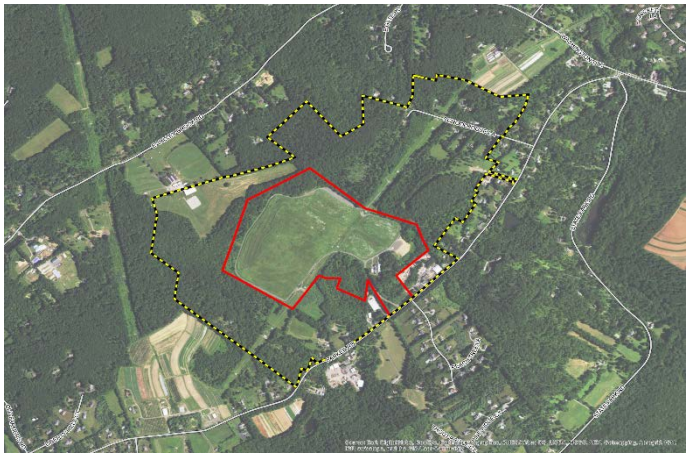

Final

Remedial Investigation Report

Combe Fill South Landfill Superfund Site

United States Environmental Protection Agency

Chester & Washington Townships, New Jersey

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ACRONYMS

°F	Degrees Fahrenheit
AALA	American Association for Laboratory Accreditation
AES	Atomic emission spectrometry
amsl	above mean sea level
ARAR	Applicable or Relevant and Appropriate Requirement
ATV	Acoustic Televiewer
B	Indicates that the compound was also detected in the method blank sample associated with the analyzed sample (a data qualifier for organic analytical results).
BHC	benzene hexachloride
bgs	Below ground surface
BERA	Baseline Ecological Risk Assessment
BGWPA	NJDEP Bureau of Ground Water Pollution Abatement
BHHRA	Baseline Human Health Risk Assessment
BOD	Biochemical oxygen demand
BTV	Background Threshold Value
CAL	Caliper
CEA	Classification Exception Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CFS	Combe Fill South
CKE	Currently known extent
CLP	Contract Laboratory Program
cm/s	Centimeters per Second
cm^2/s	Square Centimeters per Second
COC	Contaminant of Concern
COPC	Constituent of Potential Concern
COPEC	Contaminant of Potential Ecological Concern
CSM	Conceptual Site Model
CVI	Clean Venture, Inc.
cy	Cubic yards
D	Result from analysis of diluted sample (a data qualifier)
DC	Direct Current
DCA	dichloroethane

ACRONYMS (continued)

DCE	dichloroethene
DEHP	di(2-ethylhexyl) phthalate (synonym: bis(2-ethylhexyl) phthalate)
DER	Data Evaluation Report
DESA	Division of Environmental Science and Assessment
DMR	Discharge Monitoring Report
DNAPL	Dense non-aqueous phase liquid
DO	Dissolved Oxygen
DQI	Data Quality Indicator
E	Exceeded calibration range (a data qualifier)
EDD	Electronic Data Deliverable
EDP	Electronic Data Processor
ELCR	Excess Lifetime Cancer Risk
EPA	United States Environmental Protection Agency
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ERAGS	Ecological Risk Assessment Guidance for Superfund
ERI	Electrical Resistivity Imaging
ESD	Explanation of Significant Differences
ESL	Ecological Screening Level
ETS	Endangered and Threated Species
FASTAC	Field and Analytical Services Teaming Advisory Committee
FLC	Fluid Conductivity
FS	Feasibility Study
ft.	feet
FWEI	Foster Wheeler Enviresponse, Inc.
FWQS	Federal Water Quality Criteria
GAC	Granular activated carbon
GIS	Geographic Information System
GPR	Ground Penetrating Radar
GPS	Global Positioning System
GWQS	Groundwater Quality Standard
GWTP	Groundwater treatment plant

ACRONYMS (continued)

HASP	Health and Safety Plan
HDR	Henningson, Durham and Richardson Architecture and Engineering, P.C., in association with HDR Engineering, Inc.
HEAST	Health Effects Assessment Summary Table
HHRA	Human Health Risk Assessment
HI	Hazard Index
hp	Horse power
HPFM	Heat Pulse Flow Meter
HQ	Hazard Quotient
HWSS	Hazardous Waste Support Section
IASL	Indoor Air Screening Level
ICP	Inductively coupled plasma spectrometry
IDW	Investigation-Derived Waste
IEUBK	Integrated Exposure and Uptake Biokinetic Model
IGGWQC	Interim Generic Groundwater Quality Criterion/Criteria
ISGWQC	Interim Specific Groundwater Quality Criteria/Criterion
ISGWQS	Interim Specific Groundwater Quality Standard/Standards
IGWSSL	Impact to Groundwater Soil Screening Levels
ILR-RI	Interim Letter Report – Remedial Investigations
ISC	Interim Specific Criteria
IUR	Inhalation Unit Risk
J	Estimated (a qualifier for laboratory analytical data)
LLC	Limited Liability Company
LEL	Lowest Effect Level
LNR	Long Normal Resistivity
LOAEL	Lowest Observed Adverse Effect Level
LOE	Level of Effort
MAG	Magnetics
MCL	Maximum Contaminant Level
µg/L	Micrograms per Liter
mg/L	Milligrams per Liter
mg/kg	Milligrams per Kilogram

ACRONYMS (continued)

MS	Mass spectrometry
NAPL	Non-aqueous phase liquid
NCP	National Contingency Plan
NELAP	National Environmental Laboratory Accreditation Program
NHP	Natural Heritage Program
NG	Natural Gamma
N.J.A.C.	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NJGS	New Jersey Geological Survey
NOAEL	No Observed Adverse Effect Level
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NR	Single-Point Resistivity
NRDCSRS	Non-residential Direct-Contact Remediation Standard
NTU	Nephelometric Turbidity Units
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
PAH	polycyclic aromatic hydrocarbon
PAR	Pathways Analysis Report
PCE	tetrachloroethene (also: tetrachloroethylene, perchloroethylene)
PCEM	Post-construction Environmental Monitoring
ppm	parts per million
PCP	Personal Care Product
PDI	Pre-Design Investigation
piC/L	Pico Curie per Liter
PID	Photoionization Detector
PO	Project Officer
POETS	Point-of-entry treatment systems
PPCP	Pharmaceuticals and Personal Care Products
PPE	Personal Protective Equipment
PQL	Practical Quantitation Limit
PVC	polyvinyl chloride

ACRONYMS (continued)

QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QMP	Quality Management Plan
RAC	Remedial Action Contract
RAGS	Risk Assessment Guidelines for Superfund
RAL	NJDEP Rapid Action Level
RAO	Remedial Action Objective
RAR	Remedial Action Report
RAS	Routine Analytical Services
RCRA	Resource Conservation and Recovery Act
RDCSRS	Residential Direct-Contact Remediation Standard
RfC	Inhalation Reference Concentration
RfD	Oral Reference Dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RIR	Remedial Investigation Report
ROD	Record of Decision
RSCC	Regional Sample Control Center
RSL	Regional Screening Level
SARA	Superfund Amendments and Reauthorization Act
SBR	Sequencing batch reactor
SCS	Special Concern Species
SDWA	Safe Drinking Water Act
SF	Slope Factor
SGSL	Soil Gas Screening Levels
SLERA	Screening Level Ecological Risk Assessment
SNR	Short Normal Resistivity
SOCs	Synthetic Organic Compounds
SOP	Standard Operating Procedure
SOW	Statement of Work
SSA	Sole Source Aquifer
SVOC	Semi-Volatile Organic Compound

ACRONYMS (continued)

SWQS	Surface Water Quality Standard
TAL	Target Analyte List
TAME	tert-amyl methyl ether (also: 2-methoxy-2-methylbutane)
TBA	tert-butyl alcohol
TBC	To Be Considered (Criteria)
T&E	Threatened and Endangered
TCE	trichloroethylene (trichloroethene)
TCL	Target Compound List
TIC	Tentatively Identified Compound
TMP	Fluid Temperature
TOC	Total Organic Carbon
UCL	Upper Confidence Limit
UNT	Un-named Tributary
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VC	vinyl chloride
VOC	Volatile Organic Compound
VI	Vapor Intrusion
VISL	Vapor Intrusion Screening Level
Weston	Weston Solutions, Inc.
WTMUA	Washington Township Municipal Utilities Authority

Executive Summary

This report presents the findings of the United States Environmental Protection Agency (EPA) Remedial Investigation (RI) undertaken at the Combe Fill South (CFS) Landfill Superfund Site, located in Chester and Washington Townships, Morris County, New Jersey, and a summary of the findings of previous and concurrent investigation/monitoring activities conducted by the New Jersey Department of Environmental Protection (NJDEP).

CFS was a municipal refuse and solid waste landfill that accepted waste from the 1940s to 1981. Most notably, the landfill accepted chemicals, off-spec Pharmaceuticals and Personal Care Products (PPCPs), and pharmaceutical wastes from the pharmaceutical and Personal Care Product (PCPs) industry in northern New Jersey. About five million cubic yards (5,000,000 cy) of waste material buried in the landfill sit directly on fractured bedrock. The source of contamination is leachate that originates at the landfill and migrates both vertically and horizontally, resulting in impacts to both the overburden and bedrock aquifers, and surface water in the local streams.

EPA listed CFS on the National Priorities List (NPL) on September 1, 1983. NJDEP's 1986 Remedial Investigation/Feasibility Study (RI/FS) identified a wide range of Contaminants of Concern (COCs) consistent with known past disposal practices at the landfill. The remedy selected in the 1986 Record of Decision (ROD) (EPA 1986) consisted of:

1. An alternate water supply for impacted homes;
2. Capping of the landfill in accordance with Resource Conservation and Recovery Act (RCRA) requirements;
3. An active collection and treatment system for landfill gases;
4. Pumping and on-site treatment of shallow groundwater and leachate with discharge of treated water to East Trout Brook; and
5. Surface water controls; security fencing; and environmental monitoring.

Despite the 1986 ROD and subsequent closure of the landfill via capping and on-site groundwater treatment in 1995 to 1997, it was necessary to conduct additional investigations due to continuing and persistent levels of groundwater contamination.

A 2004 soil investigation conducted by NJDEP at the northern perimeter of the landfill revealed an area outside of the landfill cap containing a significant volume of pharmaceutical wastes, personal care products, and containers. NJDEP excavated this area known as the North Waste Cell in 2006 and disposed of about 27,300 tons of non-hazardous soil and debris off-site. Construction of a landfill cap extension over this area occurred in 2008.

The field activities undertaken to prepare this RI took place between 2010 and 2017. The field component included the installation of 19 bedrock monitoring wells, nine pairs of piezometers and stream gauges, and five soil borings. Samples collected for laboratory analysis included over 200 groundwater samples, 22 soil samples, 40 surface water samples, 53 potable well water samples, and 34 sediment samples, plus the required duplicate and quality assurance/quality control samples for each medium. Monitoring wells underwent short- and long-term water level monitoring. The field investigation also included several types of geophysical surveys – resistivity, Willowstick® electromagnetic, magnetic gradient and electromagnetic terrain conductivity to locate preferential flow pathways in bedrock and also possible buried drums in two locations at the landfill. Downhole investigations incorporated FLUTe™ hydraulic profiling, packer testing, and downhole geophysical

surveys. To inform the Feasibility Study (FS), additional field activities included a hydrogeological assessment consisting of an aquifer pump test, and a 1,4-dioxane treatment pilot test.

Because the landfill is a continuing source of groundwater contamination both inside and outside the landfill property boundary, the RI includes review and integration of NJDEP's analytical data for both groundwater and surface water.

The Conceptual Site Model (CSM) incorporates the results of the field surveys, field investigations, and laboratory analysis of samples to describe the nature and extent of groundwater, surface water, and sediment contamination, as well as the human and ecological risks at locations of complete pathways.

Multiple lines of evidence indicate the landfill, including the North Waste Cell, is a continuing source of groundwater contamination that is discharging to surface water. These lines of evidence include:

1. The historic waste burial practice of direct placement on fractured rock;
2. Historic and recent groundwater analytical data for the landfill and surrounding area indicating COC concentrations above standards and criteria;
3. Concentrations of three COCs - 1,4-dioxane, benzene, and TCE - were higher within the landfill property during the period of the RI (2010 through 2015) than in the surrounding area; the highest 1,4-dioxane concentrations originating at wells at the North Waste Cell, and the highest concentrations of benzene and TCE originating near the northeastern corner of the landfill;
4. Mostly different contaminants in background surface water and sediment data from locations outside the landfill's influence as compared to surface water and sediment data from within OU2;
5. Nearly radial and generally downward groundwater flow near the landfill;
6. Generally upward and sometimes artesian groundwater flow near the headwaters of several streams;
7. Detections of 1,4-dioxane in surface water;
8. Three distinct preferential groundwater flow paths in bedrock from the landfill to the northeast towards Schoolhouse Lane; and
9. Both the North Waste Cell and northeastern corner of the landfill are along the three preferential groundwater flow paths.

Eight target contaminants exceeded NJDEP Groundwater Quality Standards (GWQS) at a frequency of five percent or greater of the total number of samples: 1,4-dioxane , benzene, TCE, di(2-ethylhexyl) phthalate (synonym: bis(2-ethylhexyl) phthalate (DEHP), alpha benzene hexachloride (alpha-BHC), lead, arsenic, and chromium. Two tentatively identified compounds (TICs), phenobarbital, and tert-amyl methyl ether (TAME; synonym: 2-methoxy-2-methylbutane), exceeded the generic criteria for synthetic organic compounds (SOCs).

Groundwater Contaminant	No. of Detections	Range of Detections [µg/L]	No. of Exceedances	GWQS [µg/L]
1,4-dioxane	101	0.44 J – 290 J	101	0.4
Benzene	38	0.1 J – 90 J	26	1

Groundwater Contaminant	No. of Detections	Range of Detections [µg/L]	No. of Exceedances	GWQS [µg/L]
TCE	60	0.075 J - 4 J	9	1
DEHP	18	2 J - 15	10	3
Alpha-BHC	20	0.0025 J – 0.073	9	0.02
Lead	52	1 – 175	11	5
Arsenic	16	0.46 J - 6.4 J	8	3
Chromium (total)	35	0.53 J - 262 J	7	70

The above table summarizes analytical results of groundwater samples collected during the OU2 remedial investigation conducted between 2010 and 2015 by HDR and, which were used to develop the eight target analyte COCs described above.

The horizontal extent of 1,4-dioxane-contaminated groundwater is roughly three times longer than it is wide, and is oriented in a northeast-southwest direction, with the North Waste Cell as the “hot spot”. The contamination extends from the overhead transmission lines that run perpendicular to Parker Road southwest of the landfill, to County Route 513 aka Washington Turnpike to the northeast. To the west, the contamination extends to the southeastern portion of the horse farm, and to the east, it extends to Parker Road.

1,4-Dioxane was detected in the deepest intervals in many of the multi-level wells and in several conventional (single-depth screened wells); detections at 20 of 26 bedrock monitoring wells exceeded the criterion in the deepest sample interval. Vertical migration of 1,4-dioxane extends to the limits of bedrock transmissivity within each bedrock borehole evaluated, with an average depth of roughly 454 feet below ground surface (bgs).

Benzene exceeded the 1 µg/L criterion at four locations with concentrations up to 90 J µg/L and at maximum concentrations of 980 D µg/L in the NJDEP samples. The benzene plume is roughly half the size of the 1,4-dioxane plume, but has the same general shape. Unlike the 1,4-dioxane plume, the benzene plume appears to originate near the northeast corner of the landfill. Most exceedances for benzene were in the shallower depth intervals.

TCE exceeded the 1 µg/L criterion at five locations with concentrations up to 12 µg/L in bedrock and up to 4.3 JD µg/L in the overburden aquifer. Based on RI data, the TCE plume is largely confined to the footprint of the landfill with the exception of a finger extending northeast from the landfill to Schoolhouse Lane. No TCE exceedances were deeper than 215 to 220 feet with the exception of one duplicate result.

DEHP exceeded the 3 µg/L GWQS at seven locations with concentrations up to 15 µg/L. The DEHP plume has two separate, far-reaching lobes. One lobe extends to the southwest and south towards the transmission lines perpendicular to Parker Road all the way to the WRA series wells on either side of Trout Brook. The other lobe is to the northeast, where a narrow finger of the plume follows the Lamington River Un-named Tributary (UNT), extending past County Route 513 to the confluence of the tributary with the Lamington River. The highest concentrations (30 to 33 µg/L), which were detected in NJDEP samples, are in the area where the preferential flow paths converge near well CF-204D and groundwater flow is artesian. DEHP exceeded the GWQS at 558 feet in one location.

Alpha-BHC exceeded the 0.02 µg/L criterion at four locations with concentrations up to 0.073 µg/L. The bulk of the plume is generally within the landfill footprint. A portion outside the landfill to the northeast extends almost halfway to Schoolhouse Lane and a portion outside the landfill to the west

extends to the southern corner of the horse farm around well CF-216D. Only the samples collected in June 2014 had alpha-BHC detections. NJDEP PCEM sampling program does not include the analysis of pesticides. The deepest alpha-BHC exceedance was 365 ft. bgs, the deepest interval at that location.

Lead exceeded the 5 µg/L criterion at seven locations outside the landfill footprint in 11 RI samples with concentrations up to 175 µg/L. The locations with the highest concentrations are to the northeast. This plume begins near the northeastern landfill perimeter boundary, occupies the area up to Schoolhouse Lane, and is constrained in width by the confining ridges. From Schoolhouse Lane, a narrow finger of the plume follows the Lamington River UNT continuing to County Route 513 where it appears to terminate. The deepest lead exceedance was at 438 ft. bgs, in the deepest interval at that location.

Arsenic exceeded the 3 µg/L criterion at six locations with concentrations up to 6.4 J µg/L. Based on the RI results, the arsenic plume has two sections – a detached, narrow section to the northeast of the landfill beginning roughly half-way between the northeast perimeter of the landfill and Schoolhouse Lane and ending with a very narrow finger at County Route 513, and the main section roughly matching the landfill footprint in size and shape, but with a location offset from the landfill to the southwest. The deepest arsenic exceedance was at 362 ft. bgs, in the deepest interval at that location. In NJDEP's overburden aquifer samples, arsenic exceeded the GWQS only marginally (to 5.8 J µg/L) with the exception of one location that had concentrations of 11.2 to 44.5 µg/L.

Chromium exceeded the 70 µg/L criterion at five locations with concentrations up to 262 J µg/L. The chromium plume is very narrow and extends west to northeast from well CF-212D to well CF-201D. The deepest exceedance was at well CF-206D at 558 ft. bgs in the central section of the plume.

Phenobarbital exceeded the criterion of 5 µg/L in seven overburden wells with concentrations of up to 36 JN µg/L (well PTO-2) and in 15 bedrock wells with concentrations of up to 37 JN µg/L (well D-7). In the EPA RI samples (all from bedrock wells), it was detected at concentrations of up to 19 JN µg/L (well CF-224D), with exceedances at four wells or open boreholes (i.e., in packer testing samples prior to well completion). In the overburden wells, the criterion was exceeded at three wells within the landfill, two wells outside the southwest perimeter of the landfill, and at two wells to the northeast at Schoolhouse Lane. In the bedrock aquifer, phenobarbital contamination above the criterion was found at 15 wells, including within the landfill, on its perimeter and further to the south than in the overburden (CF-218D), as well as at wells to the northeast of the landfill up to Schoolhouse Lane. The deepest interval that exceeded the criterion was from 432 to 442 feet at well CF-204D to the northeast of the landfill.

TAME exceeded the criterion of 100 µg/L in the NJDEP samples from 11 overburden and 12 bedrock wells. The highest concentrations were 380 JNB µg/L in the overburden wells (MW-6 on the landfill's southern perimeter) and 480 JNB µg/L in the bedrock wells (CF-11D on Schoolhouse Lane). The EPA RI samples, all of which were collected from bedrock wells, did not have TAME reported as a TIC. The deepest interval with an exceedance for TAME was reported for the 244 to 254 foot interval at well WRA-3-1 to the south of the landfill, south of Parker Road.

Surface water samples from the four streams around the landfill and the seeps and springs met the surface water standards for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides and polychlorinated biphenyls (PCBs). Four metals – copper (dissolved), lead (dissolved), silver (total) and cadmium (dissolved) - were at concentrations exceeding the NJDEP Surface Water Quality Standards (SWQS) in the streams:

- Copper (dissolved) concentrations exceeded the criterion of 2.2 µg/L at all three sampling locations on East Trout Brook where concentrations ranged from 5 J to 6.7 J µg/L. On Trout Brook, only one location had an exceedance of dissolved copper. The Lamington River and Tanners Brook UNTs did not have any dissolved copper exceedances.
- Lead (dissolved) concentrations exceeded the criterion of 5.4 µg/L at two locations on the Tanners Brook UNT where concentrations ranged from 6 J to 9 J µg/L, but the dissolved lead concentration at a downstream location was below the criterion. Dissolved lead marginally exceeded the criterion only at the most upstream location on the Lamington River UNT (5.8 J µg/L).
- Silver (total) concentrations exceeded the criterion of 0.12 µg/L at two locations on East Trout Brook (0.46 J and 0.54 J µg/L).
- Cadmium (dissolved) concentrations exceeded the criterion of 0.056 µg/L at one location on East Trout Brook (0.19 J µg/L).
- Though widespread in surface water near CFS, 1,4-dioxane did not exceed the comparison criterion value (22,000 µg/L). Its presence in streams and seeps indicates that contaminated groundwater originating at the landfill is upwelling into the streams and seeps. The highest concentration of 1,4-dioxane at the Tanner's Brook UNT (35 µg/L) as well as in a sample collected by NJDEP on the Lamington River UNT north of Schoolhouse Lane (44 D µg/L) are only one order of magnitude below the highest detected concentration in the RI bedrock groundwater samples (350 µg/L). This is indicative of little dilution in surface water and that a significant portion of water in the streams originates in the aquifers.

The RI included collection of sediment samples from the same four streams as the surface water samples:

- Copper exceeded the NJDEP freshwater sediment Lowest Effects Level (LEL) of 16 milligrams per kilogram (mg/kg) at three locations on two streams with concentrations ranging from 18.2 J to 28.2 J mg/kg. The location on Tanners Brook UNT was the furthest upstream location (closest to the landfill) and bounded by locations downstream where the concentrations of copper were below the LEL.
- Lead exceeded the freshwater LEL of 31 mg/kg at three locations on the Lamington River UNT with concentrations ranging from 36.4 J to 71.4 J mg/kg. All three locations are downstream of an intervening location between the landfill and the headwaters of the Lamington River UNT where the concentration of lead was below the LEL.
- Silver marginally exceeded the freshwater LEL of 0.5 mg/kg in only one sediment sample where the concentration was 0.56 mg/kg. This sample was from the furthest upstream location on the Lamington River UNT.
- Cadmium exceeded the freshwater LEL of 0.6 mg/kg at seven locations (concentration range of 0.94 J to 2.6 mg/kg), five of which are along East Trout Brook; two are along the Lamington River UNT.
- Arsenic exceeded the freshwater LEL of 6 mg/kg at five locations with concentrations ranging from 6.3 J to 9.5 mg/kg. Distribution of these locations was amongst all streams except Trout Brook; none was from an upstream location close to the landfill.

- Mercury marginally exceeded the freshwater LEL of 0.17 mg/kg at one location on Trout Brook (0.27 mg/kg).
- Manganese exceeded the freshwater LEL of 630 mg/kg at two downstream locations on East Trout Brook (concentrations of 785 and 1,400 mg/kg). The manganese concentrations at the upstream locations closer to the landfill were below the freshwater LEL.

Soil samples collected along the landfill perimeter road did not contain concentrations of VOCs, SVOCs, pesticides or PCBs above the applicable criteria. Nine metals - aluminum, arsenic, beryllium, cadmium, cobalt, manganese, nickel, silver, and vanadium - were detected at concentrations exceeding criteria in various combinations at all five soil boring locations along the landfill perimeter road. Arsenic, which exceeded applicable criteria in a duplicate sample only, is the only metal in soil that is also a groundwater COC.

Contamination originating at the landfill enters the overburden and bedrock aquifers, shallow and deep groundwater flows transport it outward, and it predominantly discharges to surface water in the surrounding area, although some portion of the contamination remains in the bedrock aquifer. Along the migration pathways, benzene undergoes biodegradation and volatilization from the groundwater table and surface water, while 1,4-dioxane, which is less volatile, does not biodegrade, or sorb to organic matter, does not. Transport of 1,4-dioxane is via advection with minimal attenuation through these migration pathways. Although TCE is subject to reductive dechlorination, this is not evident at CFS. DEHP tends to sorb strongly to particulates, has low solubility, and will biodegrade in both water and soil under aerobic conditions. It is widespread, but at low concentrations. Transport of inorganics such as arsenic, chromium and lead, will be via adsorption to particles along the groundwater pathway and will have the potential to accumulate in stream sediments, although evidence of this mechanism is indeterminate.

The horizontal extents of the COC plumes are similar in shape, with the most predominant lobe extending from the landfill perimeter to well CF-201D to the northeast. This particular component of the plumes follows the three preferential flow pathways from the landfill to Schoolhouse Lane, then bends eastward, then north following the Lamington River UNT. This portion of groundwater contamination originating at CFS is well-defined. Transport of each COC is via the preferential flow paths in the bedrock between the two confining ridges primarily via advection, diffusion and dispersion. Because of the strong evidence of the preferential pathways and the predominant southwest-northeast groundwater flow, for areas with data gaps, it is reasonable to assume that the same transport mechanisms play a similar role throughout the site.

The vertical extents of the COCs in groundwater are highly variable and controlled by the transmissivities of individual fractures and groups of fractures. Vertical transport is through fractures, primarily via advection, downward to the limit of transmissivity at locations near the landfill, and upward at locations near surface water bodies. At depth, few, if any, transformation processes influence the concentrations of the COCs.

Transport of contaminants to surface water is from groundwater discharge to gaining streams. The continual presence of surface water contamination is evidence of a substantial mass of contaminants in overburden and shallow bedrock groundwater, continually feeding the headwaters of the streams around CFS.

It is evident from isoconcentration maps, that the source of the contaminants is the landfill itself, with two locations within the landfill predominant – the North Waste Cell at the northern corner of the landfill and the northeast corner.

1,4-Dioxane is the contaminant most frequently detected and frequently elevated above the criterion in groundwater and is also prevalent in surface water. Because 1,4-dioxane is miscible, readily transported via advection, and is recalcitrant to transformation processes, it is the most prevalent and problematic groundwater COC. The plumes associated with each groundwater COC have many similarities and all follow preferential flow paths in bedrock to the northeast of the landfill, with a similar, but less documented pattern to the southwest. Few, if any, transformation processes reduce contaminant concentrations or the spread of contamination in the bedrock aquifer.

Surface water contamination is a result of contaminated groundwater discharging to surface water. 1,4-Dioxane is prevalent in surface water, but poses little human health or ecological risks. Low concentrations of sediment contamination with polycyclic aromatic hydrocarbons (PAHs) and metals do not appear to be landfill related, and the FS will not address sediments based on the results of the Screening Level Ecological Risk Assessment (SLERA).

Construction of a municipal water supply in 2015 eliminated the pathway for humans to ingest and contact contaminated groundwater. However, as the existing GWTP cannot treat for 1,4-dioxane nor is it sufficiently capturing contaminants leaching from the landfill, groundwater contamination remains an issue should the COC plumes increase in extent beyond the water supply boundary where private wells are still in use.

The findings of the Baseline Human Health Risk Assessment (BHHRA) and SLERA are summarized below:

Receptor	Medium	Noncancer Hazard	Cumulative Cancer Risk	Ecological Hazard
Recreational user	Surface water	Adult Hazard Index (HI): 2.4E-01 Child HI: 4.6E-01	5.7E-06	NA
	Surface water downstream of GWTP	Adult HI: 3.5E-02 Child HI: 7.8E-02	8.4E-06	NA
Residentyep	Groundwater	Adult HI: 4.0E+00 Child HI: 4.9E+00	1.2E-03	NA
Aquatic biota, benthic invertebrates, amphibian, plants	Surface water / Sediment	NA	NA	Inorganics, PAHs, 2,3,4,6-tetrachlorophenol, alpha-chlordane exceedance of screening benchmarks.
Wildlife	Surface water / Sediment	NA	NA	Lowest Observed Adverse Effect Level (LOAEL)-based Hazard Quotient (HQ) of 1.7E+00 for avian invertivore exposure to vanadium in sediment. LOAEL-based HQs are less than 1 for all other Constituent of Potential Concern (COPCs) and receptor groups.

The data collected during the RI by both EPA and NJDEP are sufficient to support development of remedial alternatives in the FS and preparation of a ROD. Additional data are required to support remedial design, however, and may be incorporated into a Pre-Design Investigation (PDI), including:

- Further assessment of preferential flow paths in bedrock at areas other than to the northeast of the landfill. This may include additional Willowstick surveys or the equivalent to the southwest and west;
- Long-term pump tests at deep bedrock wells to the southwest and west to determine drawdown and yield in these areas;
- Groundwater sampling and analysis for naturally-occurring microbes, enzymes, and other analytes indicative of transformation processes to confirm the contribution, if any, to contaminant reduction;
- Continued periodic sampling of EPA bedrock wells to monitor performance and inform the pre-design and design phases with current information; and
- Bench-scale or pilot test evaluation of 1,4-dioxane treatment alternatives as an add-on to the existing GWTP.

1 Introduction

This RIR was prepared for the EPA by Henningson, Durham and Richardson Architecture and Engineering, P.C., in association with HDR Engineering, Inc. (HDR) to present the findings of the RI for the CFS Landfill Superfund Site, located in Chester and Washington Townships, Morris County, New Jersey (Figure 1-1). It also includes a review and evaluation of previous investigations and sampling conducted by NJDEP primarily between 2011 and 2015 concurrent with the EPA's investigation. The RI is part of the RI/FS being performed by HDR under Work Assignment Number 018-RICO-0256 of the EPA Remedial Action Contract 2 (RAC 2), Contract Number EP-W-09-009.

The work reported herein was performed under the EPA-approved Quality Assurance Project Plan (QAPP), the original work plan and subsequent work plan amendments and revisions (HDR 2011b, HDR 2013a, HDR 2013b, HDR 2014, HDR 2016), and in accordance with the *Interim Final Guidance for Conducting Remedial Investigation/Feasibility Studies under the Comprehensive Environmental Response, Compensation, and Liability Act* (EPA 1988).

1.1 Purpose of Report

The purpose of the RIR is to present the nature and extent of contamination in environmental media at CFS, to assess contaminant fate and transport, to present the findings of the BHHRA and SLERA, and to provide conclusions and recommendations regarding the findings of the RI and in support of the FS.

1.2 Report Organization

This RIR consists of nine sections:

Section 1.0 – Introduction provides a general description of CFS, including information on its history and previous investigations.

Section 2.0 – Field Investigation describes the activities conducted as part of the RI, including the investigation of groundwater, surface water, sediment, and soil; geophysical surveys, land surveys, and ecological surveys (wetlands and wildlife).

Section 3.0 – Physical Characteristics of CFS describes surface features, land use, topography, climate, geology, soils, surface water hydrology, hydrogeology, and ecological resources.

Section 4.0 – Nature and Extent of Contamination presents the nature and extent of contamination in groundwater, surface water, soil, and sediment.

Section 5.0 – Contaminant Fate and Transport provides information on fate and transport for COCs, a description of transport and mechanisms of migration, and presents the CSM.

Section 6.0 – Summary of Baseline Human Health Risk Assessment presents a summary of the BHRRA which includes background information relevant to the potential human receptors, data evaluation, a CSM, identification of potential human receptor populations and exposure scenarios, selection of chemicals of potential human health concern, calculation of exposure point concentrations, toxicity assessment, receptor-specific risk characterization, uncertainty analysis and conclusions.

Section 7.0 – Summary of Screening Level Ecological Risk Assessment presents a summary of the SLERA which includes background information relevant to the environmental setting and potential ecological receptors, data evaluation, a CSM indicating potential exposure pathways,

selection of chemicals of potential ecological concern, a hazard quotient evaluation using a comparison of detected concentrations to ESLs, uncertainty analysis and conclusions.

Section 8.0 – Summary and Conclusions presents summaries of the nature and extent of contamination, contaminant fate and transport, and conclusions and recommendations.

Section 9.0 – References lists the reference documents used in preparation of this RIR.

1.3 Site Description

CFS is located at 98 Parker Road, Chester Township, Morris County, NJ (Figure 1-1). In the context of this report, CFS refers to the Superfund site as a whole – i.e., it includes both the landfill itself (Operable Unit 1) and the downgradient areas and impacted media (groundwater, surface water and sediment) outside the landfill property boundary (Operable Unit 2).

Operable Unit 1

OU1 is all media within the landfill property boundary including soil and groundwater within both the overburden and bedrock aquifers. The CFS landfill is an inactive municipal landfill consisting of three separate fill areas (Figure 1-2) capped and closed in the mid-1990s (NJDEP 2011a). The landfill property covers about 115 acres on four tax parcels (Block 37, Lots 15, 16, and 16.01 and Block 17, Lot 17) and extends into portions of Chester and Washington Townships. The CFS landfill property includes an approximately 65-acre multilayered terraced cap, passive landfill gas venting system, a shallow groundwater recovery and treatment system, security fencing, surface water runoff controls, and a perimeter access road (Figure 1-3).

The shallow groundwater recovery system consists of recovery wells spaced around most of the landfill perimeter. All but one of the wells are screened at the bottom of the overburden material (recovery well RW-T is installed in bedrock) and pump through a force main to a GWTP operated by a contractor retained by the NJDEP. Operation of individual recovery wells is not continuous.[1] Groundwater treatment occurs prior to discharge to surface water at East Trout Brook. During the first two full years of operation (1998 and 1999), 39.1 and 31.6 million gallons were recovered and treated, respectively (O'Brien & Gere 2001). The plant treated approximately 19.7 million gallons of groundwater in 2010, 34.3 million gallons in 2012 (NJDEP 2015a), and 15.6 million gallons in 2016 (Chapman 2017a).

The GWTP was designed and constructed before 1,4-dioxane was identified as a COC at CFS in 2005 (Giles 2005). Before that, benzene was the primary contaminant driving the groundwater investigations at CFS. The treatment system design was to treat shallow groundwater and landfill leachate for biochemical oxygen demand (BOD), total suspended solids (TSS), total organic carbon (TOC), ammonia-nitrogen, VOCs, heavy metals, and total phenolics (O'Brien & Gere 1993). In recent years, 1,4-dioxane concentrations in effluent discharged from the plant to East Trout Brook have averaged about 20 µg/L (NJDEP 2014). Information on other constituents in the effluent is included in Section 3.5.

In 2011, an EPA contractor conducted a treatability study in order to evaluate treatment of 1,4 dioxane, using a combination of ozone addition and ultraviolet radiation, followed by polishing of the treated effluent with carbon filtration. A detailed study description is in Section 1.6. The results of

[1] The treatment plant operates below its full constructed capacity. Observations made over the course of the RI indicate that recovery wells are not always operational because of force main capacity limitations (insufficient diameter to convey maximum flow from all recovery wells at the same time) and maintenance activities.

the bench scale study indicated that for influent concentrations of up to 200 µg/L, 1,4-dioxane concentrations were reduced by approximately 70 to 80 percent with one pass through the system.

NJDEP conducted treatability and pilot test studies to assess the potential for reducing 1,4-dioxane concentrations in plant effluent to below the previous ISGWQC of 3 µg/L (NJDEP 2008, Kimball 2012, Kimball 2015, NJDEP 2015a).[2] Subsequently, HDR and a subcontractor conducted an ex-situ treatability study/pilot test using source area groundwater and treatment plant effluent. The pilot test demonstrated that synthetic adsorbent was successful in reducing 1,4-dioxane concentrations to below the current 0.4 µg/L GWQS (HDR 2017a). Based on the results of this treatability study/pilot test (the pilot test/treatability study is described in detail in the FS report), and in light of the benefits associated with this technology, a full-scale system is evaluated as an ex-situ treatment option for the remedial alternatives presented in the FS report.

In addition to operating the GWTP, NJDEP conducts post-construction environmental monitoring (PCEM), which consists of collecting groundwater, surface, and sediment samples at the landfill and in its vicinity each spring and fall (Section 1.6). The previously existing monitoring wells and the recovery wells are on Figures 1-4a through 1-4g.

Operable Unit 2

OU2 consists of groundwater in both the overburden and bedrock aquifers, surface water, sediment and soil vapor outside the landfill property boundary. Initially, the OU2 study area was generally bounded to the north by residential parcels on both sides of Schoolhouse Lane, to the east by Parker Road, and to the south and west by individual residential and agricultural (horse farm) lots adjacent to the landfill (Figure 2-1), covering approximately 444 acres. Adjustments to these initial boundaries resulted from data obtained as the RI fieldwork progressed. At completion of the RI fieldwork, the study area had expanded to the north to the confluence of the Lamington River UNT and the Lamington River, and to the south to a property adjoining an UNT of Trout Brook. The OU2 study area generally coincides with the currently known extent (CKE) of groundwater contamination designated by NJDEP. The combined boundary of the tax parcels within which OU2 investigations took place is the OU2 study area shown on Figure 1-5. One well, CF-230D, is just outside the OU2 study area boundary within the 3,000 plus acre Black River Wildlife Management Area.

1.4 Site History

The Filiberto family owned and operated CFS beginning in the 1940s as a municipal refuse and solid waste landfill and for the disposal of household and industrial wastes, animal carcasses, sewage sludge, septic tank wastes, chemicals, and waste oils. Most notably, the landfill accepted disposal of chemicals, off-spec PCPs and pharmaceutical wastes by the pharmaceutical and PCPs industry in northern New Jersey. Ownership and operation changed to Filiberto Sanitation Inc. sometime after disposal began, to Chester Hills, Inc. around 1972, and to Combe Fill Corporation around 1978.

Landfill operations ceased in November 1981 after liquidation of the Combe Fill Corporation when it filed for bankruptcy. According to landfill records summarized in the 1986 RIR prepared by Lawler, Matusky & Skelly Engineers[3] (LMS; LMS 1986), about five million cubic yards (5,000,000 CY) of buried

[2] The previous GWQC was 3 µg/L, however, the ISGWQC was 10 µg/L because the PQL was 10 µg/L (NJDEP 2008). In November 2015, the ISGWQC was reduced to 0.4 µg/L and the PQL to 0.1 µg/L. In January 2018, the 2015 ISGWQS of 0.4 µg/L was promulgated as the GWQS.

[3] LMS became part of HDR through acquisition in 2005.

waste are in the landfill. The landfill design specifications approved by NJDEP in 1972 called for the trench method of waste disposal, and it appears that this method, or some variation thereof, also took place prior to 1972. As detailed in the approved design, a trench dug to competent bedrock or to five feet above the seasonal high water was backfilled with two feet of compacted residual soil, if the bedrock was exposed. Several lifts three to five feet deep and consisting of compacted refuse and solid waste were then deposited in the trench. At the end of each working day, the operator spread one foot of residual soil over the waste in the trench.

NJDEP inspection reports from 1973 to 1981 noted numerous operating violations, including the absence of an initial layer of residual soil on the bedrock prior to waste placement and absent or inadequate final daily cover. Landfill runoff and leachate were entering the fractures in the bedrock surface in newly excavated trenches (Markewicz 1979). Other frequently observed violations included uncontrolled litter, exceeding the maximum allowable width of the operating face, and the excavation of previously deposited waste.

The inspection reports also noted that excavation and breakup of the saprolite, the weathered bedrock layer above competent bedrock, was part of trench excavation. Trench excavation reportedly commenced in what was termed the new fill area in 1972 and advanced to the west and south. As detailed in the 1986 RIR, the older sections of the landfill (pre-1972) were in the northern portion of the current landfill footprint, to the northwest and southeast of the power line right-of-way (Figure 1-2). The combined size of the older areas was approximately 15 acres. After 1972, landfilling proceeded in the area to the west and southwest of the older sections (to the northwest of the power line right-of-way only), in an area estimated at 50 acres (LMS 1986).

Listing of CFS on the NPL occurred on September 1, 1983. The 1986 RI/FS identified a wide range of COCs consistent with known past disposal practices at the landfill. Despite a ROD filed in 1986 and subsequent closure of the landfill, additional investigations were required due to continuing and persistent levels of groundwater contamination. Details on landfill operations, waste disposal activities, and additional history are in the 1986 RI/FS report (LMS 1986) and in other previous reports summarized in Section 1.6. The source of contamination in the downgradient areas outside the landfill boundary is leachate that originates at the landfill and migrates both vertically and horizontally impacting both the shallow (unconsolidated and saprolite) and deep (fractured bedrock) aquifers as well as surface water and sediment in the streams.

The deep bedrock aquifer is the major source of potable water in near CFS; however the recent completion of a municipal water line (July 2015) provides an alternate source of drinking water to the impacted area (Section 1.6).[4] Contaminants that had migrated off-site impacted potable residential wells northeast of the landfill. Water samples collected from private wells by NJDEP in the 1980s indicated that some of the private wells contained VOCs from the landfill. These initial investigations identified a core area with about 325 homes in need of an alternate water supply along Schoolhouse Lane, Parker Road, and parts of Old Farmers Road.

The remedy selected in the 1986 ROD (EPA 1986) consisted of the following:

- An alternate water supply for impacted homes;
- Capping of the landfill in accordance with RCRA requirements;

[4] Not all properties within the service area of the new water line connected to public water as a small number of property owners refused to be connected (EPA 2015d, WTMUA 2015).

- An active collection and treatment system for landfill gases;
- Pumping and on-site treatment of shallow groundwater and leachate with discharge of treated water to Trout Brook;
- Surface water controls;
- Security fencing; and
- Environmental monitoring.

After additional sampling indicated the landfill gas was not amenable to active treatment (composition and quantity), the landfill gas system changed to a passive system and EPA issued an ESD (EPA 2006). Section 1.6 describes the ROD and ESD in detail.

Completion of the landfill cap construction documents was in February 1992. The final capped area is approximately 65 acres. The GWTP, drainage ditches, landfill perimeter roads, and detention basins outside the capped area occupy approximately 20 acres. As part of the design, 65 passive gas vent wells were installed in 1994. Installation of the clay and liner portions of the cap proceeded from 1994 to early 1995 and the installation of the top soil layer was completed in November 1995. The GWTP has been in operation since June 1997 and is permitted to divert up to 130 gallons per minute (gpm; 68.4 million gallons per year).

