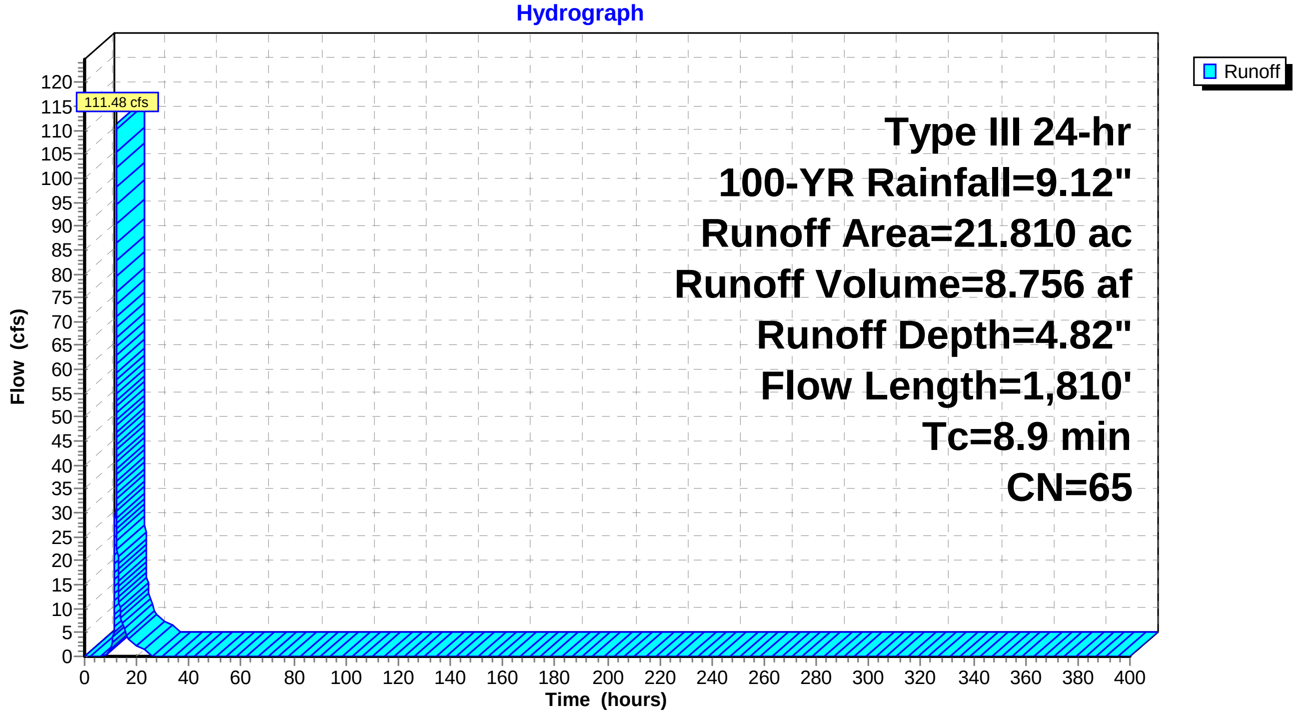
Runoff = 111.48 cfs @ 12.13 hrs, Volume= 8.756 af, Depth= 4.82"
Routed to Pond 12P : North Basin Forebay

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-YR Rainfall=9.12"

	Area (ac)	CN	Description
*	21.810	65	From CN Calc Spreadsheet
	21.810		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.1	50	0.0900	0.20		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.84"
0.9	152	0.1500	2.71		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.6	1,365	0.2280	14.39	43.16	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.00' Z= 3.0 '/' Top.W=6.00' n= 0.030 Earth, grassed & winding
2.1	152	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	91	0.0100	7.20	22.62	**Pipe Channel,** 24.0" Round Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Corrugated PE, smooth interior
8.9	1,810	Total			

Subcatchment UDF: UDF



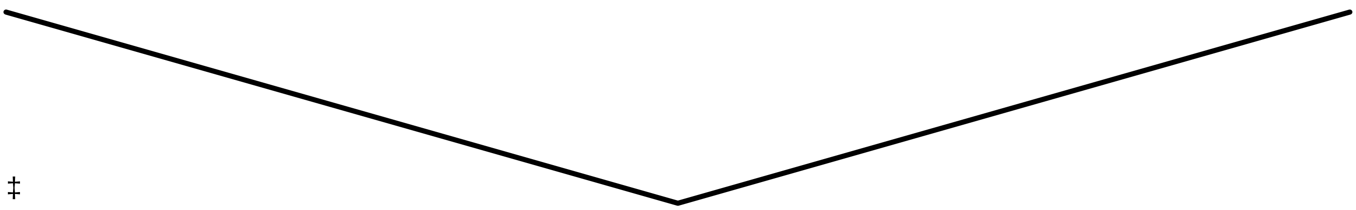
Summary for Reach 13R: SMA3 CHANNEL

Inflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 17P : SMA3B (Design Point 6)

Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Max. Velocity= 0.00 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 0.00 fps, Avg. Travel Time= 0.0 min

Peak Storage= 0 cf @ 0.00 hrs
Average Depth at Peak Storage= 0.00'
Bank-Full Depth= 3.04' Flow Area= 92.4 sf, Capacity= 1,271.47 cfs

0.00' x 3.04' deep channel, n= 0.035 Earth, dense weeds
Side Slope Z-value= 10.0 '/' Top Width= 60.80'
Length= 62.0' Slope= 0.0605 '/'
Inlet Invert= 1,028.55', Outlet Invert= 1,024.80'



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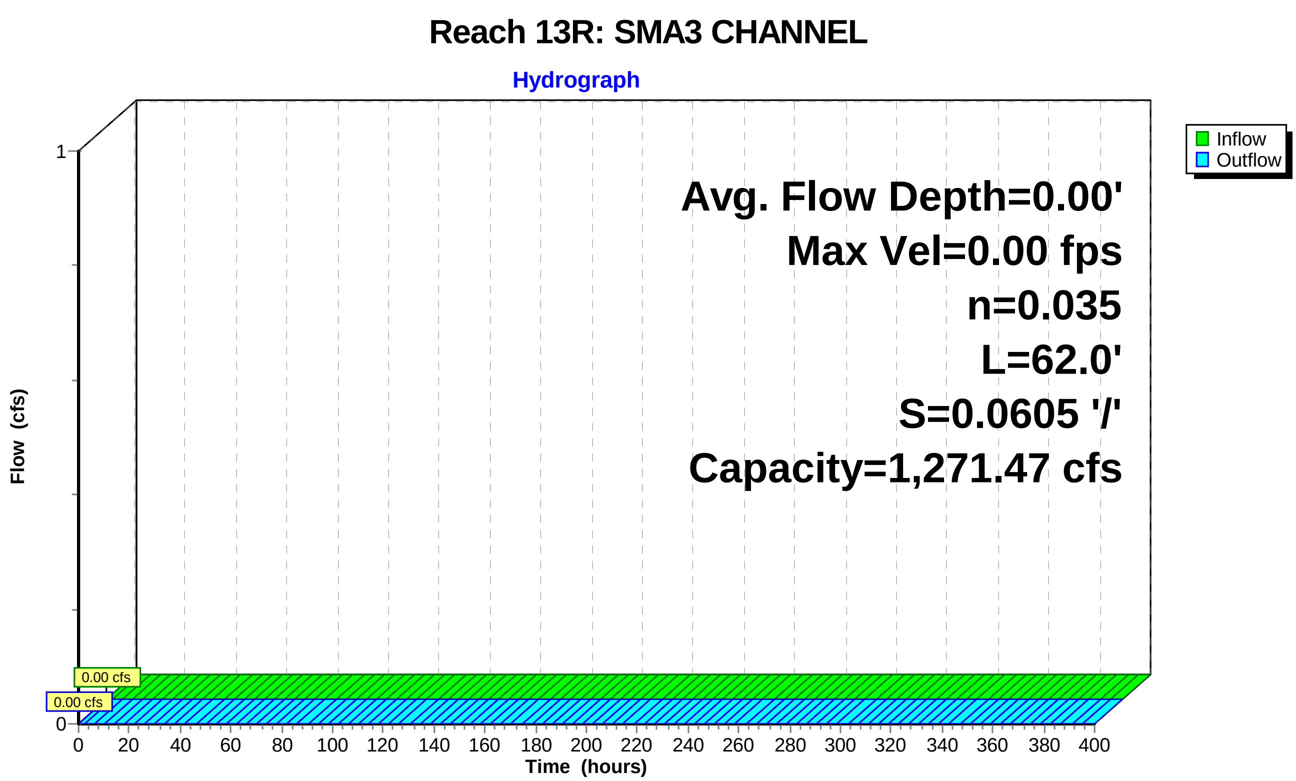


Summary for Reach 22R: Pool Ditch

Inflow Area = 40.440 ac, 0.00% Impervious, Inflow Depth = 4.04" for 100-YR event
Inflow = 103.03 cfs @ 12.50 hrs, Volume= 13.599 af
Outflow = 102.96 cfs @ 12.51 hrs, Volume= 13.599 af, Atten= 0%, Lag= 0.8 min
Routed to Pond 21P : North Access Road Open Arch Culvert #1

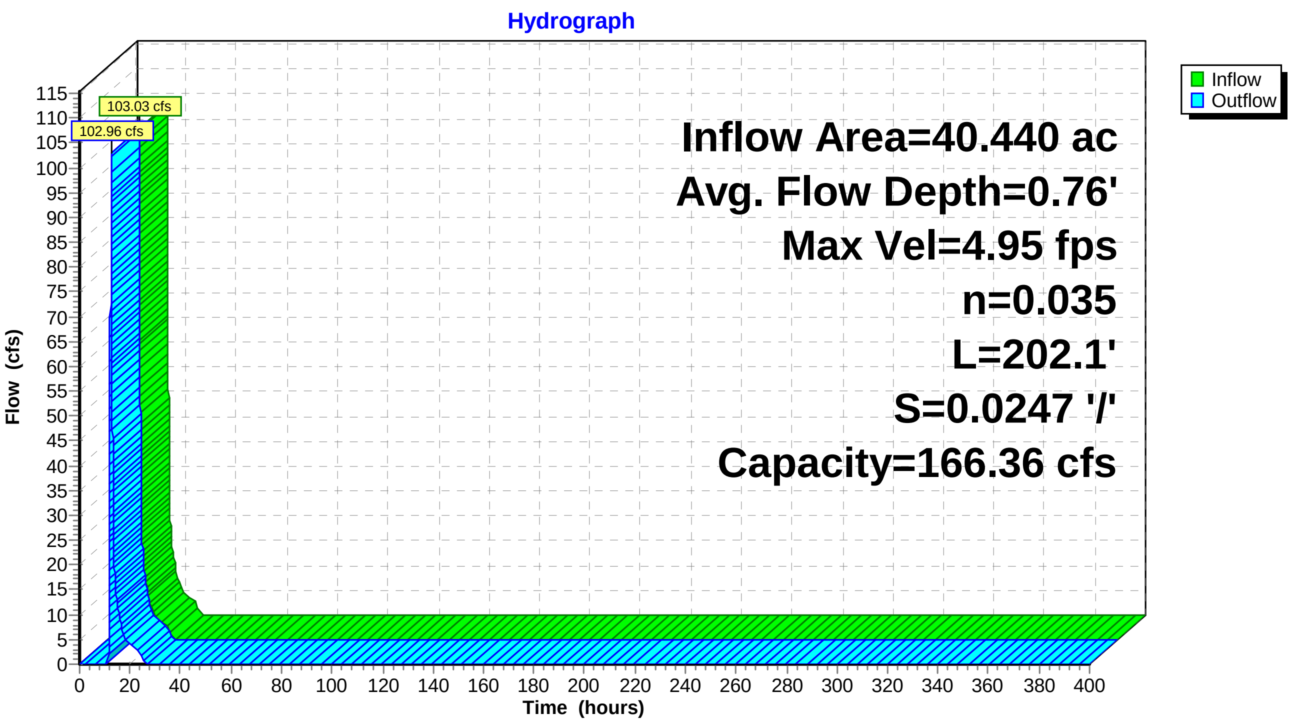
Routing by Stor-Ind+Trans method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.95 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.40 fps, Avg. Travel Time= 2.4 min

Peak Storage= 4,202 cf @ 12.50 hrs
Average Depth at Peak Storage= 0.76' , Surface Width= 32.40'
Bank-Full Depth= 1.00' Flow Area= 28.8 sf, Capacity= 166.36 cfs

22.00' x 1.00' deep channel, n= 0.035
Side Slope Z-value= 6.8 '/' Top Width= 35.60'
Length= 202.1' Slope= 0.0247 '/'
Inlet Invert= 992.44', Outlet Invert= 987.45'

‡

Reach 22R: Pool Ditch



Summary for Pond 3P: SMA-1 (Design Point 2)

[58] Hint: Peaked 0.04' above defined flood level

Inflow Area = 23.590 ac, 0.00% Impervious, Inflow Depth = 3.95" for 100-YR event
Inflow = 58.30 cfs @ 12.47 hrs, Volume= 7.758 af
Outflow = 7.72 cfs @ 14.46 hrs, Volume= 7.758 af, Atten= 87%, Lag= 119.1 min
Discarded = 0.55 cfs @ 14.46 hrs, Volume= 5.072 af
Primary = 7.16 cfs @ 14.46 hrs, Volume= 2.686 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,001.80' @ 14.46 hrs Surf.Area= 1.196 ac Storage= 4.753 af
Flood Elev= 1,001.76' Surf.Area= 1.185 ac Storage= 4.700 af

Plug-Flow detention time= 2,992.2 min calculated for 7.758 af (100% of inflow)
Center-of-Mass det. time= 2,992.1 min (3,860.6 - 868.5)

Volume	Invert	Avail.Storage	Storage Description
#1	995.00'	4.991 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

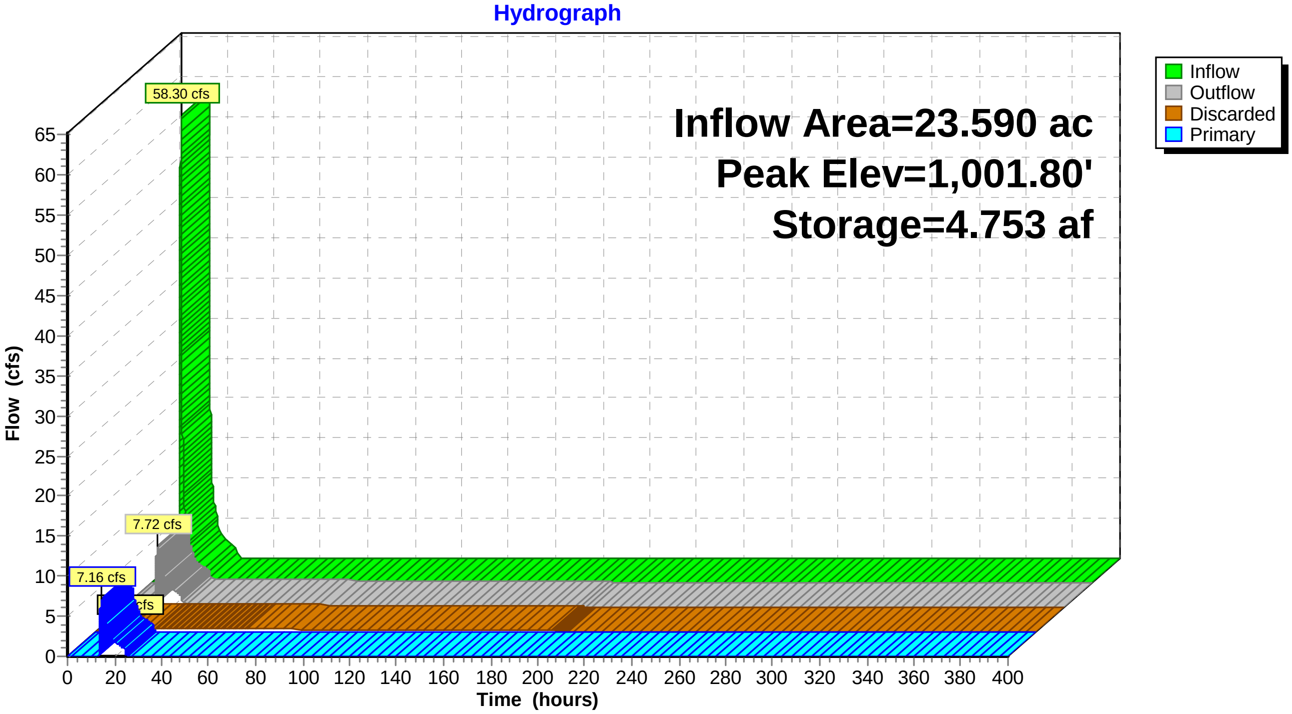
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
995.00	0.448	0.000	0.000
996.00	0.505	0.476	0.476
998.00	0.627	1.132	1.608
1,000.00	0.756	1.383	2.991
1,002.00	1.244	2.000	4.991

Device	Routing	Invert	Outlet Devices
#1	Discarded	995.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,001.55'	**20.0' long + 3.0 '/' SideZ x 15.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.55 cfs @ 14.46 hrs HW=1,001.80' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.55 cfs)

Primary OutFlow Max=7.12 cfs @ 14.46 hrs HW=1,001.80' (Free Discharge)
└─**2=Broad-Crested Rectangular Weir** (Weir Controls 7.12 cfs @ 1.35 fps)

Pond 3P: SMA-1 (Design Point 2)