A soil investigation was conducted between December 2003 and June 2004 along the northern edge of the landfill after waste materials were encountered during the installation of landfill gas probes. The soil borings and test pits installed at the time revealed an area outside of the capped landfill that contained a significant volume of pharmaceutical wastes, personal care products and drums. This area became known as the North Waste Cell (Figure 1-2). The North Waste Cell was excavated in 2006 and about 27,300 tons of non-hazardous soil and debris were excavated and disposed off-site. Approximately 500 containers ranging in volume from one gallon to 55-gallon drums were also removed, sampled, analyzed and disposed off-site. The containers included personal care items, pharmaceutical products and laboratory and chemical wastes. The excavated area was backfilled and the area restored.

Portions of the North Waste Cell were found to extend under the landfill perimeter road but were left in place so that the existing road and landfill cap were not undermined. An extension of the existing landfill cap over this area was constructed between August and October 2008 (Section 1.6).

An alternate water supply remedy was completed in July 2015 through the extension of a public water line. Seventy-three homes and businesses with a total of 80 connections are served by the new water supply (Section 1.6)

1.5 Contaminants of Concern

The list of groundwater COCs at CFS has evolved over time. Several COCs identified in the past as originating at the landfill are currently at concentrations below applicable standards, including various Freon™ compounds, methylene chloride, tert-butyl alcohol (TBA), chlorobenzenes, and ethyl ether. Others, such as tetrachloroethylene (PCE) and vinyl chloride (VC), were detected at concentrations exceeding applicable criteria in less than five percent of the RI samples. 1,4-dioxane has been considered an “emerging contaminant” by the EPA and state regulators for several years

but was not considered a target compound in environmental investigations until recently.[5] The EPA RI also identified two TICs as COCs.

The following chemicals are groundwater COCs for this RI, based on the frequency of detection and the exceedance of applicable standards and comparison criteria in the RI samples: [6]

Use/Origin	Remarks
1,4-Dioxane	
Solvent stabilizer; by-product in consumer products; used in synthesis of other products, extraction and dissolution of intermediate products in the pharmaceutical industry; solvent in paints, lacquer, varnish remover, stains, inks, resins, oils, and waxes; antifreeze additive, inert ingredient in pesticides and fumigants (Mohr 2001, Mohr et al 2010, Mohr 2013, NTP 2014).	The most likely explanation for the widespread presence of 1,4-dioxane at CFS is that it is a by-product of ethoxylated surfactants (Mohr 2013), i.e., it is frequently found in detergents, shampoos and soaps. Large amounts of off-spec pharmaceuticals and PCPs were disposed of at CFS by the local pharmaceutical and PCPs industry.
Benzene	
Used to make chemicals for manufacturing of plastics, resins, nylon, and other synthetic fibers; production of explosives, photographic chemicals, rubber, lubricants, dyes, adhesives, coatings, paint, detergents, drugs, and pesticides. Also used as a solvent and in printing, lithography, and food processing. Historic use as a gasoline additive has been greatly reduced in the US since the 1990s (NIH 2015).	Before 1,4-dioxane was identified as a COC, benzene was the primary contaminant driving the groundwater investigations at CFS. Typically detected in landfill leachate at concentrations ranging from 0.2 to 1,630 µg/L (concentrations associated with landfills as a group, not specifically CFS). Originating from household or industrial chemicals typically at concentrations less than 1 milligram per liter (mg/L) (Kjeldsen et al. 2002).
TCE	

[5] The first analyses of samples for 1,4-dioxane at CFS appear to date to 2005 for groundwater and 2006 for soil and waste materials (North Waste Cell excavation and disposal) based on documents reviewed during the RI.

[6] Only groundwater samples collected during the RI from wells considered to be compliant with NJDEP well construction standards (N.J.A.C. 7:9D Well Construction and Maintenance; Sealing of Abandoned Wells) and that were also collected using low-flow protocol were used for the determination of groundwater COCs among the analytical target compounds. Packer testing samples, pump test samples and samples from non-compliant wells were not used to determine COCs. NJDEP's samples collected concurrently with the EPA's RI samples were not included in the determination of COCs for target compounds because data validation information for the NJDEP PCEM samples was not available. As an example, thallium exceeded the standard in 24 of NJDEP's PCEM samples while it did not exceed the standard in any of the approximately 200 EPA RI samples.

Use/Origin	Remarks
Widely used chlorinated solvent, especially in metal degreasing. Also used as an inhalation anesthetic until the 1980s.	CFS is likely the source of TCE within the RI study area because of its prevalence at Superfund sites and its past use in the pharmaceutical industry.
DEHP	
DEHP is mainly used as a plasticizer in the production of polyvinyl chloride (PVC) and vinyl chloride resins (ATSDR 2002).	At CFS, its origin is likely its use as a plasticizer in enteric-coatings of solid oral drug products to maintain flexibility (large numbers of pharmaceuticals, including pills, were observed during buried drum investigations and the excavation of the North Waste Cell; Section 1.6).
Alpha-BHC	
Alpha-BHC is an isomer of hexa-chlorocyclo-hexane (HCH, aka, Lindane), an insecticide, and is a manufacturing by-product (UNEP 2007, Commission for Environmental Cooperation 2006). Use of lindane in agriculture was banned in the US in 2006 but it is still used as a second tier scabicide/ liceridant (Jaksich 2014).	Alpha-BHC was not identified as a COC at CFS prior to this RI. Its presence in groundwater may be related to agricultural uses in the area; however, given its use as a pharmaceutical treatment for lice and scabies, it may originate from pharmaceutical products disposed of at CFS.
Arsenic	
Arsenic is a heavy metal that is ubiquitous in the environment, and is also commonly found in landfill leachate. Concentrations of arsenic exceed drinking water standards in about half of groundwater monitoring wells downgradient of unlined municipal solid waste landfills (Parisio 2006).	The historical use of arsenical pesticides applied to agricultural crops (NJDEP 1999) is another potential source of arsenic because CFS and neighboring properties were once used for agricultural purposes (HDR aerial photograph review).
Lead	
Lead is a heavy metal that is ubiquitous in the environment. It is also frequently associated with municipal solid waste landfill leachate at concentrations ranging from 100 to 1,000 µg/L (Lee and Jones 1991).	Lead in CFS groundwater and surface water is likely a result of landfill leachate. Lead has also been reported as a common contaminant in 1,4-dioxane with concentrations of up to 0.25 parts per million (ppm) (Mohr 2010).
Chromium	

Use/Origin	Remarks
Metallic chromium is used mainly for making steel and other alloys. Chromium compounds in either the chromium-3 or chromium-6 forms are used for chrome plating, dyes and pigments, leather and wood preservation (EPA 2015a).	Chromium is likely a result of landfill leachate from the presence of various types of metal debris within the landfill.
Phenobarbital	
Phenobarbital is a barbiturate and a nervous system depressant and is currently used primarily for the treatment of epilepsy and seizures (Wikipedia 2018a). While the use of barbiturates peaked approximately four decades ago, phenobarbital has been detected in the influent and effluent of municipal sewage treatment facilities (Heberer 2002) and in groundwater near landfills (ACS 2006, ATSDR 2006).	Phenobarbital at CFS is attributed to large amounts of off-spec pharmaceuticals and PCPs that were disposed of at the landfill by the local pharmaceutical and PCPs industries. During the excavation of the North Waste Cell in 2006, large numbers of containers were observed and documented (see Section 1.6), including several containers with labeling information identifying phenobarbital as an active ingredient.
TAME	
TAME (aka, 2-methyoxy-2-methylbutane) is used mostly as an oxygenate for gasoline and also as a solvent in organic synthesis. It can be used as a medium for a number of reactions and as an extraction solvent (Wikipedia 2018b).	TAME at CFS likely originates from laboratory wastes that were disposed of at the landfill by the local pharmaceutical and PCPs industries.

Metals with aqueous standards based on secondary characteristics (i.e. appearance, odor and taste) being aluminum, iron and manganese, are not treated as COCs for purposes of delineation in groundwater or surface water although these metals are evaluated in the risk assessments as COPCs. Cobalt is evaluated as a COPC in the BHHRA (Appendix CC) although cobalt did not exceed the GWQS and is not considered a COC for delineation purposes.

Surface water COCs are copper, lead, silver and cadmium. Sediment COCs are PAHs, benzyl butyl phthalate, copper, lead, silver, cadmium, arsenic, mercury, and manganese. In soil, nine metals are COCs: aluminum, arsenic, beryllium, cadmium, cobalt, manganese, nickel, silver and vanadium.

1.6 Summary of Previous Investigations and Remedial Activities at the CFS Landfill

A summary of available documents, inspections, investigations, and remedial activities at the CFS landfill beginning in the early 1970s is presented in this section and summarized in the table below. Further details follow the table and are also discussed throughout the RIR.

Summary of Prior Investigations and Remedial Activities – CFS Landfill			
Date	Activity	Major Findings/Actions	Source/References
ca. 1972 to 1983	Site inspections and sampling investigations	Landfill leachate impacting streams; groundwater contaminated with VOCs	Castner 1979, Markewicz 1979, URWA 1981, NUS 1983, LMS 1986
June 1982	Geologic reconnaissance of CFS and vicinity	Determination of rock types and bedrock structure, discussion of most likely groundwater flow directions	Germine 1982
1983	Macroinvertebrate survey	Trout Brook affected by landfill leachate/surface runoff	NJDEP 1983
September 1983	NPL listing	CFS listed on the NPL	
1984	Sampling of streams, leachate and residential wells	Leachate, surface water, and wells contaminated with VOCs and metals; sediment with VOCs, SVOCs, and metals	LMS 1986
1986	Remedial Investigation	Shallow and deep groundwater at landfill and potable wells contaminated with VOCs; landfill leachate and run-off contaminating Trout Brook	LMS 1986
1986	Record of Decision	Specified capping of landfill, alternative water supply for affected residences, pumping and treatment of shallow groundwater at landfill, investigation of deep groundwater	EPA 1986
1987	Feasibility Study	Developed and evaluated remedial action alternatives	LMS 1987
1988-1991	Remedial Design field sampling and testing	Confirmed presence of VOCs in surface water, VOCs, SVOCs and metals in sediment, and VOCs in groundwater	O'Brien & Gere 1991

Summary of Prior Investigations and Remedial Activities – CFS Landfill			
Date	Activity	Major Findings/Actions	Source/References
From the early 1990s	Installation of POETS; groundwater, CKE established	NJDEP installed POETS in homes as an interim measure pending design and construction of a public water supply system. NJDEP maintained and monitored systems at residences in Chester and Washington Townships	EPA Undated; NJDEP 2004
1993	Final Remedial Design	Design specifications for landfill cap, landfill gas collection and treatment system, and groundwater recovery and treatment system; groundwater recovery system effectiveness monitoring plan	O'Brien & Gere 1993
1993-1995	Buried drum investigations	Recovery of approx. 150 buried drums from eastern perimeter of the landfill. Drums sampled and disposed of on- and off-site	Dispoto 1997, Barkett 2004
1994-1995	Capping of main landfill area	Installation of the clay and liner portions of the cap, installation of the top soil layer	NJDEP 2011a
1995	Potable Well Sampling	NJDEP begins annual potable well sampling at about 160 homes for VOCs; from 1995 to 1998, none exceeded NJ drinking water standards. Influent water samples at eight of the approximately 32 properties with POETS consistently exceeded the MCLs	EPA 2015d
June 1997	Groundwater recovery and treatment system startup	Groundwater recovery and treatment system; shallow wells along landfill perimeter (bedrock well RW-T added early 2009), discharge to E. Trout Brook	NJDEP 2011a

Summary of Prior Investigations and Remedial Activities – CFS Landfill			
Date	Activity	Major Findings/Actions	Source/References
2001-2003	Soil gas investigations	Installation of soil gas probes around landfill perimeter to delineate landfill gases outside fill area and to identify additional areas of concern; waste encountered outside landfill cap area	NJDEP 2004
December 2003 – June 2004	Soil borings and test pits investigation	Waste area outside landfill cap investigated, found to contain significant volumes of pharmaceutical wastes, personal care products, and drums	NJDEP 2004
2006	Revision of the ROD	Change from active landfill gas collection/ treatment system to passive venting system	EPA 2006
2006-2007	Excavation of fill area outside landfill cap (North Waste Cell)	Excavation of a 0.4 acre area containing hundreds of containers; off-site disposal. 1,4-dioxane detected in soil and groundwater	Walshe 2005, NJDEP 2011a, TestAmerica 2009
2008	POETS Sampling	Discovery of 1,4-dioxane in well water of homes with POETS; POETS found to be ineffective in removing 1,4-dioxane	EPA 2015d
2008-2009	Extension of landfill cap	Landfill cap extended over former North Waste Cell area	NJDEP 2011b
April 2010	Alternate Water Supply Remedy	EPA takes over Alternate Water Supply Remedy from NJDEP	EPA 2015d
2011	Potable well sampling	Potable well sampling within 1 mile from CFS; 1,4-dioxane detected at 17 properties	Weston 2011, Weston 2012
2011	EPA 1,4-dioxane treatability study	Pilot study for residential POET using ozone	Environmental Restoration 2011
2012 - 2015	NJDEP 1,4-dioxane treatability studies	Research into 1,4-dioxane treatment for GWTP effluent	Kimball 2012, Kimball 2015

Summary of Prior Investigations and Remedial Activities – CFS Landfill			
Date	Activity	Major Findings/Actions	Source/References
2013	Potable well sampling	1,4-dioxane detected in nine of 26 samples (1.2 J to 4.9 µg/L)	NJDEP 2017a
2015	Parker Road Water Main Extension	Extension of water main, connection of 73 homes and businesses	EPA 2015c, EPA 2015d, WTMUA 2015
On-going	Post-Construction Environmental Monitoring (PCEM)	Post-construction monitoring to ensure the effectiveness of the CFS landfill remedial action (groundwater and surface water sampling and analysis).	NJDEP 2009b

The first environmental concerns at CFS were related to landfill leachate that impacted nearby streams. In 1972, a fish kill in Trout Brook suspected to have been caused by leachate discharged from the landfill prompted an investigation by the New Jersey Division of Fish and Game, which in turn led to further investigations by the NJDEP. Follow-up inspections of Trout Brook and East Trout Brook, nearby springs, and wells on residential properties by NJDEP, local health officials, and interested citizens in early- to mid-1973 confirmed the release of leachate to surface waters and groundwater. [7]

Leachate collection basins designed to collect surface runoff and leachate were included as part of a landfill design submitted to NJDEP under the original permit in 1972. NJDEP site inspection reports describe the collection basins as being located west and south of the landfill. During most years of operation, based on NJDEP and other site inspections, the leachate basins merely overflowed into the headwaters of Trout Brook. The NJDEP inspections often noted odorous leachate seeps (red, brown and black in color) emanating from the western and southern edges of the new fill and overflow from the leachate basins. Seeps suspected of causing the fish kill in Trout Brook in 1972 continued to be observed during inspections until the closure of the landfill.

NJDEP, Chester and Washington Townships recommended additional leachate treatment and recycling. According to NJDEP and township files (Markewicz 1973; George and Lustig 1973, in NUS 1983), a leachate collection and recirculation system was installed and operated from July 1973 to sometime in 1976. The system reportedly pumped the collected leachate back onto the fill for re-infiltration.

In 1974, NJDEP recommended the installation of four groundwater monitoring wells, two of which were installed by Combe Fill Corporation in 1977. The wells were initially sampled for metals, phenols, cyanide and sanitary constituents. Sampling of these wells reportedly continued until May 1981.

A March 1979 NJDEP site inspection report described waste disposal procedures at the landfill as consisting of the placement of waste into large trenches. According to the report, all overburden material above bedrock (soil and saprolite) was removed, putting the waste into direct contact with the exposed fractured bedrock surface. The removed soil and saprolite was used as daily cover. Once a

[7] The names used to refer to streams near CFS have changed over time, as described in Section 3.5. Current stream names were applied when describing historic investigations as much as possible. In some instances, the lack of locations figures in historic reports prevented differentiation between the separate sections of Trout Brook.

trench had been filled with waste, another was excavated alongside it. The NJDEP observers noted surface runoff and landfill leachate entering fractures in the bedrock surface in a newly excavated trench (Markewicz 1979). Leachate emanating from the fill areas and from an overflowing sump was observed to discharge into a marshy area at the headwaters of Trout Brook (Castner 1979).

Beginning in 1980, sampling and analyses of groundwater and leachate at the landfill, local residential wells, and nearby surface waters was conducted by Chester and Washington Townships, NJDEP, and local environmental groups - the Upper Raritan Watershed Association (URWA) and Help Avoid a Landfill Tragedy (HALT). Samples collected in March 1981 by NJDEP and a contractor for URWA detected several VOCs in groundwater and surface water, including heptane, 1,1-dichloroethane (1,1-DCA), trans-1,2-dichloroethene (trans-1,2-DCE), carbon tetrachloride, methylene chloride, xylenes, TCE, and tetrachloroethene (PCE). Concentrations of several compounds, including carbon tetrachloride, TCE and trans-1,2-DCE, exceeded 100 µg/L (URWA 1981).[8]

In May and June 1981, HALT organized sampling and analysis of approximately 90 local residential wells for VOCs. NJDEP also collected additional residential well samples in June, July and September of 1981. Sampled residences included households on Parker Road, Schoolhouse Lane, and East Valley Brook Road. This sampling supplemented a Chester Township private well testing program, which was conducted from January through September 1981. Results for two residences on Schoolhouse Lane indicated the presence of chloroform at 14 µg/L and TCE at 5.8 µg/L at one home, and of trichlorofluoromethane (Freon™ 11) at 187 µg/L, at the other (NUS 1983).

Based on the sampling results, NJDEP concluded that groundwater contamination existed on-site and that it might pose a threat to local water supplies. In September 1981, NJDEP issued an order to Combe Fill Corporation to discontinue waste disposal operations upon completion of the existing lift.

In August 1982, NJDEP performed a terrain conductivity survey to determine the location and direction of groundwater contamination. Results were interpreted to indicate contaminated water associated with leachate deep within bedrock on the immediate perimeter of the landfill and potential groundwater contamination near the northeast corner of the landfill.

1982 Geologic Reconnaissance (Germine 1982)

A June 1982 geologic reconnaissance of CFS and vicinity by NJDEP identified four rock types:

- Alaskite gneiss; a buff-colored, strongly foliated gneiss principally composed of elongated streaks of smoky quartz, plagioclase (oligoclase), feldspar, hornblende and opaques, and traces of monazite with prominent parting along foliation.
- Hornblende granite; a buff to pink-colored, weakly to moderately foliated granite containing quartz, oligoclase, feldspar, and hornblende.
- Alaskite; a dark-gray, buff to brown weathering Alaskite with foliation weakly developed to absent. It is composed of quartz, oligoclase, and feldspar, with accessory hornblende and opaques.
- Amphibolite; a foliated rock containing hornblende and plagioclase. It occurs as thin bands in other rock units.

[8] A number of previous investigations reported laboratory results in parts per million or parts per billion. For consistency, all results are in micrograms or milligrams per liter for aqueous samples and in micrograms or milligrams per kilogram for solids.

The geological investigation also found consistent foliation throughout the mapped area, averaging N50°E, 80°SE. Fairly well developed joints within the landfill area were observed in three groups:

- A foliation set, which appeared to be a predominantly near-surface feature that was particularly well developed in the granite outcrop in the northern portion of the landfill;
- Conjugate shear sets, a pair of steeply dipping to vertical sets trending about N10°W and N45°W. Poorly to moderately well developed on the landfill and not noted elsewhere; and,
- Sheeting, more or less horizontal fractures, most pronounced in the top 5 to 10 feet below the soil interface. Noted only in the northern sector of the landfill.

Based on field observations, the investigator believed that most leachate would move out radially from the landfill in the near surface zone of weathering, sheeting and foliation jointing, and that the leachate would probably tend to make its way into the prevailing drainage and eventually, for the most part, into the streams near the landfill. The author expected that infiltration to deeper groundwater might occur along joints and that the highest potential for rapid transmission of contaminated groundwater would be in the direction of conjugate shear joints and/or linear features. Much faster and increased volume of leachate migration was expected by the author where the amphibolite band had been excavated (this had reportedly been done in the southwestern portion of the landfill) and the excavation backfilled with garbage.

1983 Macroinvertebrate Survey (NJDEP 1983)

In 1983, a macroinvertebrate survey was conducted to determine if benthic communities in nearby surface waters had been impacted adversely by leachate and surface runoff from the landfill. NJDEP collected samples from Trout Brook, the main stem of Tanners Brook (as a control station for this study), and the Lamington River, both above and below the confluence with Trout Brook. Tanners Brook, located to the west and north about 0.5 mile at its closest point to the landfill, flows northeast to its junction with the Lamington River. The Lamington River flows south through Hacklebarney State Park, about 1.5 miles to the southeast of the landfill, to its junction with the Raritan River, about 13 miles from the confluence of Trout Brook and the Lamington River.

As stated in the report, the East Branch of Trout Brook (now referred to as the East Trout Brook UNT) was dry at the time of the survey and could not be sampled.

The macroinvertebrate study findings were used to evaluate three different indices - species diversity, equitability, and intolerant classification. The closest station to the landfill was found to be grossly polluted (cloudy water, surface film, solids covering the substrate and widespread sewage fungus). The macroinvertebrate community consisted mainly of sludgeworms and Tubifex, species indicative of grossly polluted waters, while typical trout stream insects were absent. Conditions at the next downstream station were slightly improved (water clear, no surface film, but sewage fungus still covering the substrate). The benthic community was more diverse and a clean water species was present; however, tumors and other abnormalities were found on many Chironomidae larvae. Water quality and species diversity continued to improve with distance from the landfill at the remaining three stations on Trout Brook before its confluence with the Lamington River. The summary stated that the upper portion of Trout Brook nearest the landfill was found to be grossly degraded.

1984 Stream, Leachate, and Residential Well Sampling (in LMS 1986)

In February and April 1984, NJDEP collected leachate samples, stream water samples, stream sediment samples, and potable water samples from residential wells and a childcare facility. The information available for these sampling events, which were completed before the 1986 RI for the Site,

is limited to a partially legible copy of a document that includes a sample data summary with sample identifiers, dates and locations, sample results summaries, and laboratory data summary sheets. The 1984 sample results were also tabulated and discussed in the 1986 RIR (LMS 1986).

Several VOCs were detected in leachate samples at individual concentrations between 14 and 549 µg/L. Dichlorodifluoromethane (Freon™ 12), ethylbenzene, toluene, and trichlorofluoromethane (Freon™ 11) were reported at concentrations above 100 µg/L, and 10 other VOCs were detected at concentrations between 14 µg/L and 75 µg/L, including benzene, chlorobenzene, TCE, PCE, and vinyl chloride. One of the leachate samples had a total phenolics concentration of 130 µg/L. Inorganics analysis indicated the presence of 11 metals. Among these, zinc had the highest concentration (2,400 µg/L), followed by lead (330 µg/L), copper (140 µg/L), and chromium (130 µg/L). Concentrations for the remaining metals (arsenic, beryllium, cadmium, mercury, nickel, selenium and thallium) ranged from 0.70 µg/L for mercury to 44 µg/L for nickel.

In two sediment samples collected from a leachate location and a stream location downstream of the landfill, two VOCs (methylene chloride; 51 mg/kg and 0.066 mg/kg and toluene 0.341 mg/kg) and one SVOC (bis(2-ethylhexyl) phthalate, a.k.a. DEHP; 17,400 mg/kg) were detected, , while VOCs or SVOCs were not detected in a sediment sample collected from a background location. Nine metals were detected above reporting limits in the sediment samples. Of the nine, antimony was detected only in leachate location sediment sample and beryllium only in the background sediment sample. Of the remaining seven metals, five had the highest results at the leachate location (including arsenic at 100 mg/kg and zinc at 110 mg/kg) and two at the background location (including lead at 73 mg/kg).

In the three surface water samples, 13 organic compounds were detected in one sample at concentrations between 11 µg/L and 1,350 µg/L, and none in the other two samples. The three VOCs with the highest concentrations were toluene (1,350 µg/L), benzene (141 µg/L), and 1,1-DCA (112 µg/L). Concentrations for the remaining organics ranged from 11 µg/L to 74 µg/L. Nine metals were detected above reporting limits in the surface water samples. Lead (up to 320 µg/L), zinc (up to 590 µg/L) and copper (120 µg/L) had the highest concentrations while the highest results for the remaining metals ranged from 0.6 µg/L for mercury to 23 µg/L for chromium.

The potable well analytical results for samples collected at the residential properties and the childcare facility indicted the presence of the following VOCs (highest concentrations in parenthesis) at one or more well: chloroform (41 µg/L), dichlorodifluoromethane/Freon™ 12 (19 µg/L), methylene chloride (40 µg/L), benzene (32 µg/L), TCE (10 µg/L), and naphthalene (240 µg/L). Other VOCs were reported at concentrations below method detection limits (PCE and 1,2-trans DCE). Among the detected metals, copper and zinc were reported for most well samples at high concentrations (copper to 1,300 µg/L and zinc to 380 µg/L), which may be attributed to the use of copper pipes. The only other reported metal was mercury, which was detected at two residences with concentrations of 0.80 µg/L and 1.90 µg/L.

1986 Remedial Investigation/Feasibility Study (LMS 1986)

The field investigation portion of the 1986 RI/FS was conducted from 1984 to 1985 and consisted of the following elements:

- Borehole geophysical logging of existing wells;
- Geophysical survey to identify/define the extent of groundwater contamination and delineate areas of buried metal waste (i.e., drums);
- Soil boring and rock coring to obtain stratigraphic and structural information on soil, saprolite, and competent bedrock;

- Installation of nine deep (bedrock) and six shallow (overburden) monitoring wells;
- Test pit investigation of areas of apparent anomalies discovered during the conductivity and electromagnetic surveys;
- Aquifer pump tests to characterize the deep aquifer and slug tests to measure permeability of the saprolite;
- Water level measurements to determine groundwater flow directions; and
- Sampling and analysis of environmental media (soil, groundwater, potable water, surface water, sediment, leachate, air).

The 1986 RI revealed the presence of a wide range of contaminants. Most of the COCs were VOCs, including benzene, toluene, 1,2-DCA, chloroform, and methylene chloride.

The major findings of the 1986 RI, as summarized by LMS, were:

1. The groundwater beneath the landfill (both the shallow/saprolite and the deep/fractured bedrock aquifers) had been contaminated by hazardous substances emanating from and traceable to the landfill. Shallow groundwater was impacted at five of the six sampled wells, both within the landfill and on the landfill perimeter. A shallow well located on an adjoining property north of the landfill was found not to be impacted. The highest concentrations of total VOCs in the shallow wells was 1,556 µg/L reported for well S-1 on the western edge of the landfill (toluene – 1,370 µg/L; benzene – 64.7 µg/L; methylene chloride – 56 µg/L, and 1,1-DCA – 65.2 µg/L). Phenols were also reported for this well (270 µg/L). PCE was not reported in any of the shallow wells, and TCE was reported at only one well at 4.04 µg/L (S-3, southwest corner of the landfill). The bedrock well with the highest total VOCs (1,293 µg/L), well D-7, was also located on the western edge of the landfill. Individual VOCs detected at this well included toluene (1,140 µg/L), benzene (66.4 µg/L), methylene chloride (20 µg/L), and ethyl benzene (34.2 µg/L). Phenols were reported for this well at a concentration of 428 µg/L. The well with the second highest total VOCs (530 µg/L), well DW-4, was on the northeast side of the landfill. Individual VOCs detected at this well included benzene (252 µg/L), chloroform (155 µg/L), TCE (56.2 µg/L), methylene chloride (20.6 µg/L), 1,2-DCA (14.2 µg/L), and PCE (5.58 µg/L). Well D-2, near the west end of Schoolhouse Lane to the north of the landfill, had total VOCs of 429 µg/L. Individual VOCs detected at this well included chloroform (209 µg/L), methylene chloride (176.1 µg/L), PCE (14.3 µg/L), TCE (8.34 µg/L), 1,2-DCA (7.98 µg/L), 1,1-DCA, and 1,1-dichloroethylene (6.41 µg/L each).
2. Chloroform, 1,2-DCA, TCE, and PCE were detected in groundwater collected from potable residential wells northeast of the landfill, along Parker Road and Schoolhouse Lane. The compounds were assumed to have migrated off-site from the landfill property. Wells along Parker Road to the south appeared not to have been impacted by landfill-related contaminants.
3. Wells further downgradient from the landfill (i.e., in several different directions) were considered to be at risk of contamination due to the continued off-site migration of contaminated groundwater. Landfill contaminants moved downward into the deep aquifer and dispersed in several directions in groundwater, mostly to the northeast and southwest, but also to the east and southeast. In the case of VOCs, a distinct finger of the plume was found to extend northeast parallel to Parker Road toward the western end of Schoolhouse Lane (Figure 1-5).
4. Surface water runoff, leachate overflows/discharges, and groundwater discharging from seeps had contaminated Trout Brook.

5. Analytical results for soil samples collected during the installation of piezometers indicated the presence of several VOCs. The most widely encountered compounds, along with their highest concentrations and locations were: chloroform (maximum concentration 5,995 µg/kg, SB-4, southwest corner of the landfill), methylene chloride (3,864 µg/kg, SB-2, eastern edge of the landfill), di-n-butyl-phthalate (6,000 µg/kg, SB-3, within the landfill), carbon tetrachloride (350 µg/kg, SB-3, within the landfill), and PCE (1,395 µg/kg, SB-4, southwest corner). Soil samples collected from test pits installed to investigate magnetic anomalies indicated the presence of DEHP of up to 1,300 µg/kg, 2-butanone (270 µg/kg) and 4-methyl-2-pentanone (28 µg/kg).
6. Based on groundwater elevations determined during the RI and the depth of the waste observed in several borings, a portion of the waste body sits below the water table within the shallow aquifer.
7. Flow of shallow groundwater was determined to be predominantly to the northeast and southwest.

1986 Record of Decision (EPA 1986)

The remedy selected in the 1986 ROD for the CFS landfill consisted of:

- An alternate water supply for affected residences;[9]
- Capping of the 65-acre landfill in accordance with RCRA requirements;
- An active collection and treatment system for landfill gases;
- Pumping and on-site treatment of shallow groundwater and leachate, with discharge to East Trout Brook;
- Surface water controls to accommodate seasonal precipitation and storm runoff;
- Security fencing to restrict site access;
- Environmental monitoring to ensure the effectiveness of the remedial action; and
- A supplemental feasibility study to evaluate the need for remediation of the deep aquifer.

The ROD also included a figure delineating the VOC plume (defined by the 100 µg/L isopleth for total VOCs), which showed that the plume extended to the west, south and north/northeast outside the landfill property. To the north/northeast, the plume was shown reaching as far as Schoolhouse Lane.

1987 Final Feasibility Study Report (LMS 1987)

The 1987 Final Feasibility Study developed and screened several remedial action alternatives, and provided detailed evaluations for identified alternatives and their elements. The recommended remedial alternative consisted of:

- Providing a public water supply to affected properties;
- Security fencing, grading, filling, site preparation, and installation of a new access road;
- Construction of a multi-layered terraced cap over the landfill;

[9] In February 1995, the alternate water supply component of the ROD was suspended by NJDEP and EPA pending results of further sampling. A water line extension to 73 homes and businesses impacted or threatened by contaminated groundwater from CFS was completed by EPA in July 2015.

- Active gas venting and treatment;
- Surface water controls;
- Shallow aquifer pumping;
- On-site treatment of leachate/groundwater with discharge to East Trout Brook;
- Expanded environmental monitoring; and,
- A supplemental feasibility study to evaluate the need for remediation of the deep aquifer.

1991 Remedial Design Field Sampling and Testing Report (O'Brien & Gere 1991)

The 1991 Field Sampling and Testing Report summarizes activities completed by O'Brien & Gere Engineers, Inc. (O'Brien & Gere) on behalf of NJDEP to inform the remedial design for the CFS landfill. The purpose of the field testing and sampling program was to collect data for use in the design of the remedial action. Activities included landfill gas testing, condensate testing, fill delineation (geophysical investigation and test pits), materials investigations, landfill cover suitability and stability analyses, subsurface foundation evaluation, aquifer testing, treatability testing, percolation testing, and interim environmental monitoring of air, surface water, sediments and groundwater.

During test pit explorations earlier in 1988, O'Brien & Gere observed (in separate pits) a layer of oil floating on groundwater, strong insecticide/pesticide odors, buried drums (test pit 14, south-central perimeter), a three to four foot thick seam of Mennen Baby Magic Baby Lotion and Baby Care Soap bottles (test pit 18, along northeastern perimeter), and general trash. Based on the available information, it appears that the drums at test pit 14 were left in place (Halloran 2006).

Sampling completed during remedial design in December 1988 and May/June 1990 indicated the presence of PCE in surface water samples; chlorinated VOCs, SVOCs and metals in sediment; and chlorinated VOCs, benzene, toluene, ethylbenzene and xylenes (BTEX) in groundwater.

<u>Surface Water</u>

During the first round of surface water sampling in late 1988, low-level concentrations of chloroform (6 µg/L and 6 J µg/L, respectively) were reported in the West and East Branches of Trout Brook (now referred to as Trout Brook and the East Trout Brook UNT) and at an upstream location on the Lamington River (5 J µg/L). Detections of 4-methyl-pentanone (3 J µg/L) and 2-hexanone (4 J µg/L) at a downstream location on Trout Brook were also reported. PCE was detected at an estimated concentration of 5 µg/L at the upstream location on the Lamington River. In addition, low-level estimated concentrations of three phthalate compounds were also detected at Trout Brook and the East Trout Brook UNT (2 J µg/L to 4 J µg/L).

During the 1990 sampling event, methylene chloride, carbon disulfide and benzene were detected at single-digit µg/L concentrations at the East Trout Brook UNT sampling location, and methylene chloride at 16 µg/L at the Lamington River UNT along Schoolhouse Lane (with a concurrent detection of 4 µg/L in a method blank). For the locations on the main stem of Tanners Brook, benzene and toluene were reported at concentrations of 100 µg/L and 12 µg/L at the upstream sampling point, and 50 µg/L and 9 µg/L at the downstream sampling point. Methylene chloride at these two stations was reported as 19 µg/L and 9 µg/L, respectively. Low-level concentrations were also reported for the downstream station on Trout Brook and the upstream and downstream stations on the Lamington River. The surface water samples from Trout Brook and the East Trout Brook UNT also showed the highest concentrations of several metals, including barium, calcium, iron, magnesium, manganese,

potassium, sodium and zinc, as well as the highest values for dissolved and total solids, specific conductance, chloride and chemical oxygen demand.

Sediment

In the first round of sediment sampling in late 1988, VOCs were detected only at low concentrations in the sediment samples, with methylene chloride ranging from 7 µg/kg to 10 µg/kg. The sample from the East Trout Brook UNT had total SVOCs over 5,000 µg/kg (mostly PAHs and phthalates) along with the highest concentrations for several metals. DEHP was detected at all locations at concentrations between 140 J to 680 µg/kg, including the upstream sampling locations on Tanners Brook and the Black (Lamington) River which had the highest concentrations (680 and 430 J µg/kg, respectively). During the second round of sampling, total SVOCs in the samples from Trout Brook and the East Trout Brook UNT as well as the downstream location on the main stem reached several hundred µg/kg, mostly from several PAH compounds. DEHP was reported at concentrations between 20 J and 120 J µg/kg in the samples collected in 1990, with the highest concentration for the East Trout Brook UNT.

Shallow Monitoring Wells

Several VOCs were detected in groundwater samples from the six shallow wells (each with a 10-foot screen, with screen intervals ranging from 14 to 24 feet bgs to 54 to 64 feet bgs), including BTEX compounds (e.g., toluene to 130 µg/L), acetone (up to 330 µg/L), 4-methyl-2-pentanone (up to 32 µg/L), chlorobenzene (up to 140 µg/L), chloroethane (up to 19 µg/L), chloroform (up to 120 µg/L), 2-butanone (up to 180 µg/L), and several others (at concentrations below 10 µg/L). The locations of the highest concentrations varied between the two sampling rounds, in that well S-1 (screened at 14-24 feet bgs) at the northwest corner of the landfill showed the largest number and highest concentrations of VOCs in 1988, and well S-3 (screened from 37.5 to 47.5 feet bgs), which showed no VOCs in 1988, exhibited the highest concentrations in 1990. Detections for TCE or PCE were not reported in either event.

Deep Monitoring Wells

The highest VOC concentrations in groundwater from deep wells (i.e., wells with total depths of between 100 and 175 feet bgs and open boreholes of 44 to 80 feet in length) were detected at well D-2 during both the 1988 and 1990 sampling events (open hole from 80 to 124.5 feet bgs; near Schoolhouse Lane, north of the landfill) and well DW-4 (along the north-central perimeter of the landfill). At well D-2, methylene chloride (to 11 µg/L), acetone (up to 59 µg/L), chloroform (up to 61 µg/L), PCE (6 µg/L), 1,1-DCA (2J µg/L), and benzene (2J µg/L) were detected. For well DW-4, the compounds and concentrations were acetone (14 µg/L), chloroform (up to 94 µg/L), trans-1,2-DCE (3 J µg/L), TCE (12 µg/L), PCE (4 J µg/L), and chlorobenzene (3 J µg/L). The highest concentration of benzene was detected at well D-7 with 44 µg/L in 1990 (open borehole from 45 to 125 feet bgs; along the west-central perimeter of the landfill) after not being detected in 1988. Benzene was also detected at well D-8 at 10 µg/L (open borehole from 48.4 to 100 feet bgs; in the center of the landfill near the power line right-of-way).

1993 Final Design (O'Brien & Gere 1993)

The Final Design Report provides the design specifications for the cover system, landfill gas collection and treatment system, the shallow groundwater recovery system and the groundwater treatment system, as well as a groundwater recovery system effectiveness monitoring plan and a preliminary operations and maintenance (O&M) plan. Among the appendices are test pit logs for the 1988 investigation and boring and well logs.

1993-1995 Buried Drum Investigations and Removals (Dispoto 1997)

The recovery of buried drums from three separate areas along the eastern perimeter of the landfill is described in a March 1997 NJDEP file memorandum. The document describes the recovery and sampling of approximately 150 55-gallon drums during remedial activities at the landfill conducted between November 1993 and May 1995. The locations of the drum removal areas are described in another internal NJDEP document (Barkett 2004). The two NJDEP internal memoranda provide the following details on the buried drum investigations and removal activities:

- In November 1993, NJDEP contractor Foster Wheeler Enviresponse, Inc. (FWEI) encountered 12 drums (drums #1 through #12) during 'refuse relocating activities' near the location of Soil Gas Probe 28 on the northeast perimeter of the landfill. Seven of the drums found to not contain enough material for sampling were crushed, and placed in the landfill.
- In January 1994, FWEI again encountered drums during refuse relocating activities. Between May and June 1994, 91 drums (drums #20 through #110) were removed from the landfill and processed. Drums #20 through #51 were reported as originating from an area along the northern boundary of the landfill near Soil Gas Probe locations 21 and 38, while drums #52 through #109 were assumed to have come from an area near the eastern corner of the landfill, west of Soil Gas Probe 34 (the two reviewed NJDEP documents did not include any information on drums #13 through #19 and it appears that those numbers were not used).
- In April 1995, FWEI discovered 49 additional drums (drums #120 through #168) during the installation of the groundwater recovery system force main and excavated them between late April and early May 1995 (note that the numbers #111 through #119 were not used).
- The excavated drums were sampled for hazardous materials determination and waste characterization/disposal bulking compatibility; some drums were also sampled and analyzed individually. For the drums excavated in 1993 and 1994, all but one composite sample was reported to contain hazardous waste while the description of the 1995 samples does not include information on hazardous waste determinations. Analytical results for the composite samples or individual drum samples were not found in the available historic documents and information on the disposal of the materials was not included in the two documents.
- The inventory list for the recovered drums (*Combe Fill South Landfill, Drum Removal Area 13/14; Current Listing of Apparent Outstanding Evidence Recovery Items, 16 June 1995*) included Responsible Party Information/markings, descriptions of contents, and date found/sampled for some of the drums. Materials encountered in the recovered drums were described as pharmaceutical waste, paint-like sludges, tar-like sludge, oil-like liquid, liquids, resin-like material, and solids, with a wide range of colors. Labeling and marking information obtained from the drums indicated acetone (several drums), butyl alcohol, xylol (e.g., xylene), denatured alcohol, chloroform, AIRKEM A-33 disinfectant (n-alkyl dimethylben?)[10], petrolatum, lab packs and 'solvents for disposal'. In addition, a NJDEP sampling contractor listed methylene chloride and ethyl alcohol as observed label information (GHR 1996).

An undated sketch map of the northeastern part of the landfill provided by NJDEP (not included in any of the above documents) shows four areas along the northeast perimeter of the landfill from which buried drums were removed between 1993 and 1995, along with a 'new area of buried drums' and an

[10] The drum removal listing includes partial entries with question marks indicating partially illegible drum markings and label information.

area of ‘drums left in place and put under cap’. Some of the drum removal areas have approximate numbers of drums removed (totaling 147, closely matching the total number of drums described for the 1993 to 1995 removals above), while others do not.

The buried drums observed at test pit 14 that were reportedly left in place as described in the 1991 Remedial Design Field Sampling and Testing Report (O’Brien & Gere 1991), do not appear to be part of the effort described above. Based on available historic documents, buried drums were discovered during test pit explorations as early as 1988 (O’Brien & Gere 1989; in O’Brien & Gere 1991).

2006 Explanation of Significant Differences (EPA 2006)

The 2006 Explanation of Significant Differences revised one aspect of the ROD by modifying the provisions for an active landfill gas and condensate collection and treatment system to a passive landfill gas venting system. The change was made based on test results from studies completed after the 1986 ROD and additional tests were conducted to confirm the appropriateness and protectiveness of the change. Concentrations of landfill gas components were found to be below concentrations suitable for an active treatment system and the risk associated with landfill emissions was predicted to be below policy limits. Based on this data, the NJDEP and EPA accepted the design contractor’s recommendation for a passive system.

2006 - 2009 North Waste Cell Removal and Closure (NJDEP 2011b)

Non-native fill was encountered outside the cap limits along the northern property boundary in 2001 during the installation of landfill gas probes. This area of non-native fill, which became known as the North Waste Cell, was investigated and delineated by NJDEP between 2001 and 2005 through borings, test pits and trenches (Walshe 2005). NJDEP retained Clean Venture, Inc. (CVI), to excavate the North Waste Cell after the Responsible Parties declined to complete the work.

The removal action occurred primarily between May and August 2006. The bulk waste removed from the North Waste Cell excavation, which was approximately 480 feet long by 35 feet wide by 16 to 30 feet deep, was staged in a lined area east of the existing GWTP. Between June 2007 and October 2007, approximately 27,327 tons (1,202 loads) of nonhazardous soil and debris were disposed of at three facilities in Pennsylvania and Ohio. The encountered waste included solid waste, personal care products, pharmaceutical products and laboratory and chemical wastes. Approximately 500 containers ranging in volume from one gallon to 55-gallon drums were encountered during the excavation of the North Waste Cell, and 63 salvage drums (‘overpacks’) were generated.

A detailed review of the hundreds of photographs documenting the North Waste Cell closure provided by NJDEP to HDR in May 2012 yielded labeling and marking information indicating that containers recovered from the area had contained solvents, waste solvents, refrigerants, caustics, personal care products and pharmaceuticals (mostly human, some veterinary), as well as specialty and research chemicals. Among the identified chemicals and product ingredients were acetone, chloroform, ethyl alcohol, Freon™ 11 (trichlorofluoromethane), cyanides, bromine, phenobarbital, and formic acid. A large number of aerosol cans were also noted. Several photographs also showed that liquids (apparently paint and oily substances) were released from ruptured drums.

Post-excavation soil samples were collected from the bottom and sidewalls of the excavation and it was backfilled using NJDOT Type I-13 aggregate. Analytical results for 1,4-dioxane from different materials (waste pile, post-excavation soil, and waste material) were mostly non-detect (however, detection limits for a number of samples were above 50 mg/kg). The highest reported concentrations for 1,4-dioxane were 2.4 mg/kg in waste pile samples and 0.91 mg/kg in post-excavation soil samples. All waste material samples were reported as non-detect for 1,4-dioxane.

Portions of the North Waste Cell were found to extend under the landfill perimeter road (observed in the excavation side wall during the North Waste Cell removal), but were left in place so that the existing perimeter road and landfill cap were not undermined. In 2007, The Louis Berger Group, Inc. (Berger) evaluated the feasibility of extending the existing landfill cap over this area. The design for the extension was completed in 2008 and the cap extension (consisting of a geosynthetic clay liner, a forty mil linear low density polyethylene textured geomembrane, a geocomposite drainage net, a 12-inch drainage layer, geotextile fabric, and a 12-inch aggregate layer) was constructed by CVI mostly between August and October 2008.

In October 2008, drum waste samples were collected and analyzed. The drums were then transported off-site for disposal at CycleChem in November 2008.

During the excavation and removal of the North Waste Cell, the section of the shallow groundwater recovery system on the northern perimeter of the landfill was not operated for almost three years. The original recovery wells in the vicinity were removed in March 2006 and a replacement recovery well and force main became operational in January 2009 (NJDEP 2011a).

As part of the North Waste Cell closure, three replacement wells and a groundwater force main were installed in the former North Waste Cell area by Handex Consulting & Remediation-Northeast, LLC (Handex) between November 2008 and January 2009. Samples collected from the three replacement wells (monitoring wells D-5R and PZ-21R, and recovery well RW-U) in January 2009 had reported concentrations of 1,4-dioxane from 540 to 970 µg/L, benzene from 150 to 370 µg/L, and TBA in one sample at 190 µg/L (TestAmerica 2009). High concentrations of TICs, including tetrahydrofuran, were also reported for these samples. These detections are discussed in detail in Section 4.2.4.

Following the detection of 1,4-dioxane in groundwater and soil, NJDEP developed interim specific criteria (ISC) for 1,4-dioxane in groundwater (10 µg/L) and soil (non-residential soil remediation standard: 260 mg/kg; impact to groundwater soil screening level: 0.006 mg/kg) for the Site in 2006 (Groth 2006).[11]

2009 Pump Test (Handex 2009)

Handex conducted a pump test at a newly installed recovery well, RW-T, near the northeastern edge of the landfill in July 2009 to determine maximum sustainable yield from the well, drawdown, and hydraulic influence. Maximum drawdown was measured at 2.74 feet in a well that was about 100 feet from RW-T. Two sets of groundwater samples were collected during the pump test. Benzene (1.4 and 1.5 µg/L; GWQS 1 µg/L) and 1,4-dioxane (17 and 18 µg/L; ISGWQS at the time: 10 µg/L) exceeded the comparison criteria in these samples.[12]

CFS Landfill Post-Construction Environmental Monitoring (NJDEP 2009b)

NJDEP has been conducting post-construction environmental monitoring at CFS, as part of the requirements of the ROD for the CFS landfill. As described in the PCEM plan (PCEMP; NJDEP 2009b), NJDEP collects groundwater and surface water samples each spring and fall, and sediment

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[11] The ISGWQC (3 µg/L) and the PQL (10 µg/L) for 1,4-dioxane originally established in 2008 were revised in November 2015 to 0.4 µg/L (ISGWQC) and 0.1 µg/L (PQL). The 2015 ISGWQS (i.e., the higher of the ISGWQC or the PQL) was adopted as the GWQS in January 2018. There currently is no promulgated 1,4-dioxane soil remediation standard, nor a default impact to groundwater soil screening level (NJDEP 2013a).

[12] Three VOCs (benzene, 1,2-dibromo-3-chloropropane, and 1,2-dibromomethane) and one SVOC (atrazine) are described in the report as exceeding the GWQS; however, a review of the laboratory results during the RI indicated that only benzene and 1,4-dioxane exceeded the GWQS and that the other compounds were actually reported by the laboratory as non-detect.

samples in the fall. Which sampling locations (monitoring wells, piezometers, recovery wells, surface water, and sediment locations) are sampled during which event varies between spring and fall, and also between odd- and even-numbered years. Groundwater and surface water samples are analyzed for TCL VOCs (including MTBE, TBA and TICs) and SVOCs (including 1,4-dioxane[13] and TICs) during all sampling rounds, and each location is analyzed for inorganic trace metals once a year (some locations are sampled for trace metals biennially). The primary analytical method for metals under the PCEM is inductively coupled plasma atomic emission spectrometry (ICP-AES) because it provides information about analytes of interest to the treatment plant operation. Beginning in 2012 and every four years thereafter, metals analysis is also conducted by ICP-mass spectrometry (ICP-MS) in addition to ICP-AES.

All aqueous samples are also analyzed for degradation parameters (TOC, chlorides, ammonia-N, orthophosphate, sulfate and sulfite, nitrate and nitrite, alkalinity, and total phenols). Sediment samples are analyzed only for metals.

PCEM analytical data for sampling events completed between 2011 and 2015 (i.e., for the period during which almost all RI samples were collected) were reviewed as part of this RI. One of the goals of this review was to assess the presence and areas of the highest concentrations of the RI COCs at and near the CFS landfill, in order to identify potential source areas for the contamination in the deep bedrock aquifer. Evaluation of compounds other than the COCs identified in Section 1.5 was not part of the scope of this review as data validation could not be performed on the tabular PCEM data set (e.g., results with a B-qualifier, indicating that the compound was detected in both the sample and the associated trip blank, are presented as reported in the PCEM data without further evaluation of potential data quality implications).

Groundwater – NJDEP Overburden Monitoring Wells

NJDEP collects samples from 19 overburden monitoring wells identified in the PCEM plan. In addition, the sampling team has the option to collect one additional sample at a well of their choosing (overburden or bedrock) during the spring sampling events (e.g., in the spring of 2014, resulting in a total of 20 wells sampled during the review period; 4th quarter 2011 through 4th quarter 2015). The data summary tables for the overburden groundwater samples collected by NJDEP during the review period are included in Appendix A.

The RI COCs were detected at the following concentrations in samples from the PCEM overburden monitoring wells:

Analyte	Range of Detections [µg/L]	GWQS or IGGWQC [µg/L]	Number of wells with Exceedances
1,4-dioxane	0.37 J – 510 D	0.4	14 of 20*
Benzene	0.021 J – 37 D	1	5 of 20
TCE	0.022 J – 4.3 JD	1	1 of 20
DEHP	0.14 J – 9 B	3	1 of 20
Alpha-BHC	Not analyzed	0.02	Not applicable
Arsenic	0.22 J – 44.5	3	8 of 20
Chromium (total)	0.25 J – 22.9	70	0 of 20
Lead	0.16 J – 13.6	5	9 of 20

[13] 1,4-dioxane is considered a VOC, but can be analyzed by both VOC and SVOC methods.

Analyte	Range of Detections [µg/L]	GWQS or IGGWQC [µg/L]	Number of wells with Exceedances
Phenobarbital	2.3 JN – 36 JN	5	6 of 20
TAME	21 JN – 380 JN	100	11 of 20

*: Because the detection limit for 1,4-dioxane was 1.9 µg/L, which is higher than the current GWGS, 1,4-dioxane may have been present at other wells above the GWQS also.

The overburden wells with the highest concentrations of 1,4-dioxane in PCEM sampling were PZ-21R (510 µg/L) and RW-U (150 µg/L), both of which are adjacent to the North Waste Cell excavation area and in close proximity to the RI well with the highest 1,4-dioxane results (CF-209D-R). Other overburden wells with concentrations of 1,4-dioxane exceeding 40 µg/L (100 times the GWQS) were PTO-2 inside the landfill (48 µg/L), MW-4 outside the landfill boundary to the south (86 D µg/L), and CF-14S and CF-27S at Schoolhouse Lane to the north (67 and 65 µg/L, respectively). All overburden wells within the landfill itself had high 1,4-dioxane concentrations (21 - 510 µg/L). Concentrations of benzene greater than 10 µg/L (i.e. more than 10 times the GWGS) were reported for CF-14S and CF-27S (27 D and 37 D µg/L) and for two wells on the western perimeter of the landfill (MW-1 and CF-28S, 25 and 13 µg/L, respectively). TCE was reported above the GWQS (1 µg/L) only at well MW-1 (4.3 JD µg/L). The highest concentration of DEHP (GWQS 3 µg/L) was found at well MW-7 outside the southeast perimeter (9 B µg/L). Arsenic concentrations of at least three times the GWGS of 3 µg/L were detected only at well MW-4 (11.2 to 44.5 µg/L) and lead concentrations of 10 µg/L or higher (two times the GWQS) were found at wells CF-14S (13.6 µg/L) and PTO-2 (11.5 µg/L).[14] The range of detection of TIC COCs (phenobarbital and TAME) is presented above alongside the other COCs. Their occurrence and distribution are described in the RI groundwater results TIC section (Section 4.2.1.2) along with the RI TIC results.

The highest concentrations of the RI target compound COCs in the PCEM overburden groundwater samples during the RI period are shown on Figures 1-6A and 1-6B and incorporated into the extent of contamination figures (Figures 8-1 through 8-8). Figures 8-1 to 8-8 depict both NJDEP and EPA data.

Groundwater – NJDEP Bedrock Monitoring Wells

NJDEP collects samples from 26 bedrock monitoring wells in addition to recovery well RW-T for a total of 27 wells under the PCEM program. The data summary tables for the bedrock groundwater samples collected by NJDEP during the review period are included in Appendix A. The RI COCs were detected at the following concentrations in PCEM bedrock monitoring wells during the review period (4th quarter 2011 through 4th quarter 2015):

Analyte	Range of Detections [µg/L]	GWQS or IGGWQC [µg/L]	Number of wells with Exceedances
1,4-dioxane	0.23 J – 240 D	0.4	15 of 27
Benzene	0.014 J – 980 D	1	9 of 27
TCE	0.018 J – 12	1	6 of 27
DEHP	0.22 J – 7.5 B	3	7 of 27
Alpha-BHC	Not analyzed	0.02	Not applicable
Arsenic	0.19 J – 11.1	3	16 of 27

[14] The data qualifier B for organic analytical results indicates that the compound was also detected in a blank sample associated with the normal sample.

Analyte	Range of Detections [µg/L]	GWQS or IGGWQC [µg/L]	Number of wells with Exceedances
Chromium (total)	0.36 J – 13.7	70	0
Lead	0.11 J - 13	5	12 of 27
Phenobarbital	2.5 JN – 37 JN	5	8 of 27
TAME	2.1 JN – 480 JNB	100	11 of 27

*: Because the detection limit for 1,4-dioxane was 1.9 µg/L, above the GWGS, the compound may have been present at other wells at concentrations above the GWQS also.

In the PCEM bedrock wells, 1,4-dioxane concentrations more than 40 µg/L (100 times the GWQS) were reported for the only bedrock well within the landfill (D-6, 67 D -170 D µg/L) as well as for four wells along the landfill perimeter to the southwest and south (counter clock-wise: D-7, 76 to 140 D µg/L; MW-17, 3.7 to 46 µg/L; MW-16, 29-74 µg/L; and MW-19D, 3 – 240 D µg/L), at bedrock recovery well RW-T (9.7-43 µg/L), and CF-15D (54-76 µg/L) on the north/northeast perimeter, and at well D-2 in the area between CFS and Schoolhouse Lane (7.5 – 55 D µg/L). Concentrations of benzene greater than 10 µg/L (i.e. more than 10 times the GWGS) were reported for five wells, four of which also had some of the highest 1,4-dioxane concentrations: D-2 (4.6-140 µg/L), MW-19D (0.1 J- 980 D µg/L), CF-15D (3.4 B - 120 µg/L), and MW-16 (0.4 J-10 µg/L)[15]. The fifth well with benzene concentrations greater than 10 µg/L was CF-11D on Schoolhouse Lane (0.67-31 D µg/L). Higher concentrations of TCE (greater than 5 µg/L or 5 times the GWQS of 1 µg/L) were reported for three PCEM bedrock wells: MW-16 (0.16 J – 10 µg/L) and MW-19D (2.2-7.2 µg/L), both along the southern landfill perimeter, and CF-15D (5.5-12 µg/L), along the northern perimeter. The highest concentrations of DEHP (GWQS 3 µg/L) were found at wells MW-16 (5 JB µg/L) and D-2 (5.5 B µg/L) at the landfill and in the area between CFS and Schoolhouse Lane, and at well WRA1-3 to the south of Parker Road (7.5 B µg/L). Arsenic concentrations of at least three times the GWGS of 3 µg/L were detected only at recovery well RW-T (to 11.1 µg/L) and at well WRA1-3 to the south of Parker Road (9.7 J µg/L), which also had a lead concentration above 10 µg/L (10.1 µg/L at well WRA1-3 to the south of Parker Road). Well D-7, located on the wester perimeter of the landfill, is the only other location with a detected lead concentration above 10 µg/L (13 µg/L).The range of detection of TIC COCs (phenobarbital and TAME) is presented above alongside the other RI COCs. Occurrence and distribution of these two compounds are described in combination with the RI groundwater TIC results in Section 4.2.1.2.

The highest concentrations of the RI target compound COCs in PCEM bedrock groundwater samples during the RI period are shown on Figures 1-6C to 1-6E and incorporated into the extent of contamination figures (Figures 8-1 through 8-8). Figures 1-6C to 1-6E and Figures 8-1 to 8-8 depict both NJDEP and EPA data.

The PCEM results for the RI COCs in overburden and bedrock wells are also discussed together with the RI results in Section 8.1.1 (Nature and Extent of Contamination, Groundwater).

The review of the NJDEP data also indicated that all 24 PCEM groundwater samples collected during the RI investigation period exceeded the GWQS of 2 µg/L for thallium while none of the approximately 200 RI samples did. As described above, NJDEP uses ICP-AES as the standard

[15] For well MW-19D, the highest concentrations of 1,4-dioxane (240 D µg/L) and benzene (980 D µg/L) during the investigation period were for the sample collected in May 2012. Results for both compounds in three samples collected subsequently during the reviewed period were considerably lower (3-9.4 µg/L for 1,4-dioxane and 0.1 J – 0.25 J µg/L for benzene). Additional information that may shed light on these considerable differences was not available.

method to analyze for metals and every four years, has metals analyzed using both the ICP-AES and ICP-MS methods. Comparison of the results generated by the two methods for 2012 showed that while thallium was detected more frequently using ICP-MS compared to ICP-AES, the concentrations reported for ICP-AES analysis were significantly higher (2.5 to 4 µg/L) than the ICP-MS results (0.017 to 0.31 µg/L). A number of studies of this issue have shown that ICP-AES can have very high rates of false-positives for thallium because of severe matrix effects. In one case study for groundwater samples from a Superfund site, thallium concentrations of up to 21.6 µg/L were reported by ICP-AES while all samples were non-detect in reanalysis with ICP-MS (Chapnick et al. 2010). In light of this information and the fact that none of the RI samples showed thallium exceedances, the exceedances in the PCEM samples are considered to be false-positives or to be biased high, most likely due to matrix effects.

NJDEP Surface Water Samples

As part of the PCEM, NJDEP is collecting surface water samples at three locations on the unnamed tributary to the Lamington River north of Schoolhouse Lane (Figure 4-7) where contaminated groundwater originating from CFS discharges to surface water. During the RI, NJDEP collected five rounds of surface water samples. The RI COCs had the following concentration ranges:

Analyte	Range of Detections [µg/L]	SWQS/ESL* [µg/L]	Exceedances
1,4-dioxane	0.28 J – 44 D	22,000*	0
Benzene	0.022 J – 0.35 J	114*	0
TCE	0.064 J – 0.16 J	47*	0
DEHP	0.15 J – 1.5 J	0.3*	10 of 20 samples
Alpha-BHC	Not analyzed	12.4*	Not applicable
Arsenic	1.3 – 3.9 J	150	0
Chromium (total)	0.5 J – 2 J	42*	0
Lead	0.1 J – 9.9 J	5.4	1 of 16 samples
Phenobarbital	2.1 J – 3.5	No standard	Not applicable
TAME	150 JN – 410 JN	No standard	Not applicable

*EPA Region 5 surface water ecological screening level (ESL). No chronic surface water standard available.

Only DEHP and lead exceeded the comparison criteria. The NJDEP surface water results for 1,4-dioxane are shown on Figure 4-7 alongside those from the RI. The data summary table for the NJDEP surface water samples is included in Appendix A.

NJDEP Sediment Samples

NJDEP collected four rounds of sediment samples as part of the PCEM during the RI. Sediment samples are analyzed only for metals and none of the RI inorganic COCs exceeded the comparison criteria (described in Section 4.1.3):

Analyte	Range of Detections [mg/kg]	NJDEP Freshwater LEL [mg/kg]	Exceedances
Arsenic	0.023 – 3	6	0
Chromium (total)	0.035 – 7.8	26	0
Lead	0.052 – 10.1	31	0

The data summary table for the NJDEP sediment samples is included in Appendix A.

2011 Potable Well Sampling (EPA 2015d)

In January and June 2011, EPA contractor Weston Solutions, Inc. (Weston) sampled potable wells within approximately one mile of the landfill, including the potable well at the CFS treatment plant. The results were reported in two sampling trip reports (Weston 2011, Weston 2012) included in the EPA Remedial Action Report (RAR) for the Parker Road water main extension (EPA 2015d) and were used as supplemental information for the delineation of the 1,4-dioxane plume. Neither benzene nor TCE exceeded the GWQS in any of the samples from January or June 2011 and therefore, had no influence on depictions of the extent of contamination.

According to the reports, 160 properties were sampled in January 2011, and the samples were analyzed for VOCs and 1,4-dioxane. The influent and effluent of the CFS treatment system were also sampled at the time (46 and 48 µg/L, respectively, as indicated by the sampling codes, which were not included in the Weston reports due to confidentiality concerns, but were provided to HDR by EPA).

In June 2011, 52 properties were sampled and the samples were analyzed for VOCs, 1,4-dioxane, and formaldehyde. Properties with detections of 1,4-dioxane in January 2011, and properties in the area to the east and northeast of the landfill were resampled in June 2011. One property not sampled in January 2011 was also sampled in June 2011. The sampling results for the two rounds and the sampling trip report for the June 2011 event suggest that the landfill treatment plant influent and effluent were again sampled in June 2011, but that the samples were coded incorrectly with the identifier for the potable well at the landfill. The landfill well was non-detect for 1,4-dioxane in January 2011, and the influent and effluent had concentrations of 46 and 48 µg/L, respectively. In June 2011, the two samples at the landfill, coded for the well, had concentrations of 65 and 76 µg/L, respectively. Samples from 17 different properties had detections of 1,4-dioxane in either one or both of the sampling rounds. The analytical results for 1,4-dioxane were presented on figures included in the trip reports that grouped results with color-coding into non-detects, detections of less than 3 µg/L (13 parcels), and detections equal to or greater than 3 µg/L (four parcels).[16] The detected concentrations for 1,4-dioxane in the potable water wells ranged from 0.46 to 7.5 µg/L in January 2011 and from 0.29 to 7.6 µg/L in June 2011. During both sampling rounds, the highest concentrations were reported for properties on Schoolhouse Lane. Because of the confidential nature of residential potable water sampling results, the 1,4-dioxane results are described in the RIR only in general terms and the trip reports for the 2011 sampling events were not included in the RI appendices. The three properties with 1,4-dioxane concentrations of 3 µg/L or more in potable well water included three parcels in the area to the northeast of the landfill (on Schoolhouse Lane and Route 24/Route 513). Of the 13 properties where 1,4-dioxane was detected at concentrations of less than 3 µg/L, two were on East Valley Brook Road (northwest of the landfill), one was along Parker Road (south of the landfill), and the remaining 10 properties were along Schoolhouse Lane, Parker Road, and Route 24/Route 513 (northeast of the landfill).

2011 EPA Treatability Study (Environmental Restoration 2011)

In 2011, Environmental Restoration, LLC conducted a treatability study on behalf of EPA Region 2 in order to evaluate treatment of 1,4 dioxane in domestic water, using a combination of ozone addition

[16] Detection limits were not indicated in the sampling trip reports or the data summary tables for the two sampling rounds provided by EPA to HDR; however, the lowest reported concentrations for both sampling rounds were below the GWQS for 1,4-dioxane of 0.4 µg/L adopted in January 2018. At the time of the sampling events, the ISGWQC was 10 µg/L because the PQL was 10 µg/L. However, results were compared to the GWQC of 3 µg/L at the time.

and ultraviolet radiation, followed by polishing of the treated effluent with carbon filtration. The study consisted of three elements:

1) a bench scale study of the fully designed and operational treatment system,
2) a pilot test of the system in the field at several of the impacted locations, and
3) a pilot-scale test at the CFS treatment plant.

Details of system design and test conditions are described in the treatability study report. Samples collected throughout the study were analyzed for VOCs, SVOCs, formaldehyde (a byproduct of the chemical degradation of 1,4-dioxane), and general water quality parameters, including iron, manganese, alkalinity, and hardness. The results of the bench scale study indicated that for influent concentrations of less than 3 to 202 µg/L, 1,4-dioxane concentrations were reduced by approximately 70 to 80 percent with one pass through the system. The pilot testing at impacted residential locations was hampered by lower than expected 1,4-dioxane concentrations at the influent (<2 µg/L); however, the concentrations of formaldehyde, which was not present in influent samples, were unexpectedly high in the effluent (to 53.9 µg/L). Similar results were reported for the pilot-scale test at the CFS treatment plant.

2012 – 2015 NJDEP Treatability Studies (Kimball 2012, NJDEP 2015a)

NJDEP conducted treatability and pilot test studies to assess the potential for reducing 1,4-dioxane concentrations in plant effluent to below the previous GWQC of 3 µg/L (NJDEP 2008, Kimball 2012, Kimball 2015, NJDEP 2015a).[17] The treatability studies are described in the FS report.

2013 Potable Well Sampling (NJDEP 2017a)

NJDEP collected potable water samples from 13 residential POETS and 13 other potable raw (pre-treatment) samples in January 2013. 1,4-dioxane was detected at concentrations between 1.2 J µg/L and 4.9 µg/L in nine samples. Two of these samples were POETS influent (pre-treatment) samples and the remaining seven were other potable raw water (pre-treatment) samples. The detection limit for the sampling event was 1.9 µg/L. Because the sample identifiers were coded to protect the confidentiality of the results, HDR was not able to compare the 2013 results to EPA's 2011 potable water results. Because of the confidential nature of residential potable water sampling results, the 2013 1,4-dioxane results are described in the RIR only in general terms.

2015 Parker Road Water Main Extension (EPA 2015d)

In July 2015, EPA completed the extension of a water line and connection of 73 homes and businesses, totaling 80 connections. The homes and businesses were in an area impacted or threatened by contaminated groundwater from CFS. The completed water line provides water from the Washington Township Municipal Utilities Authority (WTMUA) to homes and businesses along Parker Road, Schoolhouse Lane, the access road to the Chester Township Park (Parker Preserve), and a small portion of Route 513 (also referred to as Route 24) west of the intersection of Parker Road and Route 513. The work also included the abandonment of 53 potable water wells. A small number of property owners that connected to the water line obtained approval to keep wells for non-potable uses from the WTMUA, under the condition that backflow preventers were installed (WTMUA 2015). Twelve wells at 10 properties remain in use. In addition, five wells were inaccessible because of their location underneath permanent structures and not abandoned. The

[17] The 2008 ISGWQC was 3 µg/L and the PQL was 10 µg/L. The November 2015 ISGWQC was 0.4 µg/L and the PQL was 0.1 µg/L, and in January 2018, NJDEP adopted the higher of the two 2015 values as the GWQS for 1,4-dioxane.

EPA RAR (EPA 2015d) and other documentation (WTMUA 2015) also indicate that some owners declined to have their properties connected to public water.

1.7 Summary of Previous Investigations of the Areas Outside the Landfill Boundary

The systematic investigation of deep groundwater outside the landfill property began in 2004 with an NJDEP investigation at an adjoining area to the northeast. EPA took over the RI of deep groundwater from NJDEP in July 2009. The previous investigations of deep groundwater are summarized in the following table and details of the earlier investigations are presented following the table and are also discussed throughout the RI. Analytical results for the previous investigations generally did not include TICs, so the potential presence of the two TIC COCs could not be verified.

Summary of Prior Investigations – Outside the CFS Landfill Boundary			
Date	Activity	Major Findings/Actions	Source/References
6/2004 – 1/2005	Millstone Crossing Development Potable Well Sampling	Boreholes for potable wells within a planned residential subdivision were contaminated with VOCs and SVOCs; remaining long open boreholes continue to provide vertical pathways to the bedrock aquifer	NJDEP 2005a
10-12/ 2004	Geophysical investigation Millstone Crossing boreholes	Characterized subsurface geology controlling the storage and movement of groundwater and the associated VOC contamination	NJDEP 2005b, Herman 2006
2005-2008	RI and Remedial Action Selection for Deep Groundwater	Deep groundwater to the north and northeast contaminated with VOCs; shallow groundwater at the landfill contaminated with VOCs, including 1,4-dioxane; sub-slab soil gas samples at Schoolhouse Lane residences did not exceed NJDEP soil gas screening levels in effect at the time	Berger 2007, Berger 2010
2010	Vapor Intrusion Screening	EPA collected and analyzed indoor air and sub-slab soil gas samples at 10 residential properties on Schoolhouse Lane and three properties on Parker Road in April 2010. Some indoor air results exceeded screening levels for 1,2-dichloroethane, benzene, ethylbenzene and TCE, but not the EPA removal action levels in effect at the time	EPA 2010a
2011	Long-term pump test at bedrock recovery well RW-T	5½ months of pumping indicated preferential drawdown in SW-NE direction; well considered usable as a recovery well for contaminated bedrock aquifer groundwater	Handex 2011

2004 Millstone Crossing Well Investigation (NJDEP 2005b, Herman 2006)

A downhole geophysical investigation of boreholes at a proposed residential subdivision, known at the time as Millstone Crossing, was completed by the New Jersey Geological Survey (NJGS) in late 2004 to assist NJDEP.[18] The investigated area is to the northeast of the landfill (Figure 1.4) and is now known as the Chester Township Parker Preserve. The subdivision could not be approved at the time because of the lack of clean groundwater for potable use.

The purpose of the investigation was to characterize subsurface geology as a control of the storage and movement of groundwater and the associated VOC contamination. Orientation of bedrock structures was determined using an optical televiewer. Fluid temperature, conductivity and electrical resistivity were logged and vertical flow inside the boreholes was determined using a heat-pulse flow meter. The total depths for the five investigated boreholes ranged from 343 feet to 511 feet. Due to equipment constraints, deeper boreholes (>550 feet bgs) could not be logged.

The investigation identified three types of planar structures:

- Compositional layering; alternating dark (amphibole/hornblende rich) to light (quartz, feldspar rich) layering or banding corresponding to granitic or gneissoid foliation;
- Fractures; brittle, planar discontinuities (without visible shear offset of any other bedrock feature cut by the fracture); and,
- Shear fractures; fractures that show shear offset of other planar features cut by this type of fracture.

The mean strike of layering at Millstone Crossing was N32°E, and the dip, 66°SE. Primary sets of mineralized fractures and shear planes were found to be dipping northwest at gentle to moderate angles (1° to 39°, and 40° to 59°, respectively), and subordinate sets of mineralized fractures dipped gently to moderately southeast. The investigation found many water-bearing zones resulting from all three types of structures, at all logged depths; however, there were three times as many water-bearing zones related to conductive fractures than to compositional layering. The densest concentration of fracture intersections was found to follow the trend of regional strike and plunge gently northeast, leading the author to conclude that structural intersection of layering fractures with subparallel, tectonic shear fractures probably results in pronounced horizontal conductivity in deep bedrock oriented along regional strike to the northeast. The eastern boundary of the plume at the time of the investigation was formed by a topographic ridge running parallel to Parker Road.

The investigation also determined upward flow for a number of wells in the low-lying area between the landfill and Schoolhouse Lane to the north.

Dark staining of the rock matrix extending as much as an inch from fractures, intersecting fractures and intersections of fractures and layers was also observed. This staining of the rock matrix was considered to be an indication of groundwater contamination along mineralized fracture planes.

[18] The subdivision was abandoned when groundwater in the boreholes for the intended residential supply wells was found to be impacted by contamination originating from CFS.

Bedrock in uncontaminated wells and along nonconductive fractures showed no apparent staining along correlative fracture sets. The staining was thought to stem from chemical alteration of iron-rich minerals, such as chlorite, that fill fractures and shear planes. Although the process chemistry was unclear, a series of chemical reactions involving the oxidation of iron and reductive dechlorination of VOCs in aqueous media was proposed to be responsible (Herman 2006).

2007-2008 Remedial Investigation and Remedial Action Selection (Berger 2010)

The Louis Berger Group, Inc. (Berger), under contract to NJDEP, performed field activities for the investigation of deep bedrock groundwater between 2005 and 2008.

NJDEP and EPA had recommended additional field activities, including borehole logging, downhole imaging and packer testing at the Millstone Crossing bedrock boreholes, sampling of landfill piezometers, sampling of stream pore water at Trout Brook and its tributaries, vapor intrusion sampling at four homes on Schoolhouse Lane, and development of a database of historic analytical results. The investigations were conducted based on results of earlier field investigations completed by Berger during 2005 and 2006 that were initially presented in an Interim Letter Report – Remedial Investigations (ILR-RI) (Berger 2007). After receiving comments on the 2007 report from NJDEP and EPA, Berger revised and presented the information in the 2010 report.

The results of the packer testing at the Millstone Crossing boreholes indicated that at seven of the nine sampled boreholes, concentrations of at least one of the COCs for this RI exceeded the GWQS for samples from one or more depth intervals. The concentration ranges for the COCs that were analyzed for and their reported detections were:

Compound	Range of Detections [µg/L]	No. of Exceeding Wells	GWQS [µg/L]
Benzene	2.1 J - 21	7 of 9 tested	1
TCE	2.4 J - 13	4 of 9 tested	1
DEHP	2.2 J – 4.5 J	1 of 1 tested	3
Arsenic	2.6 – 8.8	1 of 3 tested	3
Chromium	0.33 – 2.4 J	0 of 3 tested	70
Lead	2.3 - 15	1 of 3 tested)	5

The groundwater samples from the Millstone Crossing bedrock wells were also analyzed for 1,4-dioxane and all samples were reported as non-detect; however, the high detection limit of 100 µg/L likely masked its presence. At the time, 1,4-dioxane did not have a GWQS (an ISGWQS for 1,4-dioxane of 10 µg/L became effective February 11, 2008). Because the Millstone Crossing test wells were installed as open boreholes for future domestic potable use, and not as properly constructed monitoring wells, they act as conduits for vertical movement of contaminants in groundwater. The packer testing samples were not analyzed for pesticides, so alpha-BHC, another COC, would not have been detected.

Because exceedances of the GWQS for benzene, TCE, arsenic, and lead were identified at the deepest intervals in at least one borehole each, vertical delineation of the extent of contamination

was not achieved during the 2007/2008 packer testing. Details on the vertical delineation of the RI COCs at the Millstone Crossing boreholes is included in Section 4.1.2.3.

The results of the landfill piezometer sampling (October – November 2007) indicated that concentrations of several VOCs, including benzene (2.6 J – 480 D µg/L), TBA (50 - 400 µg/L), and vinyl chloride (5.3 µg/L) exceeded the GWQS at several locations. For TBA, the highest concentrations were reported for piezometers PZ-1 in the southwestern portion of the landfill (400 µg/L), PZ-6 in the central section (210 µg/L), and PZ-27 in the northeastern portion (110 µg/L). PZ-27 also had the highest concentrations of benzene (480 D µg/L) and shared the highest concentration of 1,4-dioxane (340 µg/L). 1,4-dioxane was detected at five piezometers at concentrations of between 38 J µg/L and 340 µg/L, with the highest concentration detected in samples from piezometers PZ-27 (northeast portion of the landfill) and at PZ-1, in the southwest portion of the landfill. Because the detection limit for 1,4-dioxane during the investigation was 100 µg/L, lower concentrations may have gone undetected in 2007. All piezometers were installed in the overburden and samples were collected using bailers.

Berger conducted the pore water sampling at Trout Brook and its tributaries (to the west and south of the landfill)[19] using 2-inch PVC wells points installed with one-foot screens below the steam bed. The results of the stream pore water sampling indicated no exceedances of NJDEP GWQS or SWQS. The pore water samples were also analyzed for 1,4-dioxane, which was reported for all samples as non-detect but with an elevated detection limit of 100 µg/L.

Because groundwater contamination in excess of GWQS was identified in bedrock potable wells and overburden wells in the residential area on Schoolhouse Lane, Berger collected sub-slab soil vapor samples at four residences in November 2007 and March 2008. The sub-slab soil vapor samples were analyzed for VOCs by EPA Method TO-15 and analytical results compared against NJDEP's Soil Gas Screening Levels (SGSL). 1,4-dioxane was not detected in any of the four sub-slab samples, while benzene was detected in three samples at concentrations between 0.71 and 3.2 µg/m^3, below the SSGL of 16 µg/m^3. 1,4-dichlorobenzene, in one sample, was the only compound that exceeded the SGSLs in any of the subslab samples, and this exceedance was not consistent with exceedances documented in groundwater samples collected along Schoolhouse Lane. Subsequent indoor air sampling to determine if the vapor intrusion pathway was complete detected benzene in basements and on the first floor of residences at concentrations from 0.45 to 2.1 µg/m^3, compared to the Indoor Air Screening Level (IASL) of 2 µg/m^3. The highest concentration of benzene was reported for a sample collected on the first floor. The results of the indoor air sampling were not deemed significant by NJDEP, and because there were no exceedances of the IASL in the basement of the residence with the first floor exceedance, it was expected that this slight exceedance of the benzene IASL may have been due to the presence of household cleaners or other unknown contributors.

2010 Vapor Intrusion Investigation (EPA 2010a)

EPA collected indoor air and sub-slab soil gas samples in residential properties near the study area in Chester Township in April 2010 and analyzed the samples for VOCs. Initial comparison of the analytical data from these samples to the indoor air screening levels (IASLs) available in 2010 indicated IASL exceedances of 1,2-dichloroethane, benzene, ethylbenzene and TCE in indoor air. None of the concentrations detected exceeded the less stringent 2007 EPA removal action levels for indoor air. There were no exceedances of the subslab soil gas screening levels in force at that time.

[19] Pore water sampling was conducted at 14 locations on Trout Brook, the East Trout Brook UNT, and an UNT of Trout Brook.

The NJDEP Vapor Intrusion Guidance, which includes screening and action levels and the actions that are required to be taken given the criteria that are exceeded, was updated in January 2018 (NJDEP 2018b). The actions vary by media and concentration. The EPA OSWER *Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air* was updated in June 2015 (EPA 2015e). As both the NJDEP and EPA documents are guidance and not regulation or promulgated standards, screening and action levels would TBCs, not ARARs.

The 2010 indoor air results were reviewed and evaluated in detail in the BHRRA (Appendix CC) which compared the data to the current EPA Residential Indoor Air Vapor Intrusion Screening Levels (VISLs) (EPA 2018a), NJDEP Generic Residential Indoor Air Vapor Intrusion Screening Levels (IASLs) (NJDEP 2018b) and NJDEP Indoor Air Rapid Action Levels (RALs) (NJDEP 2018b).

The comparison indicated that results for eight analytes exceeded the EPA Indoor Air VISLs, which are the most stringent of the criteria used. Of the eight compounds, four (1,2-dichloroethane, benzene, ethylbenzene and TCE) also exceeded the NJ IASLs. TCE had a maximum indoor air concentration of 6.4 ug/m3, which is greater than the NJ RAL of 4 ug/m3. The TCE in indoor air may originate from sources unrelated to VI within the homes, as no TCE was detected in any of the sub-slab soil gas samples. In addition, the closet locations with elevated TCE concentrations were near the perimeter of the landfill, more than a quarter mile from any residences.

Sub-slab soil gas results were compared to the current EPA Sub-Slab Soil Gas VISLs (EPA 2018a) and NJDEP Generic Residential Soil Gas VISLs (SGSL) (NJDEP 2018b).

Sub-slab soil gas results were compared to the current EPA Sub-Slab Soil Gas VISLs and NJDEP Generic Residential Soil Gas VISLs (Appendix CC). All of the samples had VOC concentrations below the screening levels, except for benzene, chloroform, and vinyl chloride, which exceeded one or both screening levels at three different properties:

- Benzene concentration of 17 ug/m^3 compared to EPA Sub-Slab VISL of 12 ug/m^3 and NJ Soil Gas VISL of 16 ug/m^3
- Chloroform concentration of 27 ug/m^3 compared to criteria of 4.07 and 24 ug/m^3, respectively
- Vinyl chloride concentration of 7.7 ug/m^3 compared EPA Sub-Slab VISL of 5.59 ug/m^3

No additional vapor intrusion sampling was performed for this RI.

2011 Long-Term Pump Test (Handex 2011)

Between September 2010 and March 2011, Handex performed a long-term pump test on bedrock recovery well RW-T with nearby observation wells, and sampling of well RW-T for chemical analysis. The scope of work consisted of pumping recovery well RW-T for an extended period of time to determine the feasibility of remediating groundwater contamination by pumping from the bedrock aquifer. The objectives of the test included determining the maximum long-term sustainable yield of RW-T, the influence of pumping RW-T on the contamination in the bedrock aquifer, and the feasibility of using RW-T as a recovery well based on observed drawdown in the bedrock and overburden aquifers.

Recovery well RW-T is a 6-inch diameter bedrock well with 8-inch outer casing set one foot into competent rock. The well is screened from 65 to 115 feet bgs. Pumping rates during the test varied from 120 gallons per minute (gpm) during the first month to between 80 and 60 gpm for the remainder of the test period. Flow rates after January 2011 were estimated because iron sludge build-up on the flow meter paddle led to malfunctions.

Water levels were measured in selected monitoring wells screened in the shallow unconsolidated and the deeper consolidated formation on a daily, weekly, and monthly basis over the duration of the pump test, and for three weeks after pumping stopped. The Handex report included groundwater contour maps for non-pumping and pumping conditions for both the unconsolidated water table aquifer and consolidated bedrock aquifer, and hydrographs (plotting groundwater levels against time to show the influence of pumping RW-T on each well and the rate of water level recovery after pumping was stopped).

Effluent samples were collected weekly for the first 60 days of the pump test and at different intervals for the remainder of the test. A total of 15 effluent samples were analyzed for VOCs, SVOCs and general chemistry parameters (including chlorides, ammonia and suspended solids). Benzene, 1,4-dioxane and TBA exceeded the NJDEP GWQS. Benzene concentrations ranged from 1.1 µg/L to 5.5 µg/L (GWQS 1 µg/L) and increased to 1.6 µg/L during the first week to a high of 5.5 µg/L in week 9. The concentrations for 1,4-dioxane (ISGWQS: 10 µg/L at the time) was 18 µg/L at the beginning of the test, increased to 24 µg/L in week 4 and remained between 24 and 28 µg/L until the end of the pump test (week 15). TBA, with a range of 47 to 110 µg/L, exceeded the GWQS (100 µg/L) in two of 15 samples (weeks 6 and 9). Other VOCs detected below GWQS were ethyl ether (74-250 µg/L), 1,4-dichlorobenzene (4.1-7.9 µg/L), and chlorobenzene (3.9-7.9 µg/L).

By the end of the pump test period (after 163 days), well RW-T stabilized at an estimated 62 gpm (+/-5 gpm) with 70 feet of drawdown. Based on the test results, Handex considered the long-term sustainable yield of RW-T to be 40 to 45 gpm with a drawdown of 45 to 50 feet.

The drawdown contour map for the test (Figure 1-2) indicated preferential drawdown in a northeast to southwest direction. The drawdown map incorporated groundwater elevation data from both the water table and bedrock aquifers since the pumping influence was found to be similar in both shallow and deeper wells. At an average flow rate of 77 gpm, up to 10 feet of drawdown was observed 630 feet to the northeast and 750 feet to the southwest of the pumping well. Drawdown in a northwest-southeast orientation from the pumping well was less pronounced, extending approximately 200 feet in either direction from RW-T. The preferred northeast-southwest orientation of drawdown suggests that the bedrock structure is controlling groundwater flow in the bedrock aquifer. This was supported by the distance-drawdown graph showing a maximum radius of influence of 1,800 feet in a northeast direction from RW-T.[20]

Handex considered the pump test results as supporting the use of RW-T as a recovery well to capture contaminated groundwater migrating in the bedrock aquifer, based on the presence of elevated concentrations of benzene and 1,4-dioxane, and the sustainable well yield.