Summary for Pond 4P: North Basin

[81] Warning: Exceeded Pond 12P by 0.72' @ 24.46 hrs

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Inflow Area =      21.810 ac,   0.00% Impervious,  Inflow Depth =   4.54"    for  100-YR event
Inflow      =     108.57 cfs @   12.15 hrs,  Volume=          8.256 af
Outflow     =       4.90 cfs @   15.83 hrs,  Volume=          8.256 af,  Atten= 95%,  Lag= 220.6 min
Discarded   =       0.72 cfs @   15.83 hrs,  Volume=          6.629 af
Primary     =       4.18 cfs @   15.83 hrs,  Volume=          1.627 af
```

Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,005.44' @ 15.83 hrs Surf.Area= 67,990 sf Storage= 263,450 cf

Plug-Flow detention time= 2,806.2 min calculated for 8.256 af (100% of inflow)
Center-of-Mass det. time= 2,806.2 min (3,653.9 - 847.7)

Volume	Invert	Avail.Storage	Storage Description
#1	1,001.00'	374,394 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

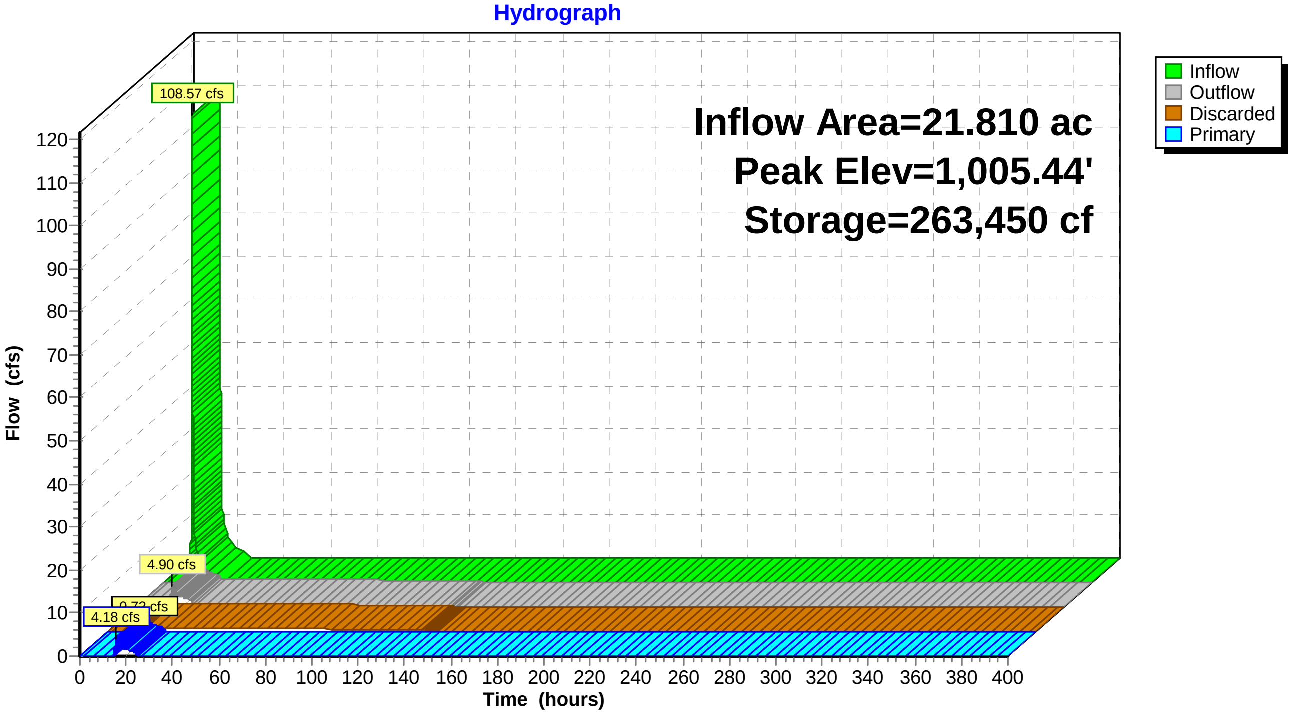
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,001.00	50,734	0	0
1,007.00	74,064	374,394	374,394

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,001.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	1,005.30'	**30.0' long + 3.0 '/' SideZ x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.72 cfs @ 15.83 hrs HW=1,005.44' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.72 cfs)

Primary OutFlow Max=4.17 cfs @ 15.83 hrs HW=1,005.44' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Weir Controls 4.17 cfs @ 0.99 fps)

Pond 4P: North Basin



Summary for Pond 5P: South Basin

[81] Warning: Exceeded Pond 18P by 0.47' @ 24.29 hrs

Inflow Area = 2.730 ac, 0.00% Impervious, Inflow Depth = 6.73" for 100-YR event
Inflow = 20.96 cfs @ 12.12 hrs, Volume= 1.532 af
Outflow = 0.22 cfs @ 23.77 hrs, Volume= 1.532 af, Atten= 99%, Lag= 698.8 min
Discarded = 0.15 cfs @ 23.77 hrs, Volume= 1.469 af
Primary = 0.07 cfs @ 23.77 hrs, Volume= 0.063 af
Routed to Pond 16P : Culvert 7

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,033.27' @ 23.77 hrs Surf.Area= 16,519 sf Storage= 57,943 cf

Plug-Flow detention time= 3,678.8 min calculated for 1.532 af (100% of inflow)
Center-of-Mass det. time= 3,678.7 min (4,492.7 - 813.9)

Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	79,299 cf	**SE Basin Storage (Prismatic)** Listed below (Recalc)

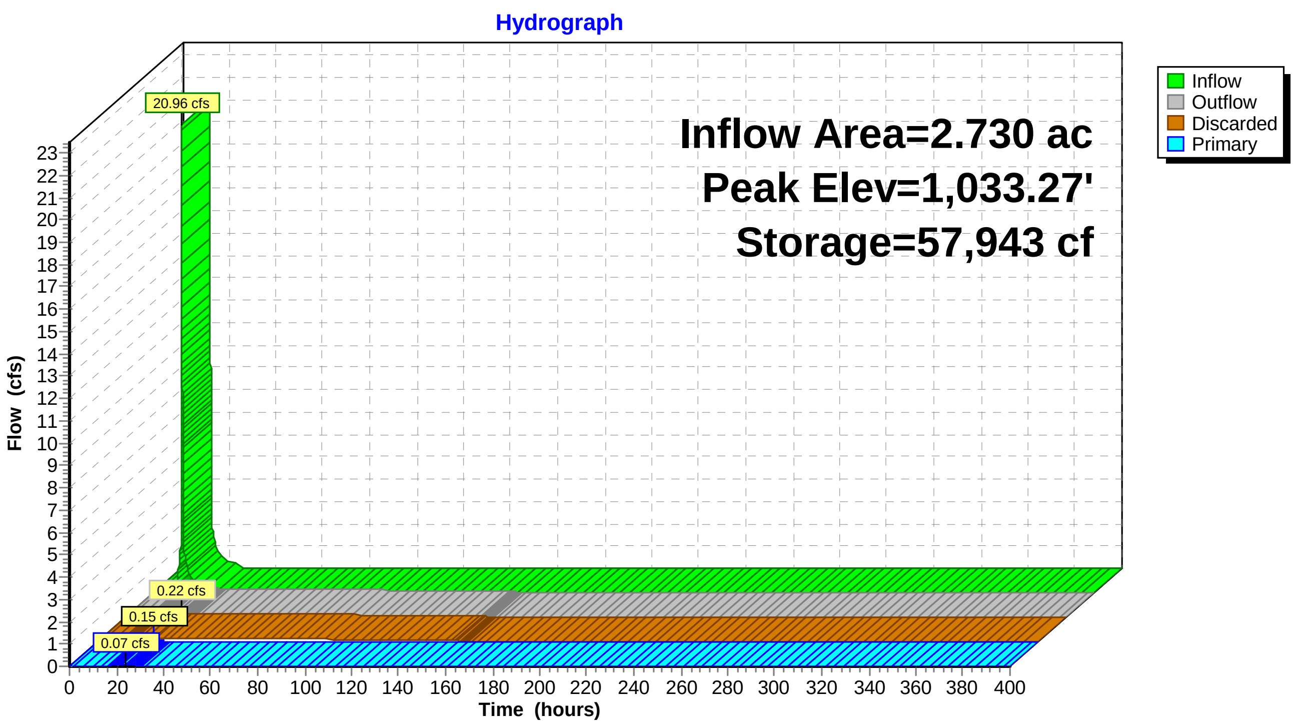
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,029.00	10,755	0	0
1,030.00	12,012	11,384	11,384
1,031.00	13,323	12,668	24,051
1,032.00	14,691	14,007	38,058
1,033.00	16,113	15,402	53,460
1,034.00	17,592	16,853	70,313
1,034.50	18,352	8,986	79,299

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,029.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	1,033.00'	**2.0" x 2.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.15 cfs @ 23.77 hrs HW=1,033.27' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.15 cfs)

Primary OutFlow Max=0.07 cfs @ 23.77 hrs HW=1,033.27' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 0.07 cfs @ 2.52 fps)

Pond 5P: South Basin



Summary for Pond 11P: SW Ditch Low Point

Inflow Area = 6.470 ac, 0.00% Impervious, Inflow Depth = 3.18" for 100-YR event
Inflow = 20.79 cfs @ 12.12 hrs, Volume= 1.712 af
Outflow = 12.64 cfs @ 12.28 hrs, Volume= 1.712 af, Atten= 39%, Lag= 9.5 min
Discarded = 0.08 cfs @ 12.28 hrs, Volume= 0.596 af
Primary = 12.56 cfs @ 12.28 hrs, Volume= 1.116 af
Routed to Pond 19P : SMA-4 (Design Point 7) (Culvert 9)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,005.53' @ 12.28 hrs Surf.Area= 8,613 sf Storage= 25,770 cf
Flood Elev= 1,006.50' Surf.Area= 8,762 sf Storage= 27,957 cf

Plug-Flow detention time= 1,194.3 min calculated for 1.712 af (100% of inflow)
Center-of-Mass det. time= 1,194.3 min (2,038.3 - 844.0)

Volume	Invert	Avail.Storage	Storage Description
#1	999.50'	27,957 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

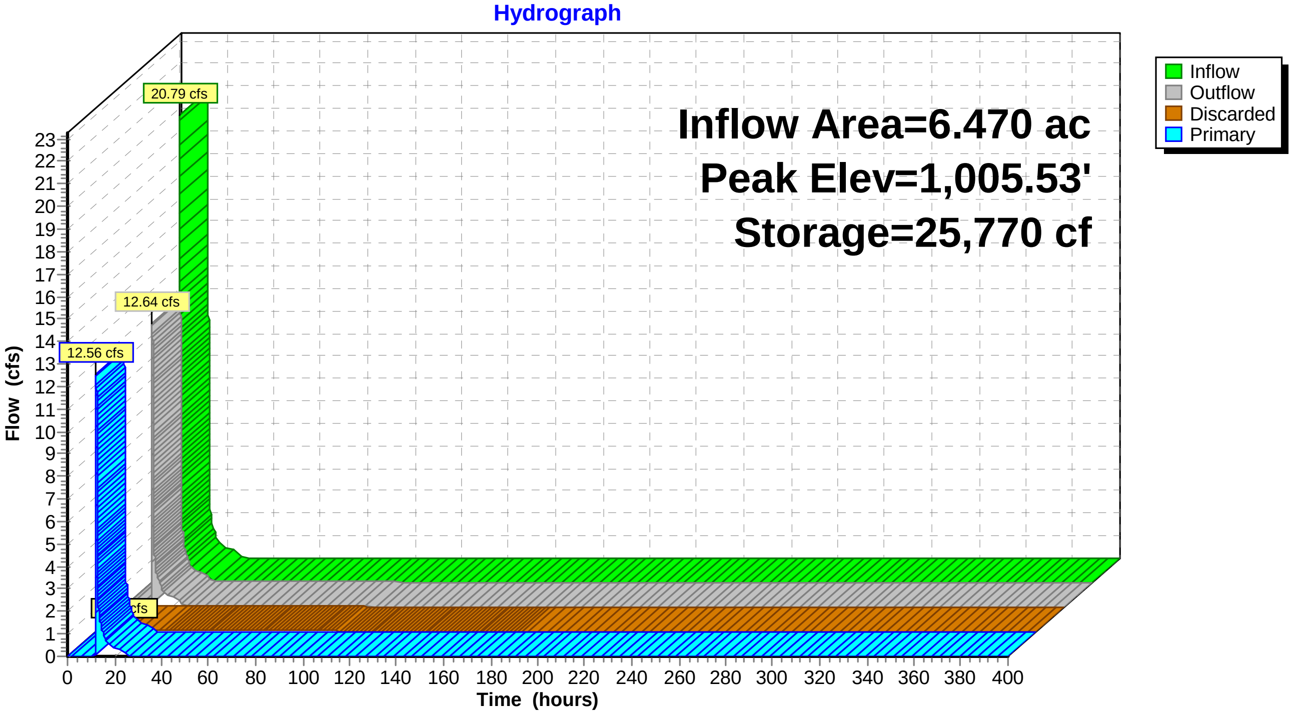
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
999.50	0	0	0
1,000.00	202	51	51
1,005.00	8,299	21,253	21,303
1,005.78	8,762	6,654	27,957

Device	Routing	Invert	Outlet Devices
#1	Discarded	999.50'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	1,000.00'	**18.0" Round Culvert** L= 131.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 1,000.00' / 997.00' S= 0.0229 '/' Cc= 0.900 n= 0.013, Flow Area= 1.77 sf
#3	Device 2	1,004.30'	**6.0" Vert. Orifice/Grate X 0.00** C= 0.600 Limited to weir flow at low heads
#4	Device 2	1,005.00'	**30.0" x 30.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.08 cfs @ 12.28 hrs HW=1,005.53' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.08 cfs)

Primary OutFlow Max=12.55 cfs @ 12.28 hrs HW=1,005.53' (Free Discharge)
└─**2=Culvert** (Passes 12.55 cfs of 14.68 cfs potential flow)
  ├─**3=Orifice/Grate** (Controls 0.00 cfs)
  └─**4=Orifice/Grate** (Weir Controls 12.55 cfs @ 2.38 fps)

Pond 11P: SW Ditch Low Point



Summary for Pond 12P: North Basin Forebay

Inflow Area = 21.810 ac, 0.00% Impervious, Inflow Depth = 4.82" for 100-YR event
Inflow = 111.48 cfs @ 12.13 hrs, Volume= 8.756 af
Outflow = 108.57 cfs @ 12.15 hrs, Volume= 8.256 af, Atten= 3%, Lag= 1.4 min
Primary = 108.57 cfs @ 12.15 hrs, Volume= 8.256 af
Routed to Pond 4P : North Basin

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,005.76' @ 12.15 hrs Surf.Area= 12,093 sf Storage= 34,476 cf

Plug-Flow detention time= 46.5 min calculated for 8.256 af (94% of inflow)
Center-of-Mass det. time= 15.8 min (847.7 - 831.9)

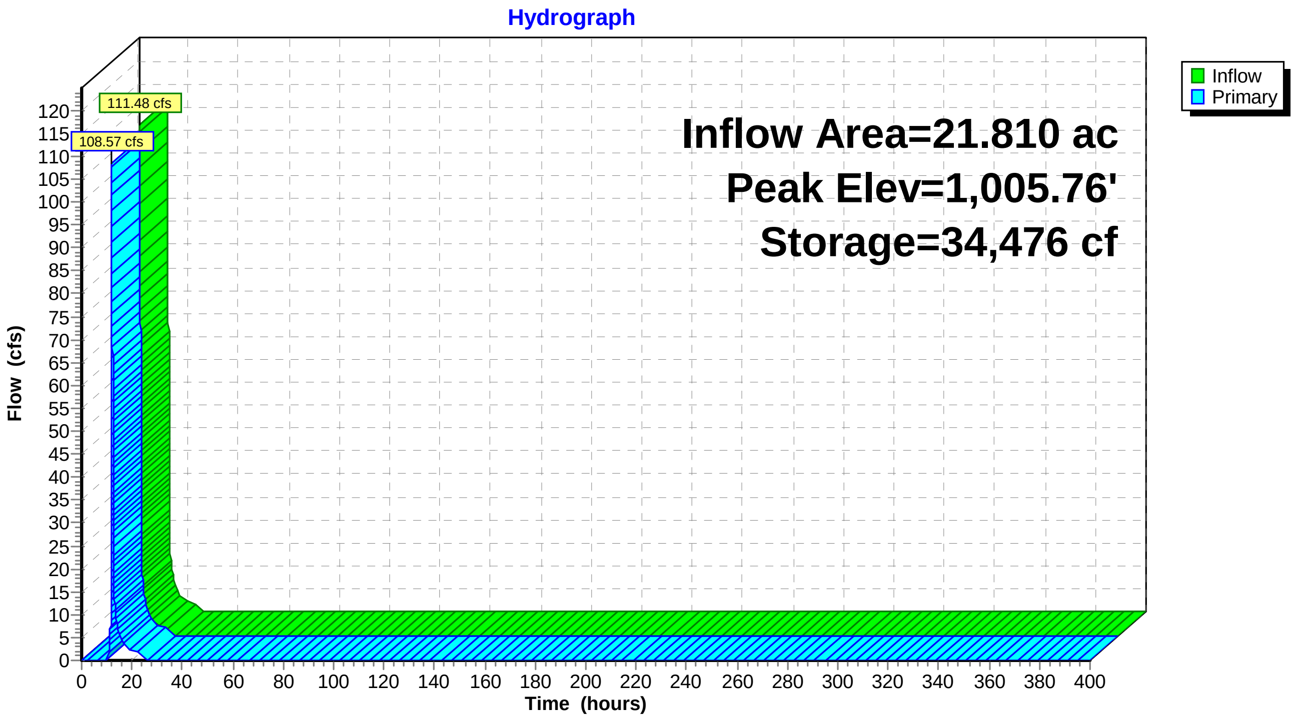
Volume	Invert	Avail.Storage	Storage Description
#1	1,001.00'	50,991 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
1,001.00	2,383	0	0
1,007.00	14,614	50,991	50,991

Device	Routing	Invert	Outlet Devices
#1	Primary	1,004.60'	**30.0' long + 3.0 '/' SideZ x 30.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=108.52 cfs @ 12.15 hrs HW=1,005.76' (Free Discharge)
└─**1=Broad-Crested Rectangular Weir** (Weir Controls 108.52 cfs @ 2.79 fps)

Pond 12P: North Basin Forebay



Summary for Pond 13P: SMA-5 (Design Point 9) (Culvert 12)

[44] Hint: Outlet device #2 is below defined storage

Inflow Area =	5.000 ac,	0.00% Impervious, Inflow Depth = 4.82"	for 100-YR event
Inflow =	28.25 cfs @	12.09 hrs, Volume=	2.007 af
Outflow =	24.81 cfs @	12.13 hrs, Volume=	2.007 af, Atten= 12%, Lag= 2.7 min
Discarded =	0.09 cfs @	12.13 hrs, Volume=	0.029 af
Primary =	5.35 cfs @	12.13 hrs, Volume=	1.549 af
Secondary =	19.36 cfs @	12.13 hrs, Volume=	0.429 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 955.00' @ 12.13 hrs Surf.Area= 0.202 ac Storage= 0.252 af

Plug-Flow detention time= 9.3 min calculated for 2.007 af (100% of inflow)
Center-of-Mass det. time= 9.3 min (838.5 - 829.2)

Volume	Invert	Avail.Storage	Storage Description
#1	953.00'	0.361 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
953.00	0.049	0.000	0.000
955.50	0.240	0.361	0.361

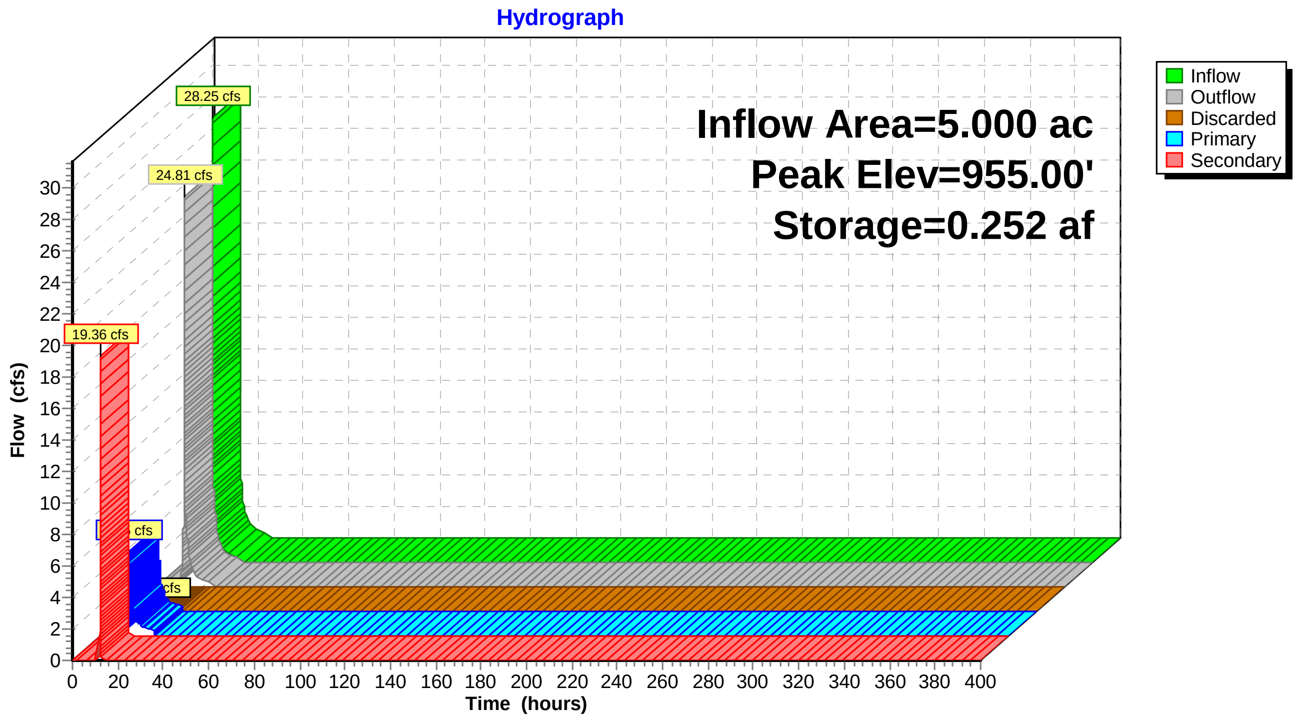
Device	Routing	Invert	Outlet Devices
#1	Discarded	953.00'	**0.460 in/hr Exfiltration over Surface area**
#2	Primary	952.50'	**12.0" Round Culvert #12** L= 40.0' Box, headwall w/3 square edges, Ke= 0.500 Inlet / Outlet Invert= 952.50' / 949.60' S= 0.0725 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#3	Secondary	954.50'	**16.0' long + 10.0 '/' SideZ x 16.4' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.09 cfs @ 12.13 hrs HW=955.00' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.09 cfs)

Primary OutFlow Max=5.35 cfs @ 12.13 hrs HW=955.00' (Free Discharge)
↑—**2=Culvert #12** (Inlet Controls 5.35 cfs @ 6.82 fps)

Secondary OutFlow Max=19.31 cfs @ 12.13 hrs HW=955.00' (Free Discharge)
↑—**3=Broad-Crested Rectangular Weir** (Weir Controls 19.31 cfs @ 1.82 fps)

Pond 13P: SMA-5 (Design Point 9) (Culvert 12)



Summary for Pond 14P: North Access Road Culvert #16

[44] Hint: Outlet device #2 is below defined storage

Inflow Area = 2.180 ac, 0.00% Impervious, Inflow Depth = 1.55" for 100-YR event
Inflow = 2.10 cfs @ 12.30 hrs, Volume= 0.281 af
Outflow = 2.05 cfs @ 12.34 hrs, Volume= 0.281 af, Atten= 2%, Lag= 2.8 min
Discarded = 0.00 cfs @ 12.34 hrs, Volume= 0.001 af
Primary = 2.05 cfs @ 12.34 hrs, Volume= 0.280 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 982.76' @ 12.34 hrs Surf.Area= 0.009 ac Storage= 0.004 af

Plug-Flow detention time= 0.7 min calculated for 0.281 af (100% of inflow)
Center-of-Mass det. time= 0.7 min (912.2 - 911.5)

Volume	Invert	Avail.Storage	Storage Description
#1	982.00'	0.004 af	**Custom Stage Data (Conic)** Listed below (Recalc)

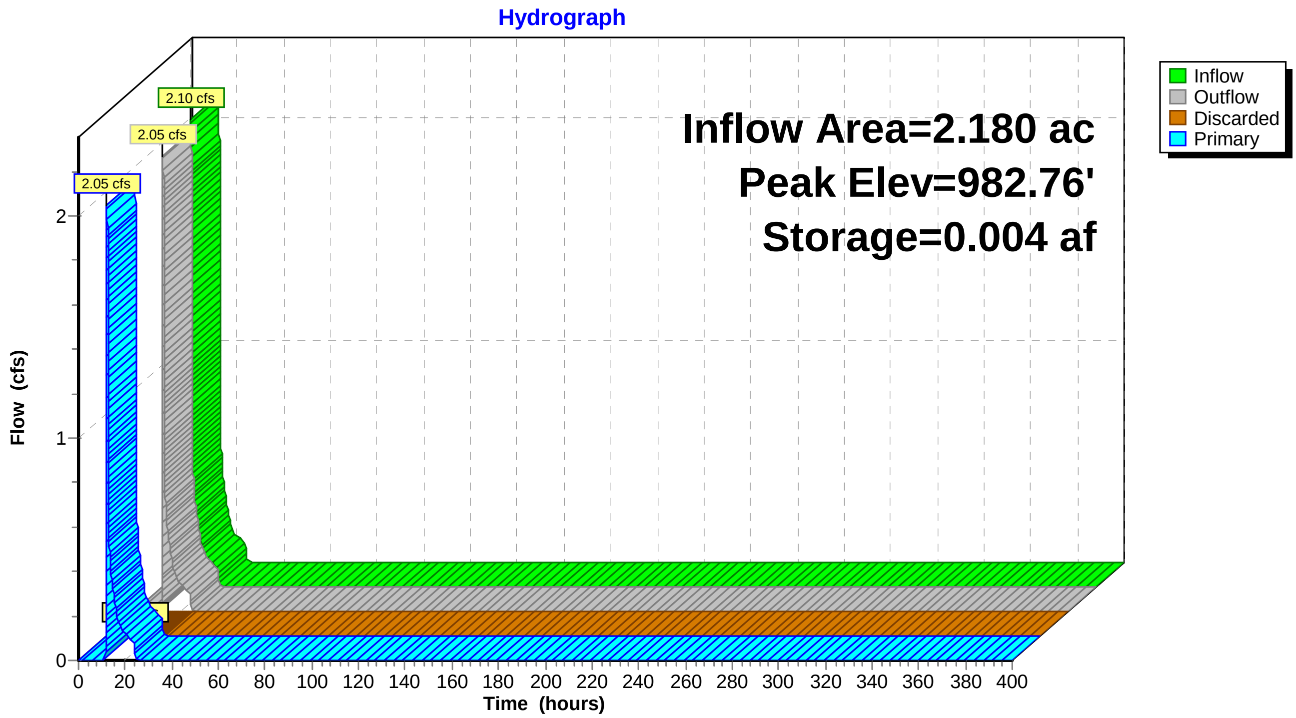
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
982.00	0.002	0.000	0.000	0.002
982.80	0.010	0.004	0.004	0.010

Device	Routing	Invert	Outlet Devices
#1	Discarded	982.00'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	981.80'	**12.0" Round Culvert** L= 50.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 981.80' / 980.92' S= 0.0176 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Discarded OutFlow Max=0.00 cfs @ 12.34 hrs HW=982.76' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=2.04 cfs @ 12.34 hrs HW=982.76' (Free Discharge)
└─**2=Culvert** (Inlet Controls 2.04 cfs @ 2.64 fps)

Pond 14P: North Access Road Culvert #16



Summary for Pond 15P: Culvert #10

Inflow Area = 0.820 ac, 0.00% Impervious, Inflow Depth = 4.32" for 100-YR event
Inflow = 4.14 cfs @ 12.09 hrs, Volume= 0.295 af
Outflow = 2.83 cfs @ 12.18 hrs, Volume= 0.295 af, Atten= 32%, Lag= 5.2 min
Primary = 2.83 cfs @ 12.18 hrs, Volume= 0.295 af
Routed to Pond 16P : Culvert 7

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,033.32' @ 12.18 hrs Surf.Area= 0.057 ac Storage= 0.022 af

Plug-Flow detention time= 3.0 min calculated for 0.295 af (100% of inflow)
Center-of-Mass det. time= 3.0 min (840.4 - 837.3)

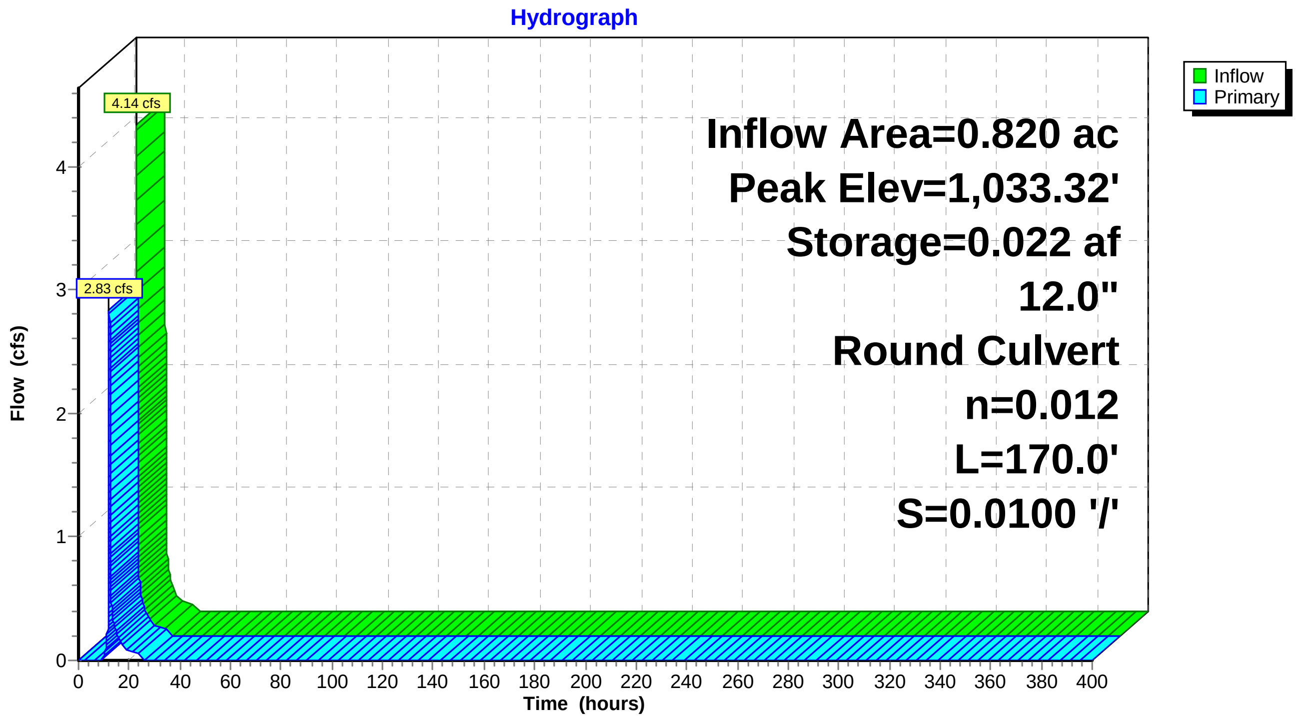
Volume	Invert	Avail.Storage	Storage Description
#1	1,032.10'	0.136 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,032.10	0.000	0.000	0.000
1,033.00	0.021	0.009	0.009
1,034.00	0.136	0.078	0.088
1,034.30	0.187	0.048	0.136

Device	Routing	Invert	Outlet Devices
#1	Primary	1,032.10'	**12.0" Round Culvert** L= 170.0' RCP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 1,032.10' / 1,030.40' S= 0.0100 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Primary OutFlow Max=2.83 cfs @ 12.18 hrs HW=1,033.32' (Free Discharge)
└─**1=Culvert** (Inlet Controls 2.83 cfs @ 3.60 fps)

Pond 15P: Culvert #10



Summary for Pond 16P: Culvert 7

[57] Hint: Peaked at 1,031.40' (Flood elevation advised)
[79] Warning: Submerged Pond 15P Primary device # 1 OUTLET by 1.00'

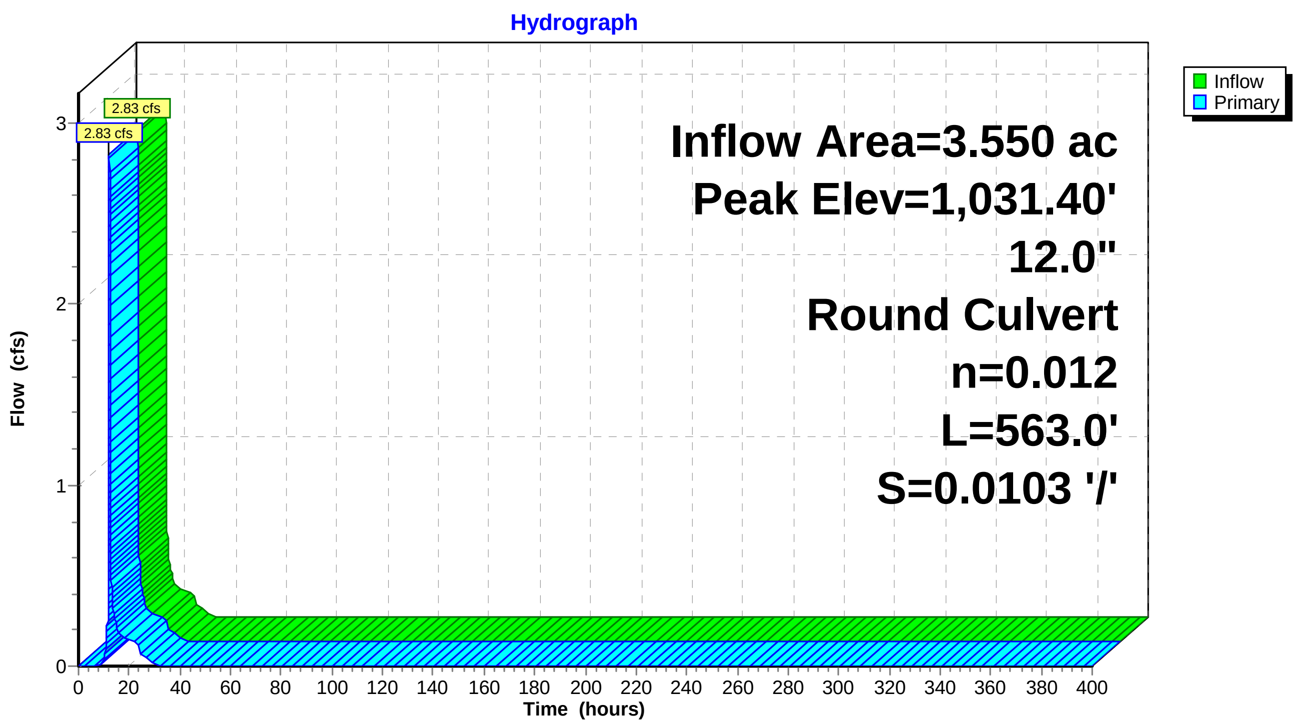
Inflow Area = 3.550 ac, 0.00% Impervious, Inflow Depth = 1.21" for 100-YR event
Inflow = 2.83 cfs @ 12.18 hrs, Volume= 0.358 af
Outflow = 2.83 cfs @ 12.18 hrs, Volume= 0.358 af, Atten= 0%, Lag= 0.0 min
Primary = 2.83 cfs @ 12.18 hrs, Volume= 0.358 af
Routed to Pond 11P : SW Ditch Low Point

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,031.40' @ 12.18 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	1,030.00'	**12.0" Round Culvert** L= 563.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 1,030.00' / 1,024.20' S= 0.0103 '/' Cc= 0.900 n= 0.012, Flow Area= 0.79 sf

Primary OutFlow Max=2.83 cfs @ 12.18 hrs HW=1,031.40' (Free Discharge)
↑**1=Culvert** (Inlet Controls 2.83 cfs @ 3.60 fps)

Pond 16P: Culvert 7



Summary for Pond 17P: SMA3B (Design Point 6)

Inflow Area = 0.440 ac, 0.00% Impervious, Inflow Depth = 4.82" for 100-YR event
Inflow = 2.49 cfs @ 12.09 hrs, Volume= 0.177 af
Outflow = 1.28 cfs @ 12.24 hrs, Volume= 0.177 af, Atten= 49%, Lag= 9.2 min
Discarded = 0.02 cfs @ 12.24 hrs, Volume= 0.082 af
Primary = 1.26 cfs @ 12.24 hrs, Volume= 0.094 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,024.61' @ 12.24 hrs Surf.Area= 0.060 ac Storage= 0.064 af

Plug-Flow detention time= 618.1 min calculated for 0.177 af (100% of inflow)
Center-of-Mass det. time= 618.1 min (1,447.3 - 829.2)

Volume	Invert	Avail.Storage	Storage Description
#1	1,022.60'	0.127 af	**Custom Stage Data (Conic)** Listed below (Recalc)

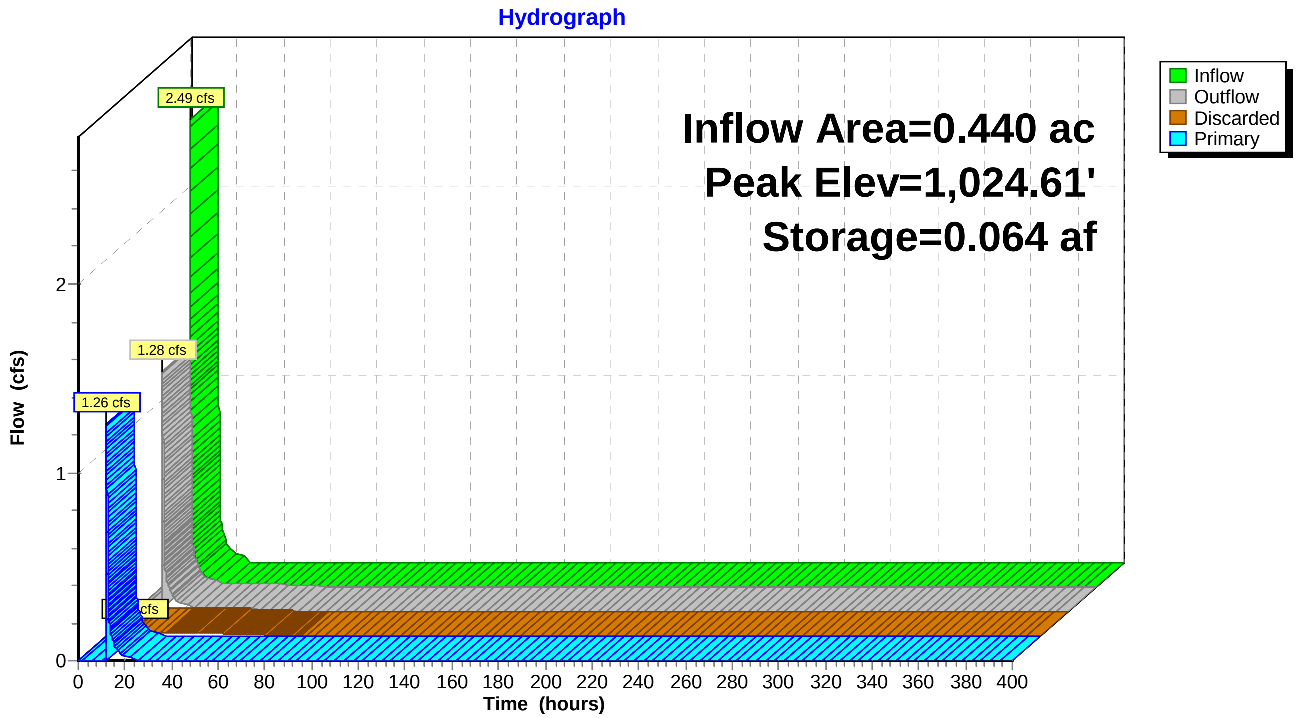
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.60	0.002	0.000	0.000	0.002
1,023.80	0.044	0.022	0.022	0.044
1,025.50	0.081	0.105	0.127	0.082

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.60'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,024.50'	**15.0' long + 3.0 '/' SideZ x 6.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.37 2.51 2.70 2.68 2.68 2.67 2.65 2.65 2.65 2.65 2.66 2.66 2.67 2.69 2.72 2.76 2.83

Discarded OutFlow Max=0.02 cfs @ 12.24 hrs HW=1,024.61' (Free Discharge)
↑**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=1.25 cfs @ 12.24 hrs HW=1,024.61' (Free Discharge)
↑**2=Broad-Crested Rectangular Weir** (Weir Controls 1.25 cfs @ 0.77 fps)

Pond 17P: SMA3B (Design Point 6)



Summary for Pond 18P: South Basin Forebay

Inflow Area = 2.730 ac, 0.00% Impervious, Inflow Depth = 7.30" for 100-YR event
Inflow = 21.29 cfs @ 12.10 hrs, Volume= 1.660 af
Outflow = 20.96 cfs @ 12.12 hrs, Volume= 1.532 af, Atten= 2%, Lag= 0.9 min
Primary = 20.96 cfs @ 12.12 hrs, Volume= 1.532 af
Routed to Pond 5P : South Basin

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,033.43' @ 12.12 hrs Surf.Area= 0.067 ac Storage= 0.167 af

Plug-Flow detention time= 66.8 min calculated for 1.532 af (92% of inflow)
Center-of-Mass det. time= 26.5 min (813.9 - 787.4)

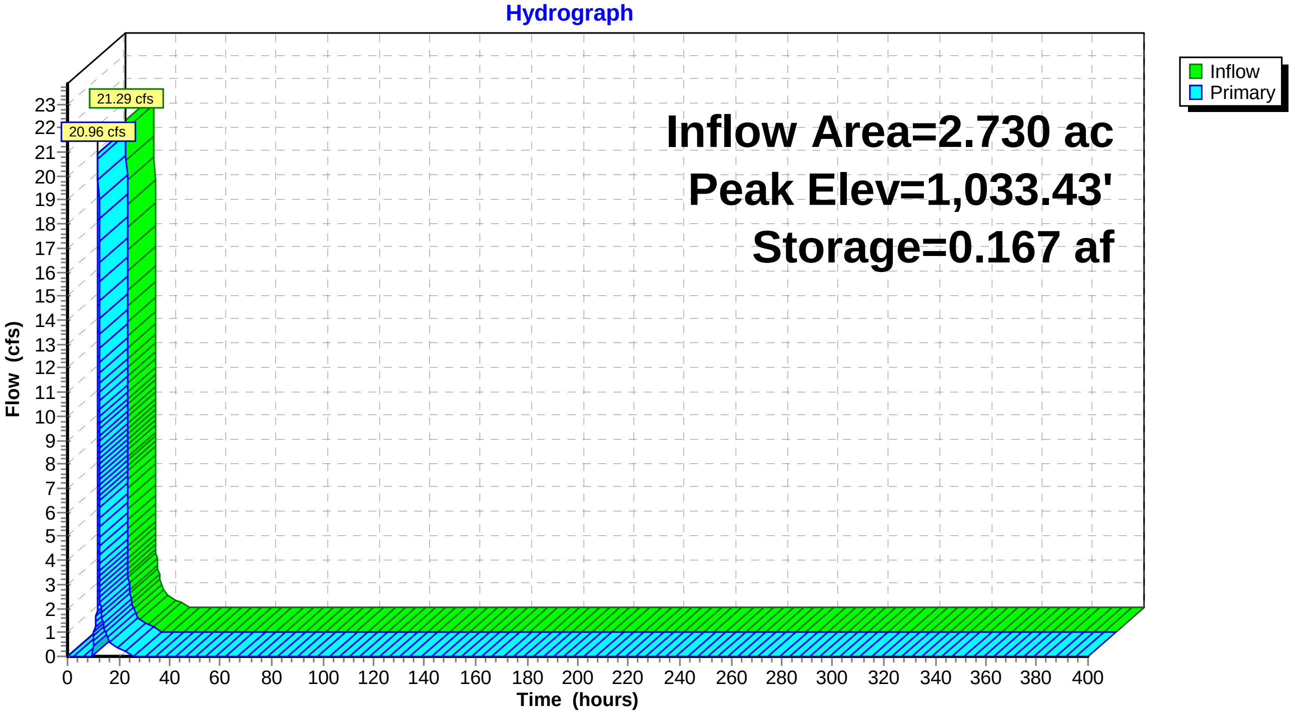
Volume	Invert	Avail.Storage	Storage Description
#1	1,029.00'	0.208 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,029.00	0.016	0.000	0.000
1,030.00	0.024	0.020	0.020
1,031.00	0.034	0.029	0.049
1,032.00	0.045	0.039	0.088
1,033.00	0.058	0.052	0.140
1,034.00	0.079	0.068	0.208

Device	Routing	Invert	Outlet Devices
#1	Primary	1,032.80'	**14.0' long + 3.0 '/' SideZ x 14.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.64 2.67 2.70 2.65 2.64 2.65 2.65 2.63

Primary OutFlow Max=20.93 cfs @ 12.12 hrs HW=1,033.43' (Free Discharge)
↑—**1=Broad-Crested Rectangular Weir** (Weir Controls 20.93 cfs @ 2.09 fps)

Pond 18P: South Basin Forebay



Summary for Pond 19P: SMA-4 (Design Point 7) (Culvert 9)

Inflow Area = 17.420 ac, 0.00% Impervious, Inflow Depth = 2.10" for 100-YR event
Inflow = 29.84 cfs @ 12.24 hrs, Volume= 3.052 af
Outflow = 14.24 cfs @ 12.59 hrs, Volume= 3.052 af, Atten= 52%, Lag= 20.9 min
Discarded = 0.12 cfs @ 12.59 hrs, Volume= 0.266 af
Primary = 1.47 cfs @ 12.59 hrs, Volume= 1.660 af
Secondary = 12.65 cfs @ 12.59 hrs, Volume= 1.126 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 990.62' @ 12.59 hrs Surf.Area= 0.296 ac Storage= 0.863 af

Plug-Flow detention time= 212.0 min calculated for 3.052 af (100% of inflow)
Center-of-Mass det. time= 212.1 min (1,100.8 - 888.7)

Volume	Invert	Avail.Storage	Storage Description
#1	987.00'	0.976 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
987.00	0.180	0.000	0.000
991.00	0.308	0.976	0.976

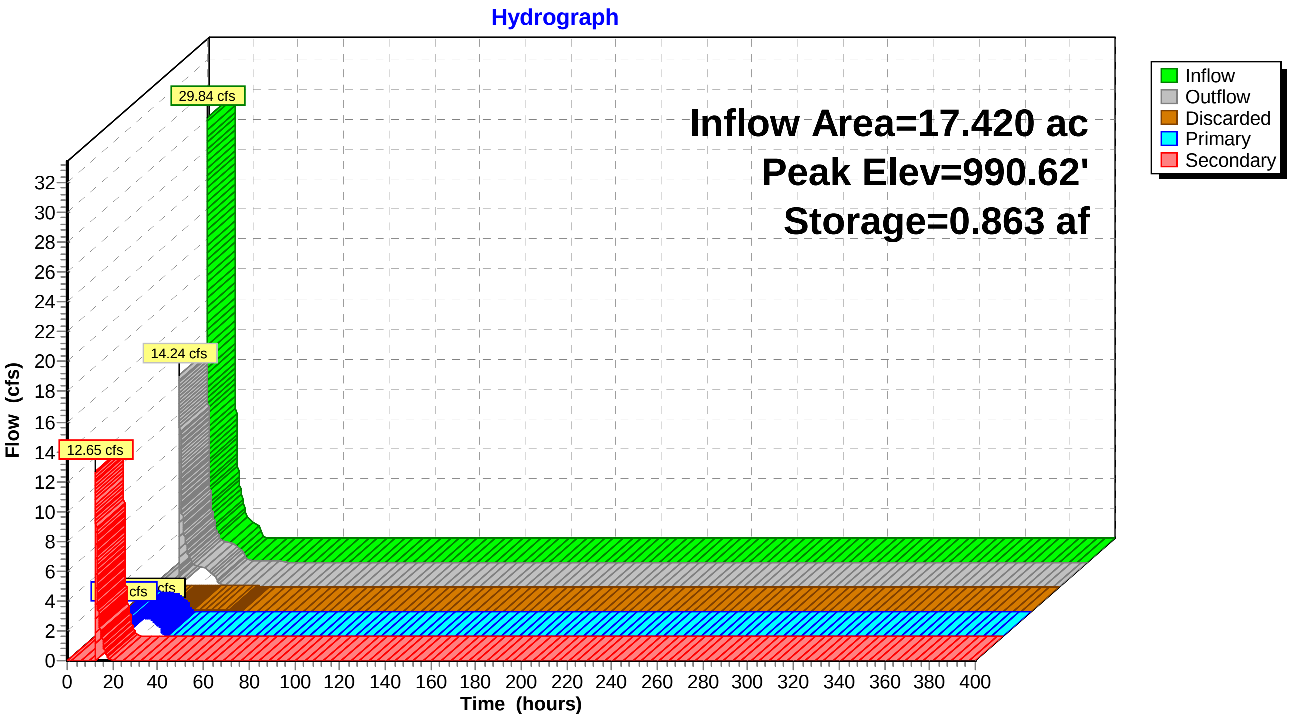
Device	Routing	Invert	Outlet Devices
#1	Discarded	987.00'	**0.390 in/hr Exfiltration over Surface area**
#2	Primary	987.50'	**4.0" Round Culvert X 4.00** L= 30.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 987.50' / 987.10' S= 0.0133 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 0.09 sf
#3	Secondary	990.00'	**8.0' long + 3.0 '/' SideZ x 5.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.34 2.50 2.70 2.68 2.68 2.66 2.65 2.65 2.65 2.65 2.67 2.66 2.68 2.70 2.74 2.79 2.88

Discarded OutFlow Max=0.12 cfs @ 12.59 hrs HW=990.62' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.12 cfs)

Primary OutFlow Max=1.47 cfs @ 12.59 hrs HW=990.62' (Free Discharge)
└─**2=Culvert** (Barrel Controls 1.47 cfs @ 4.22 fps)

Secondary OutFlow Max=12.64 cfs @ 12.59 hrs HW=990.62' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Weir Controls 12.64 cfs @ 2.05 fps)

Pond 19P: SMA-4 (Design Point 7) (Culvert 9)



Summary for Pond 20P: SMA3A (Culvert 15)

Inflow Area = 0.520 ac, 0.00% Impervious, Inflow Depth = 3.82" for 100-YR event
Inflow = 2.30 cfs @ 12.09 hrs, Volume= 0.166 af
Outflow = 2.07 cfs @ 12.13 hrs, Volume= 0.166 af, Atten= 10%, Lag= 2.4 min
Discarded = 0.01 cfs @ 12.13 hrs, Volume= 0.002 af
Primary = 2.06 cfs @ 12.13 hrs, Volume= 0.163 af
Routed to Pond 24P : SMA-2 (Design Point 5)
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Reach 13R : SMA3 CHANNEL

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,029.41' @ 12.13 hrs Surf.Area= 0.015 ac Storage= 0.006 af

Plug-Flow detention time= 4.7 min calculated for 0.166 af (100% of inflow)
Center-of-Mass det. time= 4.7 min (850.5 - 845.7)

Volume	Invert	Avail.Storage	Storage Description
#1	1,028.50'	0.019 af	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,028.50	0.001	0.000	0.000	0.001
1,029.00	0.007	0.002	0.002	0.007
1,030.00	0.031	0.018	0.019	0.031

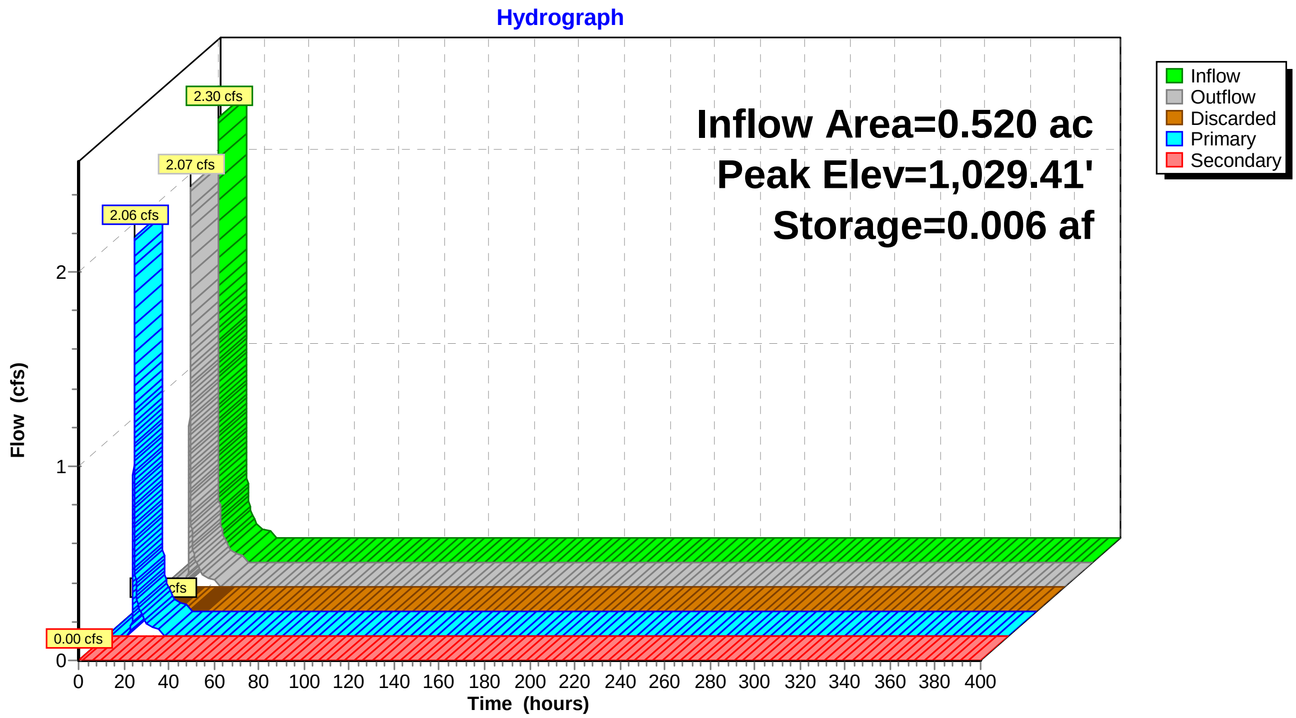
Device	Routing	Invert	Outlet Devices
#1	Discarded	1,028.50'	**0.390 in/hr Exfiltration over Wetted area**
#2	Primary	1,028.70'	**8.0" Round Culvert X 2.00** L= 109.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 1,028.70' / 1,026.63' S= 0.0190 '/' Cc= 0.900 n= 0.013, Flow Area= 0.35 sf
#3	Secondary	1,029.80'	**16.0' long + 3.0 '/' SideZ x 2.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 Coef. (English) 2.48 2.60 2.60 2.60 2.64 2.65 2.68 2.75 2.74 2.76 2.89 3.05 3.19 3.32

Discarded OutFlow Max=0.01 cfs @ 12.13 hrs HW=1,029.41' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.01 cfs)

Primary OutFlow Max=2.06 cfs @ 12.13 hrs HW=1,029.41' (Free Discharge)
└─**2=Culvert** (Inlet Controls 2.06 cfs @ 2.95 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=1,028.50' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 20P: SMA3A (Culvert 15)



Summary for Pond 21P: North Access Road Open Arch Culvert #1

[93] Warning: Storage range exceeded by 0.08'
[62] Hint: Exceeded Reach 22R OUTLET depth by 0.77' @ 12.55 hrs
[64] Warning: Exceeded Reach 22R outlet bank by 0.53' @ 12.55 hrs

Inflow Area = 89.590 ac, 0.00% Impervious, Inflow Depth = 4.26" for 100-YR event
Inflow = 238.98 cfs @ 12.50 hrs, Volume= 31.800 af
Outflow = 228.55 cfs @ 12.55 hrs, Volume= 31.781 af, Atten= 4%, Lag= 3.3 min
Discarded = 0.25 cfs @ 12.55 hrs, Volume= 0.019 af
Primary = 228.30 cfs @ 12.55 hrs, Volume= 31.762 af
Routed to Pond 22P : SMA-6/Proposed Powerline Depression (Design Point 1)

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 988.98' @ 12.55 hrs Surf.Area= 23,514 sf Storage= 33,751 cf

Plug-Flow detention time= 1.4 min calculated for 31.781 af (100% of inflow)
Center-of-Mass det. time= 0.9 min (870.6 - 869.7)

Volume	Invert	Avail.Storage	Storage Description
#1	984.65'	33,751 cf	**Custom Stage Data (Conic)** Listed below (Recalc)

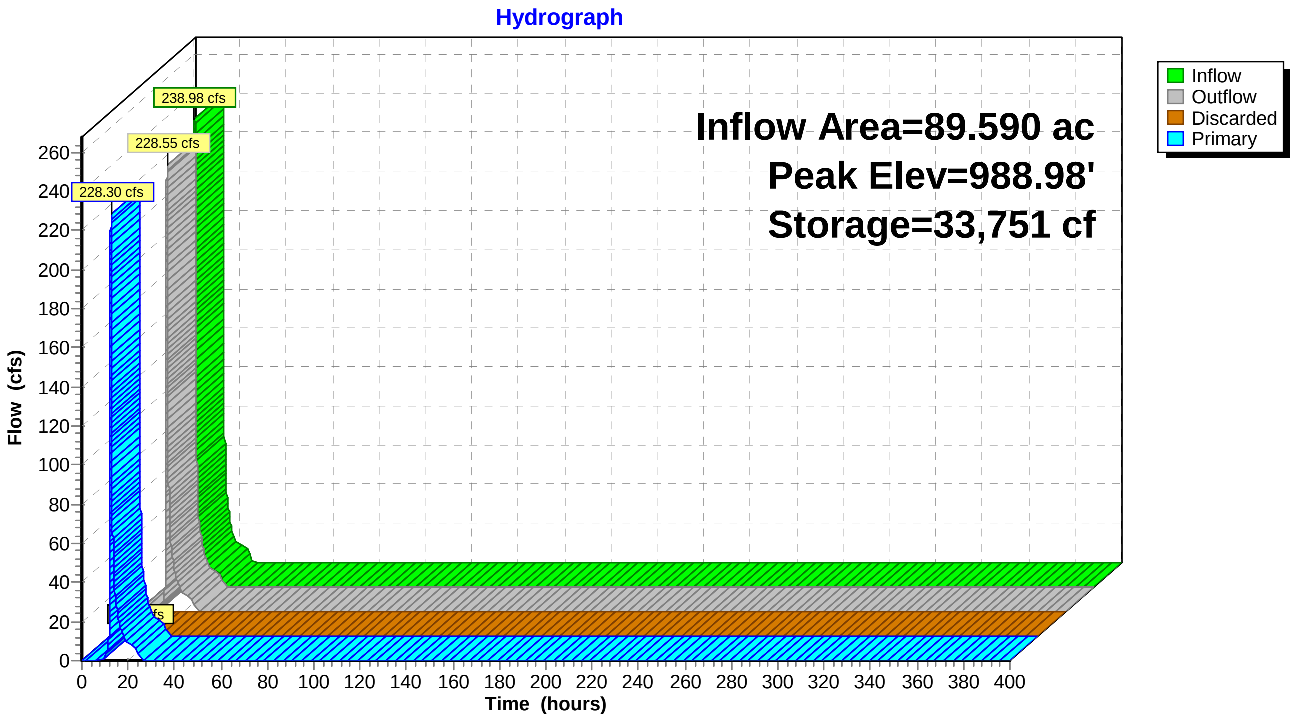
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
984.65	1	0	0	1
985.00	154	20	20	154
985.50	845	227	246	846
986.00	2,215	738	984	2,218
986.50	4,569	1,661	2,645	4,574
987.00	7,470	2,980	5,625	7,478
987.40	10,205	3,521	9,146	10,216
988.90	23,514	24,605	33,751	23,543

Device	Routing	Invert	Outlet Devices
#1	Discarded	984.65'	**0.460 in/hr Exfiltration over Wetted area**
#2	Primary	984.65'	**144.0" W x 43.2" H, R=90.0" Arch Culvert** L= 49.0' CMP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 984.65' / 982.17' S= 0.0506 '/' Cc= 0.900 n= 0.035, Flow Area= 32.36 sf

Discarded OutFlow Max=0.25 cfs @ 12.55 hrs HW=988.98' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.25 cfs)

Primary OutFlow Max=227.88 cfs @ 12.55 hrs HW=988.97' (Free Discharge)
└─**2=Culvert** (Inlet Controls 227.88 cfs @ 7.04 fps)

Pond 21P: North Access Road Open Arch Culvert #1



Summary for Pond 22P: SMA-6/Proposed Powerline Depression (Design Point 1)

[93] Warning: Storage range exceeded by 2.67'
[95] Warning: Outlet Device #1 rise exceeded
[81] Warning: Exceeded Pond 14P by 6.06' @ 12.55 hrs
[81] Warning: Exceeded Pond 21P by 0.46' @ 16.38 hrs

Inflow Area = 139.990 ac, 0.00% Impervious, Inflow Depth = 3.15" for 100-YR event
Inflow = 231.44 cfs @ 12.55 hrs, Volume= 36.798 af
Outflow = 126.53 cfs @ 12.55 hrs, Volume= 31.050 af, Atten= 45%, Lag= 0.0 min
Discarded = 0.86 cfs @ 12.51 hrs, Volume= 6.186 af
Primary = 125.68 cfs @ 12.55 hrs, Volume= 24.864 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 4
Peak Elev= 988.67' @ 12.55 hrs Surf.Area= 1.846 ac Storage= 7.150 af

Plug-Flow detention time= 852.1 min calculated for 31.050 af (84% of inflow)
Center-of-Mass det. time= 782.9 min (1,677.0 - 894.2)

Volume	Invert	Avail.Storage	Storage Description
#1	978.00'	7.150 af	**Custom Stage Data (Conic)** Listed below

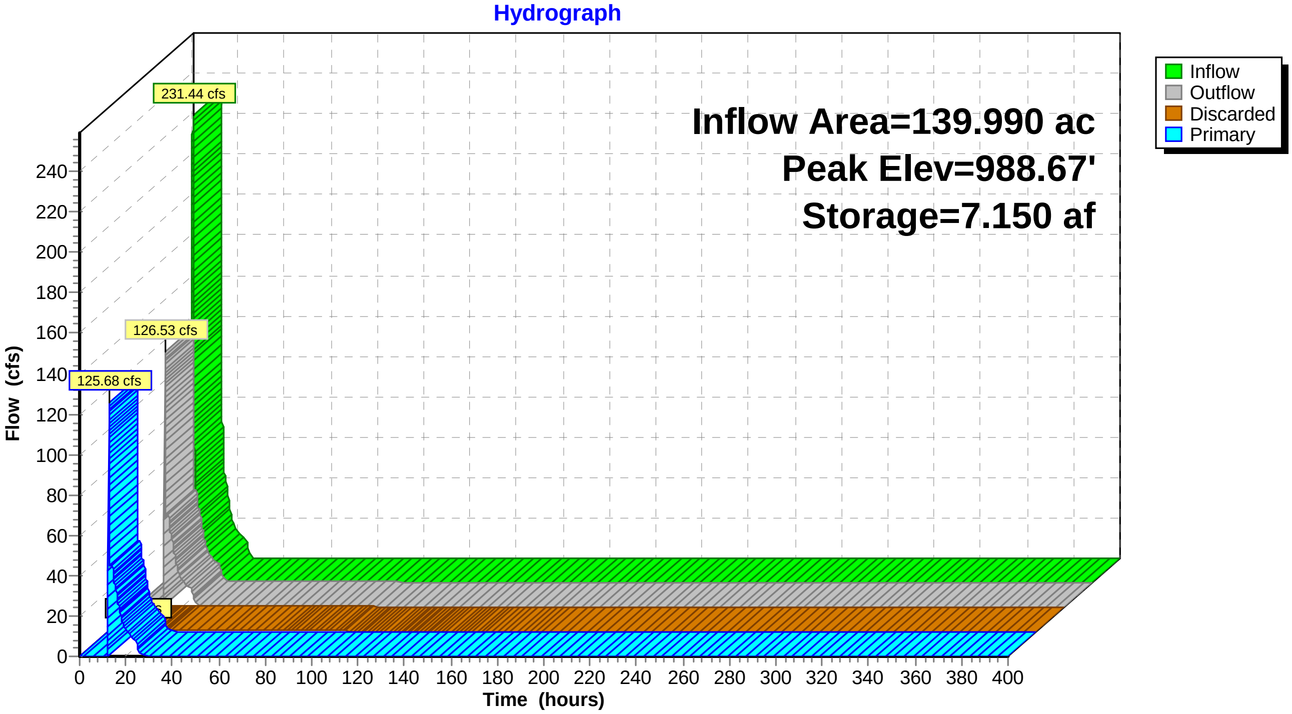
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
978.00	0.030	0.000	0.000	0.030
979.00	0.163	0.088	0.088	0.163
980.00	0.375	0.262	0.349	0.375
981.00	0.687	0.523	0.873	0.688
982.00	0.977	0.828	1.700	0.978
983.00	1.217	1.095	2.795	1.219
984.00	1.360	1.288	4.083	1.363
985.00	1.468	1.414	5.497	1.473
986.00	1.846	1.653	7.150	1.851

Device	Routing	Invert	Outlet Devices
#1	Primary	984.58'	**165.0 deg x 1.42' rise Sharp-Crested Vee/Trap Weir** Cv= 2.47 (C= 3.09)
#2	Discarded	978.00'	**0.460 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.86 cfs @ 12.51 hrs HW=988.37' (Free Discharge)
↑—**2=Exfiltration** (Exfiltration Controls 0.86 cfs)

Primary OutFlow Max=125.30 cfs @ 12.55 hrs HW=988.66' (Free Discharge)
↑—**1=Sharp-Crested Vee/Trap Weir** (Orifice Controls 125.30 cfs @ 8.18 fps)

Pond 22P: SMA-6/Proposed Powerline Depression (Design Point 1)



Summary for Pond 23P: Pool Proposed

[93] Warning: Storage range exceeded by 0.20'

Inflow Area = 40.440 ac, 0.00% Impervious, Inflow Depth = 4.29" for 100-YR event
Inflow = 107.14 cfs @ 12.50 hrs, Volume= 14.456 af
Outflow = 103.03 cfs @ 12.50 hrs, Volume= 13.599 af, Atten= 4%, Lag= 0.0 min
Primary = 103.03 cfs @ 12.50 hrs, Volume= 13.599 af
Routed to Reach 22R : Pool Ditch

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 991.00' Surf.Area= 0.335 ac Storage= 0.199 af
Peak Elev= 993.20' @ 12.50 hrs Surf.Area= 0.575 ac Storage= 1.147 af (0.948 af above start)

Plug-Flow detention time= 57.4 min calculated for 13.400 af (93% of inflow)
Center-of-Mass det. time= 17.0 min (879.4 - 862.4)

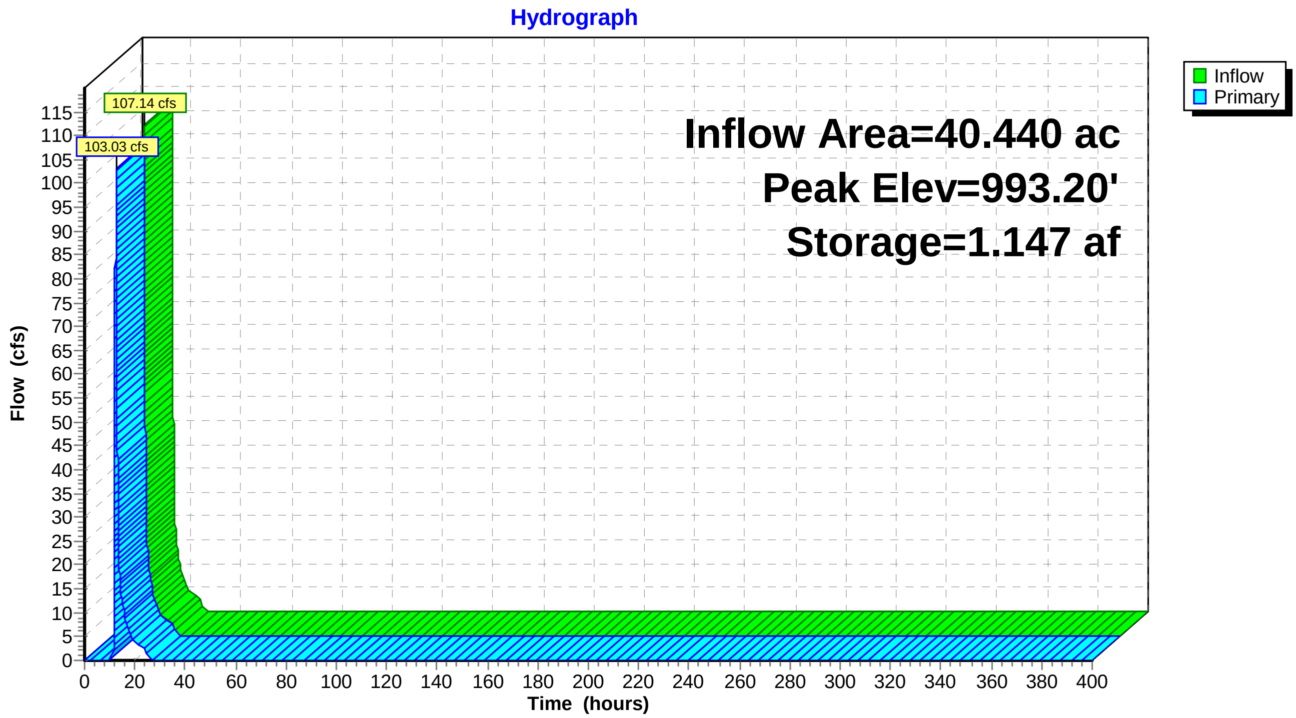
Volume	Invert	Avail.Storage	Storage Description
#1	988.50'	1.147 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
988.50	0.001	0.000	0.000
989.00	0.009	0.003	0.003
989.50	0.026	0.009	0.011
990.00	0.057	0.021	0.032
990.50	0.138	0.049	0.081
991.00	0.335	0.118	0.199
992.00	0.493	0.414	0.613
993.00	0.575	0.534	1.147

Device	Routing	Invert	Outlet Devices
#1	Primary	992.44'	**Channel/Reach** using Reach 22R: Pool Ditch

Primary OutFlow Max=102.93 cfs @ 12.50 hrs HW=993.20' (Free Discharge)
└─**1=Channel/Reach** (Channel Controls 102.93 cfs @ 4.95 fps)

Pond 23P: Pool Proposed



Summary for Pond 24P: SMA-2 (Design Point 5)

Inflow Area = 2.470 ac, 0.00% Impervious, Inflow Depth = 4.50" for 100-YR event
Inflow = 11.50 cfs @ 12.14 hrs, Volume= 0.926 af
Outflow = 0.13 cfs @ 24.09 hrs, Volume= 0.926 af, Atten= 99%, Lag= 717.2 min
Discarded = 0.13 cfs @ 24.09 hrs, Volume= 0.926 af

Routing by Stor-Ind method, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs
Peak Elev= 1,025.82' @ 24.09 hrs Surf.Area= 0.318 ac Storage= 0.797 af

Plug-Flow detention time= 3,091.1 min calculated for 0.926 af (100% of inflow)
Center-of-Mass det. time= 3,091.1 min (3,927.9 - 836.8)

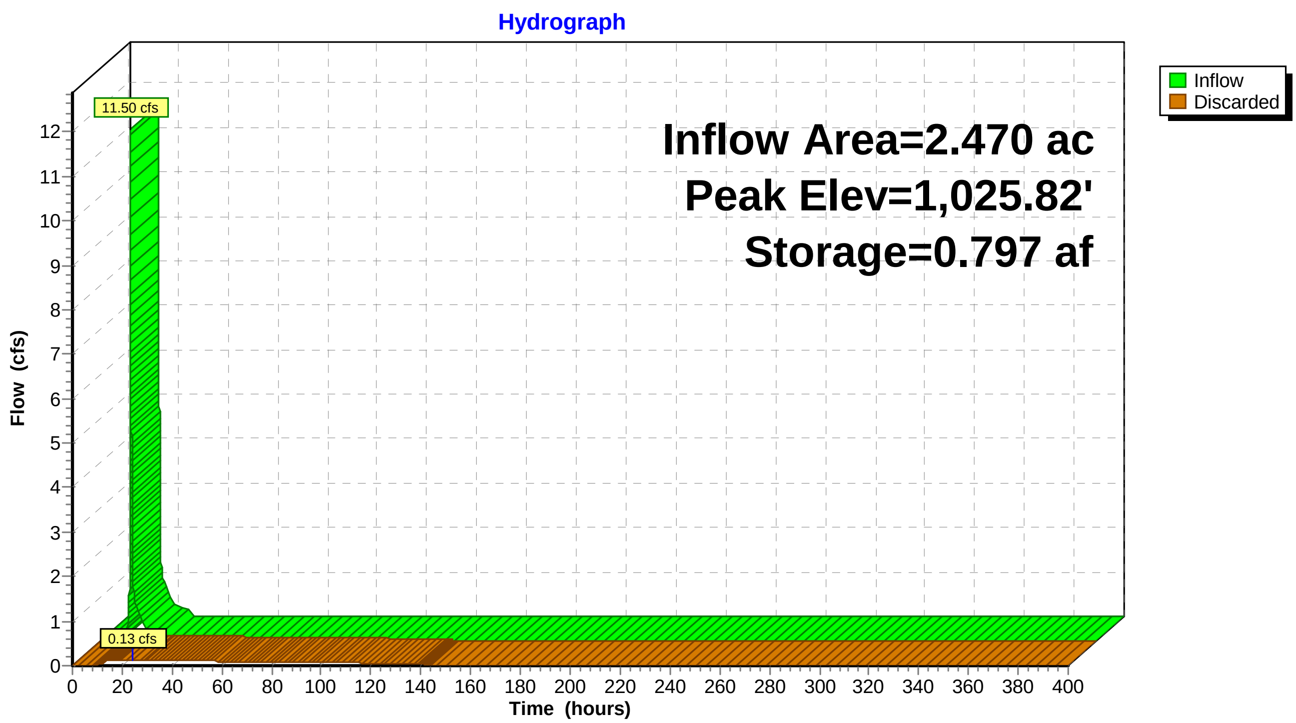
Volume	Invert	Avail.Storage	Storage Description
#1	1,022.00'	0.856 af	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
1,022.00	0.116	0.000	0.000	0.116
1,026.00	0.330	0.856	0.856	0.332

Device	Routing	Invert	Outlet Devices
#1	Discarded	1,022.00'	**0.390 in/hr Exfiltration over Wetted area**

Discarded OutFlow Max=0.13 cfs @ 24.09 hrs HW=1,025.82' (Free Discharge)
└**1=Exfiltration** (Exfiltration Controls 0.13 cfs)

Pond 24P: SMA-2 (Design Point 5)



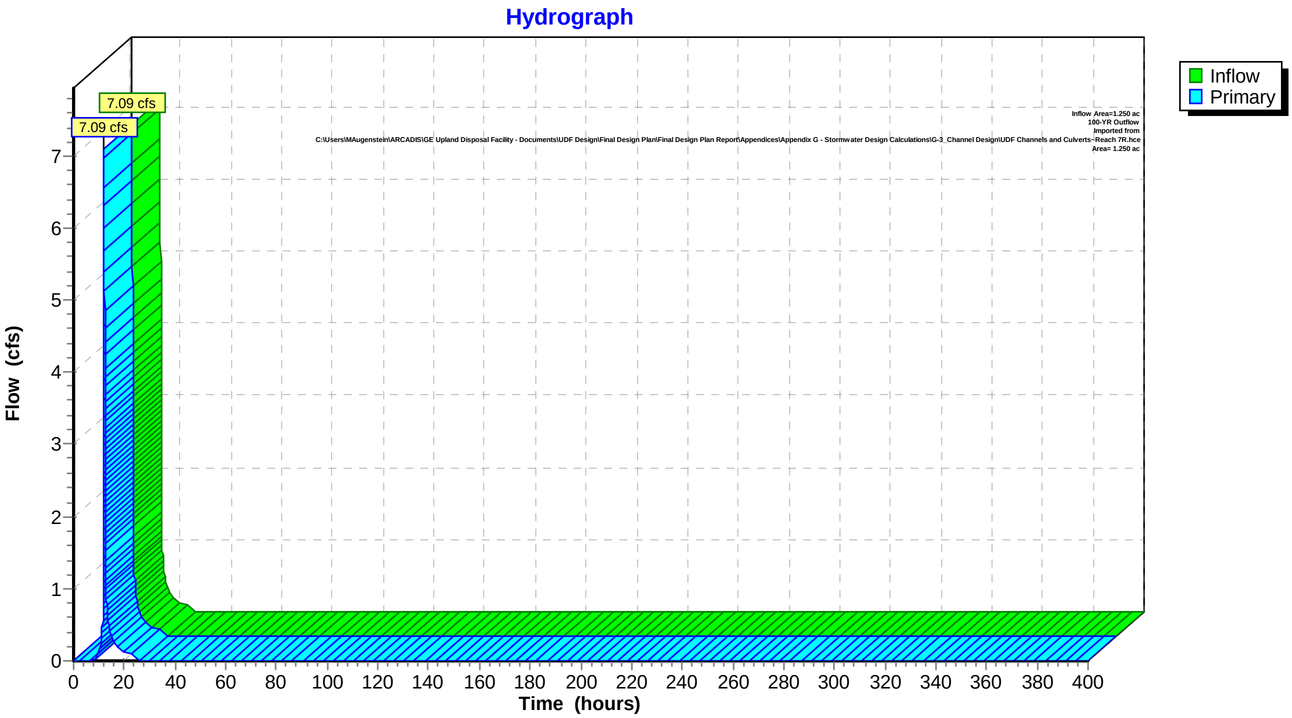
Summary for Link 9L: SW Ext. Ditch North

Inflow Area = 1.250 ac, 0.00% Impervious, Inflow Depth = 5.07" for 100-YR event
Inflow = 7.09 cfs @ 12.12 hrs, Volume= 0.528 af
Primary = 7.09 cfs @ 12.12 hrs, Volume= 0.528 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 11P : SW Ditch Low Point

Primary outflow = Inflow, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs

100-YR Outflow Imported from C:\Users\MAugenstein\ARCADIS\GE Upland Disposal Facility - Documents\UDF Desig

Link 9L: SW Ext. Ditch North



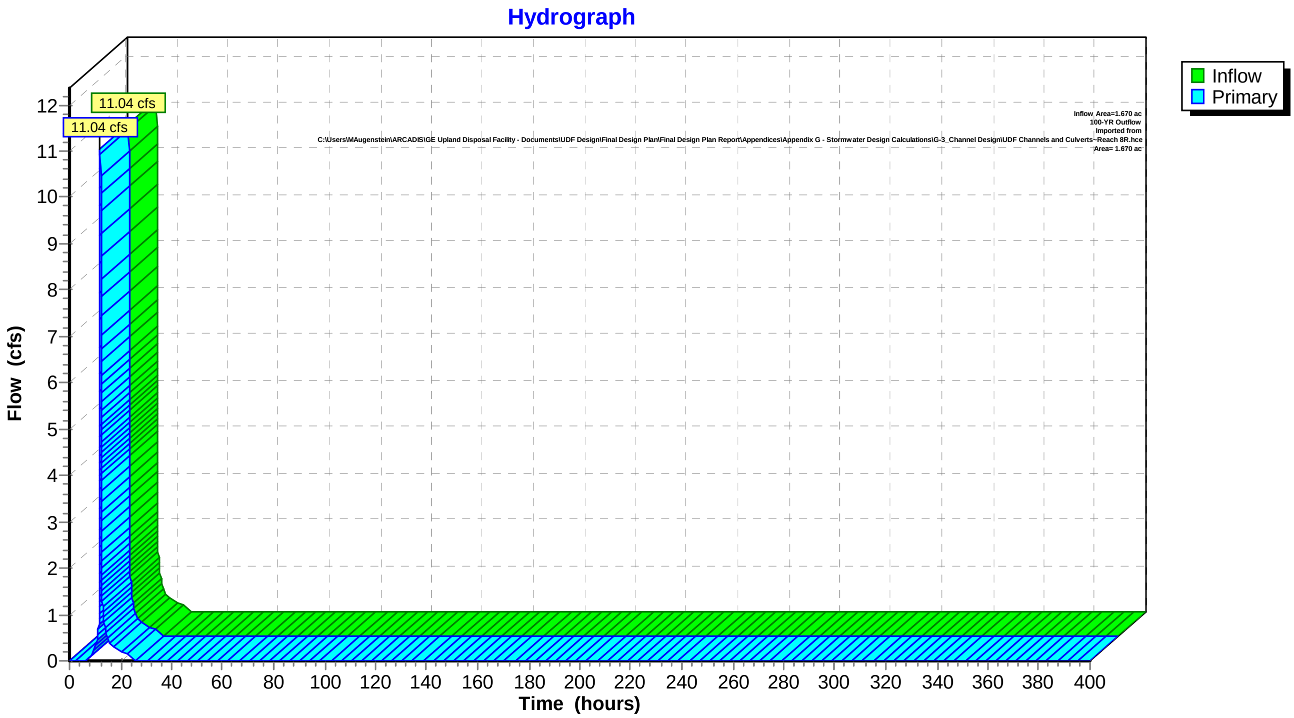
Summary for Link 10L: SW Ext. Ditch South

Inflow Area = 1.670 ac, 0.00% Impervious, Inflow Depth = 5.94" for 100-YR event
Inflow = 11.04 cfs @ 12.12 hrs, Volume= 0.826 af
Primary = 11.04 cfs @ 12.12 hrs, Volume= 0.826 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 11P : SW Ditch Low Point

Primary outflow = Inflow, Time Span= 0.00-400.00 hrs, dt= 0.01 hrs

100-YR Outflow Imported from C:\Users\MAugenstein\ARCADIS\GE Upland Disposal Facility - Documents\UDF Desig

Link 10L: SW Ext. Ditch South



Appendix H

Habitat Restoration and Mitigation Assessment Report

Habitat Restoration and Mitigation Assessment Report and Plan for Upland Disposal Facility Area

Woodland Road, Lee, Massachusetts

February 2024

Prepared for General Electric Company
Pittsfield, Massachusetts

Habitat Restoration and Mitigation Assessment Report and Plan for Upland Disposal Facility Area

Woodland Road, Lee, Massachusetts

February 2024

Prepared for
General Electric Company
1 Plastics Avenue
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1.0 Introduction and Overview

1.1 Introduction