[20] During the OU2 RI, fracture zones and preferential flow paths aligned in the direction indicated by the 2011 pump test were confirmed through the surface geophysics and Willowstick® investigations (Sections 3.2.2.6.3 and 3.6.2.2.4).

2 Field Investigation

HDR conducted the RI field investigation in four phases (I through IV) between April 2011 and July 2017. The first two phases focused on bedrock monitoring well drilling, testing, and construction. Phase I involved data collection, evaluation and determination of areas for additional geophysical investigations of groundwater and the placement of additional monitoring wells for Phase II. Phase III focused on analytical sample collection of surface water, sediment and soil. Phase IV included modifications to an existing bedrock monitoring well, an aquifer pump test, a pilot test of a 1,4-dioxane treatment system, and sampling of surface water and sediment. All phases of fieldwork included groundwater sampling. Table 2-1 provides a schedule of field activities. Section 4 includes a discussion of analytical results.

EPA provided sample analysis through the Contract Laboratory Program (CLP) and EPA's Division of Environmental Science and Assessment (DESA) laboratory, with the exception of tritium analysis (155 samples), a portion of the chloride analysis (89 samples), total dissolved solids (TDS) analysis (88 samples), TSS analysis (96 samples), and TOC analysis (99 samples), provided by a non-CLP laboratory subcontracted by HDR. A non-CLP laboratory also performed Tritium analysis on potable water samples, groundwater and surface water samples. The tritium data underwent Level 3 validation by an independent data validator retained by HDR.[21]

Sample analyses during Phase IV of the investigation consisted of the following:

Date	Sample Type	Parameters	Laboratories
January 2017	Monitoring Well Samples (pre-well modification)	VOCs, SVOCs, Pesticides, PCBs Alkalinity, chloride, cyanide, TOC, TDS, TSS Metals	TestAmerica EPA DESA CLP
Feb. 2017	Pilot test groundwater samples	1,4-dioxane Split samples with pilot test vendor: VOCs, SVOCs	Pilot Test Contractor CLP
March 2017	Monitoring Well Samples (post-well modification)	VOCs, SVOCs, Pesticides, PCBs Ammonia, chloride, metals, cyanide, TOC, TDS, TSS, sulfate	CLP EPA DESA
Sept. 2017	Surface Water (seeps, springs, streams)	VOCs, SVOCs, PCBs, metals (total and dissolved), cyanide, TOC, TDS, TSS	CLP
Sept. 2017	Sediment	VOCs, SVOCs, pesticides, PCBs, metals, cyanide, TOC, grain size, and percent moisture.	CLP

[21] Phase I of the investigation included tritium analysis of aqueous samples as an indicator of contamination having originated at the landfill, as tritium is frequently found in association with groundwater contamination originating at some types of landfills. Results indicted that this was not the case for CFS.

The majority of the field effort focused on the groundwater investigation, but the field activities also included surface water, sediment and soil sampling, geophysical surveys, land surveys, ecological surveys (wetlands and wildlife), and investigation derived waste (IDW) disposal.

HDR conducted the field investigation in accordance with the EPA-approved QAPP dated April 8, 2011. In addition to describing field activities, the following sections also include explanations of any deviations from the QAPP that occurred during the field investigation. QAPP deviations did not result in impacts to the data quality objectives for the investigations.

The Data Evaluation Report (DER) in Appendix B includes a data quality assessment consisting of a detailed review of analytical data to ensure that the data met the project measurement criteria for the data quality indicators (DQIs), representativeness, completeness, comparability, precision and accuracy. Section 2.7 includes a discussion of quality control samples collected during the RI.

2.1 Groundwater Investigation

The groundwater investigation determined the nature and extent of groundwater contamination originating from the landfill and investigated select sources of contamination (e.g., possible buried drums, North Waste Cell remains) within the landfill. The groundwater investigation included:

- Surveys
  - Resistivity Survey
  - Willowstick® Electromagnetic Survey
  - Well Condition Survey
- Groundwater Elevation Measurements
- Groundwater/Surface Water Interaction Evaluation
- Bedrock Monitoring Well Drilling and Development
- Bedrock Monitoring Well Testing
  - Downhole Geophysical Logging
  - FLUTe™ Hydraulic Profiling
  - Packer Testing
- Bedrock Monitoring Well Completion
  - Multi-port Well Completion
  - Conventional Monitoring Well Completion
- Groundwater Sampling

2.1.1 Groundwater-Related Surveys

Geophysical surveys located groundwater flow pathways and zones of preferential flow both inside the landfill boundary and in the surrounding area, informed the selection of locations for future bedrock monitoring wells, and guided the CSM.

2.1.1.1 Resistivity Survey

Phase I of the RI included a two-dimensional Electrical Resistivity Imaging (2D ERI) survey to locate water-bearing fractures. ERI also provides other information on the physical properties of the subsurface, including interpreted bedrock surface depth and stratigraphy.

The two-dimensional ERI method applies an electrical current to two electrodes in the ground and collection of electric field measurements at the ground surface. Interpretation of these measurements can help determine physical properties of the subsurface. Appendix C provides a full description of the survey methodology and the results.

Table 2-2 summarizes the six direct current (DC) resistivity profiles conducted during Phase I. Two of the profiles were to the south of the landfill and four profiles were to the north. Figure 2-3 depicts the approximate locations of the survey lines and Appendix C provides additional details. The high-tension electrical transmission lines running overhead along the utility corridor resulted in interference that limited survey data usability for the area directly under the power lines. The survey was able to produce usable data on either side of the transmission lines. The depth penetration of the ERI survey was approximately 225 feet bgs for most of the profiles. Prominent potential fracture zones occurred on five of the six profiles (Sheets 1 through 3 in Appendix C). Section 3.6.2.2.3 describes the findings of the resistivity survey.

The results of the survey aided in the development of the CSM and in locating monitoring wells for Phase I.

2.1.1.2 Buried Drum Investigation

Magnetic gradient and electromagnetic terrain conductivity (EM-31) surveys conducted in June 2011 attempted to locate and delineate potentially buried drums beneath the landfill cap that could be continuing sources of groundwater contamination. These surveys occurred at two locations on the landfill, the northeast corner and the southeast corner near the treatment plant (Figure 2-3). Review of several documents describing previous drum and test pit investigations at CFS, including Dispoto 1997, Barkett 2004, and Halloran 2006, supported the selection of drum survey locations.

The buried drum investigation included a terrain conductivity survey completed by inducing an electromagnetic current into the ground from a transmitter coil. The resulting secondary electromagnetic field, which is dependent on the conductivity of materials in the ground, is measured and recorded at a receiver coil at a fixed location. Measurements consist of conductivity and the in-phase component of the electromagnetic field (which is sensitive to the presence of metallic conductors), which are then interpreted.

The magnetic gradient survey measures the earth's magnetic field at discrete points. Buried magnetic objects will locally distort the earth's magnetic field. The survey employed the following equipment:

- EM-31 Terrain Conductivity meter
- 858 Cesium Vapor Magnetometer
- Differential Global Positioning System (GPS)

The vegetative cover on the landfill prevented the use of ground-penetrating radar (GPR) to delineate buried drums. The methods described above are both sufficient to delineate buried drums. Section 4.2.3 presents the survey results and Appendix D contains the report.

2.1.1.3 Willowstick® Electromagnetic Survey

Phase II of the RI included a Willowstick® electromagnetic survey to locate preferential groundwater flow paths beneath the landfill and to the northeast, parallel to the utility corridor.

This survey uses principles similar to the resistivity survey, but placement of electrodes is within monitoring wells at depth and/or in surface water bodies with collection of magnetic field measurements at the ground surface. Modeling and interpretation of these measurements results in a three-dimensional depiction of preferential groundwater flow paths. Appendix E provides a full description of the survey methodology and results.

The Willowstick® survey was limited to the low-lying area between the northern landfill perimeter and Schoolhouse Lane (Figure 3-11). Six separate surveys covered this area, five using separate well pairs and one using a well-surface water pair. Table 2-3 summarizes the electrode locations and depths for each survey.

The grounded transmission line towers facilitated flow of the survey's electric current up and onto the overhead power lines instead of the current remaining in the ground within the utility corridor. This resulted in a data gap for an approximately 300-foot wide area centered on the utility corridor (Figure 3-11).

HDR used the results of the Willowstick® survey to select locations for Phase II monitoring wells and refine the CSM.

2.1.1.4 Baseline Well Condition Survey

A baseline, well condition survey determined the location, condition and depth of each of the existing monitoring wells at CFS and assessed the usability of each well for monitoring purposes.

The survey identified existing monitoring wells from environmental reports and a well record search through the NJDEP Bureau of Water Allocation. The NJDEP well records search also provided abandonment reports and information on the construction of nearby potable wells, including screen interval depth, to assist in reviewing residential well sampling results.

A field effort followed completion of the well inventory, with the following objectives:

- Verify the monitoring well locations, reported depths and, if applicable, abandonment details;
- Assess the condition of each monitoring well and its surface features;
- Assess its potential for inclusion in future groundwater elevation measurement events;
- Assess its potential for inclusion in future groundwater sampling events; and
- Collect depth-to-water and depth-to-bottom measurements.

Appendix F contains the EPA Region 2 Well Assessment forms completed for this effort. The results of the well condition survey assisted the investigation team in making informed decisions as to whether to include or exclude monitoring wells from sampling events and data assessment.

2.1.1.5 Schoolhouse Lane Potable Well Condition Survey

An inventory of potable wells associated with the residences on Schoolhouse Lane (Figure 1-5) filled in data gaps from the initial NJDEP well search. NJDEP was unable to provide well records for the majority of the residences along Schoolhouse Lane. Previous residential well sampling along

Schoolhouse Lane revealed some impacted wells and some non-impacted wells with no apparent pattern to the contamination.

After opening each well, survey measurements consisted of well depth, casing depth, pump depth and well condition (the well at 6 Schoolhouse Lane could not be located). The data gathered aided in the refinement of the CSM. Table 2-4 summarizes these efforts and Appendix F contains the EPA Region 2 Well Assessment forms.

2.1.2 Water Level Elevation Measurements

HDR performed water level elevations measurements throughout the field investigation. The objectives of measuring groundwater and surface water elevations were to:

- Determine changes in groundwater elevations based on precipitation and time of year;
- Determine changes in groundwater elevations after purging during packer testing;
- Collect sufficient data to prepare potentiometric surface maps; and
- Evaluate if groundwater was discharging into surface water bodies.

2.1.2.1 Groundwater Water Level Measurements

A synoptic depth to groundwater measurement event conducted in May 2012 augmented water level measurements collected during several sampling events throughout the field investigation. The May 2012 synoptic event occurred concurrently with the monthly water level monitoring conducted by the NJDEP (i.e., HDR measured water levels in wells where NJDEP had not), thereby producing a full set of measurements. Table 2.5 provides water level measurements and water table elevations for the May 2012 synoptic measurement event, representing the most comprehensive set of measurements for the RI. Appendix G provides NJDEP's water level measurements between January 2009 and April 2015 in table format and plotted as time graphs by well type (overburden piezometers, shallow and deep bedrock monitoring wells). Figures 3-9 (Overburden Aquifer) and 3-10a (Bedrock Aquifer) depict the measuring points (monitoring well, piezometers and stream gauges) included in the May 2012 synoptic measurement event. HDR also used the NJDEP monthly depth to water measurements for bedrock wells to create additional potentiometric surface elevations figures (3-10b through 3-10d) for three additional dates in 2014 (May, August, and November).

In addition, Phase I of the RI included a long-term groundwater elevation monitoring program to establish long-term trends and to determine if the groundwater levels at CFS exhibit any influence from off-site groundwater pumping. Selected were a subset of 13 representative wells (11 bedrock wells and two overburden piezometers) for inclusion in the program (Figure 2-4). Water level logging transducers recorded water levels at 15-minute intervals for a period of three months (August through October 2012).

Table 2-8 provides a list of wells used for long-term monitoring and further details on this effort. Section 3.6.2.2.1 presents the observations for the long-term water level monitoring and Appendix H contains the hydrographs showing the water levels over time.

2.1.2.2 Groundwater/Surface Water Interaction

Phase I of the field investigation included an evaluation of the interaction between groundwater and surface water. The objectives of this evaluation were to correlate groundwater and surface water elevations and determine if groundwater discharges to surface waters.

The evaluation consisted of nine locations along Trout Brook, East Trout Brook, the Lamington River UNT along Schoolhouse Lane, and in the wetland west of the landfill. Each of the nine locations consisted of a piezometer/stream gauge pair (Figure 2-2a) with a stream gauge installation in the surface water body and a shallow piezometer on the shore as close to the stream gauge as possible.[22] A NJ-licensed surveyor measured the piezometer casing elevations.

Data loggers installed in each piezometer and stream gauge monitored water levels for a period of three months. Table 2-7 provides a list of piezometers and stream gauges and additional details of the investigation. Review of the data determined whether the streams were gaining or losing streams and concurrent precipitation data determined any changes in stream conditions based on rainfall. Sections 3.5 and 3.6.2.1.1 discuss the results of the investigation of the interaction between groundwater and surface water.

2.1.3 Bedrock Monitoring Well Drilling and Development

Bedrock borehole drilling consisted of 15 boreholes drilled during Phase I, and five boreholes drilled during Phase II, for a total of 20 boreholes for completion as monitoring wells (Figure 2-1). Table 2-9 provides the rationale for the selection of each monitoring well location.

A NJ-licensed drilling subcontractor installed the boreholes and obtained the required permits prior to drilling (Appendix I). Upon completion of drilling the open borehole, the driller installed a six-inch diameter steel surface casing at least 10 feet into competent bedrock. The driller then grouted the casing in place to seal off the remainder of the borehole from potential hydraulic connection between the overburden aquifer and the underlying bedrock aquifer.

Once the casing was in place in each borehole, the drilling method switched to air rotary using a down-hole air hammer fitted with a 5.875-inch diameter, carbide drill bit to advance a borehole of the same nominal diameter through the bedrock to the target depth. Appendix J provides the monitoring well boring logs and includes the drilling methods used for each well.

The dual rotary drilling method utilizes a rig with two drive systems, a lower rotary drive and a top drive rotary head. The lower rotary drive system advances a large diameter steel casing, equipped with a shoe, through the overburden while the top drive system simultaneously advances a drill string equipped with a downhole hammer. In this application, a 10-inch diameter temporary outer casing along with a nominal 8-inch carbide drill bit on a downhole air-hammer advanced simultaneously to bedrock. The downhole air-hammer then drilled at least 10 feet into competent rock after which the 6-inch steel casing was set and grouted in place and the 10-inch diameter temporary outer casing removed. Compressed air evacuated the drill cuttings from the borehole during drilling, diverting the cuttings directly into a roll-off container.

A geologist logged the drilling to note any changes in stratigraphy and degree of fracturing, collected and evaluated drill cuttings at approximately 10-foot intervals and measured blown yield.

Once the borehole reached the target depth, the driller developed the “open rock” well using the air-lift development method. The air-lift method involves re-advancing the drill string and tooling (air hammer) into the borehole and directing compressed air into the existing water column to discharge

[22] The driller could not install the piezometer and stream gauge adjacent to one another on the upper portion of East Trout Brook (SG109/PZ109) as saturated soils, steep slopes and difficult ground conditions limited drill rig access. Instead, the driller installed the piezometer at the treatment plant discharge channel on the hillside, approximately 14 feet above the stream. Determination of groundwater/surface water interaction at this pair was based on professional judgment and other observations made over the course of the project, in addition to the piezometer/stream gauge data.

the water at the surface. Development continued at each borehole until turbidity measurements for the discharged groundwater were less than 50 Nephelometric Turbidity Units (NTU) for three consecutive measurements taken at 10-minute intervals.

The driller installed FLUTe™ blank well liner systems in each borehole after drilling to temporarily seal the boreholes and prevent cross-contamination during the time periods between the downhole investigations (downhole geophysics, FLUTe™ hydraulic profiling and packer testing) and to satisfy NJDEP well construction requirements. N.J.A.C. Subsection 7:9D-2.4(a)4 specifies that, with the exception of wells used for aquifer pump tests, all wells constructed without screens shall not exceed 25 feet of open borehole. The driller removed and reinstalled the blank liner systems as needed, until completion of the downhole investigations when the wells were permanently completed.[23]

2.1.4 Bedrock Well Testing

The open boreholes each went through a series of tests after drilling and before completion as monitoring wells. The objectives of the testing were to determine:

- Completion of the wells as multi-port or conventional bedrock monitoring wells;
- Depths of multi-port sampling intervals or screen intervals; and
- Hydrogeologic and chemical properties.

2.1.4.1 Downhole Geophysical Investigation

This RI included downhole geophysical investigations only on wells drilled as part of this RI, not on any of the previously existing monitoring wells. In a deviation from the geophysical work plan, no downhole logging occurred at well CF-230D, as well completion and sampling immediately after drilling was necessary for decision-making purposes on the downgradient extent of the plume.

The geophysical subcontractor performed the following suite of downhole geophysical logging at 19 of the 20 bedrock wells during RI Phases I and II (Table 2-10)

- Single-Point Resistivity (NR), Long Normal Resistivity (LNR) and Short Normal Resistivity (SNR)
  - NR logs record the resistance between an electrode in the borehole and one at the ground surface. NR logs are useful in determining lithology, water quality and the location of fractures.
  - LNR and SNR logs record the electrical resistivity between electrodes on a logging probe. This survey used the following electrode spacing: 8-inches, 16-inches, 32-inches and 64-inches. LNR and SNR logs provide information on lithology and locations of fracture zones.
- Fluid Temperature (TMP)
  - TMP logs record the water temperature in the borehole. Temperature information is one of the measurements used to delineate water-bearing zones and identify flow between zones of differing hydraulic head.

[23] The driller installed the blank liners to the target depths in the boreholes unless the FLUTe™-specified cut-off velocity of 0.01 feet of liner per second occurred before the liner reached the bottom of the hole. This liner velocity was a frequent occurrence above the bottom of the borehole; however at that installation velocity the transmissivity of the borehole below the liner is approximately 0.2 cm^2/s and, therefore, cross contamination is not of concern.

- Fluid Resistivity (FR)
    - Electrical resistivity of the water in the borehole is measured which is useful in determining water-bearing zones and identifying vertical flow.
- Caliper (CAL)
    - The caliper tool measures the variation in borehole diameter by measuring electrical resistance on the caliper tool. The electrical variation is determined based on the measured resistances, and then translated to changes in diameter based on a calibration. Borehole diameter commonly affects the other log responses and the caliper log is useful in the analysis of the other geophysical logs. Increased borehole diameters also coincide with fractures or fracture zones.
- Natural Gamma (NG)
    - NG logs record the amount of natural gamma radiation emitted by the rock surrounding the borehole. Clay and shale-bearing rocks commonly emit high gamma radiation because they include weathering products that tend to concentrate sources of radiation.
- Heat Pulse Flow Meter (HPFM), under ambient conditions
    - The HPFM measures the rate and direction of groundwater flow within a borehole. Positive velocities indicate upward flow while negative velocities indicate downward flow. This survey logged non-pumping conditions within the boreholes.
- Acoustic Televiewer (ATV) (includes deviation testing)
    - ATV logs provide a high-resolution sonic image of the borehole wall. The sonic image depicts an oriented image of the acoustic reflectivity of the borehole wall. The logs identify bedding planes, fractures and the orientations of those features.

HDR removed the FLUTe™ blank liners to accommodate the downhole geophysical investigations and re-installed the liners upon completion.

Selection of packer testing intervals followed reviews of the downhole geophysical results, drilling observations and FLUTe™ hydraulic profiling results. The results also informed the determination of final monitoring well completion depths and the CSM, and provided additional information on the site-specific hydrogeology. Appendix K includes the downhole geophysical logs.

2.1.4.2 FLUTe™ Hydraulic Profiling

Hydraulic profiling, a method developed by FLUTe™, measures transmissivity over the length of a borehole while a blank well liner is installed.

During installation of the liner by eversion,[24] the water in the borehole below the liner displaces as the liner descends. The liner forces the displaced water into the surrounding formation through whatever flow paths are available within the borehole (e.g., fractures, bedding planes). The rate at which the displaced water can exit the borehole into the surrounding formation controls the liner's descent rate. As the liner everts during installation, it seals-off available flow paths sequentially from

[24] Eversion – the act of turning inside out. The well liner is installed like a rolled up sock. Instead of a foot pushing down on the bottom of the sock, potable water is used to push the bottom of the liner down the borehole.

the top to the bottom of the borehole. Each time a flow path is sealed-off, the transmissivity of the borehole beneath the liner decreases resulting in a slower liner descent rate.

Measurements during the liner installation process consist of liner eversion velocity and the excess hydraulic head inside the liner, which is the driving force for installation. The final product is a velocity profile from which transmissivities are calculated.

The FLUTe™ Hydraulic Profiling results, in conjunction with drilling observations and downhole geophysical survey results, facilitated selection of depth intervals for packer testing and aided in determining final monitoring well completion depths. The results provided further information on the site-specific hydrogeology and informed the CSM.

2.1.4.3 Packer Testing

The objective of the packer testing was to assist in selecting the well completion depths, specifically the target depths for the ports in the Water FLUTe™ wells and the screen depths for conventional wells by quantifying yield and contaminant levels in the identified fractures.

The driller conducted packer testing at 19 of the 20 RI bedrock wells on depth intervals of interest identified through drilling observations, downhole geophysics and FLUTe™ hydraulic profiling as containing potentially significant water-bearing fracture zones. In a deviation from the work plan, no packer testing occurred at well CF-230D, as well completion and sampling immediately after drilling was necessary for decision-making purposes on the downgradient extent of the plume. Table 2-12 provides details on the selected packer testing intervals for each well. Between one and four fracture zone intervals (identified based on downhole geophysical and other information) were packer tested per borehole, totaling 54 tested intervals ranging in length from five to 95 feet. The majority of the testing intervals (46 of 54) were between 10 and 20 feet in length.

The driller used a straddle packer apparatus (double packers) to isolate the selected fracture zone from the remainder of the borehole. The packer apparatus consisted of two pneumatic rubber seals (packers) separated by a length of perforated steel pipe and connected to the ground surface by a string of 2-inch steel pipe. The driller lowered a submersible pump inside the string to the testing interval and placed water level logging transducers to monitor the zones above, below and inside the packer testing interval, then inflated the packers with nitrogen gas. Packer interval development consisted of pumping the fracture zone between the packers for the maximum sustainable rate for at least fifteen minutes, or removal of three to five volumes of groundwater. HDR monitored the transducers during the pumping to ensure the packers were creating an adequate seal. Sample collection for laboratory analysis (Section 2.1.6.1) followed purging the prescribed volume of water and allowing the testing interval to recharge. Appendix L includes graphs depicting the packer testing results.

2.1.5 Monitoring Well Installation

Borehole completion consisted of either multi-port wells (Water FLUTe™) or conventional monitoring wells based on the results of the borehole testing program, with two exceptions: monitoring well CF-230D as a conventional well without prior borehole testing data, and no completion of the borehole for well CF-215D. Abandonment of borehole CF-215D followed packer testing which yielded poor water production. Nearby well CF-205D also provided delineation to the northeast, so CF-215D was redundant.

Data reduction consisted of a spreadsheet populated with downhole data results (downhole geophysics, packer testing and hydraulic profiling) by test depth interval. Criteria for selection of well

completion depth intervals were those intervals where multiple downhole tests indicated evidence of significant water bearing fractures and packer testing sample analysis indicated groundwater contamination. Well completion options included installation of FLUTe™ multi-port (multi-level) wells or conventional (single interval) monitoring wells. The project team selected conventional well completion for boreholes with only one significant water-bearing fracture, and a contaminated groundwater sample result from packer testing. Selection of the FLUTe™ multi-port well completion option was limited to boreholes having more than one contaminated water-bearing interval.

The drilling subcontractor obtained NJDEP Well Permits for each well (Appendix I). NJDEP approved permit variances for the multi-port wells along with a variance for one conventional monitoring well (CF-226D) that required a 95-foot long screen interval to yield sufficient water for low-flow sampling[25] (Section 2.1.5.5). HDR submitted well records to NJDEP providing as-built details for each well (Appendix J).

Figure 2-1 depicts the locations of the monitoring wells installed during the RI.

2.1.5.1 Water FLUTe™ Multi-Port Monitoring Wells

FLUTe™ installed 13 multi-port wells in the boreholes described in Section 2.1.3 during Phases I and II of the field investigation (wells CF-201D, CF-204D, CF-206D, CF-207D, CF-209D, CF-211D, CF-212D, CF-216D, CF-218D, CF-222D, CF-225D, CF-227D, and CF-228D). Each multi-port well has between two and five sampling ports, one for sampling each fracture zone. The fracture zones at the multi-port wells are between 5 and 10 feet long, with the exception of the longest fracture interval at well CF-216D, which is 20 feet. Modification of well CF-209D to a conventional monitoring well was necessary to conduct the pump test during Phase IV of the investigation, as described in Section 2.1.5.2. Modified well CF-209D has been renamed CF-209D-R. Table 2-11 provides well construction details for the wells installed during the RI.

Criteria evaluated for selection of Water FLUTe™ multi-port systems over other multi-port systems included:

> FLUTe™ provides a means to seal the boreholes using the blank liners between completion of the boreholes and final well completion. Removal and reinstallation is possible during multiple mobilizations.
>
> The liners serve a dual purpose as they seal the borehole and produce hydraulic profiling results during installation. Hydraulic profiling yields continuous transmissivity data over the length of the borehole.
>
> The number of possible sample ports is almost unlimited. The CFS multi-port wells have between two and five ports per well to collect multiple, depth-discrete groundwater samples from a single borehole.

The Water FLUTe™ system allows water directly from the formation to flow through a spacer into a tube inside the surface of the liner. The water flows from the port through the tube to the bottom of the borehole and then upward through a Teflon® check valve into a “U-shaped” pump system. The pump system consists of a larger diameter tube (pump tube), two check valves, and a smaller diameter tube (sample tube). The sampler applies nitrogen gas to the pump tube that pushes the

[25] N.J.A.C. Subsection 7:9D-2.4(a)4 specifies that, with the exception of wells used for aquifer pump tests, all wells constructed without screens shall not exceed 25 feet of open borehole. Therefore, the multiport boreholes required a variance.

water against the check valve through a second check valve and up the sample tube. Each port has the pump and sample tubes accessible at the ground surface.

FLUTe™ shipped the Water FLUTe™ systems to CFS on reels and installed the multi-port wells with support from the drilling contractor. Each system arrived in two pieces spooled over the same reel, the liner (liner, spacers at specified sample port intervals, and a tube from each spacer to the bottom of the liner) and the tubing bundle. The liner seals the borehole except at the spacers that allow water to flow from the formation into the system. The tubing bundle contains the pump systems for each port.

Installation of Water FLUTe™ systems is by eversion, similar to the installation of blank liners. In contrast to blank liners, however, installation of Water FLUTe™ systems is the entire distance to the bottom of the borehole. Eversion is dependent on the ability of the formation below the liner to accept the displaced water. When the formation at the bottom of the borehole cannot accept enough water to evert the liner completely, a pump tube placed beneath the liner at the bottom of the borehole pumps water from this tube, as necessary, to make room for the liner. Connection of the tubing bundle and installation the system's surface features follow removal of the pump tube and complete eversion of the Water FLUTe™.

Potable water inside the Water FLUTe™ provides the hydraulic head necessary to keep the Water FLUTe™ systems in place. If the potentiometric surface in the borehole is within 15 feet or less of the ground surface, a mixture of Baroid® weighting agent and water (aka, heavy mud) or grout in lieu of potable water provide sufficient hydraulic head, as potable water is not heavy enough alone. Removal via pumping of the denser-than-water heavy mud, if necessary, is possible because it does not cure. It is not possible to remove grout, which is a cementitious product, because it cures after hydration, therefore becoming a permanent addition to the well systems. FLUTe™ personnel determined the best Water FLUTe™ installation method on a well-by-well basis. FLUTe™ personnel determined the densities of the heavy mud mixtures for each borehole based on water levels, downhole geophysical logs and hydraulic profiling results.

When used, FLUTe™ installed grout in approximately 25-foot lifts (126 pounds of Portland cement, 28 pounds of bentonite and 30 gallons of water); installing four lifts at each well per day until grouting of the entire borehole was complete.

Table 2-11 provides details on the method used at each well (heavy mud or grout), and the approximate densities of the heavy mud.

All Water FLUTe™ ports were functional after installation. Over time, some sample ports malfunctioned due to lack of communication between the pump tube and sample tube, (i.e., after applying gas to the pump tube, no gas or water discharged from the sample tube). While a cleaning method to remove any clogs recommended by the manufacturer proved unsuccessful, the installation of T-pumps in the non-functional ports remedied the situation. T-pumps are brass t-fittings that allow both pumping and sampling from the existing pump tube.[26] The drawback of T-pumps is that it is no longer possible to measure water levels in the pump tube without removing the Water FLUTe™ system. HDR was not able to measure water levels in the Water FLUTe™ systems with T-pumps.

[26] A field technician attaches the T-pump to the existing pump tube, then inserts a smaller diameter Teflon™ tube, serving as the new sample tube, into the existing pump tube through the T-pump and tightens it in place with a compression fitting. The third connection is for the gas fitting. A field technician applies gas to the gas fitting which fills the original pump tube with compressed gas and pushes the water out of the new sample tube.

Removal of the Water FLUTe™ systems often results in damage; therefore, removal to collect water levels was not an option.

Details on T-pump installation on non-functional Water FLUTe™ ports, along with other well-specific sampling procedure deviations, follows:

- CF-201D – Port 1 sampling took place on October 18, 2012, whereas sampling of the other ports occurred on October 11, 2012. Port 1 recovery was very slow which prevented purging and sampling on the same day. Ample time for recovery allowed for Port 1 sample collection on October 18, 2012.
- CF-204D – Port 2 required T-pump installation prior to the second sampling event.
- CF-206D – Ports 1 through 4 required T-pump installation prior to the second sampling event. Sampling of these four ports utilized the new T-pumps during the VOC re-sample effort in July 2015.
- CF-207D – Port 2 was non-functional during the first sampling event. Sampling of the remaining ports took place on October 10, 2012. Port 2 sampling occurred on August 5, 2013 after installation of a T-pump. Ports 1, 3 and 4 required T-pump installation prior to the second sampling event on December 3, 2014. Sampling of each of the four ports required T-pumps during the VOC resampling effort in July 2015.
- CF-212D – Ports 1 and 2 required T-pump installation prior to the second sampling event.
- CF-216D – Port 4 was non-functional during the second sampling event. Sampling of the remaining ports took place on June 11, 2014. Sampling of Port 4 occurred on September 8, 2014 using a T-pump.
- CF-218D – Ports 1, 2 and 3 required T-pump installation prior to the second sampling event.
- CF-222D – Port 1 was non-functional during the first sampling event. Sampling of the remaining ports took place on October 9, 2012. Port 1 sampling occurred on June 11, 2014 after T-pump installation. Port 3 was non-functional during the second sampling event. Sampling of the remaining ports occurred on November 17, 2014. Sampling of Port 3 took place on December 4, 2014 after T-pump installation. Port 2 T-pump installation took place prior to the VOC resampling effort in July 2015. Sampling of each of the ports with T-pumps occurred in July 2015 during the VOC resampling effort.
- CF-225D – Port 3 recovered very slowly; sampling took place over two days.

As detailed above, in the same wells a number of ports malfunctioned while other ports remained functional as installed. This resulted in sample collection from different intervals at the same well at different times (i.e., samples from failing ports collected after the other intervals). Sampling dates in the tables and figures reflect this. The monitoring well sampling logs note use of T-pumps for sampling (Appendix M).

2.1.5.2 Conventional Monitoring Wells

Installation of six conventional monitoring wells (CF-205D, CF-223D, CF-224D, CF-226D, CF-229D, and CF-230D) in the boreholes described in Section 2.1.3 took place during Phases I and II of the field investigation. Completion of boreholes as conventional monitoring wells occurred where there was just one significant water-bearing fracture zone. The exception to this was the borehole for monitoring well CF-230D, where completion as a conventional well occurred without prior borehole testing, as described in Section 2.1.4.3.

Modification and conversion of borehole CF-209D from a multi-port Water FLUTe™ well to a conventional monitoring well (CF-209D-R) occurred during Phase IV of the field investigation. The Sampling of CF-209D took place prior to the modification to obtain a groundwater quality baseline near the former North Waste Cell before the aquifer test (Section 2.1.6.2). After sampling, the driller removed the multi-port Water FLUTe™ from the borehole, back-grouted the borehole from its drilled depth of 700 feet to a new temporary depth of 356 feet bgs, and pump tested the shortened borehole (Section 2.1.7). Upon completion of pump testing, the driller back-grouted the borehole from 356 feet bgs to 168 feet bgs, installed a new 2-inch PVC well with a 10-foot screen from 150 to 160 feet bgs, and installed a three-foot sump. The name of this new conventional well is CF-209D-R. The results of the pre-conversion sampling with the highest concentration of 1,4-dioxane (350 µg/L) at the shallowest port (Port 1, 150-160 feet bgs), was the primary driver in determining the screen interval for CF-209D-R.

Construction of conventional wells employed 2-inch schedule 40 PVC and 0.010-inch screen slot. Six out of 7 conventional wells have screen lengths of 10 to 15 feet. The seventh well (CF-226D) required a 95-foot long screen interval for reasons described in the following paragraph. The filter pack used at the conventional wells was No. 1 well gravel. Table 2-11 provides well construction details.

Well construction complied with the NJDEP Regulation N.J.A.C. 7:9D Well Construction and Maintenance; Sealing of Abandoned Wells, with the exception of well CF-226D, which required a permit variance from NJDEP to complete the well with a 95-foot long screen - necessary for adequate water production during low-flow sampling. Installation of well CF-226D was in an area described by Willowstick® as having less than predicted electric current flow meaning an area where the formation is tight and produces little water. Selection of this well location was to confirm the results of the Willowstick® surveys. The borehole for well CF-226D underwent hydraulic profiling, downhole geophysics, and packer testing in advance of well completion. The results indicated very little transmissivity, <0.01 square centimeters per second (cm^2/s) (Table 2-12), in the borehole below 105 feet bgs. Based on these results, the long screen interval does not serve as a conduit for cross-contamination between fracture zones.

2.1.6 Groundwater Sampling

Groundwater sampling included collection of samples from selected intervals in monitoring well boreholes (packer testing), collection of two samples from bedrock monitoring wells, and collection of samples from selected existing monitoring wells (previously installed by others). Sample collection also included sampling of residential wells for tritium analysis concurrently with EPA collection of potable water samples for target compound list/target analyte list (TCL/TAL) parameters.

2.1.6.1 Packer Testing Groundwater Sampling

Groundwater sampling during packer testing occurred during field investigation Phases I and II (see Section 2.1.4.3). The goal of the packer testing groundwater sampling was to provide screening-level quality groundwater data to assist in determining well completion depths. Packer testing groundwater sampling did not involve use of EPA low-flow/ low-stress sampling techniques as the goal of the testing was generation of screening-level quality data only. Analysis of packer testing groundwater samples was for trace-level VOCs, SVOCs, pesticides, PCBs, metals and cyanide through the EPA CLP, and for TDS, TSS, chloride, and TOC by a subcontract laboratory for part of the work and by EPA's DESA laboratory for the remainder of the work. A subcontracted laboratory also performed tritium analysis on the packer testing groundwater samples.

Pumping of several of the packer tested intervals produced very little water and ended up dry. Sampling occurred only after these intervals had sufficiently recharged. Samples collected for laboratory analysis totaled 57, including four field duplicates, from 53 of the 54 packer testing intervals (one interval, 370 to 380 feet bgs at well CF-212D, did not produce sufficient water to allow collection of a sample), as summarized in Table 2-12.

2.1.6.2 Bedrock Monitoring Well Sampling

HDR collected two groundwater samples from each of the 19 bedrock monitoring wells installed during the RI (13 multi-port wells, comprising 45 individual sampling intervals, and six conventional, single-depth wells) [27], as well as samples from 12 wells previously installed by others. Sections 4.3.2.1 and 4.3.2.2 provide additional information on the sampled wells.

Sampling of CF-209D took place in January 2017 prior to the pump test modification to obtain a groundwater quality baseline near the former North Waste Cell (Section 2.1.6.2). Sampling of the completed conventional well (well CF-209D-R) was in late March 2017, after completion of the pump test and two weeks post development.

Sampling of conventional monitoring wells was in accordance with EPA – Region II Low Stress (Low Flow) Groundwater Purging and Sampling Protocol (March 16, 1998) using a stainless steel bladder pump with a Teflon™ bladder and Teflon™-lined water tubing.

Sampling of multi-port wells followed the *Sampling Guidelines for Water FLUTe™ Systems installed after May 2009* developed by the manufacturer (FLUTe™ 2010).

Groundwater sample analyses consisted of trace-level VOCs, SVOCs, pesticides, PCBs, total metals, cyanide, TDS, TSS, chloride, and TOC through the EPA CLP, DESA, and/or a subcontracted laboratory. Additional analyses included ammonia, alkalinity and sulfate for the sample from monitoring well CF-209D-R in March 2017. Table 2-13A summarizes groundwater samples collected and the analyses performed.

2.1.6.3 Non-Compliant Monitoring Well Sampling

RI well sampling also included 12 monitoring wells previously installed by others and considered to be non-compliant with NJDEP well construction requirements (N.J.A.C. 7:9D); some sampled once, others twice. Well construction information for these wells revealed they were overburden/saprolite wells (CF-20S, MW-6, and S-6) or constructed out of compliance with N.J.A.C. 7:9D. Reasons for non-

[27] Twenty boreholes were drilled, but only 19 were completed as wells. One borehole (CF-215D) was abandoned due to lack of water producing zones.

compliance included construction with a casing installed above competent bedrock and a long open borehole (well D-5R), screening across the saprolite/bedrock interface, and/or completion with inadequate annular space (CF-09D, CF-12D, CF-15D, D-1, D-3, D-9, MW-18D, and MW19D).[28] Because of these deficiencies, use of the analytical data from these 12 wells was limited to determining if completion of delineation necessitated the installation of additional, compliant wells, and as an aid in refining the delineation boundaries where necessary.

Sample analyses from the non-compliant wells consisted of trace-level VOCs, SVOCs, pesticides, PCBs, total metals, cyanide, TDS, TSS, chloride, and TOC through the EPA CLP, DESA, and/or a subcontracted laboratory. Table 2-13B summarizes the groundwater samples collected at the non-compliant wells and the analyses performed.

2.1.6.4 Residential Well Sampling

HDR sampled residential wells for tritium analysis concurrently with EPA's sampling of residential wells by Weston in June 2011. HDR subcontracted the tritium analysis and provided sample jars to EPA and Weston. After collection of the tritium samples, HDR assumed custody for shipping to the laboratory. Based on information provided by Weston personnel in the field, sampling procedures varied depending on the presence of any filters or other treatment systems. Sample collection points were generally before any treatment systems. Purging of water lines and tanks was by running the tap or spigot.

2.1.7 Long-Term Pump Testing/Hydrogeologic Assessment of the Deep Bedrock Aquifer

HDR conducted a hydrogeologic assessment of the deep bedrock aquifer in the area surrounding the former North Waste Cell from January to April 2017. A detailed description of the methods, procedures and findings of the hydrogeologic assessment are included in the separate technical memorandum for the work (HDR 2017b; Appendix N). The following paragraphs provide a summary of the activities.

The objectives of the hydrogeologic assessment were to gain a better understanding of the chemical and hydraulic properties of the deep aquifer in the area surrounding the former North Waste Cell; a source area containing the highest concentrations of 1,4-dioxane in groundwater emanating from the landfill area. These objectives were achieved by collecting groundwater samples before, during, and after the pumping at the CF-209D borehole, and by monitoring the water level responses in the pumping well and a network of monitoring and recovery wells (Figure 3-15).

Prior to the aquifer pumping test, monitoring well CF-209D (originally completed as a FLUTe™ multi-port well) had to be modified to serve as the pumping well for the aquifer test. The driller removed the multi-port sampling system in late January 2017 and back-grouted the open borehole from its drilled depth of 700 feet to a new temporary depth of 356 feet bgs in accordance with NJAC 7.9D-2.9, using a Portland neat cement-water mixture installed via the pressure method through a Tremie pipe.

HDR retained the same New Jersey licensed driller to support the hydrogeologic assessment, including the modifications to CF-209D described above and support for the aquifer testing by temporarily installing test pumps and approximately 1,500 feet of discharge conveyance. The

[28] HDR reviewed well construction information for previously existing monitoring wells to determine which wells could be used for delineation or screening during the RI sampling. The well construction information and comparison against N.J.A.C. 7:9D requirements are included in Table 2-13C, which also provides the rationale for including or not including samples for delineation.

conveyance consisted of 3-inch diameter piping from the CF-209D pumping borehole to a force main cleanout tied into an 8-inch diameter force main for the on-site GWTF. Following the aquifer testing, the drillers installed a single, conventional 2-inch diameter monitoring well, identified as well CF-209D-R, inside the original borehole well and developed it.

The four stages of testing were as follows:

- Background monitoring;
- Short-term step drawdown test;
- Long-term constant rate test; and,
- Recovery Monitoring.

Background Monitoring

HDR installed pressure transducers in twelve monitoring and recovery wells between January 20 and January 27, 2017. Background monitoring concluded on January 31, 2017. The purpose of background monitoring was to monitor for water level trends that may affect the aquifer pumping tests. The pressure transducers collected measurements at one-minute intervals. Review of the background water level data from these wells informed the pumping tests and determined if there were any short or long-term water level trends within the areas surrounding the former North Waste Cell. Operation of GWTF recovery wells RW-R, RW-T, and RW-U occurred during the background-monitoring period.

Step Drawdown Test

The field team conducted a step drawdown test on February 1, 2017 to determine the flow rate of the long-term constant rate test. The test consisted of installation of a 20-horse power (hp) submersible pump, installed at 295 feet bgs, to lift water through a 2-inch galvanized steel riser to the well head, and two one-inch diameter stilling tubes - one instrumented with a 100 psi pressure transducer and the other for measuring manual water levels. The test included four 90-minute steps: 30 gpm, 50 gpm, 70 gpm, and 90 gpm. Monitoring of total deep aquifer drawdown involved taking manual and pressure transducer water level measurements from the test well and pressure transducer measurements from observation wells. The results of the step drawdown test indicated that a 7.5 hp submersible pump was suitable for the long-term constant rate test, and that a flow rate of 70 gpm was sustainable (the current operating capacity of the GWTF is approximately 70 gpm).

Long-Term Constant Rate Test

Following completion of the step-drawdown test, the driller installed a hard-wired 7.5-hp submersible pump at 250 feet bgs and pumped at an average rate of 70 gpm for the long-term constant rate test from February 2 to 27, 2017 (25 days). Monitoring of aquifer drawdown took place at the CF-209D borehole (open borehole from 95 to 356 feet bgs), and at a network of 12 monitoring and recovery wells using pressure transducers.

The GWTF lost electric power during a storm event for approximately six hours (February 12 into February 13, 2017). The pump shut off for this period and pumping resumed at the pre-set 70 gpm immediately after restoration of power. The volume of groundwater removed during the constant rate pump test was 2,463,000 gallons. HDR submitted Short Term Water Use Report Forms BWA-003 and BWA-004 to NJDEP to satisfy the conditions of the Short Term Water Use Permit-by-Rule for diversions of more than 100,000 gallons of groundwater per day for periods of less than 31 days.

The field team conducted one round of synoptic manual water level measurements on February 24, 2017, towards the end of the long-term constant-rate pumping test, using the data to generate groundwater contour maps for both the shallow and deep aquifer wells. For purposes of the pump test, shallow wells consist of overburden or saprolite wells generally screened less than 100 feet bgs. Deep aquifer wells are those where the screens are set in competent bedrock, generally screened greater than 100 feet bgs.

The average temperature and total precipitation during the long-term constant rate test were 37 degrees Fahrenheit (°F) and 1.55 inches, respectively, as measured at Somerset Airport approximately 10 miles from the Site.

Recovery Monitoring

After turning off the pump at the end of the long-term constant rate test, electronic monitoring of well water levels continued at one-minute intervals from February 27 to March 6, 2017. This data confirmed the drawdown data and any influence from other pumping or regional trends.

Recovery well RW-R returned to service at the GWTF approximately 80 minutes after the recovery monitoring started, and recovery wells RW-T and RW-U returned to service approximately two days (45 hours) and three days (84 hours), respectively, after recovery monitoring began.

Section 3.6.2.4 describes the findings of the hydrogeologic assessment and Appendix N provides the technical memorandum (HDR 2017b).

2.2 Surface Water and Sediment Investigation

Surface water and sediment sampling took place during two phases of the RI. The first phase in November 2014 investigated potential impacts from CFS groundwater discharges to surrounding streams. The second phase in September 2017 consisted of the collection of background surface water and sediment samples at locations unaffected by discharges from CFS, along with collection of seeps and springs samples to investigate these features as potential exposure pathways.

As described in Section 2.1.2.2, investigation of the interaction of groundwater and surface water occurred at nine locations along three streams and a wetland (Figure 2-2a) to correlate groundwater and surface water elevations and determine if potentially contaminated groundwater is discharging to surface waters. Water level monitoring data from the piezometer/stream gauge pairs determined whether the streams were gaining or losing streams..

2.2.1 2014 Surface Water and Sediment Sampling

An HDR environmental scientist and a terrestrial ecologist specializing in Rosgen natural stream channel design conducted a site reconnaissance to identify depositional areas in the streams and potential groundwater upwelling locations. Each of the targeted streams had three sampling transects. The sampled streams were Trout Brook (historically referred to as West Branch of Trout Brook), East Trout Brook (historically referred to as East Branch of Trout Brook), the Lamington River UNT, and the Tanners Brook UNT.

The 2014 surface water and sediment sampling programs focused primarily on depositional areas in the streams. Co-located surface water and sediment sampling locations on each transect were at approximately mid-stream. A second sediment sampling location on each transect was in a depositional area along the bank of the stream. Figure 2-2a depicts transect and sampling locations.

Sediment and dry-weather surface water sampling occurred from November 11 through 13, 2014. Wet weather surface water sampling occurred on November 18, 2014 after 1.36 inches of rain on November 17, 2014 (Weather Underground 2015).

The collection procedure for surface water samples consisted of wading into the surface water body downstream of the sample location and collecting the sample from mid-water column by directly filling the sample containers or with a bottom-filling bailer placed at the desired depth. For dissolved metals analysis, a field geologist transferred the samples from the original collection device through a 0.45-micron filter into a separate, pre-preserved sample container using a peristaltic pump. The laboratories analyzed surface water samples for TCL VOCs, SVOCs, pesticides, and PCBs, TAL metals (total and dissolved), cyanide, TOC, TDS, TSS, chloride, and alkalinity. Table 2-14a summarizes the 2014 surface water sampling event.

The collection procedure for sediment samples used a hand auger at the target location after completion of surface water sampling. Laboratory analyses for sediment samples from the zero to six-inch interval were for TCL SVOCs, pesticides, and PCBs; TAL metals, cyanide, TOC, grain size, percent moisture, and pH. Collection of sediment samples from the six to 12-inch interval utilized 5-gram EnCore® samplers for TCL VOCs analysis. Filling of EnCore® samplers was directly from the auger bucket without homogenization. Table 2-15a summarizes the 2014 sediment sampling event.

A subcontracted laboratory performed tritium analysis on surface water collected in 2011 at the same locations and in the same manner as those collected in 2014. Tritium, the hydrogen isotope, is sometimes an indicator of landfill leachate in groundwater and surface water. Tritium analysis of aqueous samples ceased prior to the 2014 sampling event as there was no indication of tritium emanating from the landfill based on the data.

2.2.2 2017 Surface Water and Sediment Sampling

Following its review of the Draft SLERA, EPA requested collection of background surface water and sediment samples along with aqueous samples from seeps and springs as potential surface water pathways of Contaminants of Potential Ecological Concern (COPECs) to ecological receptors. Spring sampling consisted of collecting two samples from a pond at the north end of Schoolhouse Lane previously exhibiting a hydraulic connection to monitoring well CF-206D during drilling. Air bubbles appeared in the pond during and after air rotary drilling of the CF-206D borehole in 2011.[29] In addition, during the Willowstick® electromagnetic survey (Appendix E), electric current traveled to depth from the pond to the preferential flow path in bedrock between wells CF-206D and CF-204D southwest of Schoolhouse Lane.

Collection of background surface water and sediment samples occurred at locations on Tanner's Brook and its tributaries, presumed unaffected by groundwater discharges or pre-landfill cap surface runoff. The background sampling established a baseline for constituents previously detected in surface water and sediment samples downstream from the landfill.

Dry-weather background sampling occurred between September 20 and 26, 2017; for details refer to the separate memorandum to EPA (HDR 2017c).[30] Collection of background surface water and sediment samples was from nine locations on two unnamed tributaries of Tanners Brook and at one

[29] Laboratory analysis did not detect trace VOCs or 1,4-dioxane in a sample from a hand dug well near the pond.

[30] During a June 2017 site walk, EPA (Ms. Pensak) had advised HDR that wet weather sampling for the background locations, seeps and spring was not necessary. Therefore, only dry weather sampling was conducted.

location on the main stem of Tanners Brook. At each location, co-located surface water and sediment sample collection was from approximately mid-stream. Sampling also took place at one spring (two samples) and two seeps (two samples each). Surface water and sediment sampling procedures and laboratory analyses in 2017 were the same as those for the 2014 samples described in Section 2.2.1. See Figure 2-2b for 2017 sample locations, Table 2-15b for a 2017 sample summary, and Appendix W for sampling logs.

2.3 Soil Investigation

HDR investigated subsurface soil exterior to the landfill perimeter to determine if remaining source areas within the landfill, such as possible buried drums and the un-remediated portion of the North Waste Cell, had contaminated adjacent soil. Soil sampling did not occur outside the landfill property boundary.

2.3.1 Soil Boring and Sampling

From November 18 through 24, 2014, the driller installed five soil borings through the overburden around the perimeter of the landfill to the depth of bedrock refusal at each location. Boring depths ranged from 18 to 72 feet bgs. Hollow stem auger borings employed split spoons to collect continuous samples. Drilling equipment decontamination between boreholes took place at the decontamination pad.

Sample collection was from materials exhibiting visual, olfactory and/or other evidence of contamination, such as photoionization detector (PID) readings above background. In the absence of any evidence of contamination or PID readings above background, sample collection was from approximately 10-foot intervals over the length of the borings.

Soil sample analyses consisted of TCL VOCs, SVOCs, pesticides and PCBs; TAL metals, cyanide and TOC. Approximately 20% of the samples also underwent grain size analysis. Table 2-16 summarizes the soil boring and sampling effort. Figure 2-3 depicts the soil boring locations.

2.4 Land Surveys

Land surveys conducted within the OU2 study area provided information for other work activities. Land surveys included one-foot contour topography, individual property boundaries, stream/culvert cross-sections, and the locations and elevations of monitoring wells, piezometers and wetland delineation flags.

A boundary survey confirmed property boundaries prior to locating monitoring wells. The survey covered an area of approximately 445 acres, including the following 30 properties; Chester Township, Block 17, Lots 2, 3, 4, 5, 6, 7, 7.01, 10, 22, 22.01, 22.02, 22.03, 22.05, 24, 31.01, 43, 44, 44.01, 44.02 and 45; Washington Township, Block 37, Lots 9, 15, 15.01, 16, 16.01, 16.02, 16.03, 17, 29 and 30. The boundary survey met the requirements of *N.J.A.C. 13:40-5.1 Land Surveyors - Preparation of Land Surveys*. The surveyor performed a boundary survey of the specified properties, easements, and rights-of-way and arranged deed/filed map searches for each property. The survey included corner markers and physical features within five feet of property lines. Acquisition of other physical features was through photogrammetric mapping.

The topographic survey extended beyond the property lines of the properties listed above and covered approximately 490 acres. The topographic survey used aerial and planimetric map techniques to gather information and display boundary, utility rights-of-way, and topographic information with one-foot contour lines. The horizontal accuracy of the control was Third Order Class I, and the vertical

accuracy was Third Order, as outlined in *FGDC Geospatial Positioning Accuracy Standards, Part 4: Standards for Architecture, Engineering, Constructions (A/E/C) and Facility Management*. Coordinates (easting, northing and elevation) for all points were to the nearest 0.01 foot.

HDR delineated and flagged wetlands, and the surveyor located and surveyed the flags. The wetland scientists also identified four stream cross-sections for surveying. The cross-sections extended 200 feet beyond the top of bank on either side. The survey included the bottom and top of bank, thalweg, edges of water, and other breaks in grade.

Survey activities also included three culvert locations; the associated streams and roads for a distance of 25 feet from each culvert. Data collected included culvert dimensions, shape, material, inverts, headwalls, wing walls, and other physical features within 25 feet of each culvert.

Surveying of 20 monitoring well boreholes and nine piezometers provided the elevations at each borehole at the ground surface and top of casing, and horizontal coordinates at the center of each well. Table 2-11 provides survey information for the new monitoring wells, and Table 2.6 for the piezometers. Surveying of stream gauges was for elevation only at the top of casing.

Surveying of eight potable wells was included the well condition survey on Schoolhouse Lane (Section 2.1.1.5). Table 2-4 provides the survey information for these wells.

The surveyor prepared Groundwater Monitoring Well Certification – Form Bs – Location Certification for each monitoring well and piezometer (Appendix O). Form B requires elevations reported in one one-hundredth of a foot and horizontal coordinates reported to one tenth of a second in latitude and longitude.

2.5 Ecological Characterization

2.5.1 Wildlife Observations

HDR conducted wildlife surveys in 2010 and 2011 to identify species that utilize habitats that may be disturbed by site work needed to access drilling locations and install monitoring wells for the collection of groundwater data. The information gathered from the wildlife surveys also informed the SLERA. The focus, in order of importance, was on federal- and state-listed wildlife (endangered and threatened species [ETS]), New Jersey special concern species (SCS), stable species (S), and non-listed or common wildlife. Wildlife identification took place during seven site visits in 2010 and four in 2011 with the intent to identify habitat usage by ETS and SC species and other common wildlife that may be disturbed by RI activities (e.g. clearing access routes, well drilling and sampling).

Wildlife biologists established 23 point-count stations in the spring and fall. The point count surveys tallied the number of species observed and/or heard over a five-minute period at a station; recording the direction and distance of the sighting and/or sound when possible on field data sheets. Incidental observations resulted in additional counts of birds, amphibians, reptiles and mammals at the point count stations before and after the five-minute point count period, while moving between stations, and while moving through various habitat types.

Eight scent stations with hair snares, smoked aluminum track plates (16 in. x 22 in.) and a visual attractant (aluminum pie plate suspended by string near the station) provided survey locations for potential bobcat use of the study area during the fall 2010 survey period.

The surveys also employed play back recordings of raptors (barred owl, red-shouldered hawk, Cooper's hawk and great horned owl) each played for five minutes with a two-minute silent period between each species while moving around the study area. Play back recordings of grassland bird

species (bobolink, grasshopper sparrow, eastern meadowlark and vesper sparrow) sounded while moving around the landfill and adjacent habitats. Opportunistic surveys of stream, pond and wetland habitats occurred during the wildlife surveys, particularly amphibians breeding in wetlands and ephemeral and intermittent pools as evidenced by the presence of eggs, amphibian larvae and recent metomorphs, juveniles and adults.

The database created from the survey efforts included point counts and incidental observations data, and enabled queries to produce tables providing information on the species and numbers observed for the stations and habitat type. Appendix P contains the body of the Wildlife Technical Memorandum. The complete memorandum, including all attachments, was previously submitted to EPA.

2.5.2 Wetland Delineation

HDR delineated freshwater wetlands prior to undertaking intrusive investigations in accordance with the protocol described in the *Federal Manual for Identifying and Delineating Jurisdictional Wetlands Intermediate-Level Onsite Determination Methods (Federal Interagency Committee for Wetland Delineation 1989)*. Wetland scientists assigned each distinct wetland its own letter designation (e.g. “WA-1”, “WA-2”, “WB-1”) and designated observation points (e.g. “OPA-1”, “OPA-2”) and marked wetland boundaries with consecutively numbered, orange fluorescent flagging tape. They also recorded field indicators of hydrophytic vegetation, hydric soil, and wetland hydrology on field data forms at several observation points located along a line perpendicular to the wetlands boundary. Observation points were on both sides of the wetland boundary (i.e. on the wetland and upland sides of the boundary), and used to determine where to locate the wetland line.

HDR surveyed wetland flags and observation points in the field using a Trimble Differential GPS with sub-meter accuracy. GPS data were post-processed using Trimble Pathfinder Office software and plotted using ESRI ArcGIS software. HDR provided a list of flags and locations to a NJ-licensed land surveyor who subsequently surveyed the boundary flags and observation points. Appendix Q provides the body of the Wetland Delineation Report and Wetland Functions and Values Assessment. The complete report, including all attachments, was previously submitted to EPA.

2.6 Investigation-Derived Waste

Site-generated waste included soil cuttings, drill cuttings, development/purge water, and decontamination fluids. IDW handling and disposal details follow.

Solid IDW

The driller placed soil boring and piezometer cuttings directly into 55-gallon drums at the drilling sites, transporting the drums to a staging area at the landfill and emptying the drums into 30-cubic yard containers until collection for off-site disposal. Monitoring well borehole cuttings went directly from the borehole into 30-cubic yard containers during both drilling phases of the RI. The moisture content in the solid IDW generated during Phase I of the RI was too high for the receiving facility. This necessitated emptying of the material in the containers onto poly sheeting, mixing with stone dust, and then loading the amended material for transport to the receiving facility. Handling of cuttings from Phase II well drilling was the same except that the material did not require mixing with stone dust.

During Phase IV, the solid IDW consisted of the Water FLUTe™ system from modified monitoring well CF-209D disposed of as non-hazardous, solid waste. Solid IDW generated from the pilot test

consisted of used Ambersorb™ media and process tubing. Waste containerization was in a 55-gallon drum transported to CycleChem in Elizabeth, NJ on July 28, 2017 for off-site disposal.

Appendix R includes the shipping documents and non-hazardous waste manifests for the solid IDW.

Liquid IDW

Water generated during drilling, development, sampling and decontamination activities went to the landfill's GWTP. Different water conveyance systems and strategies transported the water to the treatment plant depending on the location of each borehole and amount of water produced. Drilling and development of several boreholes generated large volumes of water, exceeding the capacity of conventional water management practices.

During Phase I, an IDW subcontractor transported frac tanks staged near the wells and, in one case, used a tanker truck to transport water to the treatment plant. The subcontractor used the tanker truck for the first well that produced large amounts of water (well CF-216D; 45,250 gallons trucked). When this proved inadequate, HDR devised a system consisting of pumping from roll-off containers at the drill site to frac tanks staged at the landfill via fire hoses. Once at the landfill, water discharge from the frac tanks was to a force main clean-out for the groundwater recovery well system. The force main runs around the landfill perimeter and connects the recovery wells to the treatment plant. Approximately 342,500 gallons of water went to the treatment plant in this manner (from wells CF-204D, CF-206D, CF-207D, CF-209D, CF-212D, CF-216D, CF-218D, and CF-225D). Well CF-201D was too far from the treatment plant for this method, so water transport consisted of storage in on site frac tanks and transport via tanker truck to the landfill's GWTP. About 114,750 gallons of water went to the treatment plant in this manner.

During Phase II drilling, water pumped from the well site went into a 30-yard roll-off container, then through 4-inch PVC pipe to a frac tank staged on the landfill road, and from to the treatment plant (approximately 68,000 gallons). For three Phase II wells that were too far from the treatment plant, water collected in roll-off containers went to the treatment plant via tanker truck (approximately 12,000 gallons).

Purge water from packer testing and Water FLUTe™ installation went to the treatment plant in poly tanks and purge water from well sampling went to the treatment plant in five-gallon buckets.

During Phase IV, the liquid IDW consisted mainly of purge water, pump test water, and monitoring well development water, all of which went to the GWTP. Liquid IDW generated from the pilot test consisted of concentrated 1,4-dioxance condensate from the Ambersorb™ regeneration process. The waste contained in a 55-gallon drum went to CycleChem in Elizabeth, NJ on July 28, 2017 for off-site disposal.

2.7 Field Quality Control Samples

Collection of field quality control samples was in accordance with the QAPP for the work assignment (HDR 2011a).

The purpose of collecting equipment rinsate blanks was to evaluate the potential for residual constituent contamination of environmental samples from inadequate decontamination of field equipment. The collection process for equipment rinsate blanks consisted of pouring deionized (DI) water over and/or through decontaminated equipment and collecting the rinsate. The DI water was constituent free as certified by the vendor, Environmental Sampling Supply. Collection of rinsate blanks was at a maximum frequency of one per day or at a minimum one per 20 field samples.

Analysis of constituent parameters for rinsate blanks was the same as the analysis of constituent parameters for the associated environmental samples. Preservation of the blanks was as indicated for the applicable analytical methods. In accordance with QAPP Worksheet #20, analysis of field quality control samples included 37 rinsate blanks for aqueous samples, two rinsate blanks for soil samples and seven rinsate blanks for sediment samples. Surface water sampling did not require rinsate blanks because of the use of dedicated equipment.

In addition, HDR collected three equipment rinsate samples from the Water FLUTe™ liners and tubing. For one sample, HDR poured DI water over an unused piece of liner material (sample FLB-Liner_060514); for a second sample, collection was after the decontamination of a blank liner installed in one borehole and reinstalled in another borehole. The liner decontamination was to prevent potential cross-contamination between boreholes. Rinsate blank sample collection was to verify the effectiveness of the decontamination process by pouring DI water over the liner and collecting it in a sample jar (sample CF-204D_LR). Collection of the third FLUTe™ equipment rinsate sample was by running DI water over and through a section of FLUTe™ tubing and into a sample jar (sample FLB_Tubing_060514). The laboratory reported no detections of 1,4-dioxane in the three FLUTe™ equipment rinsate samples (results of 0.5 U µg/L; see Table 9 in Appendix B).

Collection and analysis of the following samples was to verify that neither the liquids used in the decontamination process or potable water used during the RI contained 1,4-dioxane:

- A potable water sample (FL-HYD-12042014) from a nearby hydrant. Potable water was used to install the FLUTe™ liners, and the local water purveyor had not tested their supply for 1,4-dioxane;
- A sample of the DI water used in the decontamination process (sample FB_BLANK);
- A sample of DI water from a bucket used for decontamination (FB_RINSE); and
- A sample of a DI water/detergent (Liquinox™) mixture (FB_WASH).

All sample results were non-detect (0.5 U µg/L) for 1,4-dioxane (Table 9 in Appendix B).[31] In accordance with the QAPP Worksheet #20, there was no field blank collection.

Collection of trip blanks was to detect possible cross-contamination of samples resulting from handling, storage, and shipment procedures. Preparation of trip blanks consisted of filling preserved or unpreserved vials, depending on the specifications of the CLP case, with DI water prior to initiation of daily field activities. A trip blank accompanied the aqueous environmental samples through collection and shipment to the laboratory. In addition, the laboratory stored the trip blanks under the same conditions as the environmental samples. A trip blank accompanied each cooler containing aqueous samples for VOC analysis. HDR consolidated the aqueous VOC samples into as few coolers as possible to minimize the number of trip blanks required for the field program. In accordance with QAPP Worksheet #20, HDR submitted 87 trip blanks for analysis.

Analysis of field duplicate (FD) samples is to check for sampling and analytical reproducibility. The general frequency was one FD for every 20 investigative samples collected (frequency of 5%) as per QAPP Worksheet #20. FDs submitted to the laboratory are “blind” samples (i.e., the locations of the duplicate samples are in the field logbook but not indicated as “duplicate” on the chain-of-custody). Analysis of FD samples is for the same parameters as their parent samples.

[31] 1,4-dioxane is found in some detergents including brands used to decontaminate sampling equipment and to lubricate FLUTe™ systems during manufacturing.

Matrix spikes (MS) provide information about the effect of the sample matrix on the preparation and measurement methodology. Collection of MS samples was one sample for every 20 investigative samples (HDR 2011a). Sample analysis was for TAL metals, TCL PCBs, TCL pesticides, chloride and TOC.

Table 9 of Appendix B presents the analytical results for the QC samples.

3 Physical Characteristics of the Study Area

3.1 Surface Features

The main feature at the Site, the CFS landfill, is crossed by an electric utility easement running southwest to northeast from approximately elevation 810 feet above mean sea level (amsl) to elevation 820 feet amsl (Figures 1-1, 1-2 and 3-1). As described in Section 1.4, the older sections of the landfill (pre-1972) were in the northern portion of the current landfill footprint, on both sides of the power line right-of-way, covering a combined 15 acres. After 1972, landfilling proceeded in the newer sections west and southwest of the older sections (to the northwest of the power line right-of-way), covering approximately 50 acres (Figure 1-2) (LMS 1986). The surface of the landfill slopes towards the utility easement from both the northwest and the southeast (Figure 3-1).

A large section of the landfill northwest of the utility easement is located on a natural topographic high, with the highest portion of the landfill in the north-central area at approximately 875 feet amsl.[32] From this topographic high, the land surface dips steeply to the west, northwest, and north, and descends with lesser slope to the south and southeast. The remaining section of the landfill, southeast of the easement, rises to between 840 and 850 feet amsl (the older portions of the landfill). The elevation of the landfill perimeter road ranges from about 800 feet amsl in the west to 875 feet amsl in the north (Figure 3-1). Surface runoff from the landfill is captured and diverted via rip-rap filled channels to detention basins. Historically, runoff from the landfill discharged to East Trout Brook to the south, the Lamington River UNT to the north, the Tanners Brook UNT to the northwest, and Trout Brook to the west and southwest.

Two northeast trending ridges in the area north and northeast of the landfill, referred to as the northwest and northeast ridges rising to 895 feet and 880 feet amsl, respectively, are significant surface features. They frame an elongated topographical low leading from the landfill to the residential area on Schoolhouse Lane to the northeast, approximately 1,900 feet from the landfill perimeter. Surface elevations in the low area flanked by the two ridges range from approximately 815 feet amsl at the edge of the landfill to 775 feet amsl at Schoolhouse Lane (Figure 3-1).

The headwaters of several streams are in the vicinity of the landfill, including East Trout Brook to the southeast, the Lamington River UNT to the northeast, the Tanners Brook UNT to the west, and Trout Brook to the south (Figures 2-2a and 3-2).

The ridges provide surface and subsurface boundaries that constrain stormwater runoff and groundwater flow in the area north of the landfill towards Schoolhouse Lane and the Lamington River UNT. Figure 3-1 provides the topographic map for the Site.

3.2 Land Use

Area land use is primarily low-density residential (lot sizes are generally more than two acres) amidst large parcels of cleared or forested rolling hills. Although some horse husbandry and vegetable, grain, and orchard farming persist in the area, most former farmlands are now fallow.

Immediately northeast of the landfill is the 45-acre Parker Road Preserve, a low-impact recreation park owned by Chester Township (Figure 1-2). This area was the site of a proposed residential development known as Millstone Crossing that never came to fruition. The park covers the area between the two northeast trending ridges and extends north towards the residential properties

[32] The vertical datum is NAVD 88.

along Schoolhouse Lane. To northwest is a horse farm. Residential homes and several commercial establishments, including construction and landscaping companies, automotive repair and a small heating oil distributor, are located on Parker Road to the east.

Remnants of the once-viable iron ore mining industry in the area are in evidence at the Hacklebarney mines just to the south and east of CFS. Locally high iron concentrations are also distinctive characteristics of the area soils, surface waters, and groundwater.

A series of county and state parks, including the Black River County Park and Hacklebarney State Park, lie to the east and south along the Lamington River. These parks border both sides of the Lamington River from approximately the crossing of East Mill Road (County Route 513) to the border with Hunterdon County to the south. An approximately 3,000-foot section of Trout Brook, upstream of its confluence with the Lamington River, borders or lies within Hacklebarney State Park.

3.3 Climate

The Site has a continental-type climate with winters controlled by polar continental air masses and summers by tropical air masses. Throughout most of the year, the prevailing winds are from the southwest but during the cooler half of the year (generally from October to April), winds from the northwest are predominant. The average annual temperature is 49 °F with an average July high of 82 °F and an average January low of 17°F. The average annual precipitation (rainfall) is 53.23 inches and average annual snowfall is 35 inches (US Climate Data 2015).

3.4 Geology

3.4.1 Regional Geology

3.4.1.1 Physiographic Province

The Site lies in the Highlands Province of the Appalachian Mountain system. In New Jersey, the name for this region is the “Highlands”, consisting of a 20-mile-wide bank of northeast-to-southwest trending ridges and valleys extending from the Hudson Highlands of New York to the Reading Prong Region of Pennsylvania. The Highlands consist of a series of discontinuous northeast-to-southwest trending rounded ridges, separated by narrow deep valleys. Bounding the Highlands region to the northwest is the Ridge and Valley Physiographic Province. To the southeast is the Piedmont Physiographic province containing Triassic Rocks of the Newark Group.

3.4.1.2 Structural Geology

Structurally, the Highlands region consists of steep, tight, isoclinal folds that trend to the northeast. The limbs of the folds dip vertically or near vertically. The lineation of minerals constituting the metamorphic rocks have a tendency to follow closely the plunge directions of the fold axes.

The southeast boundary of the region possesses many longitudinal faults interpreted as high-angle wrench faults (Smith 1969); however, some may be reverse faults. This major fault zone is termed the Ramapo Fault. Two other small sets of faults occur in the region. One cluster lies in the Wanaque and Newfoundland Quadrangles and strikes north/south. Another set lies within the Hackettstown and Tranquility Quadrangles and strikes east/west. No significant faults lie near CFS.

3.4.1.3 Bedrock Geology

The mountains of the Highlands are composed of hard crystalline, resistant Precambrian igneous and metamorphic rocks with the valleys underlain by easily eroded shale and limestone (Lucey 1972). The Precambrian rock units consist predominantly of granites and gneisses, although some marble is present to the northeast, near Franklin, New Jersey. Paleozoic formations within the region consist of quartzites and limestones. The Precambrian rocks of the Highlands is akin to basement rock, extending to great depths below ground surface.

3.4.2 Site-Specific Geology

Figures 3-4 through 3-7 depict cross-sections with visual representations of major fractures and fracture orientations from the downhole geophysical logging program.

3.4.2.1 Overburden and Saprolite

The natural (non-fill) overburden material is composed of unconsolidated sand, silt, clay, and gravel derived from the underlying bedrock. In most area, except for the ridgelines, the overburden includes saprolite. The thickness of the overburden material at CFS generally ranges from about four feet on the ridges to 100 feet in the low-lying areas. Overburden depths on the northeast trending ridges and at the adjacent horse farm property were shallow, only about 5 to 10 feet, whereas overburden depths in the low-lying area between the northeast trending ridges and to the south of the landfill varied between 40 and 100 feet.

The soil, landfill waste, and saprolite are very permeable and account for the transmission of the majority of local precipitation to the groundwater system of the Precambrian crystalline rocks, as opposed to direct surface run-off.

3.4.2.1.1 Reworked Soils and Waste

Most of the previously existing native soil within the landfill footprint was disturbed or removed as part of historic landfill operations and the subsequent closure/remediation. As described in a site inspection report from 1979, within the waste boundary, removal of all overburden material above bedrock (soil and saprolite) was part of the trench excavation disposal practiced at the landfill. The removed soil and saprolite later served as waste cover (Markewicz 1979).

Observations made during the drilling of well D-6 in the 1980s indicated the presence of numerous voids in the fill, some measuring several feet thick, which provided significant conduits for fluid flow through the fill. On the other hand, there were observations of finer and tightly compacted fill materials which impeded fluid movement (LMS 1986).

3.4.2.1.2 Native Soil

The unconsolidated deposits are composed of soils formed from old glacial till (pre-Wisconsin Age) and/or from residuum derived from the granitic gneiss bedrock. The natural unconsolidated deposits above bedrock are often very shallow.

Soils mapped in the area belong to the following series (Web Soil Survey, 2012):

1. <u>Annandale Series:</u> This series consists of very deep, well-drained soils that formed in deeply weathered old glacial till (pre-Wisconsin Age) and underlying residuum derived mainly from granitic gneiss. Annandale soils occur on gently sloping to strongly sloping

uplands, with slopes ranging from three to 25 percent. These soils have a fragipan in the lower part of the solum. The soil in this series is mostly gravelly loam.

2. Califon Series: This series consists of very deep, moderately well- or somewhat poorly-drained soils formed either in old till or on driftless landscapes in the Northern Piedmont in colluvium from granitic gneiss on upland flats or concave slope positions. The saturated hydraulic conductivity is moderately low. Slopes range from zero to 15 percent. The soil in this series is predominantly loam.
3. Gladstone Series: This series consists of very deep, well-drained soils formed in residuum and colluvium from granitic gneiss. The saturated hydraulic conductivity is moderately high to high. These soils occur on upland divides and rolling foothills of the Highlands section of the Appalachian province, the Reading Prong section of the New England province and the Gettysburg-Newark Lowland and the Piedmont Upland sections of the Northern Piedmont province. Slopes range from zero to 65 percent. The soil in this series is predominantly gravelly loam.
4. Cokesbury Series: This series consists of deep or very deep, poorly-drained soils formed either in old till or on driftless landscapes of the Northern Piedmont in colluvium from granitic gneiss on upland depressions, headslopes or concave footslope and toeslope positions. The saturated hydraulic conductivity is moderately low. Slopes range from zero to eight percent. The soil in this series is gravelly loam.
5. Parker Series: This series consists of very deep, somewhat excessively-drained soils that formed in residuum derived from granitic gneiss bedrock. It occurs on gently sloping to very steep slopes of ridges and hills. Slopes range from three to 70 percent. The soil in this series is gravelly loam.

3.4.2.1.3 Saprolite

Saprolite is a weathered rock derived from the chemical weathering of bedrock and at CFS consists of minerals consistent with granitic material. Although commonly less competent than the parent bedrock, saprolite generally retains the parent rock mineralogy and structure. It is green-brown to yellow-brown and consists of silt, fine-to-coarse-grained sand, and many highly weathered granite fragments. The fragments are generally very soft and easily crushable.

The thickness of the saprolite varies across CFS, as shown on the cross-sections in the 1986 RI (LMS 1986) and in the boring logs for this RI (Appendix J). Prior to cap construction, saturated thicknesses of landfilled waste ranged from 15 to 20 feet in much of the fill area. During the RI, the saturated thicknesses within the overburden aquifer ranged from zero to 55 feet with an average of 20 feet in the fill area, as determined during HDR's assessment of previously existing wells in 2011. The saturated thicknesses in the areas outside of the landfilled waste ranged from zero to 115 feet with an average of approximately 42 feet.

3.4.2.2 Bedrock

3.4.2.2.1 Overview

Bedrock consists of Precambrian–age (Middle Proterozoic) Crystalline Rocks of the Reading Prong – Byram Intrusive Suite. According to the Bedrock Geologic Map of the Chester Quadrangle, Morris County, New Jersey (Volkert et al., 1990), there are two members of the Byram Intrusive suite, a

hornblende granite and microperthite alaskite. Mapping of the contact between the granite and alaskite shows it running southwest to northeast from south of the landfill to Schoolhouse Lane in the north (Figure 3-3). To the north of the landfill, the mapped contact coincides with the low-lying area between the two ridges.

The hornblende granite is a medium- to coarse-grained, grayish pink to light gray to light brownish gray gneissoid to indistinctly foliated granite and sparse granite gneiss composed principally of microcline microperthite, quartz, oligoclase, and hornblende.

The microperthite alaskite is a grayish pink to light-brownish-gray, gneissoid to indistinctly foliated alaskite composed principally of microcline microperthite, quartz, and oligoclase that also may contain un-mappable bodies of amphibolites. Figure 3-3 is a map depicting the bedrock geology at CFS and its vicinity.

Bedrock outcrops are at three locations - on the ridges to the northeast and northwest, and in isolated areas near well CF-216D on the horse farm to the northwest.

3.4.2.2.2 Site Investigation Results

Characterization of the geology of CFS occurred as part of several investigations completed before the current RI (including Germine 1982, LMS 1986, NJDEP 2005b, Herman 2006, Berger 2007, and Berger 2010). The following paragraphs present key findings from these investigations along with those from the current RI.

Rock Types

A geologic reconnaissance of CFS and nearby area by NJDEP (Germine 1982) identified four rock types:

- Alaskite gneiss; a buff-colored, strongly foliated gneiss principally composed of elongated streaks of smoky quartz, plagioclase (oligoclase), feldspar, hornblende and opaques, and traces of monazite with prominent parting along foliation.
- Hornblende granite; a buff to pink-colored, weakly to moderately foliated granite containing quartz, oligoclase, feldspar, and hornblende.
- Alaskite; a dark-gray, buff to brown weathering Alaskite with foliation weakly developed to absent. It is composed of quartz, oligoclase, and feldspar, with accessory hornblende and opaques.
- Amphibolite; a foliated rock containing hornblende and plagioclase. It occurs as thin bands in other rock units.

Observations of Hornblende granite during the 1986 RI and material consistent with hornblende granite during this RI field investigation, confirmed the 1982 findings.

Bedrock Surface

Field geologists measured depth to bedrock in soil borings and during bedrock well drilling for this RI. Use of these measurements and measurements from previous investigations resulted in generation of a bedrock surface map (Figure 3-8). The highest bedrock surface elevations found during this RI were on the ridges to the north and northeast of the landfill (867 and 863 feet amsl,

respectively). The northwestern of the two ridges extends as a bedrock high with bedrock surface elevations to 815 feet amsl through the main portion of the landfill (north of the utility corridor). From this ridge, the top of bedrock slopes to the southeast, south, and northwest.

Separating the two ridges is a southwest-northeast trending bedrock trough that slopes to the northeast and southwest. To the north of the landfill, the elevation of the bedrock surface in the trough slopes from between approximately 750 and 770 feet amsl at the landfill boundary to below 725 feet amsl near Schoolhouse Lane based on boring information. Inferred top of bedrock elevations obtained during the resistivity survey (Appendix C) indicated bedrock elevations along Schoolhouse Lane as low as 662 feet amsl. The three preferential groundwater flow pathways identified by the Willowstick® survey (Section 3.6.2.2.4) run within or on the edge of the bedrock trough. Considerably deeper bedrock elevations are in the area of the former North Waste Cell (wells PZ-21R, D-5R, and CF-209D; to 730 feet amsl) and along the northeast landfill perimeter (wells CF-211D and CF-15D; to 728 feet amsl). Both areas are along preferential flow pathways identified from the Willowstick® survey. The bedrock surface also slopes to the south from the northern edge of the landfill to 750 feet amsl south of the landfill. Further south, the bedrock surface slopes primarily southeast. Trout Brook follows the general slope of bedrock in this area.

From the western portion of the landfill, the bedrock surface slopes from around 800 feet amsl to below 760 feet amsl at the adjoining horse farm.

The resistivity survey determined depths to bedrock along the six completed profiles as ranging from less than 10 feet to greater than 120 feet (Appendix C). The interpreted bedrock interface in the area of the fracture zone (ranging from 80 to 100 feet bgs) is considerably deeper than in the surrounding areas. This indicates the presence of a southwest-northeast trending bedrock trough (NJDEP previously inferred the presence of a weathered bedrock trough from depth to bedrock determinations at a number of soil and monitoring well borings, see Giles 2010).

Bedrock Structure

The regional strike of the highly fractured bedrock is to the northeast (Figure 3-3). As described in a previous investigation, the strongly layered bedrock has compositional mineral bands consisting of quartz- and feldspar-rich light layers to dark amphibolite layers. Two sets of fractures or joints cut the layers. The intersections of fracture planes locally form hydraulic conduits for groundwater flow (NJDEP 2005b; Herman 2006).

During the RI, field geologists observed numerous bedrock fractures; these were frequently large and steeply dipping, and encountered to depths of over 600 feet bgs. Increased borehole caliper readings on the cross-sections indicate the fracture zones (Figures 3-4 through 3-7). The vast majority of fractures dip steeply in the range of 45 to 90 degrees, and a large number exceed 70 degrees (Appendix K).

3.5 Surface Water Hydrology

A large portion of the landfill north of the utility easement is located on a natural topographic high (Figure 3-1). The highest portion of the capped landfill is in the north-central section, with steep and short slopes to the west, northwest, and north, and more gradual, longer slopes to the south and southeast that direct surface runoff in these directions. To the west-southwest of the landfill near the headwaters of Trout Brook and the Tanners Brook UNT is a hardwood wetland.

The headwaters of several streams emerge near the landfill, including East Trout Brook to the southeast, the Lamington River UNT to the northeast, the Tanners Brook UNT to the west, and Trout

Brook to the south (Figure 2-2a). The confluence of East Trout Brook and Trout Brook is approximately one-half mile south of the landfill, south of Parker Road. Trout Brook joins the Lamington River (known locally, and referred to as the Black River in several reports of previous investigations) approximately three miles south in Hacklebarney State Park (Figure 3-2). Surface drainage from the northeast portion of CFS is towards the Lamington River UNT near Schoolhouse Lane, and the western portion drains towards the Tanners Brook UNT.

Runoff from the landfill is captured in rip-rap lined channels on the landfill cap. From these, runoff flows into a perimeter ditch and into on-site detention basins. Prior to capping, surface runoff and leachate from the landfill drained to the headwaters of the nearby streams.[33] In addition to a portion of the surface water runoff from the landfill perimeter road, East Trout Brook receives the discharge from the on-site GWTP. In the absence of heavy precipitation and resulting overland flow, the treatment plant effluent is the main source of water for the headwaters of this stream.

The CFS treatment plant operators collect two effluent samples per month for VOCs, SVOCs, pesticides, PCBs, metals and other analyses. In recent years, 1,4-dioxane concentrations in effluent discharged from the plant to East Trout Brook have averaged about 20 µg/L (NJDEP 2014). HDR reviewed 18 monthly discharge-monitoring reports (DMRs) submitted to the NJDEP Division of Water Quality for the period of March 2015 to March 2017. 1,4-Dioxane is the only organic compound regularly detected. Detections of three other organic compounds occurred once in 36 samples at concentrations of 1 µg/l or less. Among the metals, detections of copper and nickel occurred regularly; copper generally below 4 µg/L and nickel generally below 3 µg/L, while infrequent detections of zinc were 15µg/L and below, and arsenic less than 1 µg/L.

The RI included evaluation of area streams to determine if contaminated groundwater is impacting surface waters by evaluating the interaction between groundwater and surface water at nine piezometer/stream gauge locations (Section 2.1.2.2). The evaluation's objective was to correlate groundwater and surface water elevations and determine if groundwater discharges to surface waters. Appendix S includes charts with water elevations for each piezometer/stream gauge pair used in the groundwater-surface water interaction study. Table 2-5a presents four rounds of water level elevation measurements at the piezometer/stream gauge pairs.

Results of the groundwater-surface water interaction study found the Lamington River UNT and Trout Brook to be gaining streams (groundwater contributes to stream flow), as described in Section 3.6.2.1.1. Shallow groundwater discharges to surface water along Trout Brook to the south, the wetlands to the west, and the Lamington River UNT along Schoolhouse Lane to the northeast (Section 2.1.2.2). The upper portion of East Trout Brook is a losing stream where the treatment plant discharges its effluent, while the lower portion is a gaining stream.[34]

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[33] Surface runoff from the western and southwestern slopes historically flowed to a hardwood wetland drained by the West Branch of Trout Brook (now referred to as Trout Brook). Surface water from the eastern portion of the landfill contributed to the East Branch of Trout Brook (now referred to as East Trout Brook). Historically, landfill leachate, groundwater, and surface water runoff from the southern portion of the landfill fed the headwaters of East Trout Brook and Trout Brook (LMS 1986). Refer to Section 1.6 for additional details of the historic impact of leachate on surface waters in the area of CFS.

[34] The upper portion of East Trout Brook flows mostly when the treatment plant discharges its effluent, but rarely at other times. While the monitored stream and groundwater data from this area (stream gauge/piezometer pair SG109/PZ109, Appendix S) indicated a gaining stream at times during the recording period, this may not be representative of actual conditions based on visual observations and that the piezometer installation was not alongside the stream because of the steep slope. Piezometer installation was on the nearby hillside, approximately 14 feet above the stream (Section 2.2). Professional judgment and observations made over the course of the

3.6 Hydrogeology

3.6.1 Regional Hydrogeology

CFS is included in the Northwest New Jersey 15 Basin Aquifer sole source aquifer (SSA) under the provisions of the Safe Drinking Water Act (SDWA) in 1988 (Federal Register, Volume 53, No. 121, pages 23685 – 23687). CFS is included in the North Branch Raritan River Basin Aquifer System. Drainage basin boundaries define the basin aquifer systems and streams serve as discharge points for the flow systems. In general, the water table in the area occurs at depths 20 to 40 feet below the land surface on hilltops and intersects the land surface in valleys. It is coincident with the upper surface of streams, lakes, and swamps (Carswell and Rooney 1976). The direction of groundwater flow generally follows topography, which is generally down toward the river valleys in the uplands and up and toward the streams in the valley bottoms. Groundwater discharges from the aquifer system into streams, lakes, and swamps, by evapotranspiration, and by flow to pumping wells (EPA 1986).