This Habitat Restoration and Mitigation Assessment Report for the Upland Disposal Facility (UDF) Area has been prepared by AECOM on behalf of the General Electric Company (GE) to present the results of a habitat impact and restoration/mitigation assessment as part of the UDF Final Design associated with the Rest of River Remedial Action. That Remedial Action, including provisions for the UDF, was specified in the final Revised Resource Conservation and Recovery Act Corrective Action Permit issued by the U.S. Environmental Protection Agency (EPA) to GE on December 16, 2020 (Revised Permit).

The UDF will be sited on a 75-acre property in the Town of Lee, Massachusetts that was formerly part of an active sand and gravel quarry – a property that GE acquired from The Lane Construction Corporation in April 2021. Figure 2 shows the extent of the property acquired by GE (referred to herein as the GE Parcel). That figure also shows the maximum limits of consolidated material for the UDF (the consolidation area), the associated operational area surrounding and encompassing the limits of the consolidated material and access to these areas from the north and south of the consolidation area. In addition, the GE Parcel will contain areas for support of UDF operations. These support areas will include access points to the operational area, material and equipment staging areas, and areas for contractor use, as also shown on Figure 2.

As required by EPA, GE has evaluated the habitat impacts of the UDF construction and operation and potential measures to address such impacts. Toward that end, UDF-related habitat investigations and impact assessments were conducted between March 2022 and November 2023 in accordance with GE's Pre-Design Investigation Work Plan for the UDF (PDI Work Plan; Arcadis and AECOM 2021) and subsequent EPA conditional approvals requiring additional habitat assessments. The habitat information developed from these investigations has been presented in the *Second Revised Baseline Ecological Characterization and Habitat Assessment Report for the UDF Area* (AECOM 2024), which is Appendix C to GE's Revised *Final Pre-Design Investigation Data Summary Report for the UDF Area* (Revised Final PDI Summary; Arcadis and AECOM 2024), submitted to EPA on January 29, 2024, and is referred to herein as the UDF Baseline Habitat Assessment. The nature and extent of the UDF project activities evaluated in this habitat assessment are those described in the UDF Final Design Plan, to which this document is an appendix.

1.2 Overview

This section provides an overview of the habitat impacts associated with the UDF, as described in the UDF Final Design Plan, along with a summary of proposed habitat restoration and mitigation measures. Reference is made to the attached Figure 2, which shows the extent of the consolidation area and operational area on the GE Parcel on an aerial base; Figure 3, which depicts the GE Parcel on a U.S. Geological Survey topographic base; Figure 4, depicting soil types; and Figure 5, which presents habitat cover types on the GE Parcel. Attachment A provides representative photographs of the habitat conditions in both impact and mitigation areas.

Summary of Habitat Impacts

Habitat impacts within the consolidation area will be limited due to the prevailing habitat cover types in this area and the associated land use history as a recently disturbed earth removal area. The reasons for those limited impacts are described in Section 2. Further, consistent with recent discussions with officials from the Town of Lee, it is anticipated that, following UDF closure, the consolidation area, along with the surrounding side slopes and other disturbed areas within the operational area, will be converted to a grassland habitat area, including plant pollinator species, which will provide important habitat functions. This long-term condition is discussed in Section 2.

Activities in the operational area outside of the consolidation area will affect a greater range of habitat conditions, including a gravel pit pond and both early successional grassland/non-vegetated habitat and mature forested cover. Habitat impacts from construction activities in such areas will be addressed by several best management measures, including short-term measures (e.g., sedimentation/erosion controls and potentially time of year restrictions for some construction activities), and long-term measures (e.g., vegetative screening or buffers and habitat restoration or enhancement as grassland cover, and wetland/water mitigation). In addition, an access roadway that will be constructed to facilitate passage from the northern part of the GE Parcel to the operational and consolidation areas will impact various habitats, including an intermittent stream and bordering wetland fringe along with upland forested buffer, as discussed further below.

The impacts from the construction and operation of the UDF on the identified regulated wetlands and Massachusetts Wetlands Protection Act (MWPA) resource areas (described in the UDF Baseline Habitat Assessment) have been further evaluated during the final design process. Briefly, direct impacts to MWPA-regulated wetland resource areas will occur in two locations: (1) filling of the 0.67-acre southeastern-most gravel pit pond off the northwestern edge of the consolidation area; and (2) crossing of the intermittent stream on the northeastern side of the operational area with a small (25-foot wide) access roadway. These impacts are discussed in more detail in Sections 3 and 4. As noted there, the impacts are expected to be minor,

Summary of Proposed Mitigation Measures for Resource Area Impacts

Despite the minor functional impacts to resource areas from the filling of the on-site gravel pit pond and the access road construction, options for mitigation of these impacts have been evaluated both on-site and off-site, as discussed in Section 5. For example, although consideration was given to the creation of wetland/water habitat features in the western part of the GE Parcel along the edges of the other two gravel pit ponded areas, it was determined that, due to the grading of the steep slopes along these ponds, in combination with the presence of a transmission line right-of-way just east of the ponds, this option is impracticable.

Instead, in response to a directive in EPA's November 16, 2023 conditional approval letter for GE's August 7, 2023 Final PDI Summary for the UDF, GE has evaluated and is proposing an on-site mitigation measure involving the expansion and enhancement of vernal pool on the GE Parcel and the adjacent wetland and buffer habitat. This plan is described in Section 5. It will result in the establishment of roughly 0.42 acre of enhanced and created vernal pool and wetland habitat, along with 0.09 acre of vegetated buffer area. This proposed mitigation is considered to provide a suitable functional equivalence of important wildlife habitat to compensate for impacts to wetland resource areas, including both the impacts from the filling of the southeastern gravel pit pond and the impacts from the access road crossing of the intermittent stream.

Rare Species and Other Habitat Considerations

GE has considered the potential effects of the construction and operation of the UDF on the habitat of a species that has been listed by the U.S. Fish and Wildlife Service as endangered – namely, the northern long-eared bat (NLEB). However, given the absence of any known hibernacula, maternity roosts, or observations of NLEB at the GE Parcel, no mitigation measures are considered necessary at the UDF property to address NLEB, as discussed in Section 6.1.

In addition, GE has considered on-site measures to promote increased use of the site by monarch butterflies (a candidate species for federal listing) for potential breeding and likely migration habitat functions. GE is proposing such measures – specifically, transplanting and seeding of milkweed plants – as also described in Section 6.1.

Finally, as discussed in Section 6.2, GE has evaluated the potential for the stormwater basins and other UDF areas to attract vernal pool species and other wildlife into these areas during construction and operation of the UDF.

2.0 Final Restoration of Consolidation Area

As noted above, habitat impacts within the consolidation area will be limited due to the prevailing habitat cover types in this area and the associated land use history as a recently disturbed earth removal area. This area comprises approximately 15.5 acres, roughly 92% of which were previously subject to this past earth work and are currently either in a non-vegetated condition (2.66 acres or 17%) or composed of recently established grassland with some scattered woody shrubs and forbs (11.58 acres or 75%). Only 1.22 acres of the consolidation area (7.9%) consist of forested cover habitat. Since the habitat value of such disturbed cover conditions is generally limited to a small suite of wildlife species adapted to such disturbed conditions, and given the land use history of such recent disturbances, the impacts related to this loss of habitat will be minimal.

In addition, consistent with recent discussions with officials from the Town of Lee, it is currently anticipated that, following UDF closure, the long-term surface of the consolidation area, along with the side slopes, perimeter berm, and other disturbed areas within the operational area, will be converted to a grassland cover with the addition of plant pollinator species. Under this approach, the long-term post-closure condition of the UDF will consist of a roughly 30-acre grassland habitat area, which will not only provide a stable surface, but will also provide important habitat functions, including appeal to pollinators. Thus, the long-term habitat impacts from the UDF will be minor, and, in fact, the restored final surface will constitute an improvement in the habitat.

Grassland/open field habitats have been in declining abundance in Massachusetts for more than the past 50 years, and this decline has generated concern for a number of species that are dependent upon these habitats. While several of these are state-listed species (e.g., grasshopper sparrow and upland sandpiper), the concern extends to many other species that are not state-listed, such as field sparrow, American kestrel, savannah sparrow, and eastern meadowlark. These species, many of which were once common in Massachusetts, are becoming increasingly uncommon and have been focal species in the State Wildlife Action Plan (SWAP) (MADFW 2015) and in MassAudubon's State of the Birds Reports (MassAudubon 2013; Walsh and Servison, 2017). Establishment, preservation, and maintenance of such habitat have therefore become a priority for many conservation agencies and organizations, as discussed in Attachment B. While sites for such conservation purposes are ideally greater than 100 acres in size, grasslands/open field habitats in the range of 25 to 100 acres provide suitable conditions for many field-dependent species, as well as providing attractive complementary habitat for a wide range of other species that are drawn to the fields for food, nesting, resting and other life-cycle needs. In addition to the birds that are drawn to the fields for breeding, these open fields support a wide range of invertebrate life such as beetles, moths, and butterflies, as well as numerous species of small mammals. Adding native plants that support pollinators such as butterflies, bees, and hummingbirds, as is planned for the post-closure grassland in the UDF area, will further enhance the habitat functions in that area. These pollinators create a foundation for the entire local food chain, attracting predators such as bats, hawks, owls, fox, mustelids (e.g., weasel family), and grazers such as deer.

The UDF area would particularly benefit from a change in habitat from the present conditions to the grassland/open field habitat described above. The establishment/preservation of roughly 30 acres of grassland habitat at this site, with plant pollinator species, would improve existing conditions and contribute to the overall wildlife habitat diversity of this area. Attachment B provides additional information on the importance of grassland habitats, as well as pointing out other grassland management initiatives in this region as support for the usefulness of this habitat objective. It is noted, however, that this restoration approach would require the establishment of a stable cover of the landfill surface both during initial grow-in period and on a long-term/permanent basis.

Details regarding the construction of this grassland habitat in the closed UDF area, including planting specifications, will be provided in the Final Cover/Closure Plan for the UDF; and the long-term monitoring and maintenance requirements for it will be provided in the UDF Post-Closure Monitoring and Maintenance Plan.

3.0 Gravel Pit Pond Filling Assessment

3.1 Pond History

An important factor in assessing the habitat value of an area is understanding the land use history. This is particularly important for a man-made landscape such as that occurring in the earth removal area on the GE Parcel. Reviews of historical aerial photographs (from 1980-2020) have been conducted to develop an understanding of this land use history with respect to the southeastern gravel pit pond which is proposed to be filled off the northern limits of the consolidation area.

These historical aerial photographs indicate that the southeastern-most gravel pit pond area was initially being excavated between 1986 and 1990, but was either filled or sedimented in by side-slope erosion in 1995 (see Attachment D). In 2001, the presence of a distinct "water feature" in this area was evident on aerial photography; however, the current form of the pond had not yet been established. Aerial photography dated 2010 indicates that the current pond configuration had been established by that time, and that the pond was in active use for wash-water purposes (based upon the color of the water and evidence of activity around the pond periphery). From 2014 through 2019, the pond appears to have been largely unused, and vegetative growth appears to have developed and expanded around and within the pond to approach the current conditions. As described below, the pond has developed a dense stand of the invasive plant *Phragmites australis* (common reed) on the banks around the periphery, and erosion from surrounding slopes has continued to result in suspended sediment and sedimentation within the pond.

In short, the gravel pit pond has a very short land use history since it was created 10-15 years ago, and it appears to have been subject during that entire period to ongoing disturbance of the pond habitat from adjacent land use activities. This land use history substantially affects the habitat suitability of the pond and limits the types and extent of wildlife use to more transient species that are adapted to such disturbed conditions.

3.2 Existing Conditions

Attachment C7 of the UDF Baseline Habitat Assessment included a detailed Habitat Inventory Form for this gravel pit pond (included here in Attachment C), and this information forms the basis for this description of existing conditions. This created pond presents a small (0.67-acre) oval-shaped open water area, which, based on perimeter observations is generally less than three-feet deep, although a maximum depth over four feet is likely. The pond is ringed by a dense band of *Phragmites*, which forms a near monoculture on and around the bank of the pond. Higher portions of the bank have also been colonized by willows, poplar, and cottonwood shrubs and small trees. The full area of the pond with the vegetated bank included is 1.3 acres. There are no surface water inlets or outlets to or from the pond, although off the western side is a narrow berm of sand and gravel that separates this southeastern pond from the southwestern pond. Significant erosion is noted from overland runoff on the southern, northern, and eastern sides of the pond, which at least at times impacts water clarity in the pond while the sediment is suspended in the water column.

As described above, the southeastern pond has been inactive as part of the gravel pit operations for at least five or more consecutive years, and therefore would be considered a Pond under the MWPA regulations (310 CMR 10.04: definition of Pond).[1] As such, this area would contain Land Under a Waterbody (LUW) of 0.67 acre and 900 linear feet of Bank resource areas at the mean low water line (310 CMR 10.56 and 10.54, respectively). Specifically, the LUW encompasses the pond up to the mean low water level (which here is approximated by the lower limit of marsh emergent plant growth, which consists primarily of *Phragmites*; and the Bank of the pond extends from mean low water up to the first observable break in slope or the mean annual flood level, whichever is lower. This upper limit of Bank (i.e., top of bank) is delineated at this pond by the upper limit of the marsh emergent plant growth, which corresponds to the mean annual flood level (given that there is no discernible break in slope above mean low water within the ponded water regime). Erosion from the steep sided-slopes around the southern, eastern, and northern sides of the pond has been gradually filling in the edges of the pond for many years, resulting in a long, gradual slope of silty-sand mineral deposition extending from outside to well inside the permanently flooded portions of the pond.

3.3 Functional Impact Assessment

As described in UDF Baseline Habitat Assessment: "Considering the man-made, degraded conditions of the pond, wildlife habitat functional impacts resulting from filling of this ponded area will be minimal." In support of the qualitative assessment of the gravel pit pond, an assessment of wetland functions and values was conducted in accordance with U.S. Army Corps of Engineers (USACE) Highway Methodology Workbook Supplement (USACE 1999). This approach is a multi-disciplinary assessment of wetland functions, including the following: groundwater recharge/discharge; floodflow alteration; fish and shellfish habitat; sediment, toxicant, and pathogen retention; nutrient removal, retention, and transformation; production export; sediment and shoreline stabilization; wildlife habitat; recreation; education and scientific value; uniqueness and heritage; visual quality and aesthetics; and threatened or endangered species habitat. The assessment is a qualitative description of the physical characteristics of the wetland, including a determination of the principal functions exhibited. This method is not based on quantitative metrics, but rather provides criteria for assessing whether a wetland's characteristics could contribute to providing the functions listed above. The method entails completing a checklist of conditions pertinent to determining whether the wetland is anticipated to provide each function.

[1] Based on current regulatory criteria, the three gravel pit ponds on the GE Parcel do not constitute federally regulated waters of the United States, since they were created in upland settings for the purpose of treating water as part of the gravel pit wash-water system

Attachment E provides the results of this assessment in the form of the Wetland Function-Value Form for the southeastern gravel pit pond. Based on that assessment, there are only two functions that may rise to the level of being "principal," as defined by the USACE as functions that "are an important physical component of a wetland ecosystem and/or are considered of special value to society, from a local, regional, and/or national perspective." The two principal functions indicated for the gravel pit pond are sediment retention and wildlife habitat; two other, non-principal functions that may be provided by the pond include fish habitat and nutrient removal.

The sediment retention function, as well as nutrient removal, are related to the closed basin setting with surrounding slopes that are largely devoid of vegetation and have been eroding for many years. This is a localized function based on the man-made conditions of the earth-removal operation and would not be relevant under proposed conditions; it is therefore not a function requiring mitigation.

As described above, wildlife habitat functions of the southeastern gravel pit pond are rated as degraded and suitable only for a small suite of species adapted to such disturbed settings. As noted above, the fact that the pond was created 10-15 years ago and has been subjected to disturbance factors throughout that time span further limits the wildlife use. The man-made pond does provide habitat for several wildlife species in particular. During the 2022 site visits, American beaver (*Castor canadensis*) and muskrat (*Ondatra zibethicus*) were observed in the southeastern ponded area, with red-winged black birds (*Agelaius phoeniceus*) constructing nests in small eastern cottonwood trees surrounded by a dense stand of *Phragmites* within the banks around the periphery of the pond. However, reviews in 2023 did not record either of these mammal species, reflecting the likely transitory nature of such use. Other bird species occasionally visit the pond for feeding, including belted kingfisher and common grackle. It is also noted from 2023 reviews that the *Phragmites* growth was further expanded (from 2022) around the pond periphery, forming a monoculture in the shallow water zone around the pond banks. Predated snapping turtle nests were observed in sandy/gravelly areas adjacent to this pond, indicating that they are likely to be residing in the pond. In addition, while no fish collection was conducted, it is possible that the pond could support some tolerant warm-water fish species. Similarly, both bullfrogs and green frogs have been observed in the shallow water edge areas.

In summary, the filling of the southeast gravel pit pond is anticipated to have only minor impacts to localized wildlife habitat functions, as that pond consists of recently man-made and highly disturbed transient habitat conditions. Most of the wildlife habitat functions provided by the ponded area are also provided in the larger ponded areas along the western side of the GE Parcel and further off-site, although it is recognized that these habitat features are also disturbed and transitory.

3.4 Regulatory Assessment

As previously described, the southeastern gravel pit pond is not considered a federally regulated "water of the United States" based on current regulatory criteria, since it was created in an upland setting for the purpose of treating water as part of the gravel pit wash-water system. Accordingly, applicable or relevant and appropriate requirements (ARARs) under Section 404 of the Clean Water Act are not germane to the filling of this area.[2] However, as also described above, since the southeastern pond has been inactive as part of the gravel pit operations for at least five or more consecutive years, it would be considered a Pond under the MWPA regulations, comprising 0.67 acre of LUW and 900 linear feet of Bank at the mean low water line. As provided in the ARARs table (Table 1) in the UDF Final Design Plan, the MWPA regulatory requirements for "limited projects" associated with remediation in accordance with the Massachusetts Contingency Plan, as specified in 310 CMR 10.53(3)(q), are considered applicable to the ROR Remedial Action. Those regulations require (among other requirements) that there must be no practicable alternative (310 CMR10.53(3)(q).1), and that for impacts on resource areas, "mitigating measures shall be implemented that contribute to the protection of the interests identified in [the MWPA]" (310 CMR 10.53(3)(q).2.c). It is recognized that the review of such limited projects may also consider, as other factors, the magnitude of the alteration and the significance of the project site to the interests identified in MWPA, the availability of reasonable alternatives to the proposed activity, the extent to which adverse impacts are minimized, and the extent to which mitigation measures, including replication or restoration, are provided to contribute to the protection of the interests identified in the Act (see 310 CMR 10.53(3)). These factors have been considered here. In particular, there is no practicable alternative that would avoid an impact to the southeastern gravel pit pond, and mitigation measures are proposed that contribute to the interests of the MWPA, as described in Section 5.

[2] Notwithstanding this jurisdictional status, it is believed that the filling of this ponded area would meet the substantive requirements under the Section 404 regulations due to the absence of a practicable alternative or means to avoid the filling, as well as the proposed mitigation to compensate for the filling, as described in Section 5.

4.0 Roadway Crossing Impact Assessment

As described in the UDF Baseline Habitat Report, an intermittent stream crosses the GE Parcel from east to west, extending from Woodland Avenue through the bordering vegetated wetland (BVW) and out to the transmission line right-of-way. For site operations, it will be necessary to provide an access road across this intermittent stream to allow for north-south on-site traffic and conveyance of dredge material to the disposal/consolidation area. There is no location on the GE Parcel where access from north to south could feasibly be provided with no impact to this stream or wetland. Site investigations have been conducted by both environmental scientists and engineers to determine the best location and design for a road crossing considering environmental, engineering, logistical, and other factors. In doing so, an effort was made to select a crossing location with minimal direct impact to the stream and BVW, and design considerations were applied to minimize environmental impacts consistent with current regulatory provisions. The following sections describe the selected access road crossing location and factors considered in the design process to minimize habitat impacts:

4.1 Existing Conditions

The UDF Baseline Habitat Report provides detailed information on the BVW and associated intermittent stream that extends from Woodland Avenue across the GE Parcel to the transmission line. Attachment C provides a habitat form summarizing conditions in the BVW. As flow traverses the broader BVW area and is conveyed west between two upland hillsides, it narrows to a distinct stream-side corridor that is generally only 30-40 feet wide. The stream channel itself is typically less than 10 feet wide from bank to bank. Wooded BVW conditions border the banks of the stream to both the north and south, extending 20-30 feet off the stream banks to the upland forested hillsides. Note that under MWPA regulatory criteria, the stream itself is considered only a Bank resource, not LUW and Bank. Since the outer edge of LUW is defined as the mean low water level, which in an intermittent stream is at the downstream point where/if the stream becomes perennial, the Bank area extends up to the first observable break in slope or the mean annual flood level, whichever is lower. Further, in calculating Bank impact on an intermittent stream under the MWPA regulations, only the linear footage of the thread of the stream is considered. It is also recognized that this wetland and stream would meet the definitions of "waters of the United States," such that they would be subject to the regulatory requirements under Section 404 of the Clean Water Act.

Conditions along the intermittent stream Bank and BVW were carefully reviewed to assess alternative crossing locations geared to minimizing impacts to resource areas. In general, there is a roughly 200-foot reach of the stream where conditions are relatively similar as described above. As described below, a crossing location was selected within this reach where conditions did not pose constraints that would result in greater impacts.

4.2 Roadway Siting/Design Factors and Impact Summary

The following points summarize the selected access road crossing location and factors considered in the design process to minimize habitat impacts:

- The selected crossing location is where the intermittent stream width is minimal (typically about 10 feet wide) and where adjacent BVW width is only 10-30 feet wide;
- The width of the access road has been held to 25 feet, with minimal side-slope widening necessary beyond the roadway limits (and no side slopes at the actual stream crossing, where only a 30-foot long arch culvert will be placed);
- The resulting overall footprint of the crossing on BVW and stream/bank habitat is limited to 1,300 square feet (sf) (with roughly 1,000 sf of BVW impact);
- The intermittent stream will be spanned by an arch-culvert, such that no disturbance to the stream bottom habitat will occur; and
- The arch-culvert spans the channel width a minimum of 1.2 times the bankfull width of the stream; and
- The road crossing design complies with the Massachusetts Stream Crossing Standards (see MA Stream Crossing Handbook (mass.gov).

4.3 Roadway Crossing Regulatory Assessment

As currently designed, the overall footprint of the roadway crossing on BVW and stream/bank habitat is limited to 1,300 sf (with roughly 1,000 sf of BVW filling, and 300 sf of the stream channel being spanned with an arched culvert).

The MWPA regulatory requirements for “limited projects” under 310 CMR 10.53(3)(q) require that, for temporary alterations to resource areas, such as access roads, those areas must be substantially restored after use, with at least 75% of the surface of any area of disturbed vegetation reestablished with indigenous wetland plant species within two growing seasons (310 CMR 10.53(3)(q).2.f). In this case, assuming that the access road across the intermittent stream is ultimately removed as part of the UDF closure, the wetland area affected by the road will be restored in accordance with these requirements. In addition, as noted above, these regulations require implementation of mitigating measures for impacts on resource areas. The mitigation for impacts caused by this access road is the on-site mitigation described in Section 6.2.3.

5.0 Mitigation Measures for Resource Area Impacts

This section describes in detail the measures proposed on the GE Parcel to mitigate the habitat impacts to MWPA resource areas from UDF activities.

As described in the preceding Sections 3 and 4, the filling of the on-site gravel pit pond and the crossing of the intermittent stream and wetland by the access road construction pose minimal functional impacts. Despite this, options for mitigation of these impacts have been evaluated both on-site and off-site, with a focus on addressing any loss of wildlife habitat function. Consideration was first given to the creation of wetland/water habitat features in the western part of the GE Parcel along the edges of the other two gravel pit ponded areas. However, it has been determined that the grading of the steep slopes along these ponds, in combination with the presence of the transmission line right-of-way just east of the ponds, make the creation of such wetland/water mitigation features impracticable. Further, since these two western ponds remain in active use as washwater ponds for the ongoing earth borrow activities to the west of the GE Parcel, their use for habitat mitigation would be uncertain at best or in possible conflict with that use.

EPA's November 16, 2023 conditional approval for GE's August 7, 2023 Final PDI Summary for the UDF directed GE as follows (in Condition #1): "Due to the observed drying out of the vernal pool [at the GE Parcel] prior to wood frog metamorphosis, GE shall consider as an on-site habitat mitigation measure in the [UDF] Final Design the incorporation of features or site modifications that direct properly managed, non-impacted, surficial stormwater run-off into the vernal pool area to sustain spring water levels in the vernal pool for a longer period of time to support full development of wood frog larvae to adult emigration during all hydroperiods."

The basis for this recommendation was the following discussion in the UDF Baseline Habitat Report:

> "Surveys during both 2022 and 2023 found that the duration of flooding in the UDF vernal pool was not sufficient to allow wood frog metamorphosis to proceed to its final stage of adult emigration from the pool. The pool appears to fill reliably early in the spring to provide suitable conditions for egg deposition and larvae development; however, the pool is subject to inadequate hydroperiods for sustained larvae metamorphosis to adult wood frog stage. It appears likely that the high permeability of the underlying glacial outwash (e.g., sand and gravel) results in high infiltration rates of surface water, such that only wetter years with sustained precipitation in the April into early July period would support full development of wood frog larvae to adult emigration."

It should be noted, however, that both 2022 and 2023 were abnormally dry springs.[3]

In accordance with EPA's directive, GE evaluated potential enhancement measures at the vernal pool along Woodland Road to improve the habitat in that pool for wood frog breeding and potentially other vernal pool species. This assessment included digging of 10 soil test pits throughout the vernal pool and adjacent area, as well as detailed analyses of the surface water flows in and around the vernal pool area. The results of this assessment are incorporated in Section 5.1.

5.1 Existing Vernal Pool Conditions

As shown on Figures 2, 5 and 6, the vernal pool on the GE Parcel is a small (0.23-acre) vernal pool at the northern limit of the forested wetland along Woodland Road. This vernal pool consists of a shallow basin which has formed in a depression along the edge of the wetland. The limits of the vernal pool are generally confined to below elevation 991.5 feet, with the lowest elevation of the pool around 988.5 feet. Water depths in the pool during spring are generally one to two feet, with a maximum depth approaching three feet during high water periods within one small (approximately 560 sf) pocket located in the central part of the pool. The lower elevations of the vernal pool are relatively sparsely vegetated with herbaceous plants such as sedges, while silky dogwood forms a dense shrubby layer around the eastern margins of the deeper pool areas. The invasive shrub Morrow's honeysuckle is common at the higher elevations around the pool and in the wetland community around the vernal pool. (Photographs of the vernal pool area are provided in Attachment A, and Attachment F provides the MNHESP Vernal Pool Field Observation Form.)

The source of surface water into the vernal pool appears to be primarily shallow groundwater flow along with some runoff from the surrounding wetland and upland slopes. This localized groundwater appears perched relative to more regionalized groundwater flow, as the elevation of the wetland is generally 10-15 feet higher than the groundwater levels measured in site monitoring wells (i.e., the wetland is generally at elevation 993 feet, whereas the regional water table measured in wells along the eastern side of the GE Parcel is typically no higher than 980 feet). While the

[3] Precipitation in Pittsfield from May through August 2022 was consistently below normal, with only 9.88 inches of precipitation falling during these four months, 6.49 inches below the normal precipitation of 16.37 inches (Pittsfield MA: Local Climatological Data (weather.gov)). Western Massachusetts was in a declared drought from June through August 2022; June and July were in a "Level 1-Mild Drought." Below-normal precipitation conditions were again observed during the period from April 20 to May 24, 2023. Precipitation during these two months was only 68% of normal (5.71 inches vs. 8.41 inches). A field survey of the vernal pool on May 4, 2023 observed wood frog larvae in the pool, which had up to two feet of water depth at that time. By May 11, 2023, water levels had dropped roughly 10 inches from the May 4 conditions, and by May 18 the pool was completely dry and no tadpoles were found. May 2023 precipitation was only 58% of normal (2.18 inches vs. 3.73 inches). Despite rainfall in late May resulting in renewed flooding of the pool, no additional observations of wood frog larvae were noted in a field survey on May 24, 2023. Berkshire County was again in a designated Level 1 drought in June of 2023 (Mass.gov 2023: Drought Status | Mass.gov).[3]

forested wetland receives surface stream flow from culverts under Woodland Road south of the vernal pool, this stream flow largely bypasses the vernal pool to the south and rarely feeds surface water into the pool. Further, runoff conveyed to a culvert under Woodland Road just north of the vernal pool is directed via a ditch to a depression along the western side of the road north of the vernal pool, and again rarely provides any surface flow into the vernal pool (Figure 7). In short, the functional surface watershed that is available to feed surface runoff into the vernal pool is limited, and under these conditions the pool requires wetter than normal conditions to sustain surface water long enough during the vernal pool breeding season to ensure wood frog metamorphosis.

The obligate pool-breeding amphibian breeding season in the region may begin as early as mid-March, although more typically this season begins in early to mid-April in the Housatonic Valley. Wood frogs in Massachusetts can develop from egg to froglet in 60 days under certain circumstances, but a period of 75 to 90 days is more typically required. Wood frog tadpoles typically reach metamorphosis in mid- to late June. In short, permanent surface water in the pool would be optimally sustained from early April into late June for wood frogs to complete their breeding cycle. Under the conditions observed in 2022-2023, surface water in the vernal pool was not sustained for 60 days post egg-laying.

Another factor likely influencing the hydroperiod in the vernal pool is the existing substrate conditions, both the surface soil profile and underlying surficial deposits. Based on the 10 test pits examining these soil conditions (as shown in Attachment G), while the surface topsoils are a mucky silt (which can retard infiltration), a sandy layer underlays the surface topsoils both within the vernal pool and in surrounding uplands. While this sandy layer is likely important in conveying the shallow groundwater interflow through the wetland and even into the vernal pool, it also is expected to promote infiltration out of the vernal pool as the growing season progresses. Therefore, without ongoing surface water or precipitation sustaining the shallow groundwater levels in the wetland and vernal pool (particularly as spring progresses and tree evapotranspiration becomes more substantial), infiltration from the vernal pool into the underlying sandy layer acts to draw down the vernal pool water level to create drier surface conditions. Note that the depression north of the vernal pool is also below elevation 990 feet (i.e., similar to the vernal pool elevation) and has no surface outlet, but does not support wetland or surface water ponding due to well-drained sandy subsoils which promote rapid infiltration. Therefore, the water which is conveyed via the northern culvert into this northern depression provides minimal hydrologic support to the vernal pool area.

5.2 Proposed Vernal Pool Enhancement Plan

Based on the assessment results described above and given EPA's directive in its November 16, 2023 conditional approval letter, GE has developed a proposed on-site mitigation plan to expand and enhance the vernal pool and adjacent wetland and buffer habitat. The primary objective of the vernal pool enhancement plan is to improve the surface water regime by augmenting surface flow into the vernal pool to develop a longer, more sustained hydroperiod during the late May through June time period. In concert with this objective. the plan also includes objectives of expanding the limits of the vernal pool breeding habitat, reducing and controlling invasive plant species growth, and expanding the extent of vegetated wetland bordering the vernal pool to enhance the buffer habitat around the vernal pool and wetland area. The proposed plan to achieve these objectives is described below.

Figure 7 presents the proposed grading and hydrology plan intended to achieve the objectives specified above. The most critical feature encompassed in the plan is the re-direction of surface water flow from the culvert under Woodland Road to convey this flow toward the vernal pool instead of into the depression north of the vernal pool. This flow runs along the eastern side of Woodland Road in a swale that starts roughly 570 feet south of the culvert. The flow is generated by overland flow from a roughly 38-acre forested watershed that extends east off of Woodland Road (which is shown in an inset on Figure 7), and nearly all of this watershed is on protected open space controlled by the Massachusetts Department of Conservation and Recreation (October Mountain State Forest) and Massachusetts Department of Fish and Game (George L. Darey Housatonic Valley Wildlife Management Area). Improvements to the swale will be implemented to maximize the flow conveyed to the culvert, as the swale is currently filled with sediment and thus flow is prone to overtopping into the roadway and dispersing randomly across the road. By improving the swale (excavating it and lining it with rock), and then re-directing the swale on the west side of the road to convey the runoff toward the vernal pool, the contributing watershed to the vernal pool will be increased substantially (approaching 36 additional acres, although some of this watershed may already contribute flow to the vernal pool under some runoff conditions or events).

Proposed Grading

Additional grading changes will be implemented between the northern end of the vernal pool area and Woodland Road to promote the surface flow from the culvert into the vernal pool, as well as to expand the limits of both vernal pool and wetland habitat (Figure 7). This area will be lowered to a similar grade as the actual existing vernal pool (989-991 feet), such that surface flow diverted from the re-directed swale at the culvert will be directed toward the existing vernal pool. The area of this proposed grading is currently dominated by the invasive species Morrow's honeysuckle, so this grading will also remove much of this invasive plant growth and open the area for plantings of native wetland species. This grading will create roughly 0.16 acre of additional vernal pool habitat (below elevation 991 feet) and will also establish grades for an additional 0.06 acre (2,700 sf) of BVW around the periphery of the new vernal pool area. The existing vernal pool will not be disturbed by grading except at northern end to ensure that positive surface flow will extend into it from the north.

In grading this area for contributing surface flow into the existing vernal pool, the subsurface conditions will be prepared to reduce the permeability for infiltration (or loss) of surface water into the subsoils. It is anticipated that the area will be over-excavated by one foot to allow for a three-inch compacted silty base layer beneath at least nine inches of topsoil. The compacted silt layer will be specified to have a vertical permeability of no more than 10^{-4} m/sec; this permeability is intended to retard infiltration, but still be adequate for shallow groundwater flow to contribute to the hydrology of the expanded basin area. In addition, the northern end of the re-graded area will be filled to raise the grade slightly higher than under current conditions to ensure that flow does not overtop the new wetland area and flow into the northern depression (there is currently evidence of surface flow overtopping this area from the wetland and draining into the northern depression).

Proposed Planting Plan

As shown on Figure 8, the expanded vernal pool and BVW area, as well as the upland buffer zone around these areas to the north and northeast, will be planted with a diverse assemblage of wetland herbaceous and woody plant species to speed and direct habitat development in these resource areas. Plantings are presented in tabular form on Figure 9 along with size and quantity requirements, recommended seed mixtures and planting and construction notes.

A total of 102 plantings within and adjacent to the newly created vernal pool habitat will be installed and will include six species of woody shrubs and three tree species. All trees and shrubs are native plants that have been previously documented on the GE Parcel. In addition, a central core area (the deepest part of the pool) will be planted with herbaceous aquatic emergent plugs and overseeded along with the rest of the wetland area with a wetland seed mixture containing a variety of native sedges, rushes and grasses. This approach will ensure that a variety of plant species are available to establish under a variety of hydrologic conditions that are anticipated. Finally, a native conservation seed mix will be used to ensure stabilization of adjacent side slopes disturbed during the construction process.

Summary of Vernal Pool Enhancement Plan

The following points summarize the proposed plan for enhancing vernal pool habitat along with expanding adjacent BVW and buffer zone habitat:

- The surface water flow paths into the vernal pool will be changed to re-direct flow from an additional 38 acres of woodland watershed into the vernal pool area.
- The existing 0.23-acre vernal pool habitat will not be physically modified except at the northern end to allow for increased surface water flow into it.
- The limits of vernal pool breeding habitat will be increased by roughly 0.13 acre to the north of the existing vernal pool.
- The additional surface water drainage area directed to the vernal pool area is anticipated to extend the hydroperiod of the vernal pool to allow for successful metamorphosis of wood frog to emigrate from the pool during more years than occurred under conditions like those in 2022 and 2023.

- In addition to the additional vernal pool habitat, roughly 2,700 sf (0.06 acre) of BVW creation area will be established at the northern edge of the vernal pool, and vegetated buffer areas will be established over roughly 4,000 sf (0.09 acre) around the northern side of the mitigation area.

As a result of these improvements, roughly 0.54 acre of enhanced and created vernal pool, wetland habitat and vegetated buffer will be established. Given the critical habitat provided by vernal pool habitat and the lack of other such habitat on and in proximity to the UDF site (i.e., no NHESP Certified or Potential Vernal Pools mapped within approximately 6,000 feet of this pool; see Figure 3), this proposed mitigation is considered to provide a suitable functional equivalence of important wildlife habitat to compensate for impacts to the wetland resource areas at the UDF area. This project will thus provide mitigation for both the impacts from the filling of the southeastern gravel pit pond and the impacts from the access road crossing of the intermittent stream.

Monitoring Plan

Following completion of the vernal pool and wetland enhancement project, monitoring of the enhanced area will be conducted for five years to document the progression of the area toward achieving the objectives described above. Such monitoring will consist of assessing the hydrologic regime of the area and the growth of planted and volunteer plant species within all portions of the mitigation area (i.e., the vernal pool, expanded wetland, and planted buffer area), as well as documenting the amphibian breeding activity within the vernal pool. The components of the monitoring plan are summarized as follows:

Hydrology: Within the vernal pool enhancement and expansion areas, the hydrology will be monitored to document the hydroperiod (duration of surface water flooding) in the spring from late March to the end of June by collecting data on water depth from within the deepest part of the pool. These data will be collected in a quasi-continuous fashion using one pressure transducer datalogger placed in the deepest part of the pool and/or intermittently using a standard water level staff-gauge. The datalogger will be placed inside a two-inch diameter slotted PVC pipe that extends approximately three feet above and three feet below the surface of the substrate.

Plant Community: During the five-year monitoring period beginning at the completion of planting, monitoring and inspections will be conducted two times per year for the first three years after planting and once during the fifth year after planting. In each of the first three years after planting, GE will inspect up to three pre-established vegetation monitoring plots in the late spring after the first leaf flush (May/June) and in the summer (July/August) to quantitatively assess total percent vegetative cover, total percent herbaceous cover, total percent shrub and tree cover, and height of vegetation. In addition, a qualitative inspection of the entire mitigation area will be conducted to assess growth and survival of planted vegetation, general cover type characterization, species identification and percent coverage by species, identification of invasive species, observations of stress and/or herbivory, and characterization of soil texture and moisture. During the fifth year after planting, GE will inspect the vernal pool in the summer (July/August) using the same procedures.

During these events, based on stem counts, any dead trees or shrubs in excess of 20% of the original planting will be replaced to ensure an 80% survival rate. A 100% coverage of bare ground outside of the foliar coverage of the trees will be maintained. In addition, GE will inspect the planted vegetation for apparent vigor and growth, using best professional judgment based on accepted restoration standards and familiarity with local planting conditions, and will make recommendations to EPA in the event that GE concludes that the vegetation on average is not growing at an acceptable rate.

In addition to the above monitoring requirements, GE will implement measures during the five-year monitoring period to control the growth of invasive species within the vernal pool restoration area. The goal of this control is to ensure that no greater than 5% of any area subject to restoration is covered with invasive species. Invasive species control will be implemented as necessary, using an appropriate control method for the species being targeted; this may include herbicide applications, hand pulling, girdling, black plastic coverings, biological control, or other methods.