Groundwater flows through bedrock primarily following the secondary porosity and permeability provided by fractures. The distribution and orientation of these fractures controls the rates and directions of groundwater flow. Pumping for potable water is mostly from the weathered and fractured zone in the upper 400 feet. In the New Jersey Highlands crystalline units (including gneiss, quartzite, amphibolite and granite), high yields may be found in or near major fault zones (USGS 2015).

3.6.2 Site-specific Hydrogeology

The aquifer system that underlies and surrounds CFS is comprised of two systems, an overburden/saprolite aquifer and a fractured bedrock aquifer.

Characterization of hydrogeologic conditions at CFS took place during several prior investigations (including LMS 1986, NJDEP 2005b, Herman 2006, Handex 2009, Berger 2010, and Handex 2011). The following paragraphs present key findings from these investigations along with the findings from the current RI.

3.6.2.1 Overburden/Saprolite Aquifer

The unconsolidated overburden at CFS originates from bedrock and saprolite, as described in Section 3.4.2.1, but also includes landfilled wastes under the cap. Based on water elevation measurements collected during this investigation, a portion of the landfilled waste underneath the cap is in the saturated zone.

The major matrix of this aquifer is the saprolite, which consists mostly of sandy silt to gravelly silt based on observations and analysis completed during the 1986 RI. Pump tests completed at the time indicated that the saprolite was substantially more porous than the bedrock aquifer (LMS 1986). In the landfill area, layers of soil and saprolite reportedly covered the waste. Both the waste/fill and saprolite portions of this aquifer are non-homogeneous and anisotropic. Observations made during the drilling of well D-6 as part of the 1986 RI indicated the presence of numerous voids in the fill, some measuring several feet thick, considered to provide significant conduits for fluid flow through the fill.

project, in addition to the piezometer/stream gauge data, determined the groundwater/surface water interaction at this location.

Finer and tightly compacted fill materials that impeded fluid movement were also in the fill (LMS 1986).

3.6.2.1.3 Groundwater Elevations and Flow

Table 2-5 presents the synoptic groundwater elevation measurements collected as part of the RI in May 2012 for the overburden aquifer. Figure 3-9 depicts the groundwater elevations, contours and flow direction for this date. In May 2012, the highest groundwater elevation in the overburden aquifer was at well S-6 (screened from 54 to 69 feet bgs), on the horse farm property to the north-northwest of the landfill. Shallow groundwater flow is nearly radial from the area of highest elevation to the southwest, south, southeast, east, and northeast. Groundwater elevations and flow directions in the areas north and west of well S-6 could not be determined because of the lack of measuring points in these directions. Shallow groundwater flow in this area presumably follows the terrain to the northwest across the horse farm property towards Tanners Brook.

In the low-lying area to the northeast of the landfill, shallow groundwater flow presumably follows the terrain between the two ridges and flows northeast towards the Lamington River UNT near Schoolhouse Lane. Because there are no shallow wells in the area between wells MW-9 and MW-11 and Schoolhouse Lane, the groundwater contours generated from depth to water measurements (Figure 3-9) do not reflect this. Similarly, the lack of shallow monitoring wells in the northeastern portion of the landfill and along the eastern perimeter may overemphasize the easterly component of flow from the landfill towards Parker Road. Based on topography, a more southerly component towards nearby East Trout Brook is possible in this area.

To supplement the May 2012 information on water table elevations and groundwater flow in the overburden aquifer, HDR generated potentiometric surface elevations figures for three dates in 2014 (May, August, and November), using NJDEP monthly depth to water measurements for the landfill and the immediately area (Figures 3-9b through 3-9d). NJDEP does not monitor the outlying areas during its monthly measurements. The figures indicate that overburden groundwater generally flows from the topographically higher areas (to the north of the landfill on the landfill itself) to the surrounding areas to the west and south. Over the seven-month period covered by the three graphs, groundwater levels at some wells receded 8 and 13 feet (e.g., at wells S-6 to the north, MW-6 to the south, MW-9 to the northeast and at PZ-8 within the landfill), while others within the landfill and along its western edge showed little decline in water levels. For wells considered not influenced by the landfill's recovery system (e.g., S-6, MW-6), this reflects the expected seasonal trend of declining water levels from spring to fall. For wells in areas influenced by the landfill's recovery system, a combination of declining water levels due to seasonal trend, changes in pumping rates because of operational issues at the plant, and upward groundwater flow (e.g., in the area along the landfill's western edge) may account for the comparatively smaller overall decline in water levels.

NJDEP measured monthly depth to overburden groundwater between January 2009 and April 2015 under the post-construction environmental monitoring plan (NJDEP 2009b) in addition to the above water level measurements completed during the current RI. Plots over time for monitoring wells near the landfill (including wells within and outside of the cap area) assessed seasonal and spatial variations in groundwater levels. The resulting graphs (Appendix G) indicated similar trends in shallow groundwater elevations inside and outside the landfill area, with generally higher water tables in the spring, but without pronounced seasonal variation. The resulting groundwater contours and expected flow directions within and in the immediate vicinity of the landfill did not show any spatial disparities (i.e., groundwater elevations throughout the area all varied in the same manner).

Continuous collection of water level elevations took place over three months at two previously existing overburden piezometers at the landfill perimeter (Section 2.1.2.1). The two piezometers were PZ-8,

along the southwest side and PZ-21R, along the northeast side (Figure 2-4). The goal of the transducer study was to monitor long-term/seasonal trends and potential impacts of nearby pumping wells. Graphs showing the water levels over time for the two piezometers are in Appendix H. At piezometer PZ-8, the water level declined more or less evenly by 2.3 feet between early August and the second half of October (with a minor rebound after rainfall in September). Following a major precipitation event (Hurricane Sandy at the end of October), the water level recovered by approximately 0.25 feet. The water level at piezometer PZ-21R showed a similar seasonal trend, declining by approximately 3.5 feet between early August and late October. PZ-21R is situated between two of the landfill leachate collection/shallow groundwater extraction wells (bedrock recovery well RW-T and overburden recovery well RW-U). The intermittent pumping at the two recovery wells caused oscillations of approximately 0.75 feet, with superimposition of the data on the seasonal trend and long-term pumping drawdown. Following Hurricane Sandy at the end of October, pumping at the nearby recovery wells ceased during a multi-day power outage and the water level rebounded. The water level at PZ-21R also rebounded quickly after major precipitation events (increases of a foot or more). Both the piezometer and recovery wells are in clayey silt and saprolite. Piezometer PZ-21R is screened from 45 to 95 feet bgs, overburden recovery well RW-U is screened from 39-89 feet bgs and bedrock recovery well RW-T is screened from 65 to 115 feet bgs (during a 2009 pump test at RW-T, PZ-21R showed a drawdown of 1.86 feet, indicating pumping influence from RW-T). Just before the end of the monitoring period, on October 29, 2012, Hurricane Sandy made landfall in New Jersey. A subsequent power outage interrupted recovery well pumping; the resulting water level recovery notable in the hydrograph for PZ-21R.[35]

Based on water elevation measurements collected as part of the investigation of groundwater and surface water interaction (Section 2.1.2.2), shallow groundwater discharges to surface water along Trout Brook to the south, the Tanners Brook UNT and the wetlands to the west, and the Lamington River UNT along Schoolhouse Lane to the northeast. The upper portion of East Trout Brook to the southeast of the landfill is a losing stream while the lower portion is a gaining stream (Section 3.5).

The charts presenting water elevations for each piezometer/stream gauge pair used in the groundwater-surface water interaction study are in Appendix S. Table 2-5a contains four rounds of water level elevations measurements at the piezometer/stream gauge pairs.

3.6.2.1.4 Aquifer Characteristics

The 1986 RI included slug and pump tests of wells screened in the saprolite. The calculated hydraulic conductivity for the overburden/saprolite at that time ranged from 4.94×10^{-4} centimeters per second (cm/s) to 1.76×10^{-2} cm/s, with a geometric average permeability of 2.24×10^{-3} cm/s. Transmissivities for several wells calculated using the saturated thicknesses of the saprolite aquifer ranged from 0.45 cm^2/s to 10.21 cm^2/s with a geometric average transmissivity for the saprolite aquifer of 1.71 cm^2/s. (LMS 1986).

Additional overburden aquifer tests in 1989 were part of the remedial design for the landfill cap (O'Brien & Gere 1991). Pumps tests occurred at four locations, with transmissivities ranging from 0.95 cm^2/s 1.45 to cm^2/s, and an average of 1.56 cm^2/s. At three of the four locations, drawdown

[35] The water level in piezometer PZ-21 declined almost 3 feet in response to pumping between August 31 and September 14. The cause of this decline and the pumped wells were not apparent from the reviewed recovery well pumping records for August 2012. The records indicated that several recovery wells were not pumping from August 31 to September 12 while other wells were pumping at higher than previous rates during part of this period. On or about September 14, the water level in PZ-21R rebounded and the previous pattern of water level fluctuations in response to intermittent pumping resumed.

occurred in a bedrock observation well, indicating hydraulic connection between the overburden and bedrock aquifers.

3.6.2.2 Fractured Bedrock Aquifer

In fractured bedrock aquifers, such as the one beneath CFS, groundwater is stored and transmitted along discontinuities within the rock mass of the geologic formation. These discontinuities may include fractures, joints, cleavage planes, foliations, and schistosity partings, which together form an interconnected network for groundwater flow. The bulk of the groundwater flows through the fracture network.

3.6.2.2.1 Groundwater Elevations and Flow

Table 2-5 presents the synoptic groundwater elevation measurements collected in May 2012 during the RI for the bedrock aquifer. Figure 3-10a shows the groundwater contours. The highest groundwater elevation in the bedrock aquifer in May 2012 was at well D-1 (screened from 91 to 147 feet bgs) north of the landfill on the adjoining horse farm property. Groundwater flow in the bedrock aquifer is nearly radial from this area to the southwest, south, southeast, east, and northeast. Groundwater elevations and flow directions in areas further to the north and west of well D-1 could not be determined because of the lack of bedrock monitoring wells in this area.

To supplement the May 2012 information on water table elevations and groundwater flow in the bedrock aquifer, HDR generated potentiometric surface elevations figures for three dates in 2014 (May, August, and November), using NJDEP monthly depth to water measurements supplemented with HDR data collected during sampling events conducted at the time (Figures 3-10b through 3-10d). NJDEP does not monitor the outlying areas during monthly measurements. The figures indicate that bedrock groundwater generally flows from the landfill itself to both the southwest and northeast. This corresponds to the alignment of the highly fractured zone and bedrock trough along the mapped contact between the alaskite and granite (Figure 3-3), described in Sections 3.4.2.2.1 and 3.4.2.2.2, and the preferential bedrock groundwater flow paths identified during the Willowstick investigation (Section 3.6.2.2.4) along this trend, which are also indicated on the figures.

Over the seven-month period covered by the three graphs, groundwater levels at the bedrock wells generally fell by between 6 and 12 feet. Smaller declines were recorded at well D-5R (1 foot) and D-6 (3.5 feet) within the landfill and larger ones at recovery well RW-T and at well D-4 (both approximately 15 feet). It was not possible to evaluate in detail the influence of recovery system pumping/operation on water level changes because information was not available for the investigation period. However, the preferential drawdown in the southwest-northeast direction previously demonstrated through pump tests at recovery well RW-T (Sections 1.6 and 1.7) is evident in the lower water levels at nearby wells MW-12, -13, -14, and -16 (Figure 3-10d). For May and August 2014, the graphs show that bedrock in the northern portion of the landfill (former North Waste Cell and North Waste Cell excavation area) flows to the southwest and the northeast. In November, flows to the southwest and south are more pronounced. In addition to the synoptic water level measurements in this RI, HDR plotted over time NJDEP's monthly depth to bedrock groundwater measurements from January 2009 and April 2015 at monitoring wells in the vicinity of the landfill (including shallow bedrock wells within and outside of the cap area) to assess seasonal and spatial variations in groundwater levels (Appendix G). The resulting graphs indicate similar trends in shallow bedrock groundwater elevations inside and outside the landfill area, with generally higher water tables in the spring, but without pronounced seasonal variation. The resulting groundwater contours and expected flow directions within and in the immediate vicinity of the landfill do not exhibit any spatial disparities (i.e., groundwater elevations throughout the area all varied

in the same manner).

The purpose of continuous collection of water level elevations in the bedrock aquifer for three months at 11 bedrock monitoring wells was to monitor for long-term/seasonal trends and potential impacts of nearby pumping wells during the RI (Section 2.1.2.1). Figure 2-4 depicts the locations of the bedrock wells that were included in the transducer study. The hydrographs are in Appendix H and summary descriptions and interpretations are in Table 2-8b.

For almost all wells, the water level was lower by between two to four feet at the end of the three-month observation period.[36] Water table rebound in the days following major or repeated precipitation events occurred at some of the bedrock wells (CF-11D, CF-15D, CF-205D, CF-218D, and CF-223D). Drawdown caused by purging and sampling of several of the transducer wells in October 2012 is expressed in one-time water table elevation declines also (CF-11D, CF-15D, D-1, D-2, CF-205D, and CF-223D). At the multi-port FLUTe™ wells equipped with transducers (CF-201D, CF-206D, and CF-218D), discernable water level rebound following precipitation events occurred after some events and for some of the fracture zones monitored by the individual ports. At well CF-206D, the water level showed an overall decline over the observation period in all three monitored intervals/fracture zones, while less pronounced trends were at wells CF-201D and CF-218D and varied between the individual ports/fracture zones.

The water level elevation in well CF09D increased by about two feet from early August to late October which was an exception to the general declining trend for the water table. Well CF09D is located north of Schoolhouse Lane at the edge of a farm/nursery. Two irrigation wells are on neighboring parcels (Lot 50/Block 17 and Lot 33/Block 17), and evidence of pronounced characteristic pumping influence exerted by the irrigation wells is in the hydrograph for CF09D, expressed as regular water level oscillations characterized by linear, almost instantaneous drawdown and rebound periods. During most drawdown episodes, the water table dropped by about one foot, with maximum drawdown exceeding nine feet. The increase in water level over the observation period is likely the result of larger withdrawals before and early on during the observation period, and reduced withdrawals near the end of the growing season. Well CF09D's screen is from 145 to 170 feet bgs. Based on limited available location information, the two irrigation wells are approximately 350 to 375 feet northeast and 700 feet north of CF09D and have open intervals from 70 to 311 feet bgs and 103 to 655 feet bgs, respectively.

Just before the end of the monitoring period, on October 29, 2012, Hurricane Sandy made landfall in New Jersey. A power outage interrupted recovery well pumping; the resulting water level recovery appears in the hydrographs for a number of wells.

In addition to well CF09D, there was interpretation of pumping influences for several other wells. For monitoring wells in proximity to recovery wells, it was possible to identify or infer nearby pumping wells. For other monitoring wells not in proximity to a recovery well, it was not possible to make such attributions. For several wells, the recovery of water levels after a major power outage during Hurricane Sandy in late October appeared to be a combination of the cessation of pumping, recharge from precipitation and barometric influences. In other instances, short-term shutdowns or power outages appeared to be the cause of recharge. Table 2-8b presents observations for each of the transducer wells. Determination of vertical groundwater flow within the boreholes was part of the

[36] At several wells, sampling or unknown causes appeared to have disturbed the transducers when checking them to ensure that they were still operational. Some of these disturbances show up as abrupt offsets/apparent water level changes in the hydrographs. Any such disturbances confirmed or strongly suspected are in the hydrograph summaries (Table 2-8b).

downhole geophysical investigation completed during the RI (Section 2.1.4.1). Heat pulse flow meter measurements determined the direction and magnitude of flow within the boreholes. Vertical flow varied based on location. Generally, boreholes near the landfill exhibited downward flow and boreholes further from the landfill near the streams demonstrated upward flow. The boreholes to the north, west, and south near the landfill displayed mainly downward flows, including wells CF-227D and CF-228D. Upward flows were in the boreholes further from the landfill, especially near the streams, including well CF-201D (Lamington River UNT), wells CF-218D and CF-225D (Trout Brook), and well CF-216D (Tanner's Brook UNT). The wells at the southeast corner of the landfill, CF-223D and CF-224D, also showed upward flows. The downhole geophysical logs are in Appendix K. Two deep bedrock boreholes installed to the northeast of the landfill near Schoolhouse Lane (CF-204D and CF-206D) were artesian and overflowed onto the ground surface. The driller had to extend the casings for these two wells several feet above ground surface prior to completion as multi-port wells. Nearby well CF-207D was also artesian in early December 2011 (at the time of the borehole geophysical investigation) but did not require casing/riser extension. In addition, HDR visited five previously existing artesian wells located south of CFS on the south side of Parker Road during the well assessment in April 2011 (Figure 2-1). These wells were either overflowing from the casings (WRA2-1, WRA2-2 and WRA2-3) or water had risen inside the casing to above the ground surface (WRA3-1 and WRA3-2) (Appendix F).

A previous downhole geophysical investigation of five wells at the planned Millstone Crossing subdivision to the northeast of the landfill in late 2004 also determined borehole flow (NJDEP 2005b, Herman 2006). At the time, measurement of borehole cross-flow under natural (non-pumping) conditions in some wells was between 0.5 and 4.0 gpm. The wells known to have the highest contaminant concentrations (wells 22.08 and 22.10 in the low-lying area between the two ridges, southeast of the artesian wells CF-204D, CF-206D, and CF-207D near the west end of Schoolhouse Lane (Figure 2-1) exhibited upward flow, providing a path for vertical flows at rates of about 2.5 feet/minute under natural (non-pumping) conditions. Wells on the ridges exhibited weak downward flow. Groundwater flow and discharge occur at depths in excess of 500 feet to the northeast within the low-lying area between the ridges. Upward to local surface discharge occur at Schoolhouse Lane.

In general the vertical head gradients (0 to 0.003 ft./ft.) within the bedrock aquifer are an order of magnitude smaller than horizontal gradients (0.01 to 0.03 ft./ft.).[37] Therefore, lateral flow predominates with respect to groundwater movement and chemical transport; however, vertical flow is still an important component in the CSM.

3.6.2.2.2 Aquifer and Formation Characterization

PREVIOUS INVESTIGATIONS

Previous investigations provide information on characteristics that control groundwater flow and contaminant distribution. NJGS completed the most relevant, recent investigation in late 2004 to support NJDEP's investigation at the Parker Preserve area (the former proposed Millstone Crossing development) adjoining and northeast of CFS (NJDEP 2005b, Herman 2006). NJGS conducted a downhole geophysical investigation of five of the boreholes installed as future potable wells for the planned subdivision. [38] The purpose of the investigation was to identify and characterize the

[37] 1986 LMS RI.

[38] The subdivision is the former Millstone Crossing.

subsurface geology that controls the storage and movement of groundwater and associated VOC contamination at CFS.

NJGS's investigation found many water-bearing zones resulting from the three types of planar structures at CFS (compositional layering or banding corresponding to granitic or gneissoid foliation; fractures, brittle, planar discontinuities, and shear fractures; described in detail in Section 3.4.2.2.2), at all logged depths; however, there were three times as many water-bearing zones related to conductive fractures than to compositional layering. The densest concentration of fracture intersections followed the trend of regional strike and plunge gently northeast, leading the author to conclude that structural intersection of layering fractures with subparallel, tectonic shear fractures probably results in pronounced horizontal conductivity in deep bedrock oriented along regional strike to the northeast. A topographic ridge on the southeast side of the low-lying area formed the eastern boundary of the plume at the time of NJGS's investigation.

The NJGS investigation also observed staining and alteration of the rock matrix along conductive fractures in contaminated wells that was absent in uncontaminated wells along similarly conductive fractures. Details are in the NJGS report summary in Section 1.7 and information on the structural geology of the area from the NJGS report is in Section 3.4.2.

Aquifer testing conducted during the 1986 RI reported transmissivity values for the fractured bedrock that ranged from 0.04 cm^2/s to 3.79 cm^2/s, with a geometric average of 0.17 cm^2/s, an order of magnitude lower than in the overburden aquifer (1.71 cm^2/s).

The most prominent discontinuity features (openings), as determined from examination of outcrops of the bedrock on and near the landfill, are partings parallel to the foliation that is oriented N50°E and dipping 80°SE (LMS 1986).

In addition, joint sets present in the rock mass are oriented N35-43°E, with a vertical dip nearly parallel to the orientation of the foliation partings. The 1986 RI observed discontinuities with other orientations, but the major planar features tended to be parallel and subparallel to the foliation. Under these conditions, groundwater migration bias is in the direction of the predominant discontinuities. Permeability and transmissivity, the ability of the rock material and the aquifer to transmit water, is the greatest parallel to these planes and lower perpendicular to the same planes. This directional permeability is anisotropic (LMS 1986).

The bedrock formation produces groundwater primarily through fractures or its secondary permeability. Intersections of fracture planes locally form hydraulic conduits for groundwater flow. The mean strike of layering measured in a previous investigation is N32°E and the dip as 66°SE. The densest concentration of fracture intersections follow the trend of regional strike, and the structural intersection of layering fractures with subparallel, tectonic shear fractures results in pronounced horizontal conductivity in deep bedrock oriented along regional strike. The investigation found three times as many water-bearing zones related to conductive fractures as to compositional layering (NJDEP 2005b, Herman 2006).

Another previous investigation of the deep wells at the former proposed Millstone Crossing development (completed in the granitic gneiss bedrock formation northeast of the landfill) reported yields ranging from 0.1 to 10 gpm (Berger 2010).

CURRENT INVESTIGATION

During the current RI, calculation of borehole transmissivities resulted from the hydraulic profiling procedure discussed in Section 2.1.4.2 (both as initial/total transmissivities for the entire boreholes

below the casings at the beginning of liner eversion, and as discrete interval transmissivities for individual fractures/fracture zones). Table 3-1 summarizes this data. Appendix T contains the FLUTe™ hydraulic profiling results.

The hydraulic profiling identified five boreholes with significantly higher initial (total borehole) transmissivities: boreholes CF-201D (15 cm^2/s), CF-206D (64.9 cm^2/s), CF-216D (100 cm^2/s), CF-218D (30 cm^2/s), and CF-227D (350 cm^2/s). Initial transmissivities of the other boreholes ranged between 0.85 and 6 cm^2/s. Borehole CF-227D had the highest initial transmissivity as well as the fracture zone with the highest discrete interval transmissivity (42 cm^2/s, at approximately 476 feet bgs). Well CF-227D is at a location along the most significant preferential flow path identified in the Willowstick® electromagnetic survey. The second highest discrete interval transmissivity (16.1 cm^2/s) is at boring CF-206D for a fracture at approximately 556 feet bgs (Table 3-1).

3.6.2.2.3 Identification of Potential Fracture Zones

The two-dimensional ERI (Section 2.1.1.1) identified prominent potential fracture zones on five of six survey lines (transects). Of these five transects, four (profiles #1 through 4) were approximately perpendicular to and across the utility corridor, and one (profile #6) ran approximately south to north across Schoolhouse Lane (Figure 2-3). At survey profiles 1 through 4, prominent potential fracture zones were west of the utility corridor, suggesting a major, continuous southwest-northeast trending fracture/groundwater flow zone. The interpreted bedrock interface in the area of the fracture zone (ranging from 80 to 100 feet bgs) was considerably deeper than in the surrounding areas. This suggests the presence of a southwest-northeast trending bedrock or weathered bedrock trough previously inferred by NJDEP from depth to bedrock determinations at a number of soil and monitoring well borings (Giles 2010). Additional areas of low resistivity were east of the utility corridor, near the east end of the four transects. Because of the proximity to the edge of the survey lines, the subcontractor did not interpret these as low resistivity areas; however, they may indicate another fracture zone.

At the profile crossing Schoolhouse Lane from south to north (profile #6), the fracture zone ran in an approximately west-east direction. Here, the interpreted depth to bedrock was shallower than at the other profiles (approximately 65 feet bgs) and the fracture zone followed the Lamington River UNT. The presence of the high-tension electric lines caused data gaps in the profiles collected in the area of the utility right-of-way and prevented the detection of additional potential fracture zones along the utility corridor.

The project team used the results of the ER survey in the selection of monitoring well locations for Phase I of the RI field investigation and in the development of the CSM.

3.6.2.2.4 Focused Investigation of Preferential Flow Paths

Building on the results of the ER survey, the Willowstick® electromagnetic survey consisted of a series of increasingly focused surveys conducted to locate water bearing zones/preferential flow paths that may serve as contaminated groundwater conduits within the area between the ridges north-northeast of the landfill.[39] Section 2.1.1.3 describes the survey procedure. The findings of the Willowstick® electromagnetic survey (Appendix E) support the findings of the previous investigations

[39] Originally, the investigation called for placing electrodes at multiple depths (shallow, medium and deep horizons). However, because circuit continuity was generally poor, other electrode configurations substituted for proposed multiple surveys utilizing the same, paired wells. This approach was the best at characterizing subsurface flow patterns in the areas beneath and northeast of the landfill.

at CFS, specifically those of the 2004 NJDEP/NJGS investigation of the Millstone Crossing wells, but also provide a more detailed picture of CFS hydrogeology.

Based on earlier investigations, the NJDEP Bureau of Ground Water Pollution Abatement (BGWPA) inferred the existence of several northeast-southwest trending preferred bedrock groundwater pathways several years ago. BGWPA suspected preferred pathways in the area of recovery well RW-T, and monitoring wells D-5R and CF-15D (based on poor water quality and deeper than expected bedrock indicative of major fracture zones).

Willowstick® modeled and interpreted the magnetic field data from the electromagnetic surveys and identified three predominant preferential groundwater flow paths as well as areas with no apparent hydraulic connection to the landfill. Interference prevented modeling and interpretation of magnetic field measurements within the transmission line corridor. The Willowstick® electromagnetic survey identified three preferential flow paths, all oriented southwest to northeast and running roughly parallel to the transmission line corridor, between the landfill and Schoolhouse Lane (Flow Path #1 through #3 on Figures 3-11 through 3-13). Because of grounding of the transmission towers, the survey's electric current did not stay in the ground but flowed up onto the overhead power lines during the surveys. This resulted in a data gap for an approximately 300-foot wide corridor centered on the transmission lines, as shown in the figures in the Willowstick® report. Therefore, additional unmapped preferential flow paths may exist underneath the utility corridor, including the preferred pathway that NJDEP BGWPA suspected for the area of recovery well RW-T.

The flow path (FP) with the greatest electric current intensity, FP #1, and the path with the third greatest intensity, FP #3, are west of the utility corridor, while the flow path with the second greatest intensity, FP #2, is east of the utility corridor (Figure 3-11). All three preferential flow paths run roughly parallel in a northeasterly direction from the landfill to Schoolhouse Lane. The two western flow paths, FP #1 and #3, converge near wells CF-206D and CF-207D.[40] FP #2, to the east of the transmission lines, crosses through the former planned Millstone Crossing development (now the Chester Township Parker Preserve), where earlier groundwater investigations of deep boreholes identified benzene and TCE contamination (1,4-dioxane was not detected, but the detection limit was 100 µg/L; Berger 2010; Section 1.6). From there, FP #2 turns north to join the combined west-side flow paths near well CF-204D at Schoolhouse Lane and the Lamington River UNT. The combined flow path appears to bend east (continuity to the north was specifically investigated but not found). FP #1 runs near well D-5R, and FP #3 near well CF-15D, areas which the NJDEP had previously identified as likely being along preferential pathways leading away from the landfill source. Wells along the preferential pathways had the highest concentrations of 1,4-dioxane, benzene and the other COCs (Figures 1-6A through 1-6D, Figures 4-1A through 4-1C; Figures 4-2A and 4-2B; Sections 4.2.1.3).

The three identified preferential flow paths follow near vertical fracture zones, tilt downward (i.e., increase in depth) away from the landfill, and have both shallow (near surface) and deep (bedrock) components. The bedrock flow paths components are at approximate elevations of 600 to 640 feet amsl at FP #1 and #3, and between approximate elevations of 650 to 670 feet amsl at FP #2, based on Willowstick's® three-dimensional modeling (Figures 3-12 and 3-13).

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[40] Well CF-206D produced in excess of 173,000 gallons of water during drilling, indicating that the well is located on a major groundwater flow path. Nearby wells CF-207D and CF-204D, which the Willowstick® survey showed as not being right along the preferential flow paths (Figure 3-11), produced considerably less water (approximately 32,000 gallons at CF-207D, and less at CF-204D).

Although the survey design was to identify flow paths, the data gathered is also useful to determine areas with little or no hydraulic connection to the landfill. Both the northeast and northwest ridges flanking the low-lying area between the landfill and Schoolhouse Lane demonstrated little groundwater connection to the landfill (shown as the purple areas of lower electric current distribution in Figures 3-11 through 3-13). The “limit of pollution plume” depicted in the NJGS study at Millstone Crossing (NJDEP 2005b) roughly coincides with a line labeled “aquitard” on the Willowstick® survey maps running through the center of the northeast ridge.

HDR used the results of the Willowstick® survey to select locations for monitoring wells installed during Phase II of the investigation and to refine the CSM. The field investigation included drilling, testing and completion of wells CF-226D, CF-227D and CF-228D as monitoring wells to confirm the Willowstick® survey results and support the delineation of VOC impacted groundwater. Well CF-226D extended to 200 feet bgs on the northwest ridge and produced almost no water, confirming the “aquitard” line drawn on the Willowstick® maps in this area. Wells CF-227D and CF-228D drilled in the preferential flow paths west and east of the utility easement, FP #1 and FP #2, respectively, exhibited high transmissivities. Well CF-227D had the highest discrete interval transmissivity at approximately 476 feet bgs compared to all of the wells installed for this RI, confirming the Willowstick® survey determination of a major preferential flow path through this location. Well CF-228D had a zone of high transmissivity around 417 feet bgs.

3.6.2.3 Saprolite – Bedrock Aquifer Interaction

The main source of contamination to the bedrock aquifer is the saturated landfilled material in the overburden aquifer. The water in the saturated fill material enters fractures near the bedrock surface where transport into the deeper fracture network occurs via downward flow observed in the wells in the immediate vicinity of the landfill.

During the RI, deep bedrock boreholes near the landfill generally showed downward flow and the boreholes further from the landfill near the streams demonstrated upward flow. The boreholes to the north, west and south in the immediate vicinity of the landfill displayed mainly downward flows. Measurement of upward flows were in the boreholes further from the landfill, especially in the vicinity of the streams, including well CF-201D (Lamington River UNT), wells CF-218D and CF-225D (Trout Brook), and well CF-216D (Tanner’s Brook UNT). The wells at the southeast corner of the landfill, CF-223D and CF-224D, also showed upward flows. Two deep bedrock boreholes installed to the northeast of the landfill near Schoolhouse Lane (CF-204D and CF-206D) were found to be artesian, as were five previously existing wells (WRA2-1, WRA2-2, WRA2-3, WRA3-1, and WRA3-2) located south of Parker Road (south of CFS) (Figure 2-1).

The analysis of three years’ of measurements collected by NJDEP indicated that the groundwater elevations in the overburden and shallow bedrock in the immediate vicinity of the landfill demonstrated the same trends over time, indicating a strong connection between the two systems (Sections 3.6.2.1.1 and 3.6.2.2.1).

Additional information on the interaction of the overburden/saprolite and bedrock aquifers is in a number of previous investigations. An investigation of five deep bedrock wells in the area north of the landfill at the former Millstone Crossing development (NJDEP 2005b, described in Section 3.6.2.2.1) also determined upward flow for two wells to the south and east of the RI’s artesian wells (CF-204D, CF-206D and CF-207D).

A long-term pump test performed between September 2010 and March 2011 used bedrock recovery well RW-T on the northeast perimeter of the landfill as the pumping well and 30 observation wells

(both overburden and bedrock wells). The pump test also included repeated sampling of well RW-T for chemical analysis (Handex 2011). The goal of the pump test was to determine the feasibility of remediating groundwater contamination by pumping from the bedrock aquifer. The objectives of the test included determining the maximum long-term sustainable yield of RW-T, the influence of pumping RW-T on the contamination in the bedrock aquifer, and the feasibility of using RW-T as a recovery well based on observed drawdown in the bedrock and overburden aquifers.

Recovery well RW-T is a 6-inch diameter bedrock well screened from 65 to 115 feet bgs. Pumping rates during the test varied from 120 gallons per minute (gpm) during the first month, to between 80 and 60 gpm for the remainder of the test period. Measurement of water levels was on a daily, weekly, and monthly basis over the duration of the pump test, and for three weeks after pumping stopped. The Handex report included groundwater contour maps for non-pumping and pumping conditions for both the unconsolidated water table aquifer and consolidated bedrock aquifer, and hydrographs (plotting groundwater levels against time to show the influence of pumping RW-T on each well and the rate of water level recovery after pumping stopped).

Effluent sample collection was weekly for the first 60 days of the pump test and at different intervals for the remainder of the test. Handex performed VOC, SVOC and general chemistry analyses on 15 effluent samples. Benzene, 1,4-dioxane and TBA exceeded the NJDEP GWQS. Benzene concentrations ranged from 1.1 µg/L to 5.5 µg/L (GWQS 1 µg/L) and increased from 1.6 µg/L during the first week to a high of 5.5 µg/L in week 9. The concentration of 1,4-dioxane was 18 µg/L at the beginning of the test, increased to 24 µg/L in week 4 and remained between 24 and 28 µg/L until the end of the pump test (week 15). TBA, with a range of 47 to 110 µg/L, exceeded the GWQS (100 µg/L) in two of 15 samples (weeks six and nine). Other VOCs detected below GWQS were ethyl ether (74-250 µg/L), 1,4-dichlorobenzene (4.1-7.9 µg/L), and chlorobenzene (3.9-7.9 µg/L).

By the end of the pump test period (after 163 days), well RW-T stabilized at an estimated 62 gpm with 70 feet of drawdown. Based on the test results, Handex considered the long-term sustainable yield of RW-T to be 40 to 45 gpm with a drawdown of 45 to 50 feet.

The drawdown contour map for the test (Figure 3-14) showed preferential drawdown in a northeast to southwest direction. It incorporated groundwater elevation data from both the water table and bedrock aquifers since the pumping influence was similar in both shallow and deeper wells. At an average flow rate of 77 gpm, there was up to 10 feet of drawdown 630 feet to the northeast and 750 feet to the southwest of the pumping well. Less pronounced was drawdown in a northwest to southeast orientation from the pumping well, extending approximately 200 feet in either direction from RW-T. The preferred northeast to southwest orientation of drawdown suggests that the bedrock structure is controlling groundwater flow in the bedrock aquifer, supported by a distance-drawdown graph showing a maximum radius of influence of 1,800 feet in a northeast direction from RW-T. As indicated by the Willowstick survey (Section 3.6.2.2.4), major preferential groundwater flow pathways exist in the area to the northeast of the landfill (Figure 3-11). The strong influence of pumping on both the overburden and shallow bedrock wells, which displayed comparable drawdowns and the same preferential direction of drawdown for both the overburden and shallow bedrock aquifer (Figure 3-14) indicated a strong connection between the two aquifers.

Handex considered the pump test results supportive of the use of RW-T as a recovery well to capture contaminated groundwater migrating in the bedrock aquifer, based on the presence of elevated concentrations of benzene and 1,4-dioxane and the sustainable well yield.

Earlier pump tests completed as part of landfill cap remedial design indicated a hydraulic connection between the overburden and bedrock aquifers at three of four locations with drawdown observation

in the bedrock observation well. At the fourth location, no observation of drawdown occurred but the distance between the pumping well and the bedrock observation well was deemed too large to determine if a hydraulic connection existed or not (O'Brien & Gere 1991).

3.6.2.4 Hydrogeologic Assessment of the Deep Bedrock Aquifer

The procedures and findings of the deep bedrock aquifer hydrogeologic assessment are in a technical memorandum to EPA (HDR 2017b, Appendix N). As described in Section 2.1.7, the hydrogeologic assessment between January and April 2017 consisted of a pump test and sampling at test well CF-209D, and water level monitoring at 12 observation wells during the long-term constant rate test. The following paragraphs present the findings of the assessment.

The results of the hydrogeologic assessment of the deep bedrock aquifer suggest the existence of preferential flow paths oriented in a southwest to northeast direction, supporting the conclusions of the resistivity survey (Section 3.6.6.2) and the Willowstick® electromagnetic survey (Section 3.6.2.2.4), which identified fracture zones and preferential pathways oriented southwest to northeast. Groundwater drawdown in the deep aquifer wells monitored during the 2017 pumping test showed an area of influence extending up to 3,000 feet northeast and southwest (parallel to the overhead, high voltage electrical transmission lines) and at least 500 feet east-southeast and west-northwest (perpendicular to the transmission lines) (Figure 3-15).

Detailed findings and conclusions of the 2017 hydrogeologic assessment were:

- Shallow aquifer monitoring wells were generally not affected by the long-term pumping of CF-209D, and in some cases, showed increasing water level trends (likely the rebound of water levels after the cessation of pumping at recovery wells RW-R, RW-T, and RW-U for the aquifer pumping test, and seasonal groundwater recharge).
- Pumping of existing operational GWTF recovery wells influences groundwater elevations in overburden and saprolite wells.
- Deep aquifer monitoring wells to the southwest and northeast of pumping test well CF-209D and the former North Waste Cell exhibited the greatest drawdown, providing strong indication of preferential zones of higher hydraulic conductivity (i.e., fractures, bedding planes, contacts) oriented southwest to northeast. This finding concurs with previous findings of the presence and orientation of preferential flow paths including the results of the Willowstick® electromagnetic survey, which located three significant preferential flow paths from the area of the former North Waste Cell to Schoolhouse Lane (Section 3.6.6.3), and the presence of fracture zones indicated by the resistivity survey (Section 3.6.6.2).
- Groundwater drawdown in the deep aquifer wells during pumping of CF-209D indicated an area of influence extending up to 3,000 feet northeast and southwest (parallel to the overhead high voltage electric transmission lines) and at least 500 feet east-southeast and west-northwest. This is consistent with the results of the 2011 long-term pumping test of recovery well RW-T conducted between September 2010 and March 2011 on behalf of NJDEP. The 2010 to 2011 pumping test resulted in a drawdown of up to 10 feet at distances of 630 feet to the northeast, and 750 feet to the southwest of RW-T. Perpendicular to this orientation, 10 feet of drawdown extended only 200 feet to both the northwest and southeast of RW-T (Section 3.6.2.3).
- The 1,4-dioxane concentration dropped from 350 µg/L (GWQS 0.4 µg/L) on January

2017 before the start of the aquifer pump test (sample collected from the 150 to 160 feet bgs interval, former FLUTe™ well Port 1) to 29 µg/L on March 24, 2017, 25 days after the long-term pump test ended. This was after the extraction of 2.46 million gallons of groundwater during the pump test. The March 24, 2017 groundwater sample came from the 150 to 160 feet bgs interval at the modified conventional well, CF-209D-R.

3.7 Ecology

CFS is located in the Skylands region "which combines two of New Jersey's physiographic regions, the Ridge and Valley and the Highlands. It encompasses all or parts of Sussex, Warren, Hunterdon, Somerset, Passaic, Essex, Bergen, and Morris counties. The region contains extensive tracts of contiguous upland and wetland forests that support diverse animal populations including red-shouldered hawk, northern goshawk, cerulean warbler, timber rattlesnake, long-tailed salamander, arogos skipper and the state's only known wintering populations of Indiana bat. Bog turtles and great blue herons inhabit the extensive freshwater wetland systems found throughout the region."[41]

The NJDEP's Natural Heritage Program (NHP) Landscape Project Skylands Habitat Maps (Figure 2 in Appendix P) define existing habitats. These habitats include, but are not limited to, cropland and pastureland (20.2 acres); deciduous brush/shrubland (28.2 acres); deciduous forest (84.9 acres); mixed deciduous/coniferous brush/shrubland (4.7 acres); mixed forest (11.5 acres); old field (2.4 acres); plantation (36.1 acres); and deciduous wooded wetlands (65.4 acres).

Two federal-listed species may occur within the study area – the Indiana bat (endangered) and the northern long-eared bat (threatened, proposed for endangered listing). There are 17 state-listed species – 16 birds and one reptile – confirmed within the study area.

Direct connections of freshwater wetlands to the watercourses means that there are no isolated waters with the possible exception of one small wetland north of the landfill.

Wetlands were classified based on existing information and field assessment results according to the standard US Fish and Wildlife Service (FWS) cover type classification (Cowardin et al 1985), and consist of two major types: palustrine forested (PFO) and palustrine emergent (PEM). By far the dominant wetlands are PFO1B (palustrine forested/broadleaved deciduous/non-tidal, saturated). The presence of woody vegetation taller than 20 feet (6 meters) characterizes these wetlands.

The vast majority of wetlands in northern New Jersey are deciduous forested wetlands with many dominated by red maples. Study area wetlands are also dominated by red maples and for the most part are classified as PFO wetlands with the exception of Wetland WJ which would be classified as PEM1C (palustrine, emergent, persistent, seasonally flooded). Persistent and non-persistent grass-like plants dominate Wetland WJ (Figure 4 in Appendix P).

Within the larger classification of these wetlands, other smaller wetland types are present in patches. These include palustrine open water (POW/open water) and shrub scrub, broad-leaved deciduous, semi-permanently flooded wetlands (PSSIF). Streams are classified as riverine; sub system upper perennial, stream bed, sand (R3SB4) and the ponds as lacustrine, limnetic (deep water), unconsolidated bottom, organic (L1UB4).

Appendices P and Q include the wildlife and wetlands reports, respectively.

[41] NJ Landscape Project Version 3.1 (NJDEP 2012).

4 Nature and Extent of Contamination

This section discusses the type and distribution of contamination in the different media investigated during the RI. Section 4.1 contains the comparison criteria for the evaluation of contamination, and Section 4.2 contains the results of the investigation and their evaluation.

4.1 Applicable and Relevant and Appropriate Requirements (ARARs) and To Be Considered Criteria

Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires federal and state ARARs be met. Subpart E, Section 300.400(g) "Identification of applicable or relevant and appropriate requirements," of the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) describes the process to attain ARARs. EPA last promulgated revisions to the NCP on September 15, 1994.