Amphibian Breeding: During each of the amphibian breeding seasons of the five-year monitoring period (late March to the end of June), investigations will be conducted to document the extent and status of amphibian breeding, specifically focusing on wood frog egg mass counts, larval emergence, and status of metamorphosis through to emigration from the vernal pool. Field data collection and documentation will follow the MNHESP vernal pool certification guidelines (NHESP 2009). Surveys will include two site visits in late April and early May to search for egg masses of obligate vernal pool species, followed by one inspection every two weeks to conduct dip-net sweeps and assess larval growth and development. These inspections will continue each spring until the pool dries or amphibian larvae complete metamorphosis and emigrate from the pool. These surveys will be conducted for documentation purposes and will not be determinative of success given the annual variations typically observed in such habitats and the inability to control or manage the biological results. Corrective actions will not be taken based on these surveys apart from the actions described in the prior paragraph.

6.0 Other Habitat Issues

6.1 Potential Impacts on Threatened and Endangered Species and Measure to Address Them

As noted above, GE has considered the potential effects of the UDF construction and operation on the habitat of the northern long-eared bat (NLEB), a federally listed endangered species, as discussed in the UDF Baseline Habitat Assessment. The 1.22 acres of forested habitat in the consolidation area, as well as any forested cover on the GE Parcel, have a limited potential of providing some habitat functions for the NLEB. The NLEB winters in caves or underground mines and inhabits dead trees and trees with loose bark in forested areas for summer roosting sites and small nursery/maternity colonies. However, according to the most recent available mapping (Mass.gov January 2023), the nearest documented NLEB hibernacula is located approximately 7.6 miles west-southwest of the GE Parcel, near Rockdale Mills in the town of Stockbridge, MA. Further, no known maternity roosts are mapped on or near the GE Parcel, no observations of NLEB on or near to the GE Parcel were made during the field investigations for the UDF, and no documented NLEB observations have been reported on or near to the GE Parcel. In these circumstances, specific measures to address potential impacts on the NLEB are not considered necessary or warranted at the GE Parcel.

In addition, as directed in EPA's November 16, 2023 conditional approval letter for the initial Final PDI Summary Report (Condition #2), GE has considered additional plantings – notably of milkweed (*Asclepias syriaca*) – to promote increased use of the UDF site by monarch butterflies, a candidate species for federal listing (and a pollinator), for potential breeding and likely migration habitat functions. As noted in Section 2, the final closed condition of the UDF will consist of a roughly 30-acre grassland, including pollinator plant species (see also Attachment B). Further, there is an existing area of milkwood growth encompassing approximately 5,700 square foot within the central portion of the consolidation area., and the upland milkweed currently growing in this area contains an extensive rhizome system. In this situation, GE proposes that, prior to excavation of the consolidation area, the rhizomes of these milkwood plants will be transplanted to an existing open area along the southwestern edge of the UDF area to preserve this growth. In addition, GE will distribute milkweed seeds in other open portions around the periphery of the UDF area to encourage establishment of this plant species in other areas of the GE Parcel.

6.2 Evaluation of Attracting Wildlife into Operational Areas

In accordance with EPA's April 18, 2023 conditional approval letter for the UDF Conceptual Design Plan, this section discusses: (1) aspects of the UDF stormwater basins and associated measures that would make those basins unattractive for habitation and use by vernal pool species from the on-site vernal pool; and (2) an evaluation of other areas at the UDF site for the possibility of attracting wildlife into other operational areas during construction, as well as measures that will avoid such attraction.

Stormwater Basins and Management Areas

Based on the Final Design Plan, two stormwater basins and five Stormwater Management Areas (SMAs) will be constructed at the UDF area. The northern stormwater basin and the southern stormwater basin will treat on-site runoff; the northern basin will treat runoff from the final cover of the UDF and the gravel access roads, and the southern basin will treat runoff from the operational area south of the consolidation area, which may include buildings and limited pavement associated with parking and a paved entrance. Both stormwater basins will function as infiltration basins with exposed sandy-gravelly soil conditions maintained on the basin floor, and contributing stormwater is expected to drain fully from these basins within approximately one to two days (or a maximum of three days during a 100-year storm event). Side slopes will be maintained in a grass cover.

The five SMAs are located around the periphery of the UDF consolidation area; SMA-1 is located adjacent to the northern stormwater basin, SMA-2 and SMA-3 are located at the southern entrance to the UDF area, and SMA-4 and SMA-5 are located along the western limits of the UDF area. These SMAs would also be constructed and maintained with exposed sandy-gravelly soil conditions on the basin floor to maximize infiltration; however they will hold water for a slightly longer period, draining within approximately five to six days following a 100-year storm event.

The two species of amphibians that typically breed in vernal pools and are most likely to be attracted to the stormwater detention basins for breeding are wood frogs and spotted salamanders. Both species migrate to vernal pools from adjacent (typically forested) upland areas in the early spring (i.e., late March to early April) and deposit egg masses that are usually attached to woody vegetation within the pool. Upon hatching, larval salamanders and tadpoles will seek cover in vegetation and/or leaf litter in the pool to avoid predation as they develop, and tadpoles will graze on surfaces of leaf litter and herbaceous forbs and grasses within the pool. Both species are known to breed in pools with extended hydroperiods, typically requiring a period of 75 to 90 days for wood frog tadpoles to reach metamorphosis in mid- to late June and slightly longer into July for spotted salamanders. In addition, both species exhibit well-documented site fidelity, with high percentages of surviving metamorphs returning to their natal breeding sites upon reaching sexual maturity.

Due to the extremely short duration that the stormwater basins and the SMAs would hold water, as well as the lack of any vegetation cover that would function as egg attachment sites for adult amphibians or feeding and escape cover for developing larvae, the stormwater basins and SMAs would not be attractive to these species for breeding purposes. Moreover, the lack of a forested fringe will leave these areas fully exposed to sunlight, with no beneficial shading from forest canopies to manage pooled water temperatures, which will further diminish their attractiveness to vernal pool species. On the rare occasion that these features exhibit one to several days of standing water that coincide with the spring migration, and even assuming that some breeding takes place on these days, the egg masses would not be viable. Thus, there would be no recruitment into the local population, and no adults returning to natal ponds to attempt breeding in the future.

Other species that have been documented to use stormwater detention ponds and are present in western Massachusetts, but are more commonly associated with semi-permanently and permanently flooded hydrologic regimes, include green frogs (*Lithobates clamitans*), pickerel frogs (*Lithobates palustris*, and bullfrogs (*Lithobates catesbeianus*). These species would not be expected to use the infiltration basins and SMAs in the UDF area for breeding purposes due to the very short duration that these areas will hold water.

Adults of the vernal pool amphibians could potentially use the SMAs during the non-breeding period as temporary feeding, hydration, and/or thermoregulation sites when they are flooded. However, because the drainage areas contributing to these SMAs consist primarily of vegetated surfaces and gravel access roads, water quality would be much better than in a typical stormwater basin that receives runoff from paved surfaces including roads, parking lots. and buildings. Therefore, short-duration use of the basins by amphibians on this site is not expected to result in deleterious effects on them.

Other Operational Areas

The potential for attracting wildlife into other operational areas during UDF construction is limited due the barriers that will be in place around the entire UDF area. Notably, there will be a perimeter fence around the construction area, which will limit larger wildlife from entering much of the UDF area. While this fence may be modified in certain locations during various phases of the construction, functional fencing will remain for most of the construction process. Further, as part of the best management practices for the site construction, trenched silt fencing (and other construction fencing) will be installed at the limits of most work areas. In addition to providing sedimentation control functions (where appropriate), this fencing will restrict the movements of many wildlife species (e.g., reptiles, amphibians, small mammals) from entering into such work areas. Finally, active construction sites are typically avoided by most wildlife species simply due to the exposed conditions subject to daily activity.

7.0 References

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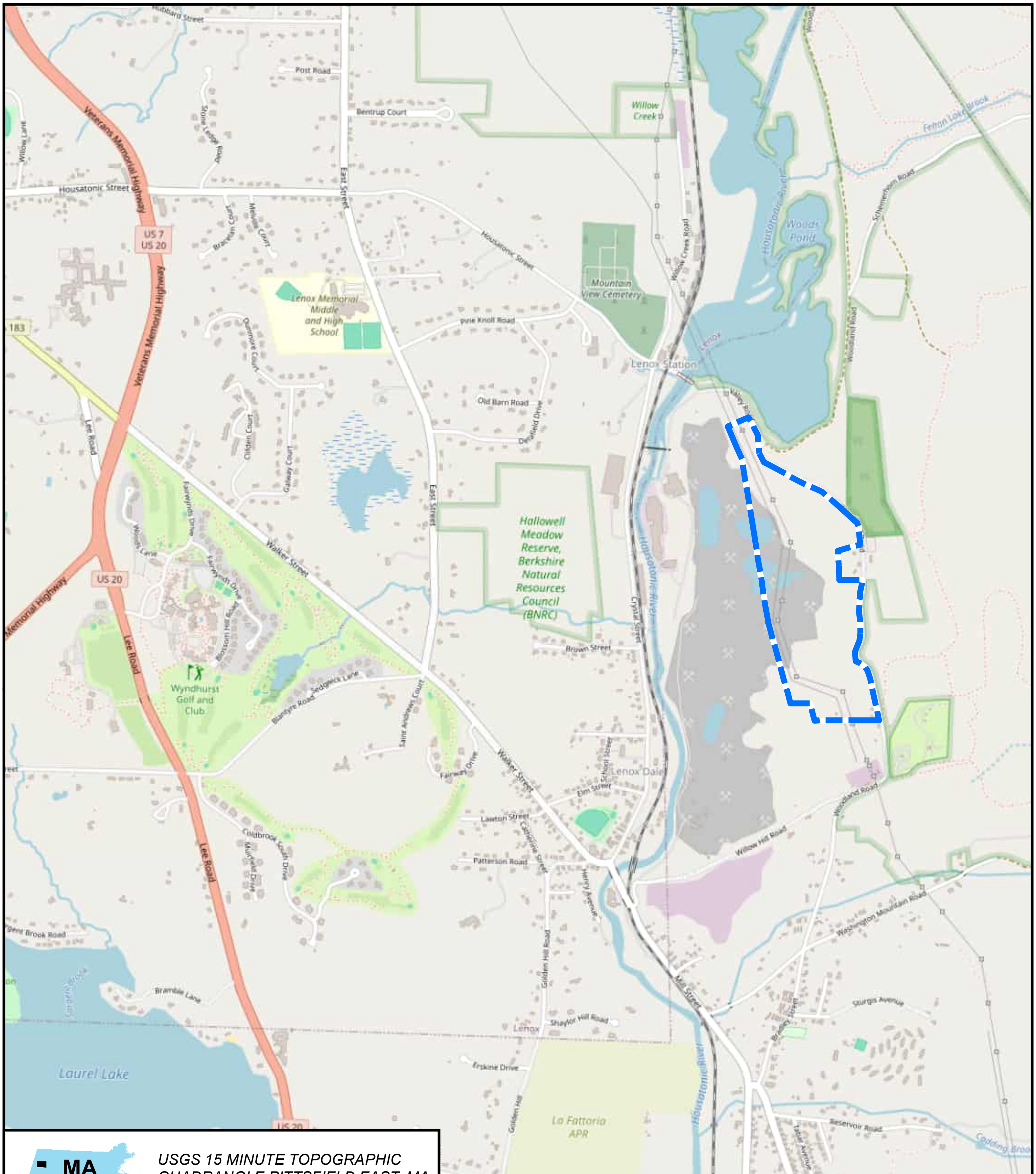
Figures



USGS 15 MINUTE TOPOGRAPHIC QUADRANGLE PITTSFIELD EAST, MA

Legend

0 850 1,700 3,400 Feet

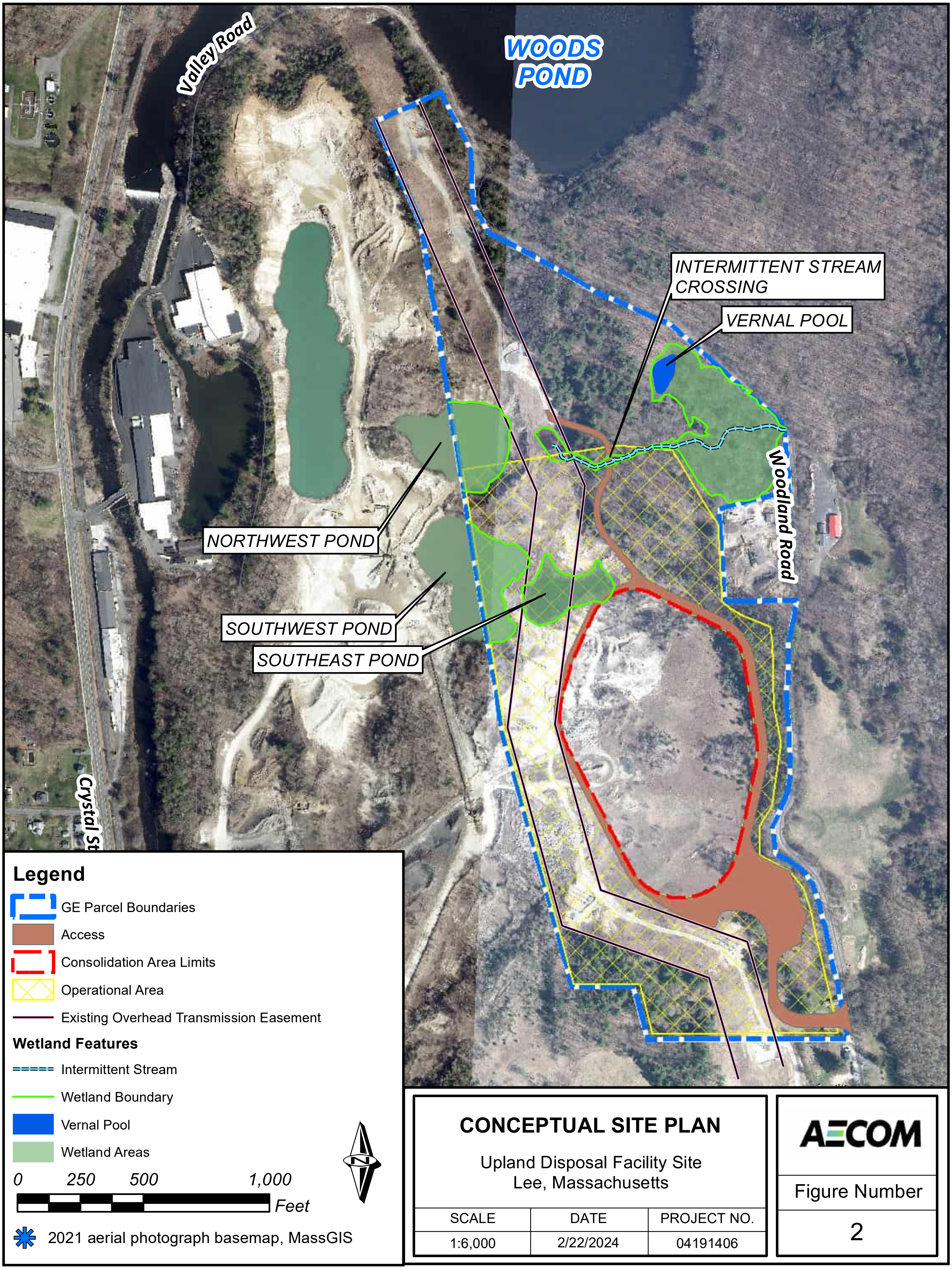
LOCATION OF GE PARCEL

Upland Disposal Facility Site
Lee, Massachusetts

SCALE	DATE	PROJECT NO.
1:20,400	2/22/2024	04191406

AECOM

Figure Number 1



CONCEPTUAL SITE PLAN

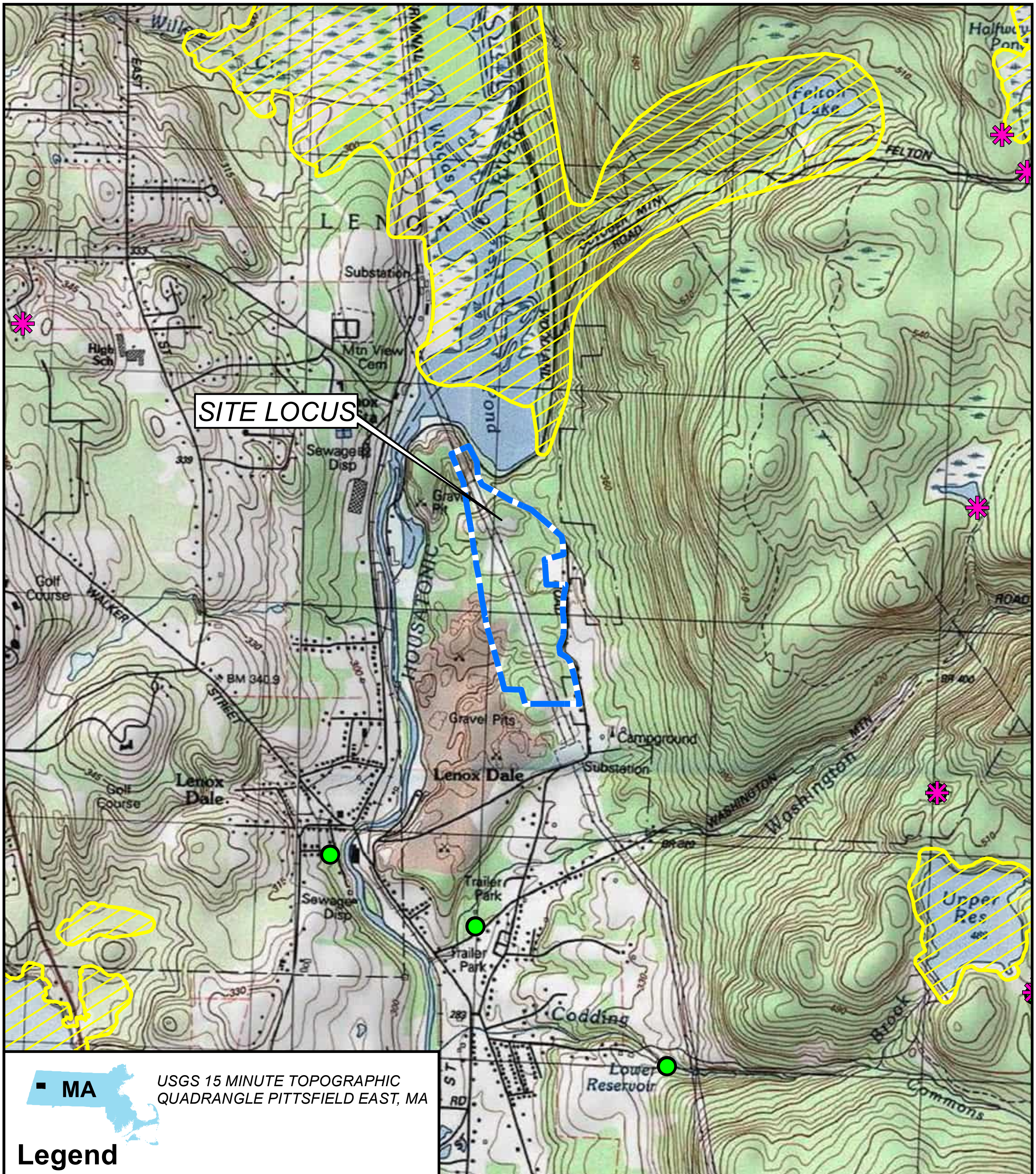
Upland Disposal Facility Site
Lee, Massachusetts

SCALE	DATE	PROJECT NO.
1:6,000	2/22/2024	04191406

AECOM

Figure Number

2



USGS 15 MINUTE TOPOGRAPHIC QUADRANGLE PITTSFIELD EAST, MA

MA

Legend

- NHESP Priority Habitats (2021)
- NHESP Certified Vernal Pools (9/15/23)
- NHESP Potential Vernal Pools

0 1,000 2,000 4,000 Feet

SITE LOCUS and NHESP PRIORITY HABITATS

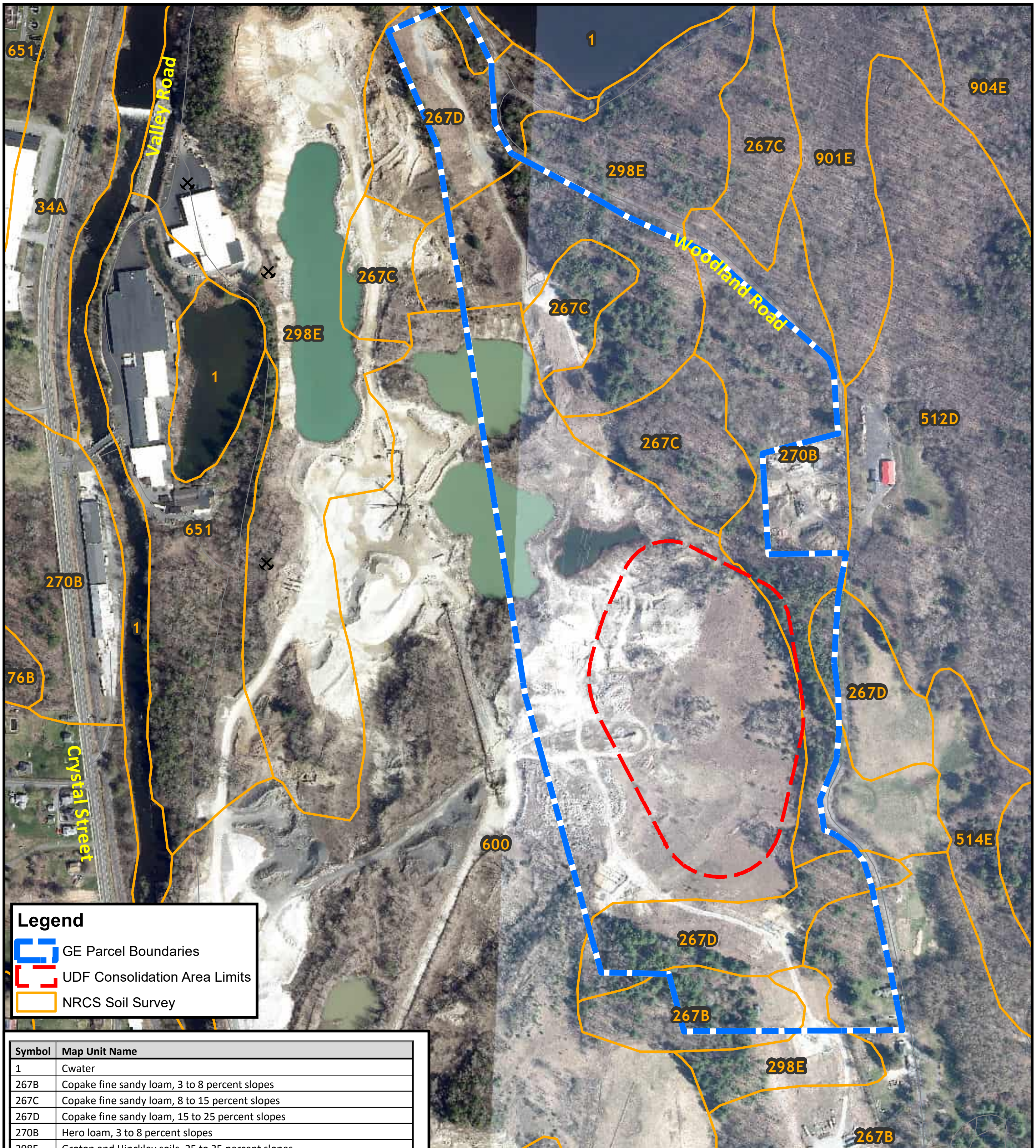
Upland Disposal Facility Site
Lee, Massachusetts

SCALE	DATE	PROJECT NO.
1:24,000	2/22/2024	04191406

AECOM

Figure Number

3



Symbol	Map Unit Name
1	Cwater
267B	Copake fine sandy loam, 3 to 8 percent slopes
267C	Copake fine sandy loam, 8 to 15 percent slopes
267D	Copake fine sandy loam, 15 to 25 percent slopes
270B	Hero loam, 3 to 8 percent slopes
298E	Groton and Hinckley soils, 25 to 35 percent slopes
34A	Fredon fine sandy loam, 0 to 3 percent slopes
500B	Amenia silt loam, 3 to 8 percent slopes
500C	Amenia silt loam, 8 to 15 percent slopes
511C	Pittsfield loam, 8 to 15 percent slopes, very stony
512D	Pittsfield loam, 15 to 25 percent slopes, extremely stony
514E	Pittsfield and Nellis loams, 25 to 35 percent slopes, extremely stony
600	Pits, gravel
651	Udorthents, smoothed
76B	Kendaia silt loam, 3 to 8 percent slopes
901E	Berkshire-Marlow association, 15 to 45 percent slopes, extremely stony
904E	Lyman-Tunbridge association, 15 to 60 percent slopes, extremely stony

2021 aerial photograph basemap, MassGIS

NRCS Soils

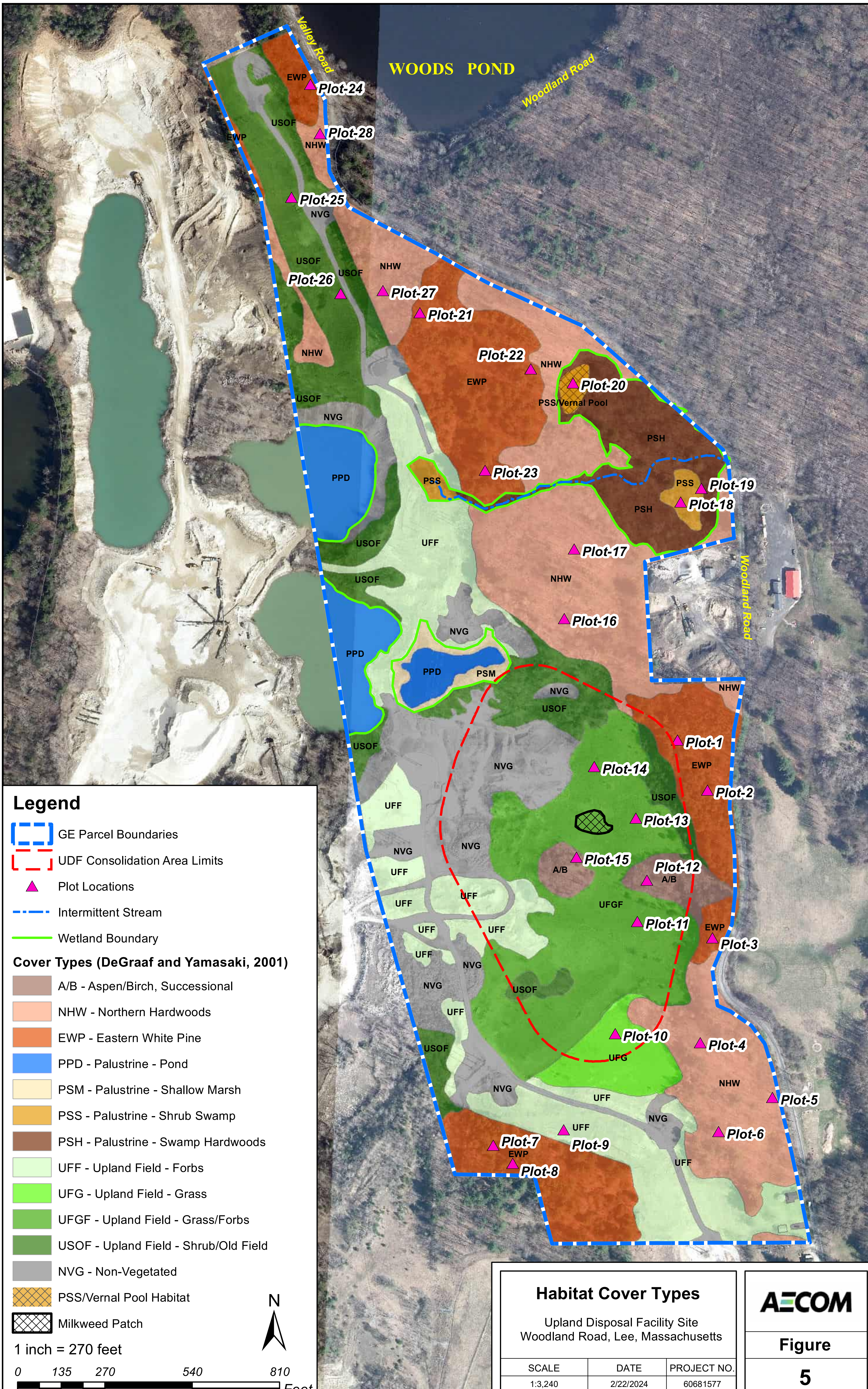
Upland Disposal Facility Site
Woodland Road, Lee, Massachusetts

SCALE	DATE	PROJECT NO.
1:6,000	2/22/2024	60681577

AECOM

Figure

4



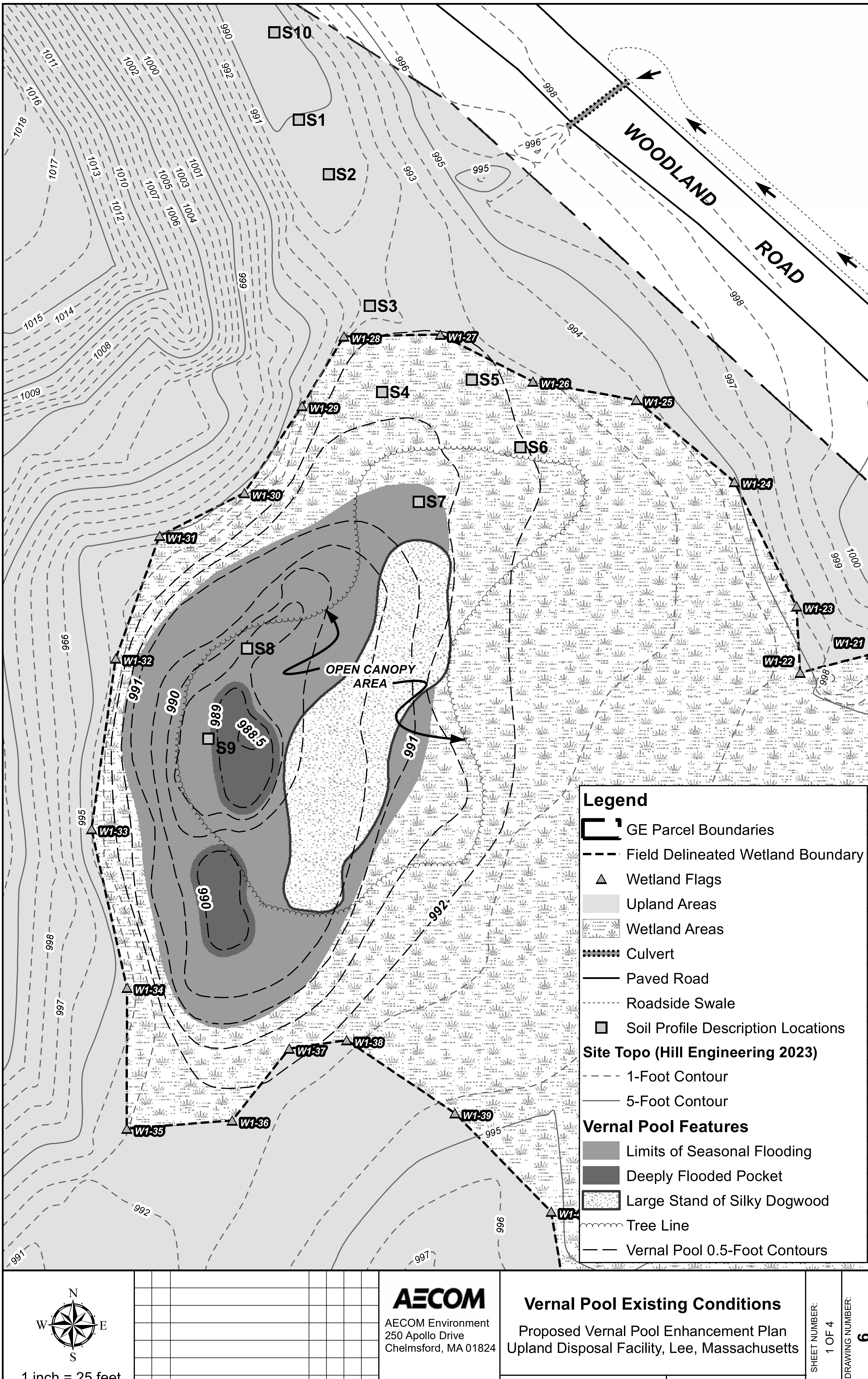
Habitat Cover Types

Upland Disposal Facility Site
Woodland Road, Lee, Massachusetts

SCALE	DATE	PROJECT NO.
1:3,240	2/22/2024	60681577

AECOM

Figure 5



N
W E
S

1 inch = 25 feet

NO.	DATE	REVISIONS	BY	CHK	APP	APP

AECOM

AECOM Environment
250 Apollo Drive
Chelmsford, MA 01824

Vernal Pool Existing Conditions

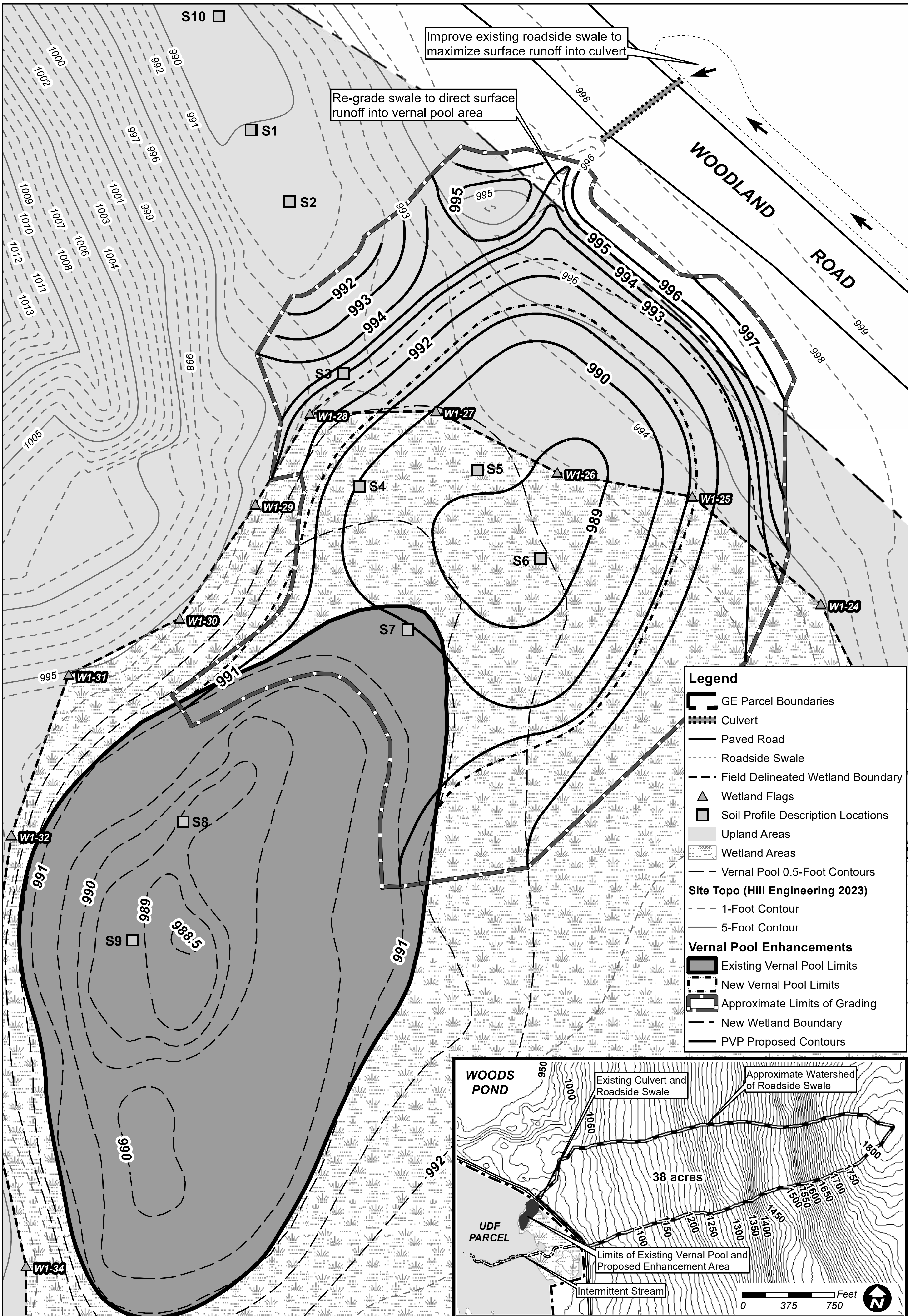
Proposed Vernal Pool Enhancement Plan
Upland Disposal Facility, Lee, Massachusetts

PROJ. NO.: 60605466

DATE: 2/2/2024

SHEET NUMBER: 1 OF 4

DRAWING NUMBER: 6



1 inch = 20 feet

NO.	DATE	REVISIONS	BY	CHK	APP	APP

AECOM

AECOM Environment
250 Apollo Drive
Chelmsford, MA 01824

Proposed Grading Plan

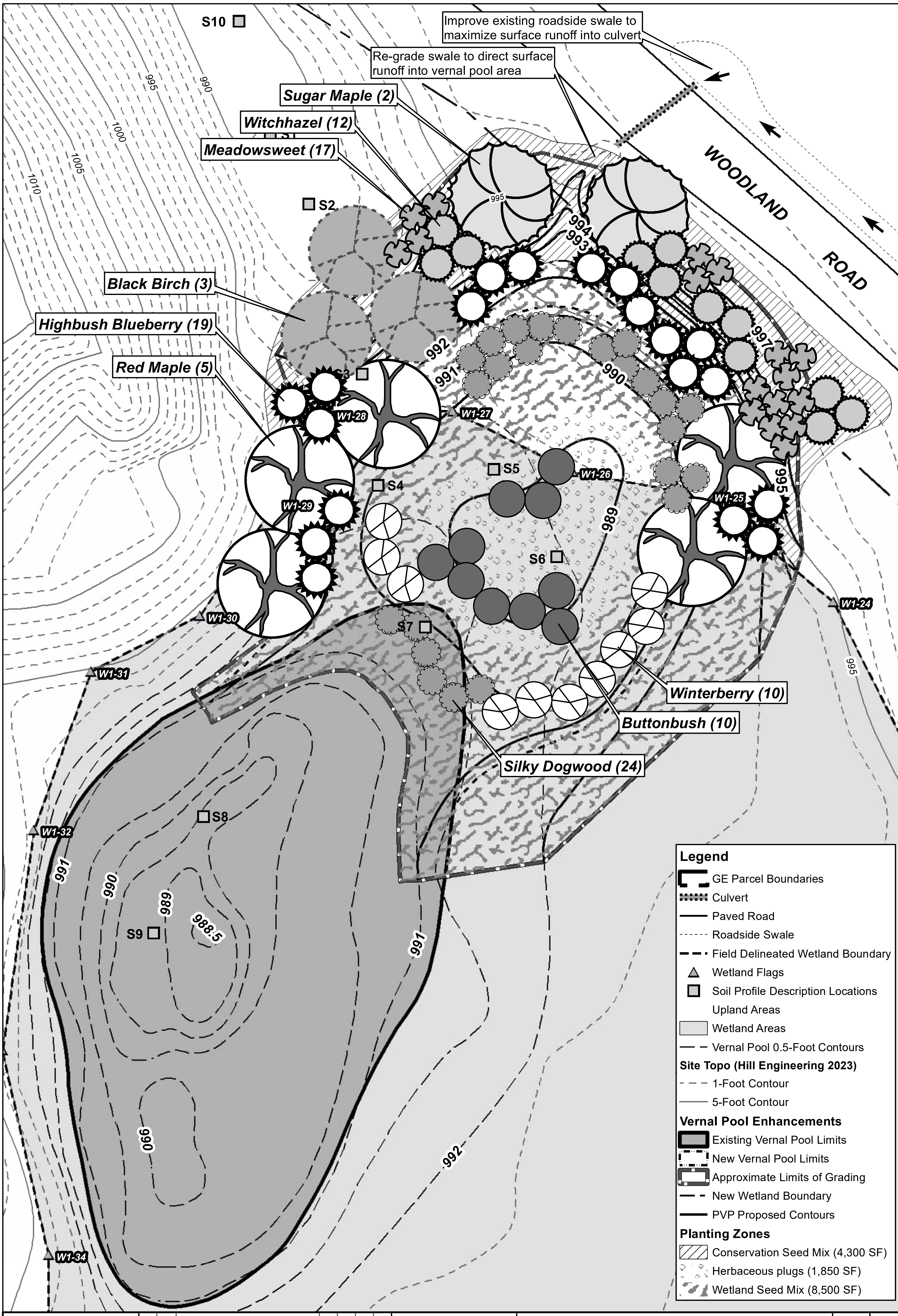
Proposed Vernal Pool Enhancement Plan
Upland Disposal Facility, Lee, Massachusetts

SHEET NUMBER: 2 OF 4

DRAWING NUMBER: 7

PROJ. NO.: 60605466

DATE: 1/31/2024



N W E S

1 inch = 20 feet

NO.	DATE	REVISIONS	BY	CHK	APP	APP

AECOM

AECOM Environment
250 Apollo Drive
Chelmsford, MA 01824

Proposed Planting Plan

Proposed Vernal Pool Enhancement Plan
Upland Disposal Facility, Lee, Massachusetts

PROJ. NO.: 60605466 DATE: 1/31/2024

SHEET NUMBER: 3 OF 4

DRAWING NUMBER: 8

Table 1. New England Wetland Plants "WetMix"

Botanical Name	Common Name	Indicator
Carex vulpinoidea	Fox Sedge	OBL
Carex scoparia	Blunt Broom Sedge	FACW
Carex lurida	Lurid Sedge	OBL
Carex lupulina	Hop Sedge	OBL
Poa palustris	Fowl Bluegrass	FACW
Bidens frondosa	Beggar Ticks	FACW
Scirpus atrovirens	Green Bulrush	OBL
Asclepias incarnata	Swamp Milkweed	OBL
Carex crinita	Fringed Sedge	OBL
Vernonia noveboracensis	New York Ironweed	FACW
Juncus effusus	Soft Rush	FACW
Symphyotrichum lateriflorum	Starved/Calico Aster	FACW
Iris versicolor	Blue Flag	OBL
Glyceria grandis	American Mannagrass	OBL
Mimulus ringens	Monkey Flower	OBL
Eutrochium maculatum	Spotted Joe Pye Weed	OBL

Table 2. New England Conservation/Wildlife Mix

Botanical Name	Common Name
Elymus virginicus	Virginia Wild Rye
Schizachyrium scoparium	*Little Bluestem*
Andropogon gerardii	*Big Bluestem*
Festuca rubra	Red Fescue
Panicum virgatum	Switch Grass
Chamaecrista fasciculata	Partridge Pea
Desmodium paniculatum	Panicledleaf Tick Trefoil
Sorghastrum nutans	Indian Grass
Verbena hastata	Blue Vervain
Asclepias tuberosa	Butterfly Milkweed
Rudbeckia hirta	Black Eyed Susan
Helenium autunale	Common Sneezeweed
Symphyotrichum pilosum	Heath Aster
Solidago juncea	Early Goldenrod
Agrostis perennans	Upland Bentgrass

Apply seed mix at the recommended rates:

1. New England WetMix at 1 pound per 2,500 square feet requires approximately 3 pounds of seed mix needed (8,500 SF / 2,500 SF = 3.0 pounds).
2. New England Conservation/Wildlife Mix at 1 pound per 1,750 square feet requires approximately 2 pounds of seed mix needed for side-slopes plus other areas (4,300 SF / 1,750 SF = 2.0 pounds)

Table 2. Proposed wetland shrubs and herbaceous vegetation.

Cover Type	Scientific Name	Common Name	Size	Quantity
Trees and Shrubs	*Cephalanthus occidentalis*	Buttonbush	3'-4'	10
	Cornus amomum	Silky dogwood	3'-4'	24
	Hamamelis virginiana	Witchhazel	3'-4'	12
	Ilex verticillata	Winterberry	3'-4'	10
	Spirea alba	Meadowsweet	2'-3'	17
	Vaccinium corymbosum	Highbush blueberry	3'-4'	19
	Acer rubrum	Red maple	4'-6'	5
	Acer saccharum	Sugar maple	4'-6'	2
	Betula lenta	Black birch	4'-6'	3
Herbaceous[1]	*Pontederia cordata*	Pickerel weed	2" Plug	25
	Sparganium eurycarpum	Broadfruit bur-reed	2" Plug	25
	Sagittaria latifolia	Broadleaf arrowhead	2" Plug	25

1. Quantity estimate based on 5-foot on center distribution.

WETLAND AND VERNAL POOL CREATION/PLANTING SPECIFICATIONS

1. ALL WORK WILL FOLLOW THE CONSTRUCTION SEQUENCE DEFINED ON THE APPROVED SITE PLANS. TOPSOIL PLACEMENT AND PLANTING WILL BE PERFORMED UNDER DIRECT SITE SUPERVISION BY A DESIGNATED WETLAND SCIENTIST. FOLLOW-UP MONITORING OF THE PLANTINGS PROPOSED IN THE PLANS WILL BE PERFORMED AS DESCRIBED IN THE UDF MITIGATION PLAN.
2. PRIOR TO THE START OF SITE WORK, ALL SEDIMENTATION AND EROSION CONTROL FENCING WILL BE INSTALLED BY THE CONTRACTOR AS DESCRIBED ON THE PLANS. AN ADEQUATE SUPPLY OF REPLACEMENT EROSION CONTROL MATERIALS WILL BE AVAILABLE ON SITE FOR EMERGENCY PURPOSES. EROSION CONTROL STRUCTURES WILL BE INSPECTED ON A REGULAR BASIS AND MAINTAINED IN GOOD ORDER UNTIL ALL EXPOSED SOILS ARE VEGETATED AND STABLE.
3. FOR EXCAVATIONS EXTENDING TO 1 FOOT BELOW EXISTING GROUND SURFACE THAT ARE ADJACENT TO MATURE TREES, THE CONTRACTOR SHALL PERFORM SUCH EXCAVATIONS BY HAND UNDER OVERSIGHT BY THE WETLAND SCIENTIST.
4. MATURE TREES WITHIN THE FOOTPRINT OF THE EXCAVATION WILL REMAIN IF FEASIBLE AND AT THE DISCRETION OF THE WETLAND SCIENTIST.
5. THE MITIGATION AREA SHALL BE OVER-EXCAVATED BY A DEPTH OF ONE FOOT. THREE INCHES OF A COMPACTED SILT LOAM OR FINER MATERIAL WILL BE PLACED OVER THE BOTTOM OF THE ENHANCEMENT AREA TO LIMIT DRAINAGE. THE REMAINING NINE INCHES WILL BE BROUGHT UP TO FINISH ELEVATIONS IN LOOSE LIFTS WITH SUITABLE SOILS AS SHOWN ON FIGURE 2. SOILS SHALL HAVE SUITABLE ORGANIC MATTER CONTENT (MINIMUM ORGANIC CARBON CONTENT OF 7% TO 12% [12% TO 20% ORGANIC MATTER] ON A DRY WEIGHT BASIS) AND GRAIN SIZE (SILT-LOAM TO LOAM TEXTURE).
6. THE PLANTING PLAN PROVIDED FOR THE VERNAL POOL ENHANCEMENT (FIGURE 4) SHALL NOT BE DEVIATED FROM WITHOUT THE APPROVAL OF THE DESIGNATED WETLAND SCIENTIST. IT IS RECOGNIZED THAT NOT ALL SPECIES MAY BE AVAILABLE AT THE TIME OF PLANTING AND SUBSTITUTIONS ARE ALLOWED WITH APPROVAL OF THE WETLAND SCIENTIST.
7. A WETLAND SEED MIX WILL BE BROADCAST AT THE APPROPRIATE RATES THROUGHOUT THE MITIGATION TO CREATE AN HERBACEOUS GROUNDCOVER LAYER. NEW ENGLAND WET MIX (NEW ENGLAND WETLAND PLANTS, AMHERST MA) IS RECOMMENDED BUT COMPARABLE ALTERNATIVE SOURCES MAY BE APPROVED BY THE WETLAND SCIENTIST.
8. AN UPLAND/CONSERVATION SEED MIX WILL BE BROADCAST AT THE APPROPRIATE RATES OVER ALL UPLAND AREAS DISTURBED BY THE PROJECT AND SIDE SLOPES OF THE MITIGATION AREA. NEW ENGLAND CONSERVATION/WILDLIFE MIX (NEW ENGLAND WETLAND PLANTS, AMHERST MA) IS RECOMMENDED BUT COMPARABLE ALTERNATIVE SOURCES MAY BE APPROVED BY THE WETLAND SCIENTIST.
9. SEED SHOULD ALWAYS BE PLACED ON BARE SOIL AND LIGHTLY RAKED OR ROLLED TO ENSURE PROPER SOIL-SEED CONTACT.
10. TREES, SHRUBS, AND HERBACEOUS PLANTS WILL BE SIZED AS SPECIFIED ON FIGURE 4. PLANT MATERIAL WILL BE INSPECTED WHEN PICKED UP AT THE NURSERY, AS WELL AS UPON DELIVERY TO THE SITE. THE PLANTING SEASON WILL BE IN THE SPRING FROM APRIL 1 THROUGH JUNE 30, AND FALL FROM AUGUST 15 THROUGH DECEMBER 15.
11. THE FOLLOWING PLANTING PROTOCOL WILL BE FOLLOWED: 1) THE PLANTING CONTRACTOR SHALL MAINTAIN THE ORIGINAL GRADE OF ROOT FLARE AFTER BEING TRANSPLANTED FROM THE NURSERY; 2) THE TREE/SHRUB PIT SHALL BE 3 TIMES THE SIZE OF THE ROOT BALL AND SHALL BE BACKFILLED WITH A PLANTING SOIL MIXTURE OF LOAM, COMPOST, AND PEAT MOSS; 3) NO FERTILIZER WILL BE USED IN THE WETLAND AREAS; 4) A TEMPORARY EARTH SAUCER WILL BE MADE; 5) PLANT MATERIAL WILL BE IMMEDIATELY WATERED.
12. A SUFFICIENT AMOUNT OF WOODY SHRUBS AND/OR SAPLINGS CUT FROM WITHIN THE MITIGATION AREA WILL BE SET ASIDE FOR PLACEMENT INTO THE POOL POST-RESTORATION TO FUNCTION AS TEMPORARY EGG ATTACHMENT SITES AND COVER FOR DEVELOPING AMPHIBIAN LARVAE. ANY COARSE WOODY DEBRIS (LOGS 4-5" IN DIA) FOUND ON OR ADJACENT TO THE SITE MAY BE DISTRIBUTED RANDOMLY THROUGHOUT THE MITIGATION AREA AT THE DISCRETION OF THE WETLAND SCIENTIST.
13. ADDITIONAL EROSION CONTROL MATTING SHALL BE PLACED ON DISTURBED AREAS AS NEEDED, OR AT THE DIRECTION OF THE WETLAND SCIENTIST.
14. FOLLOWING COMPLETION OF THE WORK EROSION CONTROLS, WHICH SURROUNDS THE WETLAND AND VERNAL POOL AREAS MUST BE REMOVED ONCE STABILIZATION HAS BEEN ACHIEVED.

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250 Apollo Drive
Chelmsford, MA 01824

Planting and Construction Notes

Proposed Vernal Pool Enhancement Plan
Upland Disposal Facility, Lee, Massachusetts

DATE: 1/30/2024

PROJ. NO.: 60605466

DRAWING NUMBER: 9

Attachments

Attachment A

Representative Photographs

PHOTOGRAPHIC LOG

Client Name: Housatonic River – Upland Disposal Facility	Site Location: Woodland Road Lee, Massachusetts	Project No. 60681577

Photo No. 1	Date: April 11, 2022	Photo No. 2	Date: April 11, 2022
VP-1 in April of 2022		Wood frog egg mass observed in VP-1 on 04/11/22.	

Photo No. 3		Photo No. 4	Date: May 19, 2022
Description: Wood frog tadpoles observed in VP-1 on 4/27/22 (left) and 5/19/22 (right).		Description: View south of VP-1	

AECOM	PHOTOGRAPHIC LOG	
Client Name: **Housatonic River – Upland Disposal Facility**	**Site Location:** Woodland Road Lee, Massachusetts	**Project No.** 60681577

Photo No. 5	**Date: July 6, 2022**	**Photo No. 6**	**Date: May 11, 2023**
Description: View south of VP-1		**Description: View north of VP-1.**	
			

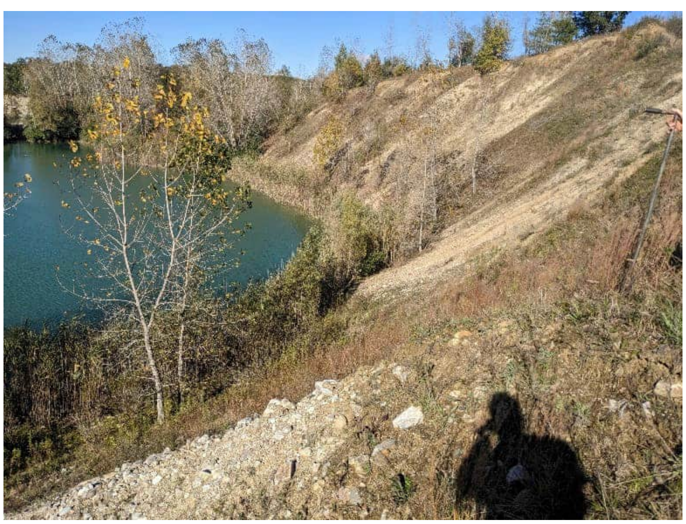
Photo No. 7	**Date: May 18, 2023**	**Photo No. 8**	**Date: May 24, 2023**
Description: View south of VP-1. Pool is dry and no tadpoles remain.		**Description: View south of VP-1. Pool has re-filled with water, but no tadpoles were found.**	
			

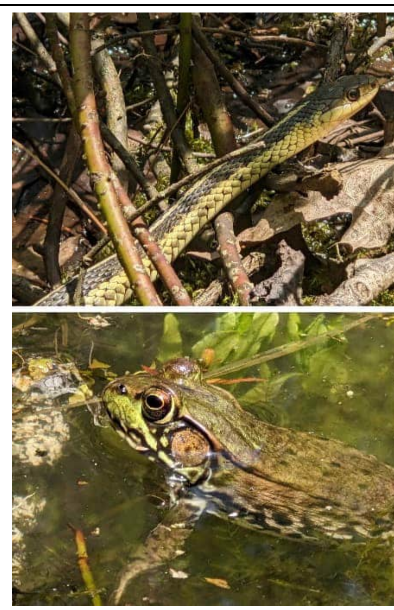
PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Housatonic River – Upland Disposal Facility	Woodland Road Lee, Massachusetts	60681577

Photo No. 5	Date: October 13, 2023	Photo No. 6	Date: November 30, 2023
Description: View south of VP-1		Description: View south of VP-1	

Photo No. 7	Date: October 13, 2023	Photo No. 8	Date: May 11, 2023
Description: Steep slopes along northwest gravel pit pond		Description: Other wildlife in VP-1, garter snake and adult green frog	





	PHOTOGRAPHIC LOG

Client Name: **Housatonic River – Upland Disposal Facility**	**Site Location:** Woodland Road Lee, Massachusetts	**Project No.** 60681577

Photo No. 9	**Date: June 29, 2023**	**Photo No. 10**	**Date: April 11, 2022**
Description: View southeast of gravel pit wash pond (southeast pond).		**Description: View south of gravel pit wash pond (northwest pond).**	
			

Photo No. 11	**Date: October, 2023**	**Photo No. 12**	**Date: July 6, 2022, 2022**
Description: View southeast, of gravel pit wash pond (southeast pond).		**Description: View north-northeast of both gravel pit ponds (southeast and southwest ponds) and the causeway between them**	
			

PHOTOGRAPHIC LOG

Client Name: **Housatonic River – Upland Disposal Facility**	**Site Location:** Woodland Road Lee, Massachusetts	**Project No.** 60681577

Photo No. 13	**Date: October 13, 2023**	**Photo No. 14**	**Date: October 13, 2023**
Description: View east of Intermittent stream upstream from access road crossing location.		**Description: View east of Intermittent stream at access road crossing location**	
			

Photo No. 15	**Date: October 13, 2023**	**Photo No. 16**	**Date: October 13, 2023**
Description: View west, looking downstream from access road crossing location		**Description: View east of intermittent stream at access road crossing location**	
			

Attachment B

Grassland Habitat Information

Attachment B: UDF Grassland Habitat **Information**

Introduction

As described in the Upland Disposal Facility (UDF) Final Design Plan, it is anticipated that, consistent with GE's recent discussions with officials from the Town of Lee, the long-term post-closure surface of the UDF consolidation area, along with the side slopes, perimeter berm, and other disturbed areas within the operational area, will be converted to a grassed cover with the addition of plant pollinator species. The resulting grassed cover area is anticipated to encompass roughly 30 acres of the UDF area. While the primary function of the grassed cover is to provide a stable surface of the consolidation area and surrounding slopes, it is recognized that the resulting open grassland habitat will provide significant wildlife habitat. Over the past several decades, numerous agencies and conservation groups have increasingly recognized grassland habitat values, and have expended considerable effort on initiatives to document this important habitat value and to preserve, create, enhance, and manage grassland habitat. This document is intended to summarize some of these efforts, particularly in Massachusetts, and to describe the factors involved in determining grassland habitat values to provide a foundation for the post-closure grassland habitat conditions at the UDF area. In addition, based on input from the Town of Lee, providing pollinator plant species within the grassland habitat will be conducted to further enhance the habitat functions provided by the completed UDF cover by making it attractive to pollinators.

Grassland/open field habitats have been in declining abundance in Massachusetts for more than the past 50 years, and this decline has generated concern for a number of species that are dependent upon these habitats. While several of these are state-listed species (e.g., grasshopper sparrow and upland sandpiper), the concern extends to many other species that are not state-listed, such as field sparrow, American kestrel, savannah sparrow, and eastern meadowlark. These species, many of which were once common in Massachusetts, are becoming increasingly uncommon and have been focal species in the State Wildlife Action Plan (SWAP) (MADFW 2015), in MassAudubon's State of the Birds Reports (MassAudubon 2013; Walsh and Servison 2017), and in current multi-organizational initiatives (Grassland Bird Conservation | Mass.gov). Establishment, preservation, and maintenance of such habitat have therefore become a priority for many conservation agencies and organizations. While sites for such conservation purposes are ideally greater than 100 acres in size, grasslands/open field habitats in the range of 25 to 100 acres provide suitable conditions for many field-dependent species, as well as providing attractive complementary habitat for a wide range of other species that are drawn to the fields for food, nesting, resting and other life-cycle needs. In addition to the birds that are drawn to the fields for breeding, these open fields support a wide range of invertebrate life such as beetles, moths, and butterflies, as well as numerous species of small mammals. These in turn attract predators such as bats, hawks, owls, fox, mustelids (e.g., weasel family), and grazers such as deer. Table B-1 provides a listing of wildlife species with habitat requirements compatible with the potential final cover conditions at the UDF area (species listed by Woodlot (2002) as potentially occurring in cultural grasslands or agricultural fields of the Reach 5-6 area of the Rest of River during some life cycle phases).[1]. Table B-2 provides a list of "species of greatest conservation need in grassland," as presented in the 2015 Massachusetts SWAP; this list includes pollinator species.

"Grassland habitat" does not refer to a monotypic condition of a grassed field. There are numerous factors that affect the wildlife utilization of a given grassland area: size of the field, juxtaposition with other habitats, plant species composition, management (particularly the mowing regime), and other land uses on and near to the site are some of the factors. Further, in some cases, the habitat uses may evolve as the site evolves, both in terms of characteristics such as plant species composition and in consideration of site management both for habitat and other uses. For example, in the case of the UDF area, as noted above, a primary function of the grassed cover is to provide a stable surface on the consolidation area

[1] The list includes 16 species of reptiles/amphibians, 96 species of birds, and 37 species of mammals.

and surrounding side slopes and other disturbed areas. This may warrant a particular planting and management regime early on to develop the needed stable cover for the UDF closure, and these may change over time following the establishment of that primary function. A primary management factor to be considered is the mowing regime (timing, frequency, and height of mowing). Given the priority of the initial surface stabilization to prevent erosion of the cover, the mowing regime during the grow-in period must be established with that objective prioritized. However, on a longer-term basis (once the surface is effectively stabilized), a mowing regime may be considered with more focus on habitat conditions as presented by the opportunity of establishing grassland habitat at the UDF, including pollinator plant species for habitat enhancement, consistent with the recent discussions with Town of Lee officials.[2]

The following sections summarize these types of considerations from several key Massachusetts grassland habitat initiatives, all of which collectively demonstrate the importance of grassland habitat and support the long-term use of the UDF area for grassland habitat. The initiatives include the following:

- The Trustees of Reservations (2009): *Ecological Management of Grasslands: Guidelines for Managers*; https://thetrustees.org/wp-content/uploads/2020/07/Grassland-Guidelines-2009.pdf;
- Mass Audubon (2013): *Massachusetts State of the Birds*; www.massaudubon.org/StateoftheBirds;
- Massachusetts Division of Fisheries and Wildlife (MassDFW, 2015): *Massachusetts 2015 State Wildlife Action Plan (SWAP)*; www.Mass.gov/info-details/state-wildlife-action-plan-swap;
- Mass Audubon (2017): *Best Management Practices for Nesting Grassland Birds.* https://www.massaudubon.org/content/download/19413/file/Best-Management-Practices_Grasslands_2017_web.pdf; and
- Massachusetts Natural Heritage and Endangered Species Program (MNHESP), Massachusetts Division of Fisheries and Wildlife (MassDFW), the Trustees of Reservations, The Nature Conservancy, and Mass Audubon (2013), *An Action Plan for the Conservation of State-Listed Obligate Grassland Birds of Massachusetts*; https://www.mass.gov/doc/an-action-plan-for-the-conservation-of-state-listed-obligate-grassland-birds-in-massachusetts/download.

Background

Grassland birds have undergone alarming rates of increased and widespread population declines between 1966 and 2010, and are reported to be in greater decline than any other bird group of North America (Sauer et al. 2011). Changes in grassland habitat have adversely impacted the success of grassland birds as a result of competing uses for these grassland areas, natural succession of grassland to forest, and changes in agricultural practices. With management of grassland areas and adjustments to agricultural production, grassland habitat may be increased and maintained for the beneficial success of grassland birds, restoring their presence in the Massachusetts landscape.

Historically, it is thought that the barren land left by the retreating of ice following the last glacial period (Wisconsin Ice Sheet, 10,000 years ago) was originally colonized with wind dispersed grasses and forbs, forming abundant grassland habitat. It is likely that a contiguous grassland from the Great Plains to the New England coast ultimately formed (MNHESP et al. 2013). Grassland birds (and wildlife) would have thrived in the region and are since then thought to exist in remaining pockets (Vickory and Dunwiddie 1997). "Support for the concept of a long-term grassland presence in New England is found in the evolution of northeastern endemic grassland dependent birds such as the eastern subspecies of the

[2] Specifications for plant seeding details for the grassland cover (e.g., composition of both grass and pollinator species seed mixes), grow-in procedures, and initial mowing regimes will be provided in the Final Cover/Closure Plan for the UDF. Long-term mowing, monitoring, and other maintenance will be described in the UDF Post-Closure Monitoring and Maintenance Plan. Long-term management of the grassland established at the closed UDF will consider, to the extent practicable, many of the issues raised in the reports summarized herein.

Henslow's Sparrow (*Ammodramus henslowii susurrans*) and Savannah Sparrow (*Passerculus sandwichensis savanna"* (MNHESP et al. 2013).

Prior to European settlement in Massachusetts, grassland habitats were primarily found on river floodplains, adjacent to wetlands that were flooded by beaver periodically, and freshwater tidal zones along coastal rivers and upstream of the salt tide range from wind and spray (MNHESP et al. 2013, Mass Audubon 2013). The observed presence of expansive open areas were recorded by early explorers (Vickeroy and Dunwiddie 1997), many of which were created and maintained by Native Americans for agriculture and hunting, along with wet grasslands created by beaver impact (Askins 1993). Native American settlement movements and practice of burning woodlands and shrublands to ease travelling and hunting also created open grassy habitats throughout the state. The practice of burning improved wildlife habitat and hunting for Native Americans, as for example, lowbush blueberries would rapidly grow with abundant berries to attract a diversity of mammals and birds.

European settlement dramatically changed the dominantly forested landscape of Massachusetts (and Northeast) in the early 1600's, with extensive clearing of fields for agriculture and the introduction of grasses from the prairies of the Midwest to a dramatic decrease of less than 40% forest by the mid-1800s (Mass Audubon 2013). Grassland habitat, including grazed pastures, hay fields ,and crop fields increased briefly to an 80% clearing for agricultural fields in the late 18^{th} and early 19^{th} centuries in Massachusetts, but then declined, leaving over 60% dominant forest habitat with remnant pockets of grassland habitat mostly along sandy coastal plain and river valleys (MNHESP et al. 2013). Since the early 1900s, most historical agricultural lands became reforested as grassland habitats succumbed to the development of coastal and agricultural lands, natural succession, and the reduction of early successional habitats created through disturbance (MNHESP et al. 2013). The comparatively small-scale agriculture status currently in Massachusetts continues to decline, and the relatively rare agricultural grasslands threaten many native species dependent on wide open early successional habitats, particularly in the more urban and suburban eastern part of the state (MNHESP et al. 2013).

Dominant forest habitat may be thought a more natural state and a conservation success with thriving forest dwelling species. However, the ongoing decline of remaining grassland pockets are reminders of the once abundant grassland habitat and associated species success, highlighting the critical need for management of remaining and potential grassland habitat as a conservation priority. As noted above, one of the fastest declining group of birds in North America throughout their range are the grassland birds (Askins 1993).

Although grasslands may be thought rare in Massachusetts history and, therefore, the decline of grassland species unimportant, the realization of overall ongoing declines of grassland bird species occurring and the "documented habitat loss in the historic core of their breeding range" (Mass Audubon 2013) creating the declining presence of grassland birds in the "core of the their range (Great Plains and Midwest)" calls for the greater need for grassland habitat management and conservation in the Northeast (MNHESP et al. 2013). Specifically, more than 97% of the native grasslands of the United States have been lost, mostly because of conversion to high-intensity agriculture in the West. That is one of the reasons that grassland birds as a group have declined more than any other group (Mass Audubon 2013).

Grassland birds, particularly the state-listed grassland species, have limited grassland habitat sites in Massachusetts, which include cultural grasslands on airports, landfills, and military installations involving land use pressures and grassland habitat conflicts. Recently, additional pressure for installing solar panels on these open sites will adversely reduce the grassland habitat available to grassland species (MNHESP 2013).

The Trustees of Reservations, 2009. *Ecological Management of Grasslands: Guidelines for Managers*[3]

To address the adverse ecological impact with loss of grasslands that not only affects Massachusetts, but also range-wide for bird and butterfly species, the Trustees of Reservations (Trustees) have presented guidelines for the ecological management of grasslands. A rapid loss of farmland in Massachusetts since the mid-1800s to "non-farm" use has created consequential declines in grassland habitat and the grassland species dependent on them, with many species now listed as "rare" and protected under the Massachusetts Endangered Species Act (MESA) and some no longer found in their once inhabited range (extirpated), such as the loggerhead shrike and regal fritillary butterfly.

The Trustees of Reservations propose grassland management guidelines for conserving, enhancing, and maintaining the cultural, scenic, and ecological values of the grassland habitats on active agricultural land and other open grasslands under their management throughout Massachusetts. The distinct grassland types under the Trustees' consideration include: agricultural fields such as hay fields which are cut at least once annually for hay, pastures grazed by livestock, and actively cultivated fields for row crops; non-agricultural grasslands that include fields maintained by mowing and old fields that are undergoing succession to forest; and the open sandplain grasslands and heathlands found on glacial outwash, primarily on Cape Cod and Islands. The Trustees propose the development of a grassland management plan or program that will primarily promote and protect the ecological values of the grassland, while working to also preserve its cultural, scenic, and historical values.

Grassland management practices including haying, grazing, mowing, and burning along with the soil conditions, climate and area of a grassland support a defined/specific plant and animal community. "No one type of grassland management will meet the needs of all grassland species" (Trustees of Reservations 2009), as illustrated, for example, by the upland sandpiper, which requires spotty, short grasses on large grassland tracts as on airports and pastures, compared to the small grassland areas with tall grasses as hay fields that support bobolinks.

Mass Audubon, 2013: *Massachusetts State of the Birds 2013.*[4] Massachusetts Breeding Birds: A Closer Look. Mass Audubon Bird Conservation Program.

The Massachusetts Audubon Society (Mass Audubon) produced the *State of the Birds (2011): Documenting Changes in Massachusetts' Birdlife* (Mass Audubon 2011a), which was a study of the status of birds found regularly in Massachusetts to more clearly define the threats contributing to significantly declining species, and further to suggest conservation actions to counter their decline. This resource, in conjunction with the *Massachusetts Breeding Bird Atlas 2 (2011)* (Mass Audubon 2011b) to help identify critically declining species, were used with further research and focus on the species' breeding ecology. This resulted in the use of "the best scientific knowledge to develop an evidence-based conservation strategy for all the breeding species in Massachusetts," which was subsequently presented in the *State of the Birds, Massachusetts Breeding Birds: A Closer Look* (Mass Audubon 2013). In this publication, focal species in decline were chosen and the conservation challenges of their focal breeding habitat were considered for recovery and management planning. It is noted that this process may present potential conflicts between management options that compete for outcomes in habitats (Mass Audubon 2013).

This report documents that there has been an apparent decline in breeding grassland and shrubland birds in Massachusetts with the decline in agricultural land since the early 1900s, particularly the eastern meadowlark, American kestrel, and savannah sparrow. Mass Audubon (2013) provides a list of other additional declining grassland bird species due to loss of agricultural land and associated barns, including

[3] https://thetrustees.org/wp-content/uploads/2020/07/Grassland-Guidelines-2009.pdf

[4] www.massaudubon.org/StateoftheBirds

the short-eared owl, northern bobwhite, vesper sparrow, barn owl, cliff swallow, upland sandpiper, horned lark, bank swallow, grasshopper sparrow, song sparrow, barn swallow, red-winged blackbird, and eastern kingbird. Initially, this was due to succession to forest; however, more recently, the conversion to forest has not increased even though agricultural lands and grasslands continue to dwindle. "Today, the loss of our fields and shrublands appears to be driven more by human development than by succession—a factor that has taken its toll on our forests as well" (Mass Audubon 2013).

Mass Audubon (2013) lists ten defined habitats of breeding species that are declining and provides a case study of a species chosen to represent seven of the habitats. Two species are chosen to be representative of the grassland, agricultural land, and open fields habitat: the eastern meadowlark and the cliff swallow. The case studies of these species are summarized in Exhibit B-1, as both of these species could benefit from the addition of grassland habitat at the UDF area.

Massachusetts Division of Fisheries and Wildlife, 2015: *Massachusetts 2015 State Wildlife Action Plan (SWAP)*.[5]

In this 2015 update of the Massachusetts State Wildlife Action Plan (SWAP), Mass DFW presented the 570 Species of Greatest Conservation Need (SGCN) in Massachusetts, the 24 types of habitats and their descriptions that support these species and related threats, and the recommended conservation actions necessary to maintain and protect them (Mass DFW 2015). The 24 SWAP habitats are divided into three categories representative of their relative sizes by acreage across the state: large-scale, medium-scale, and small scale. Grasslands are categorized as medium-scale with 71 Species of Greatest Conservation Need. The 24 SWAP habitats generally do not correspond to specific natural communities, but are categorized more broadly to include and describe the species' life history based on their essential requirements.

As noted in the SWAP, grasslands in Massachusetts are dependent on disturbance to maintain grassland habitat and prevent the natural course of a dominant woody vegetation habitat. Disturbances are typically caused by human actions but also include natural disturbances. At the historical peak of agriculture, agricultural fields were abundant, but pastures, hay fields, crop fields and other agricultural grasslands are now relatively rare in Massachusetts, with loss of the disturbance by active farming and the growth to forest, particularly in the eastern more urban and suburban half of the state.

As noted, the grasslands habitat supports 71 species that are listed as SGCN. Seven species of state-listed and SCGN birds in Massachusetts are highly dependent on grassland habitat for nesting, for overwintering, or during migration. Most of the nesting sites for these species are near the coast. However, the upland sandpiper, vesper sparrow, and grasshopper sparrow are also found in scattered inland locations, mostly grasslands at airports (e.g., Westover Air Reserve Base). Five other SGCN birds that are uncommon and declining in the state are also associated with grassland habitats; these are the eastern meadowlark, eastern whip-poor-will, northern bobwhite, American kestrel, and American woodcock.

Despite the significant decline, there is an array of persisting grasslands in Massachusetts that may overlap or blend into other habitats designated by the SWAP which are maintained through natural or anthropogenic disturbances. Grasslands may be best classified by describing them based on characteristics such as edaphic characteristics as wet or dry, the disturbance history as natural or anthropogenic, and the species composition as predominantly warm-season or cool-season, and/or predominantly native or introduced species. Common combinations of these characteristics describe certain grassland habitats in Massachusetts, such as abandoned agricultural land, active agricultural

[5] www.Mass.gov/info-details/state-wildlife-action-plan-swap

land, airports and military, dry native grasslands, and savannas. The conditions more applicable to the UDF area may be summarized as follows:

- **Active agricultural land** are pastures, hay fields, and crop fields typically found on mesic soils planted with introduced, cool-season grasses. Grazing livestock and harvesting of hay or other mechanical cutting maintain these grasslands; however, active agricultural use restricts grassland habitat and wildlife values.
- **Abandoned agricultural land** consists of inactive pastures, hay fields, and crop fields, which provide transitory grassland habitat. Pastures and crop fields are typically found on mesic soils, and when abandoned, introduced, cool-season grasses grow and become dominant creating a habitat suitable to more common and widespread species of wildlife that include important game animals. Without management, increasing overgrowth of the abandoned agricultural grasslands occurs, causing loss of suitable grassland habitat for grassland species.

Mass Audubon, 2017: *Best Management Practices for Nesting Grassland Birds.*[6]

Mass Audubon has developed a guide for "Best Management Practices for Nesting Grassland Birds," presenting its recommendations to support and enhance grassland habitat for grassland birds, with conservation efforts focused on five species that are designated "Species of Conservation Concern" in the Massachusetts SWAP: the upland sandpiper, vesper sparrow, grasshopper sparrow, bobolink, and eastern meadowlark. Although these species have historically been more abundant in the Midwest, Mass Audubon emphasizes the vital importance and contribution of Northeast populations to the success of populations region-wide. With grassland species in decline nationwide, there is a need for range-wide conservation efforts to promote populations. In these conservation efforts, Mass Audubon further points out the unique importance of grassland species at the edge of their range, as Massachusetts, to achieve a maximum genetic diversity for optimal resilience and sustainability of grassland species.

This document includes a case study for Canoe Meadows in Pittsfield. In 2016, Mass Audubon utilized best management practices to create maximum grassland habitat of fields at the Canoe Meadows Wildlife Sanctuary. Although fields of 10 acres or more are considered the minimum to support any grassland birds, larger fields of 20 or more acres can successfully accommodate more breeding pairs, and the larger the area the more. Three fields, comprising 34 acres, 11 acres, and 10 acres, were recognized by Mass Audubon to have the potential to offer "prime grassland habitat" for grassland bird species by removing three acres of pines and a three-acre tract of invasive shrubs to create one large, widely open field of about 70 acres that "should prove very attractive to grassland birds" (Mass Audubon 2017).

Massachusetts Natural Heritage Endangered Species Program, Massachusetts Division of Fisheries and Wildlife, Mass Audubon, the Trustees of Reservations, and The Nature Conservancy, 2013. *An Action Plan for the Conservation of State-Listed Obligate Grassland Birds of Massachusetts.*[7]

Developing conservation plans is a key strategy for protecting populations of grassland birds. One such plan was finalized and approved in 2013 by the Massachusetts Fisheries & Wildlife Board. This plan was developed by MNHESP and MassDFW in collaboration with the Trustees of Reservations, The Nature Conservancy, and the Massachusetts Audubon Society. Their report presents a state-wide action plan

[6] https://www.massaudubon.org/content/download/19413/file/Best-Management-Practices_Grasslands_2017_web.pdf

[7] https://www.mass.gov/doc/an-action-plan-for-the-conservation-of-state-listed-obligate-grassland-birds-in-massachusetts/download. Accessed on-line February 2024.

which identifies specific targeted conservation goals for state-listed grassland birds (MNHESP et al. 2013).

The purpose of the report is to present a state-wide action plan for two grassland-obligate bird species listed pursuant to MESA: upland sandpiper (*Bartramia longicauda*) and grasshopper sparrow (*Ammodramus savannarum*). The MESA-listed vesper sparrow (*Pooecetes gramineus*) is included in this plan to a lesser degree, but is in need of its own specific action plan. The report states: "The intention of this plan is to pool the knowledge, resources and management ability of grassland stakeholders in the Commonwealth to initially assess and prioritize conservation needs of these species in the State, and then use these resources to effectively realize specific targeted conservation goals. Although the initial focus of this report is on three MESA-listed species, the greater goal is to eventually develop plans for all grassland-obligate bird species in the State." The report also makes the points discussed in the remainder of this section.

The population of grasslands birds is declining at a faster rate than any other group of birds in Massachusetts and in North America. In Massachusetts, grassland birds in general and state-listed species in particular have been increasingly confined to a small number of sites, many of which are airports, landfills, and military installations. Recently, a push for solar panel ground installations is putting pressure on grassland bird habitat at a variety of sites including landfills and airfields which can adversely impact grassland bird habitat at these sites. Conserving adequate habitat will benefit the entire suite of grassland birds, as well as other grassland-dependent plants and animals, many of which are also listed pursuant to MESA.

Nearly the entire suite of grassland birds is undergoing range-wide population declines, and this is especially noticeable in Massachusetts. According to the North American Breeding Bird Survey (United States Geological Survey), annual declines for species in this group are 9.6% for eastern meadowlark (*Sturnella magna*), 6.2% for American kestrel (*Falco sparverius*), 4.9% for field sparrow (*Spizella pusilla*), and 3.1% for savannah sparrow (*Passerculus sandwichensis*) in Massachusetts between 1966 and 2010 (Sauer et al. 2011). These species, once common in Massachusetts, are becoming increasingly uncommon and have become focal species in the State Wildlife Action Plan (SWAP) and Mass Audubon's State of the Birds Report. Reasons for declines of these species are likely multifaceted, but habitat loss certainly plays a role.

While it is often argued that return to forest reflects a more natural state, this argument overlooks the fact that open, early successional habitats have been an important part of the Massachusetts landscape since the retreat of the Wisconsin Ice Sheet. The development of coastal and agricultural lands, natural succession, and the reduction of early successional habitats created through disturbance has resulted in a greatly reduced amount of early successional habitats in Massachusetts.

As many native species associated with open habitats continue to decline, their viability in the region has become tenuous and is now generally recognized by conservation organizations that managing grassland and shrubland habitat in Massachusetts is a conservation priority to maintain the Commonwealth's full biodiversity. Given the ongoing declines of grassland birds in the core of their range (Great Plains and Midwest), managing for these species in the Northeast has increased in importance.