There are differences between the identification and analysis of applicable vs. relevant and appropriate requirements. Applicability is a legal and jurisdictional determination, while the basis for determination of relevant and appropriate is professional judgment, considering the environmental and technical factors specific to a site.

To be applicable, a requirement must directly address the circumstances at the site. Applicable requirements are defined as “those cleanup or control standards, or other substantive environmental protection requirements, criteria, or limitations promulgated under Federal environmental or State environmental or facility siting law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site" (55 FR 8814). In order for the requirement to be applicable, it must meet jurisdictional prerequisites.

These jurisdictional prerequisites include:

- The party being subject to the law
- The substances or activities must be under the authority of the law
- The law must be in effect at the time activities occur
- The law requires, limits or protects the types of activity in question

A requirement that is relevant and appropriate may not meet one or more jurisdictional prerequisites for applicability but still makes sense at the site, given the specific circumstances. Evaluating the relevance and appropriateness of a requirement requires careful consideration of the eight comparison factors in CFR Title 40, 300.400(g) (2).

There is greater flexibility in determining relevant and appropriate requirements; i.e., it may be "relevant," in that it covers situations similar to those at the site, but may not be "appropriate" and, therefore, may not be well suited to conditions at the site. Portions of a requirement or regulation may be relevant and appropriate; however, meeting each substantive requirement is necessary for a requirement to be applicable.

In order to be relevant and appropriate, consideration of a requirement is in terms of whether the circumstances at the site are sufficiently similar to those regulated by the requirement.

“Relevant and appropriate” cleanup standards, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law, are those that while not

considered applicable, address problems or situations similar to those at the CERCLA site, and whose use is suited to the site. Judgment of the relevance and appropriateness is by comparing characteristics of the remedial action, physical circumstances of the site and other factors with those included in the requirement itself.

This is a two-step process, requiring a determination first of relevance, where the requirement pertains to the type of remedial action being taken, location of the action, or chemicals and related conditions at the site. Second, a determination of whether it is appropriate focuses on the nature of the items, in question, characteristics of the site, circumstances of the release, and proposed remedial action. The requirement is appropriate if suited to the particular site. The action must comply with requirements that are determined to be both relevant and appropriate. Once a requirement is determined to be relevant and appropriate, compliance is the same as if it were applicable.

EPA has classified both types - applicable or relevant and appropriate – of ARARs into three categories, depending on whether triggering of the requirement is by the presence of a specific chemical, characteristics of a specific location, or a particular response action.

1. Chemical-specific ARARs are risk-based, numeric cleanup standards, e.g., MCLs established under the Safe Drinking Water Act, and federal water quality criteria (FWQC) established under the Clean Water Act.
2. Location-specific ARARs are restrictions on the concentration of hazardous substances or on activities in environmentally sensitive areas, e.g., restrictions within floodplains, wetlands.
3. Action-specific ARARs are technology- or activity-driven requirements, resulting largely from provisions of RCRA and the Clean Water Act.

ARARs are promulgated, legally enforceable federal and state requirements. In contrast, "TBC" values include non-promulgated, non-enforceable criteria, advisories, guidance and proposed standards generated by the federal or a state government. TBCs may assist in interpreting ARARs or determine preliminary remediation goals when ARARs do not exist. Once identification of a TBC occurs and becomes part of a Superfund ROD, it is enforceable within the context of the remedial action that is the subject of the ROD.

The project team used screening criteria consisting of ARARs (promulgated standards) and TBCs (screening criteria) as benchmarks to evaluate the nature and extent of contamination at CFS.

4.1.1 Groundwater

The ARARs used for groundwater results comparison for purposes of delineation are the NJDEP GWQS) and (NJDEP 2018c, NJDEP 2015a-d); and for tritium, the 40 CFR §141.16 MCL, based on average annual concentrations assumed to produce a total body dose of 4 millirem per year. Also used for groundwater results comparison are the NJDEP IGGWQC (NJDEP 2018c), which are considered TBCs.

4.1.2 Soil

The ARARs used for soil results comparison for purposes of delineation are the N.J.A.C. 7:26D Remediation Standards (NJDEP 2017a). N.J.A.C. 7:26D contains soil remediation standards for both residential and non-residential direct contact, referred to as RDCSRS and NRDCSRS, respectively. For samples collected from the saturated zone, for comparison this RI uses the more conservative standard of the RDCSRS and NRDCSRS.

For soil samples collected from the vadose or unsaturated zone, consideration is given to three values: the RDCSRS and NRDCSRS which are the promulgated soil standards, and the default Impact to Groundwater Soil Screening Levels (IGWSSLs) which are TBCs. The IGWSSLs are contaminant concentrations in the unsaturated zone that, if exceeded, are likely to result in groundwater impacts.

Except for a few chemicals, the default IGWSSLs are more conservative than the RDCSRS or NRDCSRS. In NJ, investigators must develop site-specific IGWSSLs for contaminants in vadose zone soils or adopt the default values for a site.[42] For samples collected in the unsaturated zone, this RI uses the most conservative of the RDCSRS, NRDCSRS and default IGWSSLs for comparison criteria.

4.1.3 Sediment

There are no promulgated standards for sediment results comparison. The TBCs used for comparison for purposes of delineation in this RI are the NJDEP freshwater sediment quality criteria known as the lowest effect levels (LELs). LELs are concentrations at which adverse impacts to benthic organisms may begin to occur (level tolerated by most benthic organisms). The criteria are presented in NJDEP's Site Remediation Program (SRP) Ecological Screening Criteria (ESC) table, last updated March 10, 2009 (NJDEP 2009a). The table consists of a list of screening criteria from various sources. When there is more than one criterion for a contaminant in the table, this RI uses the most conservative value.

4.1.4 Surface Water

The ARARs used for surface water results comparison for purposes of delineation are the NJDEP fresh water aquatic chronic criteria in N.J.A.C. 7:9B SWQS, last amended April 4, 2011 (NJDEP 2011c). For compounds without aquatic chronic criteria in N.J.A.C. 7:9B SWQS, this RI uses the aquatic chronic criteria values from NJDEP's ESC table (NJDEP 2009) which are TBCs. In addition, this RI uses the Region 5 ESL (EPA 2003) as the 1,4-dioxane comparison criterion as there is no SWQS or ESC.

The NJDEP fresh water aquatic chronic criteria apply to either dissolved or total concentrations. Six metals (cadmium, chromium III, copper, nickel, silver and zinc) have hardness-dependent aquatic criteria calculated for this RI using metal-specific formulas provided in N.J.A.C. 7:9B and site-specific $CaCO_3$ (hardness) values. Comparison of the calculation results is to either a total concentration criterion, dissolved concentration criterion, or hardness-dependent criterion, depending on the instructions provided with the substance list in N.J.A.C. 7:9B.

4.2 Remedial Investigation Results

This section presents the analytical results for groundwater, soil, sediment and surface water samples collected from 2011 through 2017. The landfill's location on a local topographic high precluded the collection of background groundwater samples. Collection of surface water and sediment background samples occurred at stream locations to the north and west of CFS, presumed unaffected by groundwater from the landfill (Sections 2.2 and 4.2.2.1).

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[42] When calculating site-specific IGWSSLs, variables (fraction organic carbon and dilution attenuation factor) are adjusted based on site-specific data. However, adjustments would result in IGWSSLs higher than the most conservative default levels.

4.2.1 Groundwater

HDR collected groundwater samples for both delineation and decision-making (screening) during the RI. Results for RI samples from monitoring wells installed during the RI and from monitoring wells previously installed by others facilitated delineation of the extent of contamination in the overburden and bedrock aquifers (Table U-1 in Appendix U). Results from the NJDEP PCEM sampling conducted during the period of the RI (Section 1.6; data summary tables in Appendix A) also contributed to delineation efforts.

The purpose of analyzing packer testing samples was to determine well completion depths as detailed in Sections 2.1.4.3 and 2.1.6.1. The packer testing results were also supplemental information for the delineation of the horizontal and vertical extent of contamination, in instances where packer testing results exceeded standards, but monitoring well sampling results did not. In those cases, use of the packer testing results was for delineation of the horizontal and/or vertical extent of contamination. Table U-2 in Appendix U contains the packer testing analytical results.

Because of the differences in sampling protocols and intervals sampled, the packer testing data and monitoring well data would not meet typical data quality objectives for comparability, but are still useful for screening purposes. For example, 49 of the 54 packer intervals were between 10 and 30 feet long, four were shorter than 10 feet, and one was 95 feet long, while 35 of 45 multi-level FLUTe™ ports spanned jntervals shorter than 10 feet (Tables 2-11 and 2-12). Keeping these limitations in mind, a cursory comparison of packer testing and monitoring well analytical results indicated that:

- For identical or similar depth intervals, the 1,4-dioxane results for approximately half the wells packer tested were close to those for the monitoring well samples, while for the other half, the two date sets exhibited poor agreement, with monitoring well results higher by up to an order of magnitude;
- The concentrations of 1,4-dioxane in the packer testing samples ranged from 0.58 to 240 µg/L (i.e., all detections exceeded the GWQS of 0.4 µg/L; the reporting limit was 0.5 µg/L). 1,4-dioxane was detected in 33 of 54 packer tested intervals and in 12 of the 19 sampled boreholes; the concentrations for the well samples ranged from 0.44 to 350 µg/L;
- The highest concentrations of 1,4-dioxane in both the packer testing and monitoring well sampling were for well CF-209D; with packer testing results for the borehole (50 to 240 µg/L) in the same range as those for the completed multi-port monitoring well (34 to 350 µg/L);
- For benzene, concentrations in the packer testing samples ranged from 0.39 to 110 µg/L, with exceedances of the GWQS of 1 µg/L in 19 samples; the concentrations for the well samples ranged from 0.1 to 90 µg/L;
- The benzene results for four wells situated to the northeast of the landfill exhibited considerable differences between the packer testing and well sampling results. For three of these wells (CF-204D, CF-206D, and CF-227D), the packer testing results were noticeably higher, while for the fourth well, the reverse was the case.

Use of the packer testing results for delineation did not extend the footprint of the 1,4-dioxane plume (Figure 8-1). For well CF-204D near Schoolhouse Lane, the packer testing results for the deepest interval (13 µg/L for 432-442’ bgs) were considerably higher than those from the deepest sampling interval of the completed well (0.85 µg/L, 433-438’ bgs). The horizontal extent of the benzene plume Figure 8-2) expanded because of the packer testing results as samples from wells to the west (CF-216D) and northeast (CF-227D) of the landfill exceeded the standard in the packer samples, but not

in the samples from the completed wells. For TCE (Figure 8-3), the packer testing results extended the plume to the northwest to include well CF-212D (1.2 µg/L in two packer intervals). DEHP exceeded the standard in samples from five packer tests but not in samples from the same completed wells (CF-201D, CF-204D, CF-209D, CF-218D, and CF-226D), as well as from borehole CF-215D (not completed as a monitoring well), extending the DEHP plume to include these wells/boreholes (Figure 8-4). Alpha-BHC (Figure 8-5) did not exceed the standard in any packer testing samples. For lead (Figure 8-6), the exceedances for samples from packer-tested borehole CF-215D extended the plume to the northeast of the landfill, and for arsenic, the plume was extended to the south to include well CF-223D and to the northeast to include well CF-201D based on the packer testing results (Figure 8-7). None of the chromium results in packer testing samples exceeded the standard. Exceedances for phenobarbital in packer testing samples occurred only at wells that also exceeded the compound's criterion in the completed well samples. TAME did not exceed the comparison criterion in the packer testing samples.

Besides the differences in sampling protocols and intervals sampled discussed above, collection of packer testing samples and monitoring well samples from the same locations occurred during different time periods. The only certainty in use of the two data sets is the detection of a contaminant is evidence for its presence at a location, but a non-detection is not evidence of its absence at a location.

Similar to the lesser data quality of the packer testing sample results, samples from 12 wells (CF09D, CF-12D, CF-15D, CF-20S, D-1, D-3, D-5R, D9, MW-6, MW-18D, MW-19D, and S-6) previously installed by others and not constructed in accordance with NJDEP well construction requirements, lead to a cautious reliance on the resulting analytical data (Section 2.1.6.3). Use of the analytical results for samples from these wells was also as supplemental information for delineation purposes. Where results for the non-compliant wells indicated exceedances of COC standards and compliant well sampling results did not, use of the results from the non-compliant wells was limited to delineation of the horizontal and vertical extent of contamination and not acceptable for risk assessment. Based on the non-compliant wells analytical results, extension of the benzene, TCE and lead plumes (Figures 8-2, 8-3, and 8-6) includes the area represented by bedrock well MW-18D; the lead plume expansion also includes well CF-09D (Figure 8-6). Concentrations in samples from four wells (D-5R, MW-6, MW-18D and MW-19D) exceeded the comparison value for the TIC phenobarbital in the non-compliant samples and provided delineation of phenobarbital. Concentrations of the TIC TAME did not exceed the comparison criterion in these samples.

Consideration of analytical results for the non-compliant well samples also helped in determining the necessity of additional compliant wells to complete the delineation. Table U-3 in Appendix U presents the analytical results for the non-compliant well samples.

Analysis of groundwater samples consisted of TCL VOCs, SVOCs, pesticides and PCBs; TAL metals (unfiltered), cyanide, TDS, TSS, chloride, TOC and tritium. Tritium analysis ceased after Phase I packer testing because most results were non-detect and there was no apparent correlation between groundwater originating at the landfill and tritium detections (Table V-1, Appendix V).

4.2.1.1 Bedrock Monitoring Wells (RI and Pre-RI Compliant Wells)

Table U-1 in Appendix U provides a summary of the analytical data for the bedrock monitoring wells.

During Phases I through III of the field investigation, field geologists collected two groundwater samples from each of the 45 sampling ports (also referred to as sampling intervals) of the 13 multi-port wells which are CF-201D, CF-204D, CF-206D, CF-207D, CF-209D, CF-211D, CF-212D, CF-

216D, CF-218D, CF-222D, CF-225D, CF-227D, and CF-228D. The same sampling protocol took place at the six conventional (single-depth) bedrock monitoring wells being CF-205D, CF-223D, CF-224D, CF-226D, CF-229D, and CF-230D installed over the course of the RI.

Sample collection was also from six bedrock monitoring wells installed by others prior to the RI, wells CF-10D, CF-11D, CF-22S, WRA2-1, WRA3-2, and WRA3-3. A review of the well construction information for these wells (Table 2-13C) confirmed that they had been constructed in accordance with NJDEP requirements (N.J.A.C. 7:9D). Observations of damage to the pads and curb boxes of wells CF-10D, CF-11D, and CF-22S, located in Schoolhouse Lane, were made during the well condition assessment. The curb box at well CF-10D was filled with water and sediment and the well's integrity was questionable (Appendix F).

During Phase IV in early 2017, modifications made to multi-port well CF-209D were in order to use it as a test well during the aquifer test (Section 2.1.5.2). Prior to the modification, HDR sampled all four ports of the multi-port FLUTe™ well in January 2017 to obtain updated information on groundwater quality near the former North Waste Cell (Section 2.1.6.2). After sampling, the driller removed the Water FLUTe™ sampling system from the borehole; the borehole was partially back-grouted, and used for the aquifer test (Section 2.1.7). Following aquifer testing, additional modification to the borehole consisted of completion as a new single-screened well - CF-209D-R. Development and sampling of the modified well took place in March 2017. In total, field geologists collected six groundwater samples during Phase IV (five from FLUTe™ well CF-209D and one from modified conventional well CF-209D-R).

Presentation of analytical results for bedrock monitoring wells is by parameter group below. Figures 4-1A, -B, and -C depict the results for organic compounds with concentrations above comparison criteria by well location and sampling depth, and Figures 4-2A and 4-2B depict results for inorganic compounds with concentrations above comparison criteria.

VOCs

Five VOCs - 1,4-dioxane, benzene, TCE, PCE, and 1,2-DCA - exceeded their GWQS in the samples from the RI and pre-RI compliant monitoring wells (Figures 4-1A through –C):

Compound	No. of Detections	Range of Detections [µg/L]	No. of Exceedances	GWQS [µg/L]
1,4-dioxane	101	0.44 J – 290	101	0.4
Benzene	38	0.075 J – 90 J	26	1
TCE	60	0.11 J - 4 J	9	1
PCE	20	0.12 J - 2 J	2	1
1,2-DCA	40	0.18 J - 3.2	1	2

1,4-dioxane, benzene and TCE are COCs as these constituents were detected at concentrations exceeding comparison criteria at a frequency greater than or equal to five percent of the total number of samples. 1,4-dioxane was detected in all but 16 samples. The detection limit for 1,4-dioxane of 0.5 µg/L[43] was above the current GWQS of 0.4 µg/L, thus all detections exceeded the criterion. Note that the TBC criterion of 0.4 µg/L for 1,4-dioxane, currently the GWQS, went into effect on November 25, 2015 subsequent to collection and analysis of the RI Phase I through III groundwater samples. Adoption of the 0.4 µg/L 1,4-dioxane criterion as the GWQS by NJDEP on January 16, 2018 means that the TBC criterion became an ARAR effective that day. At the time of

[43] The detection limit was 0.5 µg/L for the samples collected during RI Phases I through III; for the six samples collected during Phase IV, it was 0.1 µg/L.

collection of the Phase I through III groundwater samples, the TBC criterion for 1,4-dioxane was 10 µg/L. [44] Detections of 29 other VOCs were at concentrations below their GWQS or did not have a GWQS for comparison (Table U-1, Appendix U).

Rejection of analytical results for a significant percentage of the groundwater samples occurred at rates greater than eight to almost 40 percent for individual compounds. The DER (Appendix B) provides further discussion of the rejected results. During Phases I through III, the reported detection limits for two compounds, 1,2-dibromo-3-chloropropane and 1,2-dibromoethane, of 5 µg/L, exceeded the GWQS (0.02 and 0.03 µg/L, respectively). During Phase IV, the reported detection limits for the same two compounds exceeded the GWQS in one of six samples (CF-209D-R, 3/24/2017).

SVOCs

DEHP was the only SVOC in groundwater that exceeded the GWQS in the samples collected during Phase I through III of the RI (Figures 4-1A and 4-1B). DEHP is a COC because it was detected at concentrations exceeding the comparison criterion at a frequency greater than or equal to five percent of the total number of samples. Detected concentrations ranged from 2 J to 15 µg/L in 17 samples. Of these, 10 samples exceeded the GWQS of 3 µg/L. Detections of seven other SVOCs were at concentrations below their GWQS in the Phases I through III samples, or did not have a GWQS (Table U-1, Appendix U). During Phase IV, there were detections of 12 SVOCs. Detections of all 12 compounds occurred in only one of the six samples collected during this phase (CF-209D, 227 to 237' bgs). Ten of the 12 detected compounds were PAHs, and four of the 12 compounds reached or exceeded their GWQS:

Compound	Concentration [µg/L]	GWQS [µg/L]
Benzo(a) anthracene	0.17	0.1
Benzo(a) pyrene	0.15	0.1
Hexachlorobenzene	0.15	0.02
Ideno (1,2,3-c,d) pyrene	0.2	0.2

The four SVOCS that exceeded the GWQS only in samples collected during Phase IV are not COCs because the exceedance rates were below five percent of the total number of samples collected during the RI.

During Phases I through III, the reported detection limits for 11 SVOCs (4,6-dinitro-2-methylphenol, atrazine, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, hexachlorobenzene, hexachlorobutadiene, indeno(1,2,3-cd) pyrene, and pentachlorophenol) exceeded the GWQS in the samples. The detection limits for these compounds ranged from 5 to 10 µg/L, while the GWQS ranged from 0.02 to 3 µg/L. Rejection of results for pentachlorophenol occurred in 12 samples. During Phase IV, the reported detection limit for one SVOC (4,6-dinitro-2-methylphenol, 10 µg/L) exceeded the GWQS (1 µg/L) in all six samples, and the reported detection limits for five other SVOCs (atrazine, bis(2-chloroethyl)ether, DEHP, hexachlorobenzene, and hexachlorobutadiene) exceeded the GWQS in one sample (CF-209D-R, 3/24/2017) (Table U-1, Appendix U). The detection limits for several SVOCs, including some of the

[44] The previous 1,4-dioxane ISGWQS of 10 µg/L was exceeded in 46 of 101 samples.

detected PAHs, were one to two orders of magnitude lower during Phase IV than during Phases I through III.

Pesticides

Concentrations of one pesticide, alpha-BHC, exceeded the GWQS (0.02 µg/L) in eight samples, and were below the GWQS in another 14 samples (Figures 4-1A and 4-1B). Alpha-BHC is a COC as detected concentrations exceeding the comparison criterion occurred at a frequency greater than or equal to five percent of the total number of samples. The concentrations of alpha-BHC above the GWQS ranged from 0.022 J to 0.073 µg/L. Detections of 11 other pesticides were at concentrations below the GWQS or did not have a GQWS for comparison (Table U-1, Appendix U). During Phases I through III, the reported detection limits for all analyzed pesticides were below the corresponding GWQS and only a small number of analytical results (between one and seven results for five of the compounds) were rejected during data validation. During Phase IV, the reported detection limits for six pesticides (aldrin, alpha-BHC, beta-BHC, gamma-BHC, p,p'-DD, and p.p'-DDT) exceeded the GWQS in one sample (CF-209D-R, 3/24/17).

PCBs

Concentrations of detected PCBs did not exceed GWQS. Aroclor 1260 was the only detected PCB compound, with concentrations of 0.12 J and 0.2 µg/L in two samples (GWQS of 0.5 µg/L) (Table U-1, Appendix U).

Metals and Cyanide

The following 10 metals exceeded the corresponding GWQS in at least one bedrock groundwater sample collected during HDR's RI:

Metal	No. of Detections	Range of Detections [µg/L]	No. of Exceedances	GWQS, [µg/L]
Manganese	115	0.76 J - 4,960	72	50
Iron	99	31.6 J - 44,700	63	300
Lead	51	1 – 175	11	5
Sodium	117	3,100 - 489,000	9	50,000
Arsenic	16	0.46 J - 6.4 J	8	3
Chromium (total)	35	0.53 J - 262 J	7	70
Aluminum	16	20.7 - 18,400	7	200
Beryllium	8	0.23 J - 2.5 J	2	1
Nickel	64	0.44 J – 149	2	100
Cadmium	3	0.33 J - 20.3	1	4

Lead, arsenic, and chromium are COCs because detections of these constituents occurred at concentrations exceeding comparison criteria at a frequency greater than or equal to five percent of the total number of samples. Manganese, iron, sodium and aluminum are not COCs for purposes of this RI as these metals are naturally occurring, all but aluminum are nutrients, and all are secondary contaminants in that the basis for the comparison criteria is primarily aesthetic considerations (i.e., taste, odor and appearance). Figures 4-2A and 4-2B present the sample results for inorganic compounds at concentrations above criteria.

Note that the highest concentrations for five of the 10 metals exceeding their GWQS were for samples from different depth intervals in one well (CF-207D, December 2014). Further, the highest concentrations of four of the five metals (aluminum, arsenic, beryllium and lead) were in the sample with the highest visually described turbidity and the highest TSS concentration of all samples collected during the RI, indicating entrained sediment. Overall, the visually turbid samples at this well accounted for 19 of the 27 GWQS exceedances for metals from the upper three depth intervals collected in December 2014. The observed turbidity decrease with depth in these samples corresponds to a general decrease in metals concentrations. As shown on Figure 4-2B, the concentrations of lead and the other metals decreased slightly with depth from the first to the second depth interval, and by an order of magnitude from the second to the third depth interval.

The remaining five metals with concentrations exceeding the GWQS were in samples from five separate wells - CF-10D, CF-206D, CF-222D, CF-226D, and WRA3-3 (Figures 4-2A and 4-2B).

Detections of 10 other metals and cyanide were at concentrations below the GWQS or did not have a GQWS for comparison (Table U-1, Appendix U).

The observations for the metals concentrations at well CF-207D suggested that because groundwater samples were not filtered, entrained sediment may have contributed to the total metals results in some of these samples. While a correlation between turbidity readings and concentrations of arsenic, lead, and chromium was not evident in scatter plot diagrams of results versus turbidity in this small dataset, the sample from 106 to 111 feet bgs at CF-207D had the highest TSS concentration of all bedrock groundwater samples analyzed during the RI (630 mg/L). In contrast, the sample collected from this interval in June 2014 had low TSS (<10 mg/L) and only iron and manganese exceeded the GWQS. Elevated concentrations of several metals in the samples with observed turbidity or higher turbidity readings included several of the overall highest metals results:

Metal	Concentration [µg/L]	Well	Sampling Date	Interval	Turbidity[45] [NTU]
Aluminum	18,400, 17,400, 2,380	CF-207D	12/2014	Three ports, 106 to 417 feet bgs	Visually turbid
Aluminum	1,920	CF-10D	11/2014	145 to 170 feet bgs	29.5
Beryllium	2.5 J , 2.1 J	CF-207D	12/2014	106 to 111 feet bgs; 182 to 192 feet bgs	Visually turbid
Chromium	94.2, 71.2	CF-207D	12/2014	106 to 111 feet bgs; 182 to 192 feet bgs	Visually turbid
Iron	44,700	WRA3-3	10/2012	80 to 103 feet bgs	109

[454545] Because it is not possible to conduct turbidity measurements using flow-through cells when sampling FLUTe™ multi-port wells, the lack of turbidity measurements for these samples necessitates a reliance on visual observations alone. For well CF-207D, descriptions of the samples collected in December 2014 from the three ports in the sampling log (from shallow to deep) are turbid, turbid, clearer, and clear (Appendix M). In personal communication, the sampler subsequently used the terms ‘coffee-colored and ‘tea-colored’ for the three upper intervals.

Metal	Concentration [µg/L]	Well	Sampling Date	Interval	Turbidity[45] [NTU]
Lead	13.9 – 175	CF-207D	12/2014	Three ports, 106 to 417 feet bgs	Visually turbid
Lead	63.8, 1.8 J, 20	CF-204D	8/2013, 9/2014	155 to 160 feet; 433 to 438 feet bgs	No observation
Nickel	149	CF-207D	12/2014	412 to 417 feet bgs	Visually turbid
Sodium	489,000	CF-10D	11/2014	145 to 170 feet bgs	29.5

The detection limits for the inorganic analytes were below the GWQS, except for antimony and thallium (which was not detected, but had reporting limits above the GWQS for several dozen samples), arsenic, beryllium, cadmium, and lead. Rejection of analytical results during data validation occurred for copper (two samples), cyanide (one sample), nickel (four samples), and zinc (23 samples) (Table U-1, Appendix U).

Other Analytes

Detection of chloride was in all 116 groundwater samples analyzed at concentrations ranging from 1,3 to a maximum of 880 mg/L in well CF-10D, the only sample that exceeded the GWQS of 250 mg/L. HDR attributes this exceedance to road salt entering the well as described previously. In November 2014, the well had a chloride concentration of 880 mg/L (versus 52 mg/L in 2012) and an unusually high pH of 11.42 (8.04 standard units in October 2012). Likewise, the sodium concentration in the November 2014 sample was an order of magnitude higher than the October 2012 sample (Figures 4-2A and 4-2B). The value for TDS (1,600 mg/L) was the highest of any bedrock groundwater sample collected during the RI, and the only one above the TDS GWQS of 500 mg/L, suggesting intrusion of storm water runoff into the well. TDS concentrations ranged from 41 mg/L to 1,600 mg/L, with nine samples reached or exceeding the GWQS of 500 µg/L (Table U-1, Appendix U).

4.2.1.2 Tentatively Identified Compounds in Groundwater

TICs are compounds of interest in this RI because of the documented disposal of PPCPs and related production wastes at CFS. Consistent detections of TICs that were ingredients of PPCPs, or related to the manufacture and degradation of PPCPs at CFS, including phenobarbital and tetrahydrofuran, occurred during previous NJDEP sampling events over many years. Pharmaceutical products excavated from the North Waste Cell listed phenobarbital as an ingredient on the labels (Section 1.6).

Approximately 100 TICs, the majority unnamed, were detected in the RI groundwater samples. . The TICs are summarized along with the TIC results for the samples collected by NJDEP during the period of the RI investigation in data summary tables provided in Appendix BB. The summary data tables include a TIC analyte summary (Table BB-1A), a location (by well) summary for total carcinogenic and total non-carcinogenic SOCs (Table BB-1B) and the results for TICs by sample (Table BB-1C).

Comparison of analytical results for the RI groundwater samples and NJDEP's results under the PCEM program during the RI investigation period indicated the two datasets varied with respect to

the number of reported TICs, with NJDEP's data generally including a larger number of named TICs than the RI data. To avoid underestimation of TICs, consideration of both the NJDEP and RI data together determined if TICs were COCs; delineation of TIC extent used both datasets.

The applicable comparison criteria for TICs in groundwater are the IGGWQCs for SOCs in Class II Ground Water (NJDEP 2018c):

Constituent	IGGWQC
SOCs defined as carcinogens in N.J.A.C. 7:9C-1.4 lacking specific or interim specific criteria	5 µg/L each 25 µg/L total
SOCs defined as non-carcinogens in N.J.A.C. 7:9C-1.4 lacking specific or interim specific criteria	100 µg/L each 500 µg/L total

- The criteria apply to SOCs identified as having "evidence of carcinogenicity" or "lacking evidence of carcinogenicity" based upon available scientific evidence. Chemicals are classified as carcinogens or noncarcinogens for the purposes of risk assessment according to the weight of evidence utilized by USEPA in the National Primary Drinking Water Regulations (50 FR 46880-46901 (1985)). The IGGWQC do not apply to naturally occurring organic chemicals.
- SOCs: Any compounds that contain at least one carbon atom and that result from purposeful chemical synthesis, whether as products, by-products, or waste, or from the purposeful refinement of naturally occurring substances. Where a chemical substance is sometimes found in nature and sometimes synthesized, it shall be considered an SOC only to the extent or in the proportion produced or isolated by human activity. Naturally occurring organic chemicals in their natural location are not considered a pollutant pursuant to the Ground Water Quality Standards.

Two TICs, phenobarbital and TAME, exceeded the IGGWQC for carcinogenic and non-carcinogenic SOCs, respectively, in more than five percent of the samples from the combined datasets (i.e., the RI investigation samples and the NJDEP PCEM samples described in Section 1.6; for a total of 403 samples). The exceedance frequencies were 14.6% for phenobarbital and 7.4% for TAME.

Phenobarbital concentrations ranged between 2.3 JN and 37 JN µg/L, exceeding the IGGWQC of 5 µg/L in 16 RI investigation samples at 10 locations, and in 51 NJDEP PCEM samples at 13 locations from the same time periods (Figure 1-6D). Exceedances occurred within the landfill and to the southwest and northeast (Figure 8-9), including in the area between the landfill and Schoolhouse Lane, and in wells on Schoolhouse Lane itself (wells D-2, CF-204D, CF-27S, and CF-11D). The highest phenobarbital concentrations (>20 µg/L) were for samples from four previously existing monitoring wells within the landfill (PTO-2 – 36 JN µg/L, D-5R – 33 JN µg/L, and MW-16 – 32 JN µg/L) and on its western perimeter (D-7 – 37 JN µg/L) (Figure 1-6D). Of these four wells, one is an overburden well (PTO-2) and the other three are shallow bedrock wells (screened or open boreholes beginning at 45 to 50 feet bgs). Delineation is incomplete for the vertical extent of phenobarbital-contaminated groundwater because it exceeded the IGGWC in several single-depth wells. The deepest detection above the IGGWQC was in a packer-testing sample from the CF-205D borehole (432-442 feet bgs, 12 NJ µg/L).

Concentrations of the TIC TAME ranged between 2.1 JN and 480 JNB 37 JN µg/L and exceeded the IGGWQC of 100 µg/L in 30 of the NJDEP PCEM samples from 22 locations; however, it was not a named TIC in the RI samples (Figure 8-10). Exceedances occurred in all directions from the landfill, including in the area between the landfill and Schoolhouse Lane and on Schoolhouse Lane itself (wells D-2, CF-27S, and CF-11D). The highest TAME concentration was in a sample from bedrock well CF-11D on Schoolhouse Lane, northeast of the landfill (480 JNB µg/L), Samples from eight

additional wells, both overburden and bedrock, in and around the landfill exceeded the IGGWQC (100 µg/L) by at least a factor of three (Figure 8-10). Delineation is incomplete for the vertical extent of groundwater contaminated with TAME because it exceeded the IGGWQC in several single-depth wells. The deepest detections above the IGGWC were for well CF-15D to the northwest of the landfill (165 to 190 feet bgs, 140 µg/L) and WRA3-1 (229 to 254 feet bgs, 160 µg/L) to the south (south of Parker Road).

TICs other than COCs – Carcinogenic SOCs

In addition to phenobarbital, two other TICs exceeded the IGGWQC for individual carcinogenic SOCs of 5 µg/L (Table BB-1A), but at a frequency of less than five percent. The first compound, n,n-dimethyl formamide, had concentration exceedances in eight samples from four wells (CF-15D, CF-209D, CF-28S, and MW-1). The highest concentrations (21 to 56 µg/L) were at overburden well CF-28S and bedrock well CF-15D. Bis-chloromethylether exceeded the IGGWQC for individual carcinogenic SOCs of 5 µg/L in two samples (9.4 NJ to 10 µg/L) from two wells (CF-204D on the west end of Schoolhouse Lane and CF-216D at the horse farm to the northwest of the landfill, respectively) (Table BB-1C). NJDEP PECM samples collected during the RI investigation time period did not have bis-chloromethylether.

Eight samples from six wells exceeded the IGGWQC for the sum of carcinogenic SOCs (25 µg/L) during the RI investigation period. The range of the exceeding sums was 26 to 56 µg/L (Table BB-1B). In seven of the eight samples, phenobarbital was the only compound contributing to the sum of carcinogenic SOCs, while in the remaining sample, n,n-dimethyl formamide was the only contributing compound. Of the six wells with sample exceedances, one overburden well (PTO-2) is within the landfill, one bedrock well (D-5R) is next to the North Waste Cell, and four wells (overburden well CF-28S and bedrock wells D-7, CF-15D and MW-16) are on different sections of the landfill's perimeter (Figure 4-2C). Three of the wells are less than 75 feet deep, two reach to about 125 feet bgs, and one is a deeper bedrock well (CF-15D, 165-190 feet bgs). Cross-section Figures 3-4 and 3-5 show the total carcinogenic and total non-carcinogenic results for three of the wells against depth.

TICs other than COCs – Non-Carcinogenic SOCs

In addition to TAME, 17 non-carcinogenic TICs had concentrations greater than the 100 µg/L IGGWQC for non-carcinogenic SOCs but at a frequency of less than five percent. Sulfur, with two separate listings, was one of the compounds detected as a TIC, but it is not a SOC. Therefore, the IGGWQC does not apply. Another TIC, oleic acid, is a naturally occurring compound found in various animal and vegetable fats and oils. It does not meet the definition of a SOC.[46] Of the remaining 14 compounds (Table BB-1A), 13 exceeded the 100 µg/L criterion in only one sample each, and the remaining compounds (bis(7-methyloctyl) phthalic acid ester, to 520 µg/L and n-butyl benzenesulfonamide, to 420 µg/L) exceeded the criterion in five and nine samples, respectively (Table BB-1c). Concentrations of individual compounds with concentrations above the 100 µg/L IGGWQC ranged from 110 to 800 µg/L.

[46] Oleic acid is used as an expedient in pharmaceuticals (i.e., a bulking agent, filler or diluent, or to support the therapeutic properties of the active ingredient) and as an ingredient in moisturizers. Its sodium salt is a major component of soap (Wikipedia 2018c). Its presence in landfill leachate and groundwater at CFS is consistent with the disposal of personal care and pharmaceutical products and wastes at CFS.

Three samples from wells D-2, PZ-21R, and D-5R during the RI investigation period exceeded the IGGWQC for the sum of non-carcinogenic SOCs (500 µg/L). The range of exceeding sums was 556 to 2,471.3 µg/L (Table BB-1B). Two of the wells are in the area of the former North Waste Cell excavation (overburden well PZ-21R, 45-95 feet bgs, 2,471.3 µg/L; bedrock well D-5R, 50-125 feet bgs, 685 µg/L). The third bedrock monitoring well D-2 (80-124.5 feet bgs, 556 µg/L) is between the landfill's northern perimeter and Schoolhouse Lane, in the area characterized by preferential flow from the landfill to the northeast (Figure 4-2C). Cross-section Figures 3-4 and 3-7 show the total carcinogenic and total non-carcinogenic results for three of the wells against depth.

TICs associated with PPCPs are site-related constituents because the landfill accepted waste from PPCP manufacturers. During the excavation of the North Waste Cell in 2006, NJDEP observed and documented large numbers of containers with PPCPs (see Section 1.6), including several items with labeling information identifying phenobarbital as an active ingredient. Subsequent detections of several PPCP-related compounds were in wells installed at the former North Waste Cell area (TestAmerica 2009), including tetrahydrofuran at concentrations up to 30,000 µg/L. However, information provided by NJDEP (Robbins 2016) indicated that some of the compounds detected in replacement monitoring wells D-5R and PZ-21R at the North Waste Cell excavation area and at recovery well RW-U in January 2009, including the high concentration of tetrahydrofuran and possibly other TICs, were one-time detections not repeated after the initial sampling event. NJDEP stated that representatives sampled the replacement wells shortly after construction using PVC cement (constructed of the wells occurred in late November and early December 2008). A review of the composition of several currently available PVC cement and primer formulations by HDR indicated that the products contain tetrahydrofuran, methyl-ethyl ketone, acetone, cyclohexanone, ethyl acetate, and PVC resins as main ingredients.

During the RI, tetrahydrofuran detection was at a very low frequency and all concentrations were below 10 µg/L. A review of the NJDEP PCEM analytical results for the period from the second quarter of 2011 through the fourth quarter of 2015 indicated that the detection of the compound only in a single sample collected in May 2012 from bedrock monitoring well MW-19D, at a concentration of 30 JDN µg/L.

Based on the information provided by NJDEP and the presence of tetrahydrofuran concentrations three orders of magnitude below the January 2009 result, NJDEP's conclusion that the high concentrations of several TICs (mostly tetrahydrofuran and ethyl ether) at the wells in January 2009 relate to the use of PVC cement shortly before sampling is plausible. It is not possible to exclude a minor contribution from the landfill itself or the waste in the former North Waste Cell area for these compounds based on historic detections predating the installation of the North Waste Cell area replacement wells. Tetrahydrofuran was historically detected at the Millstone Crossing wells, and the simultaneously detected high concentrations of 1,4-dioxane and benzene in these samples also indicate landfill-related contamination.

Detections of PPCP-related compounds occurred in a majority of the RI groundwater samples, including those from wells farthest from the landfill (Table BB-1, Appendix BB) and in all directions from the landfill. Detections of PPCP-related compounds co-occurred in most of the samples with 1,4-dioxane detections. The co-location of PPCP-related compounds and 1,4-dioxane can be visualized through a comparison of BHRRA Attachment E, Figure E.1 (RI Appendix CC), which shows the distribution of PPCPs detections, with the estimated extent of 1,4-dioxane in bedrock groundwater (BHHRA Attachment E, Figure E.2, included in RI Appendix CC). It further supports the co-location of the PPCPs with 1,4-dioxane.

4.2.1.3 Horizontal Extent of Groundwater Contamination in Deep Bedrock

A discussion of contaminants with concentrations exceeding the GWQS or comparison criterion at a frequency of five percent or greater of the total number of samples follows. For a discussion of the horizontal extent of contamination for the two TIC COCs, phenobarbital and 2-methoxy-methylbutane, determined to be COCs based on the exceedance frequencies of the combined RI and NJDEP PCEM datasets, refer to Section 4.2.1.2. Note Figures 8-1 through 8-9 display data in addition to what are discussed in this section to include packer testing and non-compliant well sampling results in the depiction of the horizontal extent of groundwater contamination. Results discussions that follow only include those for EPA RI wells and previously installed compliant wells. Minimum and maximum concentrations discussed below may not be the same as shown on the horizontal extent figures. Refer to Section 4.2.1 for the rationale behind selection of wells.

1,4-Dioxane

Concentrations of 1,4-dioxane above the 0.4 µg/L GWQS were in 20 of 26 of the bedrock monitoring wells sampled during the RI, and at locations in all directions from the landfill (Figures 4-1C and 8-1).

The highest concentrations of 1,4-dioxane were in samples from monitoring well CF-209D, located just to the northeast of the former North Waste Cell. Criterion exceedances were for all sampled depth intervals (spanning 150 to 345 feet bgs) with concentrations ranging from 34 to 55 µg/L in June 2014, 140 J to 290 J µg/L in September 2014, and 40 to 350 µg/L for the samples collected in January 2017 (Figure 4-1C). Following the modification of multi-port FLUTe™ well CF-209D to a conventional well in March 2017, the sample collected from the new single-depth well (CF-209D-R, screened from 150 to 160 feet bgs), had a 1,4-dioxane concentration of 29 D µg/L. Collection of this occurred after the aquifer pump test at borehole CF-209D (Section 2.1.6.2), which removed 2.46 million gallons of water from the aquifer over 26 days. Prior to converting well CF-209D from a multi-port to a single-depth well, the 1,4-dioxane concentration in the 150 to 160 foot interval was an order of magnitude higher (350 µg/L). Future sampling may indicate if the aquifer pumping test removed a considerable mass of 1,4-dioxane in the area northeast of the former North Waste Cell, or if concentrations will rebound.

Concentrations of 1,4-dioxane an order of magnitude or greater above the current GWQS of 0.4 µg/L were also in samples from six wells installed during the RI between the landfill and Schoolhouse Lane to the northeast (concentrations 10 times the 0.4 µg/L GWQS or greater only):

- CF-204D 14 to 93 µg/L 155 to 200 feet bgs (2 of 3 ports)
- CF-205D 14 µg/L 150 to 160 feet bgs (single-depth well)
- CF-206D 5.1 to 35 µg/L 86 to 558 feet bgs (4 of 5 ports)
- CF-207D 7.4 to 38 µg/L 106 to 111 & 412 to 417 feet bgs (2 of 4 ports)
- CF-211D 6.4 J to 24 J µg/L 124 to 365 feet bgs (3 of 3 ports)
- CF-227D 6.9 to 42 µg/L 110 to 482 feet bgs (3 of 4 ports)
- CF-228D 4.1 to 18 µg/L 58 to 419 feet bgs (3 of 3 ports)

Somewhat lower but similar concentrations were in well samples from other areas:

East of the landfill:

- CF-222D 6.6 to 39 µg/L 92 to 170 bgs (3 of 3 ports)
- CF-223D 6.3 µg/L 145 to 160 bgs (single-depth well)
- CF-224D 19 to 29 µg/L 145 to 160 feet bgs (single-depth well)

South of the landfill:

- CF-218D 22 to 40 µg/L 171 to 693 feet bgs (3 of 3 ports)
- CF-225D 6.4 J to 23 µg/L 106 to 362 feet bgs (2 of 3 ports)

West of the landfill:

- CF-216D 20 to 44 µg/L 51 to 273 feet bgs (3 of 4 ports)
- CF-212D 38 µg/L 153 to 158 feet bgs (1 of 2 ports).