The three species targeted in this report are obligate grassland species with a similar breeding range that extends from Alberta to the northeastern Atlantic Coast. The core of their ranges lies in the Great Plains with sporadic occurrences throughout the majority of their broad breeding distribution. All three species have experienced long term population declines throughout the majority of their range, especially in eastern North America.

In general, declines of grassland birds in New England are attributed to agricultural intensification and forest regeneration following farm abandonment (Askins 1993). Upland sandpiper and grasshopper sparrow populations are considered to be area-sensitive, meaning that they are only found nesting in large patches of suitable habitat. Upland sandpipers are rarely found in grassland patches smaller than 125 acres, and grasslands of this size only support small numbers of grasshopper sparrows (Vickery et al. 1997, unpublished data from Massachusetts in MNHESP files).

Although this plan doesn't address all grassland birds, the large grasslands being targeted for the conservation of upland sandpipers and grasshopper sparrows will benefit the entire suite of grassland birds (e.g., eastern meadowlark, bobolink) as well as species of concern in other taxonomic groups (e.g., reptiles, invertebrates, plants). Additionally, there are other grasslands in Massachusetts that support important populations of non-listed grassland birds including agricultural lands, landfills, utility rights-of-way, and airfields. According to the report, more than ten specific sites in western Massachusetts have been reported as consisting of potential grassland habitat, including a gravel pit in Pittsfield and a landfill in Amherst. The report recognizes the need to directly address the conservation of all grassland birds by developing best management practices for grassland habitats throughout the Commonwealth.

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Exhibit B-1:

Case Studies of Two Grassland Bird Species from Mass Audubon (2013)

Case Study: Eastern Meadowlark (*Sturnella magna*)

Status: Local and strongly declining; conservation action urgent; State Wildlife Action Plan listed

Although known to nest in various grassland habitats, eastern meadowlarks prefer moderately tall grass open fields intermixed with an abundant herbaceous undergrowth of forbs (non-grass herbs) and thick ground cover of dead grasses and other plant litter attractive for nesting materials. Eastern meadowlarks construct their nests from surrounding vegetation in a depression on the ground, concealed among thick grasses. In addition, the dense grass and forb habitat aptly conceals the meadowlark as it forages on the ground for its diet mainly of large insects, mostly crickets and grasshoppers, as well as seeds.

The once commonly seen eastern meadowlark sitting on a fencepost overlooking a grassy field cheerily singing has become increasingly rare in Massachusetts with the loss of agricultural habitat from succession and urban development, loss of quality habitat due to agricultural intensification practices, and loss of grasslands by encroaching field edge growth. Through farming intensification practices, a modern high-quality hay field will have the thick herbaceous growth removed. Haying and mowing, or high livestock grazing intensity and trampling cause egg, chick, and adult mortality during the breeding season. Predation by prowling domestic cats has also been shown to kill up to 3.7 billion birds annually in the U.S. Also, the use of chemicals that are generally toxic to birds and people, or the newer chemicals with specific toxicity to the plant eaters such as the crickets and grasshoppers in a meadowlark's diet, or toxicity to plants through direct chemical application to the seeds of the meadowlark diet, contribute to their decline.

Management for suitable grassland habitat through habitat restoration and preservation is critical to reverse the decline of the eastern meadowlark. No comprehensive national plans exist for eastern meadowlarks, though the USGS Northern Prairie Wildlife Research Center has issued a report titled 'Effects of management practices on grassland birds: Eastern meadowlark' (Hull et al. 2019). Grasslands require continual management, or disturbance in succession, to prevent woody vegetation growth and maintenance of a grassland with diverse vegetation. When used with careful attention, and absence during the breeding season, mowing, haying, grazing and/or burning are successful management methods. A rotational schedule is recommended with management practices of mowing and haying outside of the breeding season, and grazing at a low-moderate intensity. Although not annually, incomplete burning is also recommended on a schedule of every 3-5 years. Posts may also be strategically placed to avoid mowing paths to attract the eastern meadowlark to a grassland field habitat.

Case Study: Cliff Swallow (*Petrochelidon pyrrhonota*)

Status: Local and strongly declining; conservation action urgent

Historically, cliff swallows built their mud nests in colonies on cliff faces in the western mountain ranges of North America. Although the "inferior Northeast geology" could not compete for the attraction of the cliff swallow, the cliff swallow began to spread east when European settlement progressed west, offering the convenient widespread shelter of artificial location nesting sites, more specifically where a vertical wall and horizontal covering could now be found in the underside of bridges, eaves of buildings, and sides of barns (Mass Audubon 2013). The cliff swallow was common in the western half of Massachusetts by 1839, and still spreading eastward. By 1850, cliff swallows were locally abundant continent-wide and familiar residents of village and farmstead (Mass Audubon 2013). However, the house sparrow was introduced that year, more than 100 times, to combat tree-eating moths. House sparrows are very aggressive and take over other birds' nests for their own use, including the cliff swallow. House sparrows destroy the eggs of 12-15 cliff swallow colony nests before selecting the nest they want. Studies have also shown much reduced nesting success of cliff swallows from cohabitation with house sparrows due to their aggressive defense of territory surrounding their own nest. The cliff swallow was devastated by the house sparrow and by 1955 cliff swallows had become rare and local in most localities, according to Griscom and Snyder's *The Birds of Massachusetts* (1955). In Massachusetts, they continued to decline as recorded in the 1979 Atlas 1 (with 144 blocks) compared to the 2011 Atlas 2 (with only 69 blocks), illustrating a surprising less than half of the breeding remaining with absence east of the Worcester Plateau and the southeastern parts of the state, except on the Elizabeth chains. Cliff swallows show a significant decreasing Breeding Bird Survey trend in Massachusetts from 1967-2009 (Mass Audubon 2013).

The jug shaped nests of cliff swallows in Massachusetts are mostly found on buildings near open to semi-open grassy areas with a nearby water body to provide the grass and mud to build their nests, and an abundance of flying insects for food. With the threat to cliff swallows created by the presence of house swallows, open abandoned farmland would better suit the cliff swallow as house sparrows are attracted to the livestock grain in active farms. Little is known about the New England cliff swallow's migratory pathways and the wintering habitats visited; however, pesticide use in breeding, migrating or wintering habitats poses great risk to cliff swallows as they are aerial insectivores.

Primarily, the factors having the greatest impact causing the cliff sparrow population decline included their competition with house sparrows, habitat loss, and pesticides. Mass Audubon (2013) offers a summary of impacts through the years that helped contribute to their decline, including:

- Agricultural acreage has dwindled markedly in the last century and with it the barns, farmhouses, muddy cow yards, and extensive buggy pastures and hayfields that are the mainstays of a cliff swallow's existence.
- Many farm buildings that remain have (unintentionally) been made cliff swallow-proof, exchanging the broad eaves and rough unpainted wood of yesteryear for sleeker, more maintenance-free exteriors on which the swallows' adobe homes will not stick.
- Like barns, many of the bridges that harbored cliff swallow colonies here for many years are being replaced with new spans that the birds have not recolonized. In the Midwest, by contrast, bridges and large culverts made largely of concrete continue to be swallow magnets.
- The eradication of pest insects in agriculture with broad-spectrum insecticides, such as the relatively new neonictotinoids (neurotoxins), can effectively eradicate much of an aerial insectivore's food.
- In a densely populated state like Massachusetts, homeowner use of pesticides on lawns and gardens—which tend to be applied in far greater concentrations than in agricultural applications—may also be reducing insect densities in the air column.

Bridge and building structures occur along the Housatonic River which could provide nest sites for the cliff swallow. A habitat need for this species is that of open grasslands which are not in active agricultural use, and with nearby water sources. The UDF area offers the potential of 30 acres of such habitat which could benefit the local cliff swallow population.

Table B1: Wildlife Species with Habitat Requirements Compatible with Anticipated Final Cover Conditions on the UDF*

Scientific Name	Common Name
Herpetofauna	
Terrapene c. carolina	Eastern box turtle
Thamnophis s. sirtalis	Eastern garter snake
Lampropeltis t. triangulum	Eastern milk snake
Coluber c. constrictor	Northern black racer
Storeria d. dekayi	Northern brown snake
Storeria o. occipitomaculata	Northern red-bellied snake
Diadophis punctatus edwardsii	Northern ringneck snake
Opheodrys vernalis	Smooth green snake
Clemmys guttata	Spotted turtle
Glyptemys insculpta	Wood turtle
Anaxyrus americanus	American toad
Anaxyrus fowleri	Fowler's toad
Lithobates pipiens	Northern leopard frog
Lithobates palustris	Pickerel frog
Glyptemys muhlenbergii	Bog turtle
Sternotherus odoratus	Common musk turtle
Avifauna	
Empidonax alnorum	Alder flycatcher
Anas rubripes	American black duck
Corvus brachyrhynchos	American crow
Spinus tristis	American goldfinch
Falco sparverius	American kestrel
Setophaga ruticilla	American redstart
Turdus migratorius	American robin
Spizelloides arborea	American tree sparrow
Scolopax minor	American woodcock
Icterus galbula	Baltimore oriole
Riparia riparia	Bank swallow
Hirundo rustica	Barn swallow
Strix varia	Barred owl
Cyanocitta cristata	Blue jay
Spatula discors	Blue-winged teal
Vermivora cyanoptera	Blue-winged warbler
Dolichonyx oryzivorus	Bobolink
Toxostoma rufum	Brown thrasher
Molothrus ater	Brown-headed cowbird
Branta canadensis	Canada goose
Bombycilla cedrorum	Cedar waxwing
Setophaga pensylvanica	Chestnut-sided warbler
Chaetura pelagica	Chimney swift
Spizella passerina	Chipping sparrow

*Species listed are those listed by Woodlot (2002) as potentially occurring in cultural grasslands or agricultural fields of the Reach 5-6 area of the Rest of River during some life cycle phases.

Scientific Name	**Common Name**
Petrochelidon pyrrhonota	Cliff swallow
Tyto alba	Common barn owl
Quiscalus quiscula	Common grackle
Chordeiles minor	Common nighthawk
Corvus corax	Common raven
Acanthis flammea	Common redpoll
Gallinago gallinago	Common snipe
Geothlypis trichas	Common yellowthroat
Accipiter cooperii	Cooper's hawk
Junco hyemalis	Dark-eyed junco
Sialia sialis	Eastern bluebird
Tyrannus tyrannus	Eastern kingbird
Sturnella magna	Eastern meadowlark
Sayornis phoebe	Eastern phoebe
Megascops asio	Eastern screech owl
Pipilo erythrophthalmus	Eastern towhee
Contopus virens	Eastern wood-pewee
Sturnus vulgaris	European starling
Spizella pusilla	Field sparrow
Dumetella carolinensis	Gray catbird
Bubo virginianus	Great horned owl
Ammodramus henslowii	Henslow's sparrow
Eremophila alpestris	Horned lark
Haemorhous mexicanus	House finch
Passer domesticus	House sparrow
Troglodytes aedon	House wren
Passerina cyanea	Indigo bunting
Charadrius vociferus	Killdeer
Calcarius lapponicus	Lapland longspur
Empidonax minimus	Least flycatcher
Asio otus	Long-eared owl
Anas platyrhynchos	Mallard
Zenaida macroura	Mourning dove
Geothlypis philadelphia	Mourning warbler
Leiothlypis ruficapilla	Nashville warbler
Colinus virginianus	Northern bobwhite
Cardinalis cardinalis	Northern cardinal
Colaptes auratus	Northern flicker
Circus hudsonius	Northern harrier
Mimus polyglottos	Northern mockingbird
Setophaga americana	Northern parula
Stelgidopteryx serripennis	Northern rough-winged swallow
Aegolius acadicus	Northern saw-whet owl
Lanius borealis	Northern shrike
Setophaga palmarum	Palm warbler

*Species listed are those listed by Woodlot (2002) as potentially occurring in cultural grasslands or agricultural fields of the Reach 5-6 area of the Rest of River during some life cycle phases.

Scientific Name	Common Name
Falco peregrinus	Peregrine falcon
Spinus pinus	Pine siskin
Setophaga discolor	Prairie warbler
Progne subis	Purple martin
Buteo jamaicensis	Red-tailed hawk
Agelaius phoeniceus	Red-winged blackbird
Phasianus colchicus	Ring-necked pheasant
Columba livia	Rock dove
Pheucticus ludovicianus	Rose-breasted grosbeak
Buteo lagopus	Rough-legged hawk
Archilochus colubris	Ruby-throated hummingbird
Passerculus sandwichensis	Savannah sparrow
Plectrophenax nivalis	Snow bunting
Anser caerulescens	Snow goose
Melospiza melodia	Song sparrow
Actitis macularia	Spotted sandpiper
Leiothlypis peregrina	Tennessee warbler
Tachycineta bicolor	Tree swallow
Baeolophus bicolor	Tufted titmouse
Cathartes aura	Turkey vulture
Zonotrichia albicollis	White-throated sparrow
Meleagris gallopavo	Wild turkey
Setophaga petechia	Yellow warbler
Coccyzus americanus	Yellow-billed cuckoo
Icteria virens	Yellow-breasted chat
Setophaga coronata	Yellow-rumped warbler
Vireo flavifrons	Yellow-throated vireo
Mammals	
Eptesicus fuscus	Big brown bat
Canis latrans	Coyote
Tamias striatus	Eastern chipmunk
Sylvilagus floridanus	Eastern cottontail
Scalopus aquaticus	Eastern mole
Pipistrellus subflavus	Eastern pipistrelle
Urocyon cinereoargenteus	Gray fox
Sciurus carolinensis	Gray squirrel
Parascalops brewer	Hairy-tailed mole
Lasiurus cinereus	Hoary bat
Mus musculus	House mouse
Myotis sodalis	Indiana myotis
Myotis lucifugus	Little brown bat
Mustela frenata	Long-tailed weasel
Sorex cinereus	Masked shrew
Zapus hudsonius	Meadow jumping mouse
Microtus pennsylvanicus	Meadow vole
Sylvilagus transitionalis	New England cottontail

*Species listed are those listed by Woodlot (2002) as potentially occurring in cultural grasslands or agricultural fields of the Reach 5-6 area of the Rest of River during some life cycle phases.

Scientific Name	Common Name
Myotis septentrionalis (keeni)	Northern myotis
Blarina brevicauda	Northern short-tailed shrew
Rattus norvegicus	Norway rat
Microtis pinetorum	Pine vole
Erethizon dorsatum	Porcupine
Procyon lotor	Raccoon
Lasiurus borealis	Red bat
Vulpes vulpes	Red fox
Mustela erminea	Short-tailed weasel
Lasionycteris noctivagans	Silver-haired bat
Myotis leibii (subulatus)	Small-footed myotis
Lepus americanus	Snowshoe hare
Synaptomys cooperi	Southern bog lemming
Mephitis mephitis	Striped skunk
Didelphis virginiana	Virginia opossum
Peromyscus leucopus	White-footed mouse
Odocoileus virginianus	White-tailed deer
Marmota monax	Woodchuck
Napaeozapus insignis	Woodland jumping mouse

*Species listed are those listed by Woodlot (2002) as potentially occurring in cultural grasslands or agricultural fields of the Reach 5-6 area of the Rest of River during some life cycle phases.

Table 4-23: Species of Greatest Conservation Need in Grasslands

Taxon Grouping	Scientific Name	Common Name
Reptiles	*Heterodon platirhinos*	Eastern Hog-nosed Snake
	Opheodrys vernalis	Smooth Greensnake
Birds	*Ammodramus savannarum*	Grasshopper Sparrow
	Asio flammeus	Short-eared Owl
	Asio otus	Long-eared Owl
	Bartramia longicauda	Upland Sandpiper
	Chaetura pelagica	Chimney Swift
	Circus cyaneus	Northern Harrier
	Colinus virginianus	Northern Bobwhite
	Dolichonyx oryzivorus	Bobolink
	Eremophila alpestris	Horned Lark
	Falco sparverius	American Kestrel
	Pooecetes gramineus	Vesper Sparrow
	Progne subis	Purple Martin
	Scolopax minor	American Woodcock
	Sturnella magna	Eastern Meadowlark
	Tyto alba	Barn Owl
Mammals	*Synaptomys cooperi*	Southern Bog Lemming
Beetles	*Cicindela purpurea*	Purple Tiger Beetle
	Nicrophorus americanus	American Burying Beetle
Lepidoptera	*Abagrotis nefascia*	Coastal Heathland Cutworm
	Callophrys irus	Frosted Elfin
	Cycnia inopinatus	Unexpected Cycnia
	Erynnis persius persius	Persius Duskywing
	Euchlaena madusaria	Scrub Euchlaena
	Dargida rubripennis	The Pink-streak
	Grammia phyllira	Phyllira Tiger Moth
	Heterocampa varia	Sandplain Heterocampa
	Ptichodis bistrigata	Southern Ptichodis
Bees	*Anthophora walshii*	Walsh's Anthophora
	Epeoloides pilosula	Macropis Cuckoo Bee
	Macropis ciliata	Ciliary Oil-collecting Bee
	Macropis nuda	Naked Oil-collecting Bee
	Macropis patellata	Patellar Oil-collecting Bee
Plants	*Agalinis acuta*	Sandplain Gerardia
	Aristida purpurascens	Purple Needlegrass
	Asclepias purpurascens	Purple Milkweed
	Calystegia spithamaea	Upright False Bindweed
	Carex bushii	Bush's Sedge
	Carex mesochorea	Midland Sedge
	Carex polymorpha	Variable Sedge
	Corema conradii	Broom Crowberry
	Crataegus bicknellii	Bicknell's Hawthorn
	Crocanthemum dumosum	Bushy Rockrose
	Cyperus houghtonii	Houghton's Flatsedge
	Dichanthelium ovale ssp. *pseudopubescens*	Commons' Panic-grass
	Dichanthelium scabriusculum	Rough Panic-grass
	Eleocharis microcarpa var. *filiculmis*	Tiny-fruited Spike-sedge
	Gamochaeta purpurea	Purple Cudweed
	Gentiana linearis	Narrow-leaved Gentian
	Hypericum hypericoides ssp. *multicaule*	St. Andrew's Cross
	Lathyrus palustris	Marsh-pea
	Lechea pulchella var. *moniliformis*	Beaded Pinweed

Table B-2 (continued)

Taxon Grouping	Scientific Name	Common Name
	Liatris novae-angliae	New England Blazing Star
	Linum intercursum	Sandplain Flax
	Linum medium var. *texanum*	Stiff Yellow Flax
	Lupinus perennis	Wild Lupine
	Malaxis bayardii	Bayard's Adder's Mouth
	Nabalus serpentarius	Lion's Foot
	Panicum philadelphicum ssp. *gattingeri*	Gattinger's Panic-grass
	Scleria pauciflora	Papillose Nut-sedge
	Scleria triglomerata	Tall Nut-sedge
	Senna hebecarpa	Wild Senna
	Silene caroliana ssp. *pensylvanica*	Wild Pink
	Sisyrinchium fuscatum	Sandplain Blue-eyed Grass
	Spiranthes vernalis	Grass-leaved Ladies'-tresses
	Symphyotrichum concolor	Eastern Silvery Aster
	Symphyotrichum praealtum	Willow Aster
	Triosteum perfoliatum	Broad Tinker's-weed
	Viola adunca	Sand Violet
	Veronicastrum virginicum	Culver's-root
	Verbena simplex	Narrow-leaved Vervain

Attachment C

Habitat Inventory Forms
For the Southeast Gravel Pit Pond and On-Site BVW

Note: Field investigations and forms were completed by AECOM between April and July of 2022; staff initials on the forms are as follows:

SE: Scott Egan
JS: Julia Stearns
DL: Dennis Lowry

General Electric Housatonic Rest of River
Gravel-Pit Pond Habitat Inventory Form

I. General Information

Upland Disposal Facility Property – Southeastern-most gravel-pit ponded area
Site Name

Lee, Massachusetts
Location/Physical Description

April 11, April 27, May 19 and July 6, 2022
Date(s) of Site Visit(s) and Data Collection

Variable
Weather Conditions During Site Visit

SE, JS, DL
Field Staff Performing Evaluation

07/04/23
Date this form was completed

II. Site Description

A. Pond Characterization

Physical Dimensions (ft): Length 365 Width 180 Depth >4 Area 1.3 acres

Sediment / Substrate composition:

% Sand 90 % Silt <1 % Clay <1 % Gravel/cobble 10

% Boulder Bedrock 0 % Organic matter <1

Bank stability / Observed erosional conditions: Significant erosion occurring from overland runoff on the south and north sides.

B. Bordering Habitat Types

Wetland

- ☐ Transitional floodplain forest
- ☐ High terrace floodplain forest
- ☐ Red maple swamp
- ☐ Vernal pool
- ☐ Black ash-red maple-tamarack calcareous seepage swamp
- ☐ Deep emergent marsh
- ☐ Shallow emergent marsh
- ☐ Shrub swamp
- ☐ Wet meadow
- ☐ Other ____________

Upland

- ☒ Northern Hardwoods-Hemlock-White Pine Forest
- ☐ Rich mesic forest
- ☐ Red Oak-Sugar Maple Transition Forest
- ☐ Agricultural fields
- ☒ Cultural grassland
- ☐ Successional northern hardwoods
- ☐ Spruce-fir-northern hardwood forest
- ☐ Developed/disturbed cover types
- ☒ Other Non-vegetated, open sand and gravel areas

Notes:

C. Hydrology

Stream gradient adjacent to pond: ***N/A*** ☐ Low Gradient ☐ Mid-Gradient ☐ High-Gradient

Pond Hydrology

☐ Dam Controlled (describe dam): ______

Describe any other inlets, outlets, and other surface water inputs to pond: ______

Pond is an isolated/excavated wash basin in former sand and gravel mining area

Water level fluctuation: Stable, groundwater controlled.

Field-Derived Evidence of Hydrologic Conditions

- ☐ Clear natural line impressed on bank
- ☐ Bed and banks
- ☐ Shelving
- ☐ Wrack lines (litter and debris)
- ☐ Scour and/or Deposition
- ☐ Line of mud or silt on tree trunks/vegetation
- ☐ Changes in character of soil
- ☒ Water staining
- ☐ Vegetation matted down, bent or absent
- ☒ Changes in plant community
- ☐ Destruction of terrestrial vegetation
- ☐ Debris stuck on overhanging tree limbs
- ☐ Other______

D. Inventory of Aquatic Plant Community: Bank/shoreline vegetation

% Cover:

Overall Aquatic Vegetation	Floating -Leaved Cover	Emergent Cover
0%	0%	30%

Plant Lists (species that comprise 10% or more of the vegetative cover in each strata, or any amount of an invasive plant species; "*" designates a dominant plant species for the strata):

Strata	Plant Species	Strata	Plant Species
	Phragmites australis		
	Salix nigra		
	Populus deltoides		
	Equisetum hyemale		

Strata: AL=Algal, AM=Aquatic Moss, RV=Rooted Vascular, FV=Floating Vascular, PE=Persistent Emergent, NE=Non-persistent Emergent

III. Important Habitat Features

Wildlife Food

Important aquatic food plants (smartweeds, pondweeds, wild rice, bulrush, wild celery)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Cover/Perches/Basking/Denning/Nesting Habitat

Trees (live) > 30” DBH adjacent to pond

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Tree cavities in trunks or limbs in or adjacent to pond

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Small mammal burrows on banks of pond

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Dense herbaceous cover on banks of pond (voles, small mammals, amphibians & reptiles)

☒ Abundant ☐ Present ☐ Absent ☐ Not Applicable

Large woody debris in contact with the water (fish & turtles)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Rocks, crevices, logs, tree roots or hummocks under water’s surface (fish, turtles, snakes, frogs)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Rocks, crevices, fallen logs, overhanging branches or hummocks at, or within 1 m above the water’s surface (fish, turtles, snakes, frogs, wading birds, wood duck, mink, raccoon)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Live or dead tall standing vegetation overhanging water or offering good visibility of open water (e.g., bald eagle, osprey, kingfisher, flycatchers, cedar waxwings)

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Other Important Habitat Characteristics

Flat rocks and logs on banks or within exposed portions of the pond (cover and basking for herpetofauna)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Underwater banks of fine silt and/or clay (beaver, muskrat, otter)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Undercut or overhanging banks (fish, small mammals, mink, weasels, turtles)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Mud flats

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Wildlife Dens/Nests (if observed)

Bank swallow colony(ies) (adjacent to pond)

☐ Abundant ☐ Present ☐ Absent ☐ Not Applicable

Turtle nesting sites

☒ Abundant ☐ Present ☐ Absent ☐ Not Applicable

Nest(s) present of ☐ Bald Eagle ☐ Osprey ☐ Great Blue Heron

Den(s) present of ☐ Otter ☐ Mink ☐ Beaver

Other nests or dens (identify species): Red-winged blackbirds

Emergent Wetlands within Pond (if Applicable)

Emergent wetland vegetation at least seasonally flooded during the growing season (American bittern, wood duck, green heron, black-crowned night heron, rails [sora, king, Virginia], moorhen, coot, etc.)

Flooded > 5 cm ☐ Present ☒ Absent

Flooded > 25 cm (pied-billed grebe) ☐ Present ☒ Absent

IV. Connectivity with Adjoining Natural Habitats

☐ No direct connections to adjacent areas of wildlife habitat (no connectivity function)

☒ Pond has a limited number of connectors to adjacent areas of habitat (somewhat important for connectivity function)

☐ Pond is embedded in a large area of natural habitat with unimpeded connection between pond and other habitats (high connectivity function)

V. Rare Species and MNHESP Core Area Habitat Designation

☐ Core Area 1 ☐ Core Area 2 ☐ Core Area 3 ☐ Core Area 4

☒ Federally listed threatened or endangered species habitat (including species with known overlapping habitat): Northern Long-eared Bat (Endangered), Monarch Butterfly (Candidate species for Listing)

☐ State-listed species habitat (including species with known overlapping Priority Habitat): None

Rare species direct observations during current field surveys (list): None

VI. Incidental Direct Wildlife Observations

Red-winged blackbird (adults and nests) Bullfrog	
Green frog Common snapping turtle (eggs)	
Muskrat Beaver	
Kingfisher Damselfly larvae	
Water strider Whirlygigs	

VII. Habitat Degradation (identify specific location within pond if applicable)

☐ Evidence of significant levels of dumping

☒ Evidence of significant erosion or sedimentation problems

☒ Presence of invasive plants (e.g., purple loosestrife, *Phragmites*, Eurasian water-milfoil); identify and estimate approximate percent coverage of invasive plants;

Common reed (*Phragmites australis)* dominant (100% cover) in fringe around bank of pond.

☒ Evidence of other human disturbance; describe: Man-made / excavated pond in former sand and gravel mining operation

Upland Disposal Facility and GE Parcel Habitat Inventory Form for Palustrine Wetland Cover Types (Includes all Palustrine cover types: PSH, PSS, PSM, and PPD)

General Electric Housatonic Rest of River
Upland Disposal Facility and GE Parcel Habitat Inventory Form for Palustrine Wetland Cover Types

I. General Information

Upland Disposal Facility
Site Name

Lee, Massachusetts
Location/Physical Description

April 11, April 27, May 19 and July 6, 2022
Date(s) of Site Visit(s) and Data Collection

Variable
Weather Conditions During Site Visit

SE, JS, DL
Field Staff Performing Evaluation

11/16/22
Date this form was completed

II. Site Description

A. Hydrology/Water Regime

- ☐ Permanently flooded
- ☐ Intermittently exposed
- ☐ Semi-permanently flooded
- ☒ Seasonally flooded
- ☐ Upland
- ☒ Saturated
- ☐ Temporarily flooded
- ☐ Intermittently flooded
- ☐ Artificially flooded

B. Community Cover Type(s)

Wetland

- ☐ Transitional floodplain forest
- ☐ High terrace floodplain forest
- ☒ Red maple swamp
- ☒ Vernal pool
- ☐ Black ash-red maple-tamarack calcareous seepage swamp
- ☐ Deep emergent marsh
- ☒ Shallow emergent marsh
- ☒ Shrub swamp
- ☐ Wet meadow

Upland

- ☐ Northern Hardwoods-Hemlock-White Pine Forest
- ☐ Rich mesic forest
- ☐ Red Oak-Sugar Maple Transition Forest
- ☐ Agricultural fields
- ☐ Cultural grassland
- ☐ Successional northern hardwoods
- ☐ Spruce-fir-northern hardwood forest
- ☐ Developed/disturbed cover types
- ☒ Gravel pit pond

Bordering Riverine/Aquatic Habitat

- ☐ High-gradient stream
- ☐ Medium-gradient stream
- ☐ Low-gradient stream
- ☐ Moderately alkaline lake/pond

☐ Backwater ☒ Former Gravel Pit/Forested Uplands

C. Inventory (Plant community)

% Cover:

51-75	51-75	1-5	6-15	26-50
Trees (> 20’)	Shrubs (< 20’)	Woody vines	Mosses	Herbaceous

Plant Lists (species that comprise 10% or more of the vegetative cover in each strata; “*” designates a dominant plant species for the strata):

Strata	Plant Species	Strata	Plant Species
Tree	Acer rubrum	Herbaceous	Lilium lancifolium
Tree	Populus deltoides	Herbaceous	Onoclea sensibilis
Shrub	Cornus amomum	Herbaceous	Eutrochium maculatum
Shrub	Alnus incana	Herbaceous	Carex stricta
Shrub	Salix nigra	Herbaceous	Osmunda cinnamomea
Woody vines	Vitis riparia	Herbaceous	Phragmites australis

D. Inventory (Soils)

Fredon	Poorly and somewhat poorly drained
Soil Survey Unit	Drainage Class
Silt Loam	20 inches
Texture (upper part)	Depth

Representative Soil Pit Log

Soil Horizon	Depth (inches)	Color	Soil Texture	Mottling
A	0-10	10YR 3/2	Silt loam	
B1	10-20	10YR 5/2	Silt loam	10YR 5/4, 7.5YR 5/8
Notes:				

III. Important Habitat Features

Wildlife Food

Important Wetland/Aquatic Food Plants (smartweeds, pondweeds, wild rice, bulrush, wild celery)

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Important Upland/Wetland Food Plants (hard mast and fruit/berry producers)

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Shrub thickets or streambeds with abundant earthworms (American woodcock)

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

<u>Cover/Perches/Basking/Denning/Nesting Habitat</u>

Shrub and/or herbaceous vegetation suitable for veery nesting

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Trees (live or dead) > 30" DBH

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Standing Dead Trees (potential for cavities and perches):

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Tree Cavities in trunks or limbs:

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Small mammal burrows:

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Dense herbaceous cover (voles, small mammals, amphibians & reptiles)

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Large woody debris on the ground (small mammals, mink, amphibians & reptiles)

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Rocks, crevices, logs, tree roots or hummocks under water's surface (turtles, snakes, frogs)

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Rocks, crevices, fallen logs, overhanging branches or hummocks at, or within 1m above the water's surface (turtles, snakes, frogs, wading birds, wood duck, mink, raccoon)

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Rock piles, crevices, or hollow logs suitable for:

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

☐ otter ☐ mink ☐ porcupine ☐ bear ☐ bobcat ☐ turkey vulture

Live or dead standing vegetation overhanging water or offering good visibility of open water (e.g., osprey, kingfisher, flycatchers, cedar waxwings)

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Depressions that may serve as seasonal (vernal/autumnal) pools

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Standing water present at least part of the growing season, suitable for use by

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

☒ Breeding amphibians ☒ Non-breeding amphibians (foraging, re-hydration)

☒ Turtles ☒ Foraging waterfowl

Sphagnum hummucks or mats, moss-covered logs or saturated logs, overhanging or directly adjacent to pools of standing water in spring (four-toed salamander)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

<u>Important habitat characteristics</u>

Medium to large (> 6”), flat rocks within a stream (cover for stream salamanders and nesting habitat for spring & two-lined salamanders)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Flat rocks and logs on banks or within exposed portions of streambeds (cover for stream salamanders and nesting habitat for dusky salamanders)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Underwater banks of fine silt and/or clay (beaver, muskrat, otter)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Undercut or overhanging banks (small mammals, mink, weasels)

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Vertical sandy banks (bank swallow, kingfisher)

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Areas of ice-free open water in winter

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Mud flats

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Exposed areas of well-drained, sandy soil suitable for turtle nesting

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

<u>Wildlife dens/nests (if observed)</u>

Turtle nesting sites

☐ Abundant ☒ Present ☐ Absent ☐ Not Applicable

Bank swallow colony

☐ Abundant ☐ Present ☒ Absent ☐ Not Applicable

Nest(s) present of ☐ Bald Eagle ☐ Osprey ☐ Great Blue Heron ☐ NLE Bat ☐ Other

Den(s) present of ☐ Otter ☐ Mink ☒ Beaver

Emergent Wetlands (if Applicable)

Emergent wetland vegetation at least seasonally flooded during the growing season (wood duck, green heron, black-crowned night heron, king rail, Virginia rail, coot, etc.)

Flooded > 5 cm ☐ Present ☒ Absent

Flooded > 25 cm (pied-billed grebe) ☐ Present ☒ Absent

Persistent emergent wetland vegetation at least seasonally flooded during the growing season (mallard, American bittern, sora, common snipe, red-winged blackbird, swamp sparrow, marsh wren)

Flooded > 5 cm ☒ Present ☐ Absent

Flooded > 25 cm (least bittern, common moorhen) ☐ Present ☒ Absent

Cattail emergent wetland vegetation at least seasonally flooded during the growing season

Flooded > 5 cm (marsh wren) ☐ Present ☒ Absent

Flooded > 25 cm (least bittern, common moorhen) ☐ Present ☒ Absent

Fine-leafed emergent vegetation (grasses and sedges) at least seasonally flooded during the growing season (common snipe, spotted sandpiper, sedge wren)

Flooded > 5 cm ☐ Present ☒ Absent

Flooded > 25 cm (least bittern, common moorhen) ☐ Present ☒ Absent

V. Habitat Degradation

☐ Evidence of significant levels of dumping

☒ Evidence of significant erosion or sedimentation problems

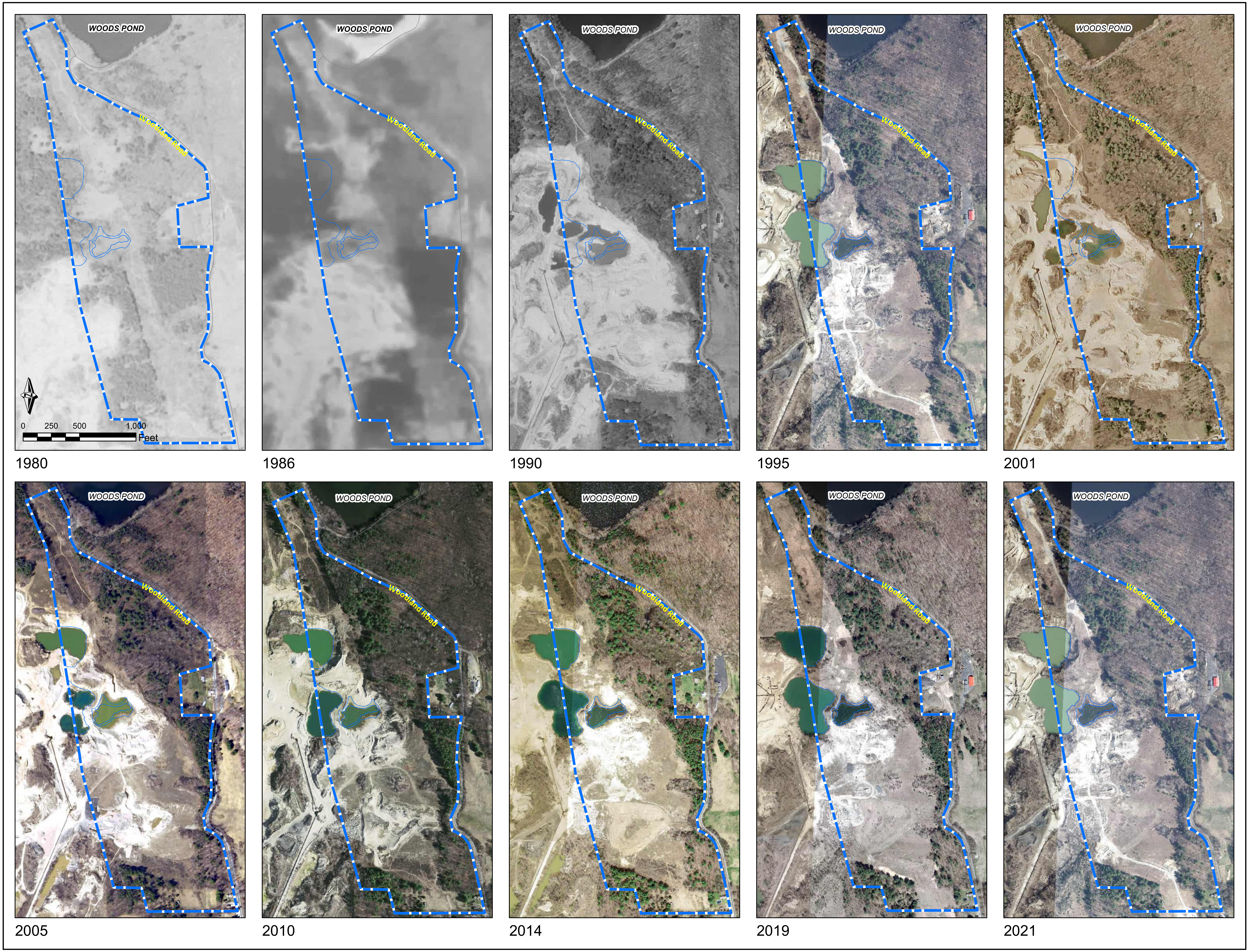
☒ Significant invasion of exotic plants (e.g., purple loosestrife, *Phragmites*, glossy buckthorn)

☐ Disturbance from roads or highways ☐ Evidence of fire

☒ Evidence of other human disturbance

Attachment D

Historic Aerial Photography


WOODS POND
Woodland Road
0 250 500 1,000
Feet
1980
1986
1990
1995
2001
2005
2010
2014
2019
2021

Attachment E

Wetland Function and Value Form

for Southeast Gravel Pit Pond

Wetland Function-Value Evaluation Form
Project Name: UDF Southeast Gravel Pit Pond

Total area of Evaluation Unit: ~1 acre **Is area part of a wildlife corridor?** No

Adjacent land use: Earth Removal

Distance to nearest roadway or development: 500'

Dominant wetland/aquatic systems present: Man-made pond

Contiguous undeveloped buffer zone present? No

Upland communities present: Exposed earth, fallow ground

Rare species habitat? No

Other unique or notable ecological conditions:

Site I.D.: Southeast Gravel Pit Pond

Latitude: 42°20' **Longitude:** 73° 14'

Prepared by: AECOM **Date:** Jan 2024

Wetland Impact
Type: Response actions for PCB impacted soils
Area:

Evaluation based on:
Office: **Field:** 2022-2023
Delineation completed? Yes

Function/Value	Suitability Y	Suitability N	Rationale (Reference #*)	Principal F/V	Comments
Groundwater Recharge/Discharge		X	3,4,5,15		Although in outwash, no signs of discharge or recharge
Floodflow Alteration		X	3,6,9		Not in floodplain and not connected to a stream for flood storage function
Fish and Shellfish Habitat	X		2,6,8,10		Some potential for tolerant warmwater fish spp.
Sediment/Toxicant Retention	X		1,3,4,5,10,16	**F**	Traps sediment shed from surrounding slopes
Nutrient Removal	X		2,3,5,7,8,10,14		Potential for nutrient to be trapped in basin
Production Export		X	4,5,6		No opportunity for export
Sediment/Shoreline Stabilization	X		1,3,6,7,12,13,15		Of only localized value
Wildlife Habitat	X		7,13,16,17,20	**F**	Habitat suitable for herpetofauna, beaver, muskrat, & several bird species
Recreation		X	No conditions met		Not available for recreation
Educational/Scientific Value		X	No conditions met		Not available for education
Uniqueness/Heritage		X	13,14,17,21		Not in suitable setting
Visual Quality/Aesthetics		X	2,12		Not visible by public
ES Endangered Species Habitat		X	No conditions met		No T&E species
Other					

*See USACE NED 1995. Highway Methodology Workbook, Wetland Functions and Values, A Descriptive Approach

Attachment F

MNHESP Vernal Pool Field Observation Forms

Natural Heritage & Endangered Species Program
Massachusetts Division of Fisheries & Wildlife

III. Vernal Pool Field Observation Form

For use with the *Guidelines for the Certification of Vernal Pool Habitat, March 2009.*

For Office Use Only

THE NHESP STRONGLY RECOMMENDS THAT LANDOWNER PERMISSION BE OBTAINED PRIOR TO COLLECTING CERTIFICATION DOCUMENTATION. IT IS THE SOLE RESPONSIBILITY OF AN INDIVIDUAL PROVIDING VERNAL POOL CERTIFICATION INFORMATION TO ENSURE THAT ALL ACTIVITIES ASSOCIATED WITH GATHERING SAID INFORMATION COMPLY WITH THE LAW.

1. Pool Location (Please complete a separate form for each pool).

Town Lee Potential Vernal Pool # (if known)__________

Pool Name or Tracking # (e.g., Elm St. VP, VP#1) VP-1

Written Directions to Pool (required): From the intersection of Valley Road and Woodland road in Lee, Massachusetts, drive approximately 2,220 linear feet south-southeast along Woodland to the pool, located on your left (to the west of Woodland Road). The pool is visible from Woodland Road

INSTRUCTIONS:

Please provide all information requested. Attach additional pages if needed. All required biological & physical evidence must be documented by photos, video, or audio of suitable quality (resolution, focus, indicators of scale) so species ID can be confirmed & pool features assessed. Documentation must be labeled. Sign/date the form; incomplete forms will be returned.

Additional Instructions for *Specific* Numbered Boxes:

1. Include an identifying name or tracking # for your pool & use it to label photos, maps, & any other documentation. If you used the Potential Vernal Pool (PVP) datalayer (available at MassGIS), include the PVP #. Written directions must be included with landmarks to help navigate to the pool.

3. 3A & 3B are for certification by the Obligate Species Method. Provide photos, video, or audio (chorusing) of the required breeding evidence or fairy shrimp **AND** photo(s) or video of the pool holding water.

2. Pool/Species Observation Dates (month/day/year):

First date pool observed April 11, 2022 Last date pool observed July 6, 2022

First date species observed April 11, 2022 Last date species observed May 19, 2022

3B. Biological Evidence: *Fairy Shrimp*

Date Observed (m/d/y)__________

3A. Biological Evidence: *Obligate Amphibians*

Indicate breeding evidence and date observed for each species. Evidence must include ≥1 of the following for certification: congressing salamanders **OR** ≥5 pairs wood frogs in amplexus **OR** salamander spermatophores **OR** a full wood frog chorus (calls constant, continuous, & overlapping) **OR** a total of ≥5 egg masses, regardless of species **OR** ≥1 MESA-listed salamander egg mass(es). Each individual egg mass or mated pair required for certification (e.g., all 5 wood frog egg masses) must be photographed or videotaped. If more than the minimum required number is observed, photo the required number, and count or estimate the total number and indicate in the table below.

SPECIES *State-listed species	Dates	COURTING ADULTS	Dates	SPERMATOPHORES	Dates	# EGG MASSES	Dates	SALAMANDER LARVAE	Dates	TRANSFORMING JUVENILES
Spotted salamander										
Blue-spotted salamander *										
Jefferson salamander *										
Marbled salamander *										
Unidentified Mole salamander										

SPECIES	Dates	# MATED PAIRS (≥ 5 pairs)	Dates	Full Chorus (calls continuous & overlapping)	Dates	# EGG MASSES	Dates	TADPOLES	Dates	TRANSFORMING JUVENILES
Wood frog	4/11/22	0	4/11/22	1-3 wood frogs	4/11/22	3	4/27/22 5/19/22	50-100 5-10		
TOTAL(S)		0		2		3		55		

Instructions (continued)

4. Certification by the Facultative Amphibian Method - provide photo, video, or audio (chorusing) of the required breeding evidence and photo(s) or video of the pool holding water **AND** dry.
6. Provide information to help distinguish the pool & assess its features.
7. All required biological & physical evidence must be documented by good quality photos, video, or audio.
8. Indicate the 3 required maps submitted.

4. Biological Evidence: *Facultative Amphibians*

Breeding evidence[1] of ≥ 2 species must be documented by photos, video, or audio.

BREEDING AMPHIBIANS	DATE OBSERVED month/day/year	BREEDING EVIDENCE[1] OBSERVED
Spring peeper		
Gray treefrog		
American toad		
Fowler's toad		

Breeding evidence[1] includes: full breeding choruses (call constant & overlapping), ≥ 5 adults in amplexus, any # of egg masses, tadpoles, and/or transforming juveniles in pool.

5. Rare Wetland Species

Were MESA-listed species observed using this pool?

☐ Yes ☒ No

If yes, please submit a Rare Animal Observation Form with photo & map to the NHESP (available at www.nhesp.org).

6. Description of Pool and Surroundings ~ **Please describe to the best of your ability and knowledge.**

Dimensions (please include measurements or estimates):

Approx. Length: 185 feet Approx. Width: 60 feet Approx. Maximum Depth: 46 inches

Describe distinctive features (roads, structures, boulders, foot trails, vegetation types, etc.) which are visible from or near the pool that would help someone recognize it.

Flooded pool in early spring with dense stand of silky dogwood

Origin of the pool (check): ☒ Natural depression ☐ Human-made pool/ditch ☐ Created wetland/pool ☐ Other or Unknown (describe)____

The pool's hydroperiod is most likely: ☒ Seasonal (drying out in most years) ☐ Semi-permanent (drying partially in most years) ☐ Permanent

Describe any inlet or outlets to/from the pool and their permanence (e.g., streams, culverts, etc).

No direct inlet or outlet observed, although pool is a deeper depression within a larger red maple swamp with an intermittent stream to the southeast of the pool.

Land use in vicinity of pool (approx. 100 ft from pool edge – check all that apply): ☒ upland forest ☐ forested wetlands ☐ emergent marsh/scrub-shrub wetland ☐ agricultural/grassland/meadow ☐ residential/commercial ☒ other Dirt road

7. Documentation Submitted – Label with pool name or tracking #, town, date taken, observer's name.

☒ Photo(s) ☐ Video ☐ Audio

☒ Obligate Species ☐ Facultative Species ☒ Pool Holding Water ☐ Dry Pool

8. Maps Submitted

Pool locus must be delineated & identified with your pool name or tracking #.

3 REQUIRED MAPS:

☒ USGS Topographic Map - 1:24,000 or 1:25,000 or better

☒ Color orthophoto - 1:12,000 or better

and ≥1 of the following:

☐ Assessor's map (Map and Plot #)

☐ Professional survey

☐ Sketch map - with directions and distances from permanent landmarks

☒ GPS longitude/latitude coordinates:

Latitude = 42.345340

Longitude = -73.237261

9. Property Owner Information - Landowner information is optional & is available from local tax assessor's offices.

Name General Electric Company

Address____

Town____ State____ Zip____ Assessors Map/Pcl#____ (if known)

10. Observer Information & Signature – Must be filled out & signed.

Name Scott Egan

Address 250 Apollo Drive

Town Chelmsford State MA Zip 01824

Telephone 603-547-5651 E-mail Scott.egan@aecom.com

I hereby certify under the pains and penalties of perjury that the information contained in this report is true and complete to the best of my knowledge.

Signature____ Date____

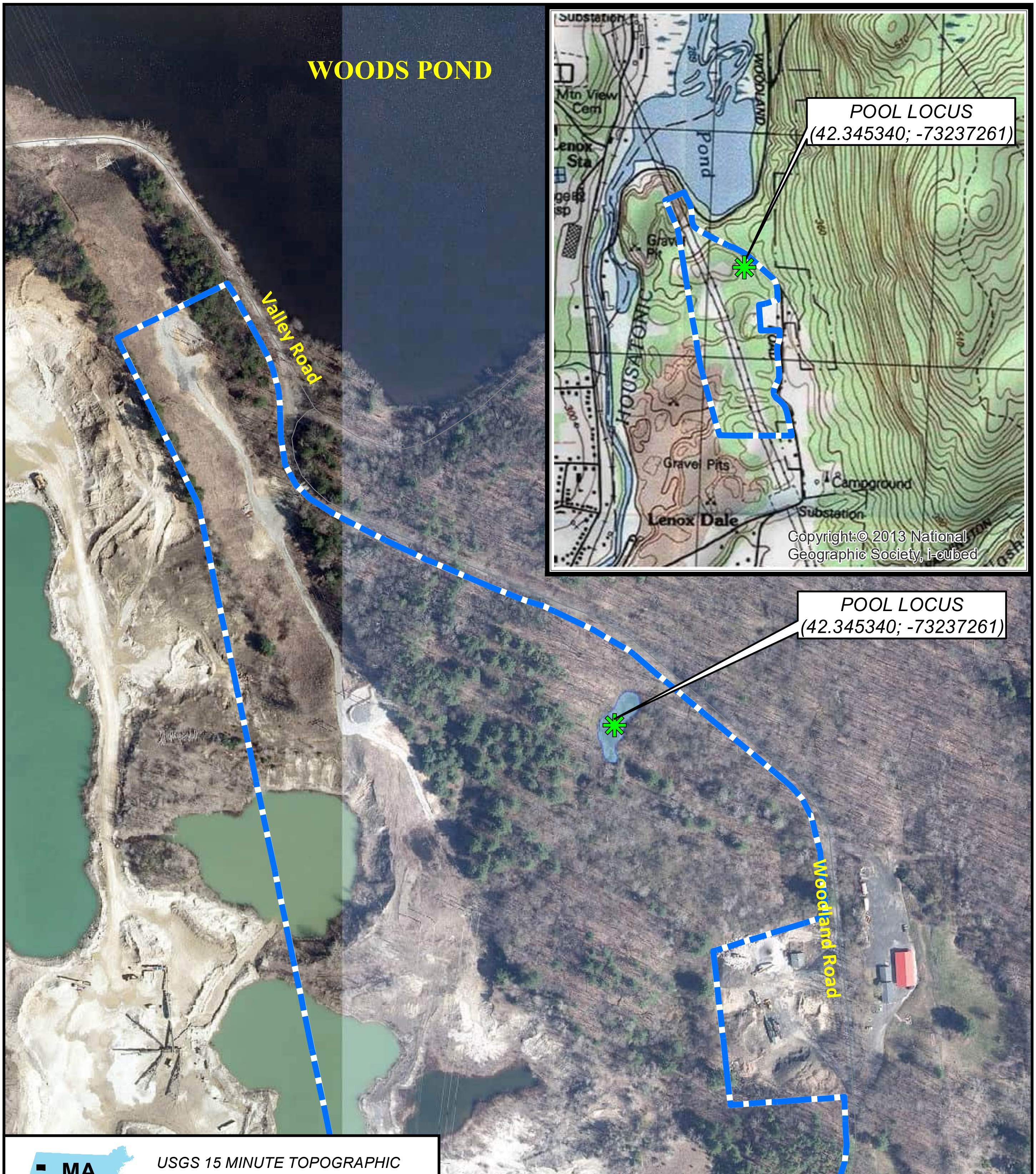
Signature of Adult, if Observer is under 18 years of age____

All submissions and supporting documents will be retained by the NHESP and, with the exception of information for MESA-listed species and the identity of minors, are available to interested parties under the Public Records Law.

SEND COMPLETED, SIGNED FORM & SUPPORTING DOCUMENTATION TO:

NHESP - Vernal Pool Certification
MA Division of Fisheries & Wildlife
1 Rabbit Hill Rd.
Westborough, MA 01581

For questions call 508-389-6360



MA

USGS 15 MINUTE TOPOGRAPHIC QUADRANGLE PITTSFIELD EAST, MA

Legend

UDF Property Boundaries

0 1,000 2,000 4,000 Feet

N

POTENTIAL VERNAL POOL

Upland Disposal Facility Site
Lee, Massachusetts

SCALE	DATE	PROJECT NO.
1:24,000	11/16/2022	04191406

AECOM

Figure Number

1

AECOM

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Great Pond Improvement District	Great Pond Phase 5 Development / 500 Groton Road Parcel	60669903

Photo No. 1	**Date:** 4/11/22	**Photo No. 2**	**Date:** 4/11/22
Description: View west of vernal pool		**Description:** three wood frog egg masses observed in the pool	

Photo No. 3	**Date:** 4/11/22	**Photo No. 4**	**Date:** 4/27/22
Description: View east back towards Woodland Road		**Description:** 50-100 tadpoles observed in vicinity of 4/11/22 egg masses and shallow water along northern shoreline	

PHOTOGRAPHIC LOG

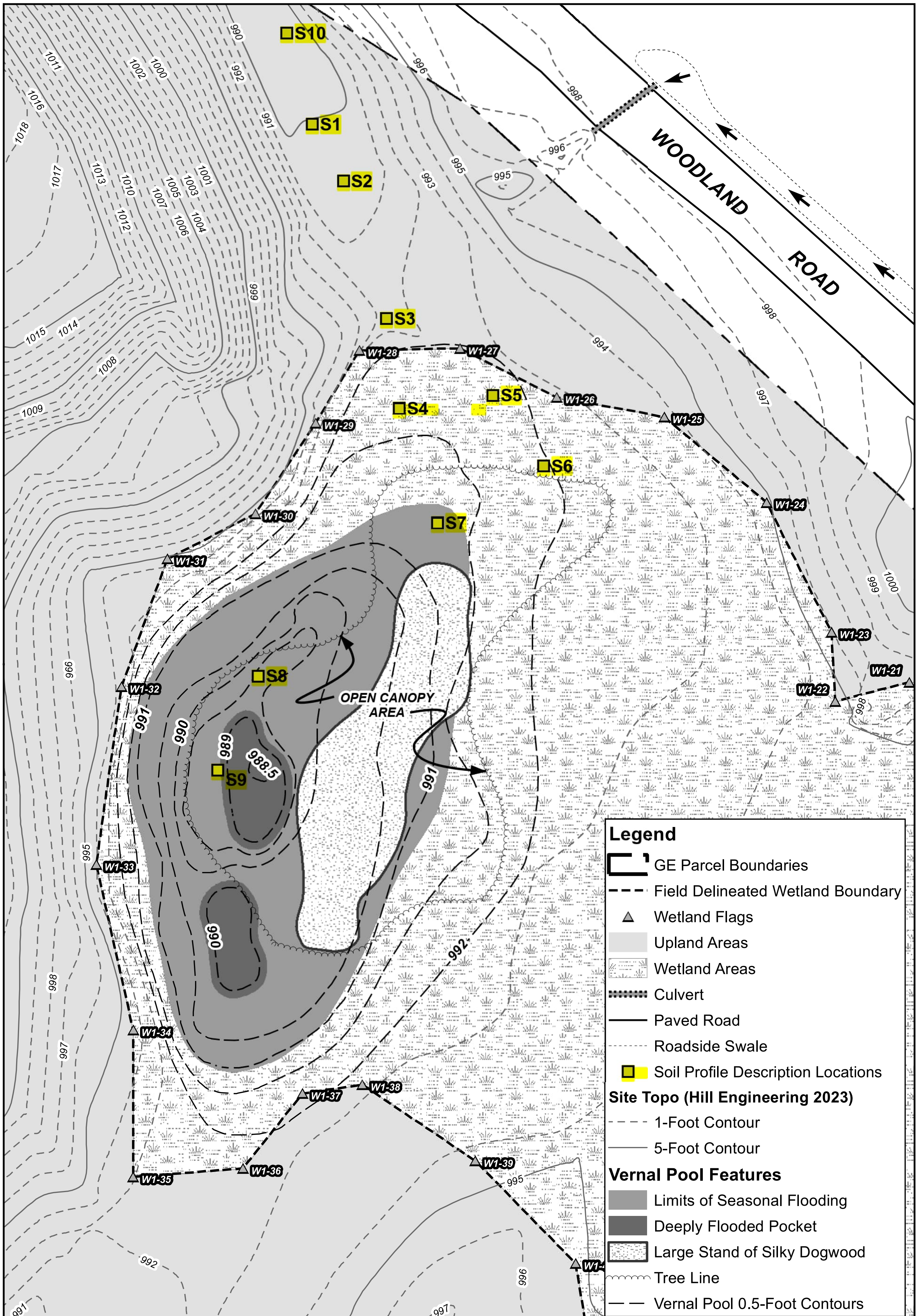
Client Name: Great Pond Improvement District	Site Location: Great Pond Phase 5 Development / 500 Groton Road Parcel	Project No. 60669903

Photo No. 1	**Date:** 5/19/22	**Photo No. 2**	**Date:** 5/19/22
Description: View west of vernal pool. Only about 4 inches of water remaining in western portion of pool		**Description:** View east back towards Woodland Road. This portion of the pool is dry but saturated to the surface.	
			

Photo No. 3	**Date:** 4/11/22	**Photo No. 4**	**Date:**
Description: 5-10 wood frog tadpoles observed in flooded portion of pool		**Description:**	
			

Attachment G

Vernal Pool Soil Test Pits



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1 inch = 25 feet

NO.	DATE	REVISIONS	BY	CHK	APP	APP

AECOM

AECOM Environment
250 Apollo Drive
Chelmsford, MA 01824

Vernal Pool Existing Conditions

Proposed Vernal Pool Enhancement Plan
Upland Disposal Facility, Lee, Massachusetts

PROJ. NO.: 60605466

DATE: 2/2/2024

SHEET NUMBER: 1 OF 4

DRAWING NUMBER: 6

Vernal Pool Soil Test Pit Logs
Test Pits Logged on November 30, 2023

Soil Pit Log—S1

Soil Horizon	Depth (inches)	Color	Soil Texture*	Mottling
	0-2.5’	10YR 4/4	SiL	
	2.5-3’	10YR 4/3	FSL	
	3-4’	10YR 3/3	SiL	

Notes: Appears to have been excavated and backfilled with loam.

Similar profile observed 20’ North (S10) in lowest pocket.

Soil Pit Log—S2

Soil Horizon	Depth (inches)	Color	Soil Texture*	Mottling
	0-3’	10YR 4/4	FSL	
	>3’	10YR 4/3	SL	

Notes:

Soil Pit Log—S3

Soil Horizon	Depth (inches)	Color	Soil Texture*	Mottling
		10YR 3/3	Gravel to Cobble Fill With FSL	

Notes: Appears to be old berm. Low point where flow from Vernal Pool overtops pool area.

*SiL=Silt Loam; FSL=Fine Sandy Loam; SL=Sandy Loam; VFLS=Very Fine Loamy Sand
All soil textures estimated in the field using standard hand criteria

Soil Pit Log—S4

Soil Horizon	Depth (inches)	Color	Soil Texture*	Mottling
	0-2.5’	10YR 4/4	FSL	
	2.5-3’	10YR 4/3	Mixed SL-FSL	Streaked and Mottled
	3’		FSL with gravel/cobbles	

Notes: In invasive honeysuckle (Lonicera morrowi) between Vernal Pool and berm.

Soil Pit Log--S5

Soil Horizon	Depth (inches)	Color	Soil Texture*	Mottling
	0-2’	10YR 3/2	SiL	
	2->4’	10YR 5/4	VFLS	

Notes: In nettles at edge of Vernal Pool.

Soil Pit Log—S6

Soil Horizon	Depth (inches)	Color	Soil Texture*	Mottling
	0-8”	10YR 3/3	SiL	
	8-12”	10YR 5/3	FSL	
	12”-2’	10YR 4/3	SiL	
	>2’		Gravelly SiL	

Notes:

*SiL=Silt Loam; FSL=Fine Sandy Loam; SL=Sandy Loam; VFLS=Very Fine Loamy Sand
All soil textures estimated in the field using standard hand criteria

Soil Pit Log—S7

Soil Horizon	Depth (inches)	Color	Soil Texture*	Mottling
	0-20”	10YR 3/3	SiL	
	20”-30”	10YR 4/3	FSL	
	30”-3’	10YR 5/4	VFSL with gravel	

Notes: In bare leaf layer beneath elm/grape cover.

Soil Pit Log—S8

Soil Horizon	Depth (inches)	Color	Soil Texture*	Mottling
	0-2’	10YR 3/2	LSilt	
	2-3’	10YR 4/3	VFLS	

Notes: In deep pool east edge

Soil Pit Log—S9

Soil Horizon	Depth (inches)	Color	Soil Texture*	Mottling
	0-2’	10YR 3/2	Mucky silt	
	2-3’	10YR 6/4-6/6	VFLS	Streaked and Mottled

Notes: In middle of deep pool. (Photo on log).

*SiL=Silt Loam; FSL=Fine Sandy Loam; SL=Sandy Loam; VFLS=Very Fine Loamy Sand
All soil textures estimated in the field using standard hand criteria

Soil Pit Log—S10

Soil Horizon	Depth (inches)	Color	Soil Texture*	Mottling
	0-2.5’	10YR 4/4	SiL	
	2.5-3’	10YR 4/3	FSL	

*SiL=Silt Loam; FSL=Fine Sandy Loam; SL=Sandy Loam; VFLS=Very Fine Loamy Sand
All soil textures estimated in the field using standard hand criteria

Appendix I

Greenhouse Gas Emission Calculations

UDF Construction - Energy & Air Compiled Results

Category	Total Energy	GHG	NOx	SOx	PM	NOx + SOx + PM	HAPs
	MMbtus	lbs CO2e	lbs	lbs	lbs	lbs	lbs
On-site (Scope 1)	**54,652**	**8,832,746**	**66,736**	**2,120**	**1,335**	**70,191**	**2**
Grid Electricity Generation (Scope 2)	**172.948**	**28,063**	**56**	**115**	**1**	**172**	**5**
Transportation (Scope 3a)	**15,455**	**2,499,119**	**17,864**	**563**	**378**	**18,805**	**56**
Other Off-Site (Scope 3b)	**16,215**	**2,418,803**	**6,967**	**7,229**	**1,388**	**15,584**	**555**
Remedy Totals	**86,494**	**13,778,731**	**91,623**	**10,027**	**3,102**	**104,752**	**618**

Values that are forwarded to the "Summary" tab are indicated in orange.

Voluntary Renewable Energy Use	Unit	Quantity	
On-site renewable energy generation or use	MMBtu	**0**	
On-site biodiesel use	MMBtu	**0**	
Biodiesel and other renewable resource use for transportation	MMBtu	**0**	
On-site renewable energy generation or use + on-site biodiesel use + biodiesel and other renewable resource use for transportation	MMBtu	**0**	*(This value is the sum of the three rows above)*
Voluntary purchase of renewable electricity	MWh	**0**	
Voluntary purchase of RECs	MWh	**0**	

This worksheet is not intended for user input. Values on this worksheet are obtained from the following file:
SEFA_calculations_(121718).xlsx

UDF Operation 15 yr - Energy & Air Compiled Results

Category	Total Energy	GHG	NOx	SOx	PM	NOx + SOx + PM	HAPs
	MMbtus	lbs CO2e	lbs	lbs	lbs	lbs	lbs
On-site (Scope 1)	**129,829**	**17,371,969**	**131,255**	**4,169**	**2,625**	**138,049**	**4**
Grid Electricity Generation (Scope 2)	**45,696**	**2,321,426**	**9,919**	**9,692**	**498**	**20,109**	**299**
Transportation (Scope 3a)	**2,078**	**331,623**	**578**	**11**	**50**	**639**	**106**
Other Off-Site (Scope 3b)	**23,543**	**2,952,283**	**6,010**	**14,562**	**1,413**	**21,986**	**896**
Remedy Totals	**201,146**	**22,977,301**	**147,762**	**28,434**	**4,586**	**180,783**	**1,305**

Values that are forwarded to the "Summary" tab are indicated in orange.

Voluntary Renewable Energy Use	Unit	Quantity	
On-site renewable energy generation or use	MMBtu	**0**	
On-site biodiesel use	MMBtu	**0**	
Biodiesel and other renewable resource use for transportation	MMBtu	**0**	
On-site renewable energy generation or use + on-site biodiesel use + biodiesel and other renewable resource use for transportation	MMBtu	**0**	*(This value is the sum of the three rows above)*
Voluntary purchase of renewable electricity	MWh	**0**	
Voluntary purchase of RECs	MWh	**0**	

This worksheet is not intended for user input. Values on this worksheet are obtained from the following file:
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