In addition, the 1,4-dioxane concentration at one pre-existing bedrock monitoring well near Schoolhouse Lane (CF-11D, 145 to 170 feet bgs) exceeded the GWQS by more than an order of magnitude (6.5 µg/L).

It was not possible to horizontally delineate the extent of groundwater impacted with 1,4-dioxane above the GWQS (Figure 8-1) during the RI, because NJDEP lowered the criterion by more than an order of magnitude (from 10 µg/L to 0.4 µg/L) after the samples had been collected and analyzed. The analytical method reporting limit of 0.5 µg/L during Phases I through III of the RI was higher than the new criterion. While the highest concentrations of 1,4-dioxane were at the northeast edge of the landfill just off the former North Waste Cell and in the area between the landfill and Schoolhouse Lane, samples from monitoring wells in all directions from the landfill and from the shallowest to the deepest depth intervals exceeded the GWQS of 0.4 µg/L (Figure 4-1C). Samples from wells that did not have detections above the criterion do not fully delineate the horizontal extent of 1,4-dioxane contamination in their respective areas (well CF-226D to the north, well CF-230D to the northeast, and wells CF-229D, WRA3-3, and WRA2-1 to the south). While 1,4-dioxane was not detected in these wells above the criterion, the screened intervals in these wells are comparatively shallow, and nearby deeper wells showed impact with 1,4-dioxane above the criterion (i.e., CF-201D near CF-230D in the northeast, and WRA3-2 near the three wells to the south). In these limited areas, delineation of the horizontal extent of contamination may be complete in the shallow bedrock, but the vertical extent (i.e., the extent of contamination in deep bedrock) is not (Section 4.2.1.3).

Benzene

Samples from five wells had benzene concentrations above the GWQS of 1 µg/L. Three of the wells (CF-204D, CF-206D, and CF-207D) are in close proximity to each other near Schoolhouse Lane northeast of the landfill, one (CF-209D-R) is located just to the northeast of the former North Waste Cell, and the two remaining wells (CF-212D and CF-224D) are west and south of the landfill, respectively (Figures 4-1A, 4-1B and 8-2).

Samples from two wells near Schoolhouse Lane had the highest benzene concentrations with 90 µg/L at well CF-207D (106 to 111 feet bgs) and 70 µg/L at well CF-204D (195 to 200 feet bgs). The highest concentrations of benzene did not occur at the same locations as the highest 1,4-dioxane concentrations (Figures 1-6C, 8-1 and 8-2). Well CF-206D, which is slightly northwest of well CF-207D, had lower benzene concentrations, ranging from 1.5 to 15 J µg/L (the highest result in the interval from 147-152 feet bgs). The vertical extent of benzene contamination above the GWQS at these wells ranged from 155 to 200 feet bgs at CF-204D, to 86 to 558 feet bgs at CF-206D, to 106 to

609 feet bgs at CF-207D. Samples collected at wells CF-204D and CF-207D in October 2012 and August 2013 had the highest benzene concentrations (Figure 4-1A). Sample concentrations in the same wells and depth intervals were consistently lower in 2014 and 2015 by up to an order of magnitude (Figure 4-1B). These considerable variations of benzene concentrations over time in the area northeast of the landfill match the historic trend for well D-2 in the area between the landfill and Schoolhouse Lane. For a 10-year period ending in 2009, benzene concentrations at well D-2 varied between sampling by factors up to five, as shown on a benzene concentration time-trend graph prepared for NJDEP (Berger Undated). The graph also indicated a decreasing trend over time at this well, from >500 µg/L in late 1999 to <100 µg/L in 2009.

At well CF-209D-R (150 to 160 feet bgs), the benzene concentration in the sample collected from the modified well in March 2017 was 9.2 µg/L. Samples from the same depth interval at the prior multi-port FLUTe™ well (CF-209D) at this location had benzene at 0.4 J µg/L in September 2014 and 0.37 µg/L in January 2017. Collection of the 2014 and 2017 samples occurred before the aquifer pump testing at the CF-209D borehole.

The benzene concentrations above the GWQS for the two deep bedrock wells south of the landfill, well CF-224D (3.2 J to 3.9 µg/L, 140 to 160 feet bgs) and well CF-212D (1.9 J to 5.8 J µg/L, spanning 98 to 158 feet bgs), were generally lower than at the wells to the northeast.

Samples from five other wells had benzene concentrations below the GWQS: CF-209D, CF-218D, CF-222D, CF-226D, and CF-227D. With the exception of well CF-218D (171 to 693 feet bgs), these benzene detections were from intervals between 105 and 200 feet bgs (Figures 4-1A and 4-1B).

Figure 8-2 depicts an inferred horizontal extent of benzene-impacted groundwater above the GWQS to the northwest where concentrations at well CF-216D were below the GWQS, but above the GWQS at well CF-212D. Complete horizontal delineation is shown to the south (wells CF-223D, CF-225D, WRA3-2, WRA3-3, and CF-229D), northeast (wells CF-11D, CF-211D, CF-228D CF-205D and CF-201D), southeast (well CF-223D), and north (well CF-226D).

TCE

Samples collected from five wells during the RI had TCE concentrations exceeding the GWQS of 1 µg/L:

- CF-10D (1.1 µg/L, 145 to 170 feet bgs in November 2014), northeast of the landfill along Schoolhouse Lane;
- CF-211D (1.8 J to 4 J µg/L, two ports, 124 to 131 and 215 to 220 feet bgs, both in June 2014 and September 2014) on the northeast perimeter of the landfill;
- CF-222D (1.5 µg/L, 92 to 96 feet bgs, November 2014);
- CF-224D (1.7 and 1.6 J µg/L, 145 to 160 feet bgs, both October 2012 and November 2014) east of the landfill; and
- CF-228D (1.1 µg/L, 409 to 419 feet bgs, September 2014) northeast of the landfill (Figures 4-1A and 4-1B).

All five wells with TCE concentrations above the GWQS are aligned in the southwest-northeast trending area identified as having preferential groundwater flow in the 2011 long-term pump test (Handex 2011) and the 2017 pump test. Samples with the highest TCE concentrations came from the central portion of this alignment at the edge of the landfill (1.8 J to 4 J µg/L, well CF-211D). The highest concentrations of TCE in NJDEP's bedrock well samples collected during the RI sampling

period were from wells MW-16 (3 to 10 µg/L), CF-15D (5.5 to 12 µg/L), MW19D (2.2 to 7.2 µg/L), and D4 (0.16 J to 3.8 µg/L). Wells MW-15D, MW-16, and MW19D are in the same southwest-northeast trending preferential groundwater flow direction as the RI well, CF-211D, with the highest TCE concentrations.

Horizontal delineation of TCE in the deep bedrock aquifer is inferred in all directions from the landfill except southeast.

DEHP

DEHP exceeded the GWQS of 3 µg/L at wells:

- CF-10D (3.8 J µg/L, 145 to 170 feet bgs, November 2014);
- CF-206D (3.1 J µg/L and 15 µg/L, 553 to 558 and 86 to 91 feet bgs, respectively; October 2012);
- CF-227D (11 µg/L, 110 to 120 feet bgs), and CF-230D (8 µg/L, 120 to 135 feet bgs) to the northeast of the landfill;
- CF-212D (3.8 J µg/L, 98 to 103 feet bgs, October 2012) to the west;
- CF-222D (4.2 J to 15 µg/L, 165 to 170 feet and 134 to 139 feet bgs, respectively, October 2012) to the east; and
- CF-225D (4.3 J and 5.4 µg/L, 106 to 111 and 357 to 362 feet bgs, respectively; October 2012) to the south of the landfill (Figures 4-1A, 4-1B and 8-4).

The extent of DEHP-impacted groundwater in the bedrock aquifer is inferred and has not been delineated horizontally to the north/northeast, where the GWQS was exceeded at the most downgradient well (CF-230D), and to the west and southwest (above the GWQS at wells CF-212D and CF-225D) (Figure 8-4).

Alpha-BHC

Alpha-BHC, with a range of detections from 0.022 J to 0.073 µg/L, marginally exceeded the GWQS of 0.02 µg/L at four wells:

- CF-209D (0.022 J to 0.073 µg/L, four ports from 150 to 345 feet bgs);
- CF-211D (0.024 J and 0.031 J µg/L, 215 to 220 and 360 to 365 feet bgs, respectively);
- CF-227D (0.023 and 0.041 µg/L, 110 to 120 and 150 to 160 feet bgs, respectively). The three preceding wells are on the northeastern perimeter or to the northeast of the landfill; and
- CF-216D (0.051 J µg/L, 268 to 273 feet bgs) on the horse farm property to the west (Figure 4-1B).

All exceedances were in samples collected in 2014; samples collected in 2012 and 2013 did not have exceedances of alpha-BHC.

The horizontal extent of bedrock groundwater impacted by alpha-BHC has been delineated to the north; the extent in the other directions is inferred (Figure 8-5).

Lead

Samples from wells northeast of the landfill near Schoolhouse Lane had the highest concentrations of lead (GWQS of 5 µg/L):

- CF-207D (13.9 to 175 µg/L, spanning three ports from 106 to 417 feet bgs); and
- CF-204D (20 to 63.8 µg/L, with GWQS exceedances in the 155 to 160 feet and 433 to 438 feet bgs intervals) (Figures 4-2A and 4-2B).

The high lead concentrations at well CF-207D were in the December 2014 samples that had considerable turbidity/sediment, while samples collected in 2013 having no reported turbidity were non-detect for lead (reporting limit of 10 µg/L). In addition to lead, several other metals, including arsenic, aluminum, beryllium, iron, manganese, and chromium, exceeded their GWQS at this well. The entrained sediment appears to have contributed to the elevated metals concentrations.[47]

Other samples with lead concentrations above the GWQS in the area northeast of the landfill were from wells CF-10D and CF-206D (each at 8.7 J µg/L) and CF-201D (8.7 µg/L). Lead concentrations marginally exceeded the GWQS at well CF-223D (6.1 J µg/L) to the east of the landfill and at well CF-225D to the southwest (5.9 J µg/L).

The horizontal extent of lead-impacted bedrock groundwater is inferred to the west (wells CF-216D, CF-212D), north (well CF-226D), northeast (wells CF-201D, CF-205D, CF-211D, and CF-230D below the GWQS), east (CF-223D), and south (CF-218D, CF-229D, and WRA-wells). To the southwest, the sample from well CF-225D marginally exceeded the GWQS. The well is outside the inferred extent of the plume (Figure 8-6).

Arsenic

Arsenic concentrations exceeded the GWQS of 3 µg/L at wells:

- CF-224D (3.1 µg/L, 145 to 160 feet bgs) to the east of the landfill;
- CF-10D (4.5 J µg/L, 145 to 170 feet bgs in November 2014) to the northeast;
- CF-207D also to the northeast (3.8 J to 6.4 J µg/L, 2 ports, 106 to 192 feet bgs, December 2014);
- CF-212D (3.8 J to 4.9 µg/L, 153 to 158 feet bgs) to the west;
- CF-216D (4.8 µg/L, 51 to 71 feet bgs) also to the west; and
- CF-225D to the southwest (3.1 µg/L, 357 to 362 feet bgs).

The samples from wells CF-10D and CF-207D had observed turbidity, indicating that sediment contributed to the total metals results. In addition, given the surrounding area's long history of agricultural use and associated pesticide application, it would be difficult at these low concentrations to conclude the arsenic in groundwater is entirely landfill-related.

The horizontal extent of arsenic-impacted deep groundwater is inferred to the northeast (wells CF-205D, CF-211D, CF-201D and CF-230D below the GWQS), east (CF-223D), and south (CF-218D, CF-229D, and WRA-wells), but to the southwest and west three wells (CF-225D, CF-216D, and CF-212D) exceeded the GWQS (Figure 8-7).

Chromium

Samples from three wells to the northeast had chromium concentrations exceeding the GWQS of 70 µg/L:

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[47] While a positive correlation between turbidity readings and metals concentrations could not be established (Section 4.2.1.1), it was noted that the sample from CF-209D, 106-111 feet bgs had the highest TSS concentration of all bedrock groundwater samples analyzed during the RI (630 mg/L), indicating the presence of significant solids.

- CF-201D (83.7 µg/L, 240 to 245 feet bgs);
- CF-206D (91.8 and 262 J µg/L, two ports, 278 to 283 and 553 to 558 feet bgs); and
- CF-207D (71.2 and 94.2 µg/L, two ports, 106 to 111 and 412 to 417 feet bgs).

A sample from well CF-212D to the west of the landfill also had a chromium exceedance (70.5 µg/L, 153 to 158 feet bgs) in December 2014 (Figure 4-2B).

Samples collected in October 2012 at these locations were non-detect with reporting limits of 2 µg/L. The sample with the highest chromium concentration, a duplicate sample collected at well CF-206D (262 J µg/L, 278 to 283 feet bgs) also had elevated concentrations of other metals, including iron, manganese and nickel, suggesting that the December 2014 results may have been impacted by entrained sediment. The parent sample of this duplicate had a chromium concentration of non-detect (reporting limit 10 µg/L) and concentrations of other metals in the parent sample were an order of magnitude lower that in the duplicate, further suggesting that the chromium result may be an artifact of sample collection/handling or analysis, and not representative of groundwater quality. In addition, chromium exceeded the GWQS at well CF-224D (127 µg/L, 145 to 160 feet bgs) along the perimeter road at the east side of the landfill in October 2012. The horizontal extent of chromium is mostly inferred (Figure 8-8).

Other Metals

A discussion of the distribution of metals other than those that are COCs (arsenic, chromium, and lead) with concentrations above the GWQS follows and is shown on Figures 4-2A and 4-2B. The other metals with concentrations above the GWQS were:

Metal	No. of Wells* >GWQS	GWQS (µg/L)	Maximum Concentration (µg/L)	Well and Intervals with highest concentrations
Manganese	20	50	4,960	CF-222D (92 to 96 feet bgs)
Iron	18	300	44,700	WRA3-3 (80-103 feet bgs; high turbidity, 109 NTU)
Sodium	4	50,000	489,000	CF-10D (145 to 170 feet bgs)
Aluminum	3	200	18,400	CF-207D (106 to 111 feet bgs)
Nickel	2	100	149	CF-207D (412 to 417 feet bgs)
Beryllium	1	1	2.5 J	CF-207D (106 to 111 feet bgs)
Cadmium	1	4	20.3	CF-226D (105-200 feet bgs)

*Of the 26 compliant bedrock wells.

The spatial distributions of these metals were as follows:

Aluminum

Aluminum exceeded the GWQS (200 µg/L) at three wells in the area northeast of the landfill, CF-10D, 1,920 µg/L, 145 to 170 feet bgs; CF-230D, 460 to 620 µg/L, 120-135 feet bgs, and CF-207D, 18,400 µg/L, 106-111 feet bgs, 17,400 µg/L, 182-192 feet bgs, and 2,380 µ/L, 412-417 feet bgs (Figures 4-2A and 4-2B). Aluminum is not a groundwater COC as it exceeded its comparison criterion at a frequency of less than five percent of the total number of samples. Further, the basis for the GWQS is secondary characteristics - appearance, odor and taste, not health-related.

Cadmium

Cadmium exceeded the GWQS of 4 µg/L in one sample from well CF-226D (20.3 µg/L, 105-200 feet bgs), collected in September 2014 (Figure 4-2A). For the first sample collected from this well in June 2014, the concentration was non-detect with a reporting limit of 1 µg/L. The sample had low turbidity readings, exhibited no other GWQS exceedances, and the results for other metals were not remarkably higher than in the first sample, suggesting that the cause of the elevated cadmium concentration was not entrained sediment. Well CF-226D is located on a ridge north of the landfill, at a location considered a local groundwater divide. Well CF-226D had no GWQS exceedances of VOCs or other organics, indicating that the singular cadmium exceedance may not be from impacted landfill groundwater. Cadmium is not a groundwater COC as it exceeded its comparison criterion at a frequency of less than five percent of the total number of samples.

Iron

Samples with iron concentrations 10 times the GWQS or greater were from wells to the south (WRA3-2, WRA2-1, WRA3-1), east (CF-222D), and northeast of the landfill (wells CF-209D, CF-227D, CF-207D, and CF-10D) (Figures 4-2A and 4-2B). Iron is not a groundwater COC because it is naturally occurring and the basis for the GWQS is secondary characteristics - appearance, odor and taste, not health-related.

Manganese

Samples with the highest manganese concentrations were from well CF-222D on the eastern perimeter of the landfill (2,730 to 4,960 µg/L, three ports, 92 to 170 feet bgs). High concentrations of iron and sodium in this sample, along with exceedances of the GWQS for 1,4-dioxane, DEHP and TCE, are indicative of impacts from shallow groundwater/landfill leachate at this well. Samples with manganese concentrations of 500 µg/L (10 times the GWQS) or greater were from wells near the former North Waste Cell (well CF-209D), to the north (CF-227D) and to the south of the landfill (well CF-218D) (Figures 4-2A and 4-2B). Concentrations exceeding GWQS were also detected at wells CF-207D, CF-222D, and CF-228D. Manganese is not a groundwater COC because it is naturally occurring and the basis for the GWQS is secondary characteristics - appearance, odor and taste, not health-related.

Nickel

Samples with nickel exceeding the GWQS of 100 µg/L were from two wells in the area northeast of the landfill, CF-206D (136 J µg/L, 278 to 283 feet bgs, and CF-207D 149 µg/L, 412 to 417 feet bgs, December 2014) (Figure 4-2B). The sample from well CF-206D also had concentrations of other metals above GWQS (described in the discussion of chromium results above) considered artifacts of sample collection or handling or analysis, and not representative of groundwater quality. Nickel is not a groundwater COC as it exceeded its comparison criterion at a frequency of less than five percent of the total number of samples.

Sodium

Samples with sodium concentrations exceeding the GWQS of 50,000 µg/L were from wells CF-222D and CF-225D to the south and southwest of the landfill, well CF-10D to the northeast, and well CF-224D to the east (Figures 4-2A and 4-2B). Sodium is not a groundwater COC as it exceeded its comparison criterion at a frequency of less than five percent of the total number of samples. Further, the basis for the GWQS is primarily secondary characteristics - appearance, odor and taste, not health-related.

In summary, multiple groundwater flow directions from the landfill source control the horizontal distribution of the COC concentrations in bedrock groundwater. As the landfill sits on a topographical high, groundwater flow is to the west, south and northeast. Several features modify this nearly radial groundwater flow. The first is a southwest to northeast-oriented bedrock trough at the boundary of two geological formations running through the southeast portion of the landfill. The second is a group preferential flow pathways following the bedrock trough in the area northeast of the landfill;[48] and the third consists of aquitards to the west and east of the bedrock trough to the north of the landfill. Wells along the preferential flow pathways had the highest concentrations of 1,4-dioxane, benzene and the other COCs (Figures 1-6A through 1-6D, Figures 4-1A through 4-1C; Figures 4-2A and 4-2B). In some cases, bedrock wells in close proximity to each other, such as well pairs CF-211D/CF-15D, CF-209D/D-5R, and CF-224D/MW-19D, exhibited considerable differences in COC concentrations (mostly 1,4-dioxane and benzene) (Figure 1-6C). In each of the above well pairs, the sampling intervals (single and multi-port) did not overlap so the samples at neighboring wells were from different depths. In addition to the described horizontal flow components, vertical flow occurs through mostly steeply dipping bedrock fractures.

Downward flow from the overburden to the bedrock aquifer occurs at and near the landfill. Wells further from the landfill, especially in the low-lying area between the landfill and Schoolhouse Lane, and wells closer to discharge features, generally demonstrate upward flows. Changes in vertical flow direction can produce discontinuous contamination, such as in the area between the northeast side of the landfill where well RW-U has high 1,4-dioxane concentrations but nearby wells MW-9 through MW-11 are minimally impacted by comparison (Figure 1-6A).

4.2.1.4 Vertical Extent of COC Contamination in Deep Bedrock Groundwater (OU2 RI Samples)

1,4-dioxane, benzene, DEHP, alpha-BHC, TCE, lead, arsenic, and chromium were detected at concentrations exceeding criteria at the deepest intervals in one or more multi-level monitoring wells and/or in conventional wells sampled for this RI, meaning that the vertical extent of contamination of the COCs, as described in detail below, was not fully delineated during this RI. Information from a previous investigation of deep boreholes (Berger 2010) was also included in the following sections. The vertical extent of contamination for the two TIC COCs, phenobarbital and 2-methoxy-methylbutane, which were determined to be COCs based on the frequencies of exceedance in the combined RI and NJDEP PCEM datasets (they did not exceed the 5% threshold in the RI samples), is discussed in Section 4.2.1.2.

1,4-Dioxane

Samples with the highest 1,4-dioxane concentrations in the RI bedrock wells were from an almost 200-foot interval at wells CF-209D and CF-209D-R in the former North Waste Cell Excavation area (Figures 3-4 and 4-1C). NJDEP samples with higher concentrations were from shallower areas nearby (overburden well PZ-21R) as indicated on the cross-section through the northern portion of the landfill (Figure 3-4). The samples with the deepest detection of 1,4-dioxane above the GWQS (0.4 µg/L) was from the deepest interval sampled during the RI (688 to 693 feet bgs, well CF-218D; Figure 3-7). Samples from the deepest intervals at 20 of the 26 RI bedrock monitoring wells had concentrations of 1,4-dioxane exceeding the GWQS (Figures 3-4 through 3-7 and Figure 4-1C). Thus, it was not possible to vertically delineate 1,4-dioxane contamination at 20 of 26 locations during the RI. The exceedances in the deepest intervals occurred in all directions from the landfill

[48] Additional preferential flow pathways likely exist in areas not surveyed.

and only one multi-port well (CF-201D, located northeast of the landfill) did not have an exceedance for 1,4-dioxane in the deepest sampled interval (Figure 3-4). Samples from five conventional, single-depth wells also did not exceed the detection limit for 1,4-dioxane.

During a 2007/2008 packer testing investigation by others of nine open boreholes known as the Millstone Crossing wells northeast of the landfill (Berger 2010), the laboratory detection limit for 1,4-dioxane was 100 µg/L. At this reporting limit, all samples were non-detect; however, these results are not useful in light of the current standard. During the RI, the concentrations of 1,4-dioxane in the samples from the two wells installed in the former Millstone Crossing/Parker Preserve ranged from non-detect (<0.5 µg/L in well CF-205D) to 18 µg/L (409 to 419 feet bgs, well CF-228D), the latter being the sample from the deepest interval at the two wells (Figures 3-5 and 4-1C). Packer testing samples from between 110 and 154 feet bgs at the CF-215D borehole at the Parker Preserve (not completed as a monitoring well) were non-detect (<0.5 µg/L).

Benzene

During the RI, benzene exceeded the GWQS of 1 µg/L to a depth of 609 feet bgs (CF-207D; 604 to 609 feet bgs, Figure 3-4) and the vertical extent of benzene contamination in deep groundwater was not delineated in three areas around the landfill (Figures 4-1A and 4-1B). Northeast of the landfill, two wells had benzene concentrations above the GWQS in the deepest intervals (CF-207D; 604 to 609 feet bgs and CF-206D; 553 to 558 feet bgs, Figure 3-4). To the east, vertical delineation was not achieved at well CF-224D (145 to 160 feet bgs, Figure 3-5), and on the western perimeter of the landfill, benzene exceeded the GWQS in the deepest interval at well CF-212D (153 to 158 feet bgs, Figure 3-4).

During the 2007/2008 packer testing investigation at the Millstone Crossing wells (Section 1.7), investigators were not able to vertically delineate benzene because concentrations exceeded the GWQS in the deepest sampled intervals at several of the wells. The deepest sample with benzene above the GWQS was from the 660 to 685 foot interval at well 22.12, with a benzene concentration of 9.2 µg/L. The detection limit for benzene during the 2007/2008 investigation (5 µg/L) was higher than the GWQS (1 µg/L). Because this may have prevented the detection of benzene at concentrations between the GWQS and the detection limit (the lowest reported benzene concentration was an estimated 2.1 µg/L), the vertical extent of benzene contamination may be greater than suggested by the 2007/2008 data.

TCE

The deepest detection of TCE above the GWQS of 1 µg/L was reported for the 409 to 419 feet bgs interval at well CF-228D in the area northeast of the landfill. The vertical extent of TCE contamination above the GWQS was not delineated along the eastern perimeter of the landfill where the deepest interval at well CF-224D (145-160’ bgs) exceeded the standard, or in the area northeast of the landfill (well CF-228D, 409-419 feet bgs interval above the standard) (Figures 4-1A and 4-1B).

During the 2007/2008 packer testing investigation at the Millstone Crossing wells (Berger 2010), the investigators also failed to achieve vertical delineation of TCE. Concentrations exceeded the GWQS in the deepest sampled interval at one well (well 22.14, 525-550 feet bgs, TCE 12 µg/L). The deepest delineated TCE concentration above the GWQS was from the 658 to 683 foot bgs interval at well 22.16 (2.8 J µg/L), meaning that TCE contamination above the GWQS exceeded 683 feet bgs at that time. The detection limit for TCE during the 2007/2008 investigation (5 µg/L) was higher than the GWQS (1 µg/L). Because this may have prevented the detection of TCE at concentrations between the GWQS and the detection limit (the lowest reported TCE concentration was an

estimated 2.4 µg/L), the vertical extent of TCE contamination may be greater than suggested by the 2007/2008 data.

DEHP

RI samples had DEHP concentrations above the GWQS of 3.1 µg/L as deep as 553-558 feet bgs (CF-206D, northeast of CFS near Schoolhouse Lane), and in the deepest intervals of five wells situated to the northeast (three wells, to 558 feet bgs) and west/southwest (two wells, to 362 feet bgs) of CFS (Figures 4-1A and 4-1B). While the detection limit for DEHP during the RI (5 µg/L) was higher than the GWQS (3 µg/L), the lowest reported concentration (2.0 J µg/L, estimated) was below the detection limit.

During the 2007/2008 packer sampling investigation at the Millstone Crossing wells (Berger 2010), three samples from one of the nine boreholes (22.16) were analyzed for SVOCs. DEHP concentrations were above the GWQS in all three samples (from intervals spanning 225 to 250 feet bgs, 421 to 446 feet bgs, and 725 to 745 feet bgs, near the bottom of the borehole). Concentrations increased with depth (2.2 J µg/L, 3.2 J µg/L, and 4.5 J µg/L) and exceeded the GWQS in the two deeper intervals.

Alpha-BHC

RI samples had Alpha-BHC concentrations above the GWQS of 0.2 µg/L to a maximum depth of 365 feet bgs (Figures 4-1A and 4-1B). At two locations on the northeast perimeter of the landfill (CF-209D and CF-211D), concentrations in the deepest intervals exceeded the GWQS and vertical delineation was not achievable. Investigators did not perform pesticide analysis on samples collected during the 2007/2008 packer testing investigation at the Millstone Crossing wells.

Lead

Lead concentrations exceeded the GWQS (5 µg/L) to a maximum depth of 438 feet bgs during the RI. At three wells (CF-204D, CF-10D, and CF-223D), the samples from the deepest intervals exceeded the GWQS, meaning that the vertical extent of lead contamination was not delineated at these locations (Figures 4-2A and 4-2B). During the 2007/2008 packer sampling investigation at the Millstone Crossing wells (Section 1.7), investigators analyzed samples from three boreholes for metals. Lead concentrations in three of seven samples from one borehole (22.16) exceeded the GWQS, including the sample from the deepest interval (720 to 745 feet bgs).

Arsenic

Arsenic exceeded the GWQS (3 µg/L) to a maximum depth of 362 feet bgs during the RI. The vertical extent of groundwater impacted with arsenic above the GWQS was delineated at two of six impacted wells (CF-207D and CF-216D); the remaining four wells (CF-10D, CF-207D, CF-212D, CF-224D, and CF-225D) had arsenic above the GWQS in the deepest/only sampled depth interval (Figures 4-2A and 4-2B). During the 2007/2008 packer sampling investigation of the Millstone Crossing wells (Section 1.7), samples from three boreholes were analyzed for metals. Arsenic concentrations in samples from one well (22.16), including the deepest sample (720 to 745 feet bgs), exceeded the GWQS.

Chromium

Chromium exceeded the GWQS of 70 µg/L to a maximum depth of 558 feet bgs during the RI. At three wells (CF-206D, CF-212D, and CF-224D), the samples from the deepest intervals exceeded the GWQS, meaning that the vertical extent of lead contamination was not delineated at these locations (Figures 4-2A and 4-2B). During the 2007/2008 packer testing investigation at the Millstone

Crossing wells (Section 1.6), chromium (0.33 J to 2.4 µg/L) did not exceed the GWQS in the samples from the single borehole (named 22.16) analyzed for metals.

Although clean intervals exist below the deepest contaminated zones for some contaminants at various well locations, the presence of COCs at some of the deepest sample locations illustrates that organics and metals in groundwater have migrated via steeply dipping bedrock fractures to the deepest intervals investigated in individual monitoring wells during the RI. The vertical extent of groundwater contamination is as deep as the fractures that create the pathways at any single location. The deepest historic detection of CFS-related groundwater contamination was in a Millstone Crossing borehole at 745 ft. bgs (borehole named 22.16). The deepest detection in the RI wells was 693 ft. bgs. The vertical extent generally coincides with the terminal depth of transmissive fractures.

For RI/FS delineation purposes, the vertical extent of groundwater contamination is the depth at which the rate of liner eversion during FLUTe™ hydraulic profiling, or transmissivity of the remaining borehole, is near zero, such that the liner will no longer evert; or the greatest depth of contamination based on analytical results unless it is deeper than the maximum depth of eversion. This is summarized in Table 4-1 which presents the estimated vertical extent of groundwater contamination at each well location. Contamination below liner eversion depths or near zero transmissivity may have come from shallower zones during drilling, downhole geophysics or liner removal. The deepest vertical contamination could also be associated with smaller fractures or groups of smaller fractures within recharge areas.

Within the investigation area, the average elevation in bedrock where each borehole's transmissivity is near zero is approximately 476 feet (site vertical datum) (Table 4-1 and Figures 3-4 through 3-7). The transmissivity limit is based on the maximum depth of liner eversion observed during FLUTe™ hydraulic profiling (Section 2.1.4.2). The transmissivity limit was deepest (i.e., at the lowest elevations) at wells CF-218D to the southwest of the landfill and in line with the bedrock trough (elevation 77.2 feet), and CF-201D near the Lamington River (elevation 120.7 feet), indicating deeply fractured bedrock in the areas represented by these wells that provide deep conduits for vertical movement of groundwater. The highest elevations/shallowest transmissivity limits were at wells on the ridges west and east of the bedrock trough northeast of the landfill, including well CF-226D, elevation 773 feet, to the west; and wells CF-2015D, elevation 791.8 feet, and CF-205D, elevation 683.4 feet, on the ridge east of the bedrock trough (Table 4-1). These wells are along areas identified as aquitards in the Willowstick™ survey (Figure 3-11).

The depth limits of transmissivity for all profiled wells are shown on the cross-sections (Figures 3-4 through 3-7). For wells with strong upward vertical flow (e.g., artesian wells CF-204D, CF-206D, and CF-207D; Section 3.6.2.1) hydrostatic pressure, rather than actual borehole transmissivity limits, prevented further liner eversion. While the upward flow acts as a barrier to downward vertical migration of contaminants at these locations, deeper contaminated groundwater, if present at these locations, can migrate to shallower depths and eventually discharge to surface water.

Evaluation of Groundwater Contamination

Concentrations of several historical COCs have steadily declined over time and no longer exceed the applicable GWQS. These compounds are no longer COCs. This group of compounds includes TBA, various Freon™ compounds, and diethyl ether (ethyl ether).

The horizontal and vertical extent of bedrock groundwater impacted with 1,4-dioxane concentrations above 0.4 µg/L was not delineated during the RI as described in the preceding sections. Concentrations of 1,4-dioxane started to decline after the North Waste Cell was excavated but still remain above the GWQS as the contaminant does not readily degrade under most conditions, and is transported mostly unimpeded with groundwater flow.

Concentrations of benzene, the main COC prior to the first detections of 1,4-dioxane, have remained above the GWQS despite benzene's ability to degrade under aerobic conditions. This may be indicative of a continuing source within the landfill.

The landfill serves as a continuing source of deep groundwater contamination outside the landfill based on the following:

- Historic trends of contaminant concentrations;
- NJDEP groundwater analytical data for the period of the RI (Section 1.6);
- Groundwater flow directions from the landfill to the surrounding area; and
- The presence of preferential groundwater flow pathways from the landfill to the north towards Schoolhouse Lane (Section 3.6.2.2.4).

The highest 1,4-dioxane concentration (510 µg/L) in groundwater during the period of the RI was at overburden piezometer PZ-21R in the northeast section of the landfill alongside the former North Waste Cell excavation (Figure 1-6A). Nearby RI bedrock monitoring well CF-209D had the highest 1,4-dioxane concentration (350 µg/L) of any bedrock well and of any well outside the landfill area during this period (Figure 1-6C). Well CF-209D is approximately 60 feet northeast of PZ-21R; both wells are along the strongest preferential groundwater flow pathway identified during the RI (Figure 3-11). The aquifer test at well CF-209D in early February 2017 established a strong hydraulic connection between the two wells, as indicated in the hydrographs for piezometer PZ-21R in the technical memorandum for the aquifer pump test (Appendix N).

For benzene, the highest concentrations in samples from the landfill area during the RI were from two bedrock wells in the eastern portion (CF-15D and MW-19D, 110 D and 980 D µg/L). The two wells are on the perimeter of the landfill, outside the cap and in the southwest-northeast trending bedrock trough. Well CF-15D is along another preferential groundwater flow pathway identified during the RI that follows the bedrock trough to the north towards Schoolhouse Lane (Figure 3-11). The two wells are also near former buried drum locations, and both this area and the former North Waste Cell excavation area are main source areas for benzene and 1,4-dioxane apart from the landfill itself.[49]

Recent analytical data for individual GWTP recovery wells indicated low benzene concentrations, ranging from 0.13 to 0.53 µg/L (Chapman 2017b). In contrast to the high benzene and 1,4-dioxane concentrations in recent and historic groundwater samples collected near the landfill, low concentrations in recovery wells suggest incomplete capture of leachate and overburden groundwater and/or inadvertent capture of clean groundwater mixing with contaminated groundwater.

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[49] Historically, samples from the shallow-depth replacement wells in the former North Waste Cell area collected in January 2009, shortly after the waste cell was removed, at monitoring wells D-5R (160 µg/L) and PZ-21R (150 µg/L), and recovery well RW-U (370 µg/L) had the highest concentrations of benzene (TestAmerica 2009). The samples also contained high concentrations of 1,4-dioxane (540 to 970 µg/L). During earlier sampling of landfill piezometers in late 2007, one location in the northeast portion of the landfill (PZ-27, screened from 15 to 55 feet bgs) had a benzene concentration of 480 µg/L (Berger 2010).

As was noted in Section 4.2.1.1, the sampling locations with the highest benzene concentrations during the RI (CF-204D and CF-207D) had considerably lower concentrations, by one order of magnitude, in the second set of samples. These considerable variations of benzene concentrations over time reflect similar historic fluctuations at pre-RI well D-2 in the area between the landfill and Schoolhouse Lane. For a 10-year period ending in 2009, benzene concentrations at well D-2 varied by factors up to five between sampling events (benzene concentration time-trend graph in Berger Undated). The cause of these considerable fluctuations may be changes in groundwater conditions during wetter and drier times. In the case of well CF-204D, the water depths (transducer readings for the sampled multi-port intervals) in the upper two intervals were considerably greater (approximately 21 and 23 feet) during the second sampling round, with no benzene detections. When water depths were shallower during round one, concentrations of benzene were 21 and 70 µg/L. Both wells were at times artesian and located along the preferential groundwater flow pathways from the landfill to the northeast near Schoolhouse Lane.

No pattern was discernable for locations with considerable differences in 1,4-dioxane concentrations between the first and second sets of groundwater samples, such as generally higher concentrations in the first or second rounds. Of four FLUTe® multiport wells sampled in October 2012 and again in November 2014 (CF-205D, CF-218D, CF-222D, and CF-223D), two had higher concentrations in the first round of samples, and two in the second round (Figure 4.1C). Typically, seasonal water table fluctuations would affect wells in a similar manner, but in the case of CFS wells, this was not a cause for the differences in concentrations.

A number of samples that had high turbidity and/or high TSS also had elevated concentrations of lead, arsenic and a number of other metals, as detailed in Section 4.2.1.1. Based on these observations, entrained sediment at least partially contributed to some of the highest concentrations of some metals.

4.2.2 Surface Water and Sediment

As described in Section 2.2, two phases of sampling of surface water and sediment sampling took place during the RI. The investigation during the first phase in November 2014 targeted areas potentially affected by groundwater discharges from CFS. During the second phase in September 2017, the investigation focused on background sampling at locations presumed unaffected by groundwater discharges from CFS in addition to sampling of seeps and a spring as expressions of complete groundwater exposure pathways.

4.2.2.1 Surface Water and Sediment Background Sampling

Collection of background surface water and sediment samples occurred in September 2017 at ten locations (Figure 2-2b) to inform the SLERA conclusions (Section 7).

Background Surface Water Samples

Table X-3 (Appendix X) includes the background surface water analytical results. The background surface water samples had no detections of VOCs, including 1,4-dioxane; and one detection of an SVOC, DEHP, in one sample (TUSW0013) at a concentration of 5.9 µg/L (criterion of 0.3 µg/L). The background surface water samples also had two detected pesticide compounds, alpha-chlordane in sample TUSW0006 at a concentration of 0.00067 µg/L (no criterion), and endrin in sample TUSW0008, at concentration of 0.00047 µg/L (below the criterion of 0.036 µg/L). There were no detections of PCBs and none of the detected metals concentrations exceeded criteria. Detection limits, however, for total silver and dissolved cadmium exceeded the criteria.

Background Sediment Samples

Tables Y-4 and Y-5 (Appendix Y) contain the background sediment analytical results. Detections in background sediment samples included two VOCs without comparison criteria, acetone (26 J to 100 µg/kg) and methyl ethyl ketone (19 J to 82 µg/kg); and SVOCS in three of the ten background sediment samples. One of the samples (TUSD011) had acetophenone, a compound without a sediment criterion, at 47 µg/kg. Detections of SVOCs in two samples (TUSD0015 and TUSD0016) were ten and nine PAH compounds, respectively. Three of the PAHs exceeded sediment criteria: benzo(a)anthracene, 120 J - 160 J µg/kg (LEL: 108 µg/kg), benzo(a)pyrene, 190 J µg/kg (LEL: 150 µg/kg), and pyrene, 210 J – 230 J µg/kg (LEL: 195 µg/kg). There were no PCBs detections in the background sediment samples. None of the reported metals concentrations exceeded the LEL criteria. For cyanide, the single reported detection (0.13 mg/kg) exceeded the LEL (0.0001 mg/kg). The detection limits, however, for several SVOCs and cyanide exceeded the criteria for some or all of the samples, and for silver and cadmium in one or more samples.

The contaminant "profiles" of the background surface water and sediment samples are dissimilar to those from the downstream reaches of the streams impacted by CFS.

4.2.2.2 Surface Water and Sediment Characterization Sampling

As described in Section 2.2, HDR conducted surface water and sediment sampling in two phases during the RI to assess potential impacts from CFS groundwater discharges.

During the first phase in November 2014, collection of surface water and sediment samples was from three transects on each of the four streams in the area surrounding CFS (Trout Brook, East Trout Brook, Lamington River UNT, and Tanners Brook UNT) (Figure 2-2a). On each transect, one co-located surface water and sediment sample location was placed at approximately mid-stream and a second sediment sample location was placed in a depositional area along the bank of the stream. The scope of work consisted of the collection of two rounds of surface water samples - one dry-weather sample and one wet-weather sample, following a major rain event. Collection of sediment samples were on the same days as the dry-weather samples. Figure 2-2a shows the 2014 stream sampling locations. Tables 2-14a (surface water) and 2-15a (sediment) provide the relative position of each sample location along the sampling transects (mid-stream or bank), sample depths and analyses.

During the second phase in September 2017, collection of one spring and four seep samples occurred in the area near Schoolhouse Lane (Figure 2-2b). Appendix W contains the surface water and sediment sampling logs.

Tables X-1 and X-2 in Appendix X present analytical data summaries for surface water samples. Tables Y-1 and Y-2 in Appendix Y present the sediment data summaries. Figures 4-4 and 4-5 (sediment) and Figure 4-6 (surface water) depict results for compounds that exceeded comparison criteria. Concentrations of 1,4-dioxane did not exceed the surface water criterion, and there were no detections in sediment. See Figure 4-7 for the RI and NJDEP PCEM results for 1,4-dioxane detections between 2011 through 2015.

4.2.2.2.1 Surface Water

2014 Stream Sampling

No VOCs exceeded the SWQS in stream samples collected in 2014. Eighteen of 24 surface water samples had 1,4-dioxane detections with concentrations ranging from 0.48 J to 61 µg/L. Neither

NJDEP nor the EPA have a SWQS for 1,4-dioxane. With concurrence from the EPA ecological risk assessor, HDR used the EPA Region 5 ESL of 22,000 µg/L for comparison in this RI. Despite the high screening criterion, the streams are clearly impacted by 1,4-dioxane. Other detections of VOCs in addition to 1,4-dioxane included:

- 1,2,4-Trichlorobenzene in one sample (0.3 J µg/L);
- Ethyl ether in three samples (2.2 J to 4 J µg/L);
- Acetone in one sample (2.7 J µg/L);
- Dichlorodifluoromethane in one sample (0.16 J µg/L);
- TCE in two samples (0.4 J µg/L and 0.22 J µg/L); and
- 1,2,3-Trichlorobenzene in two samples (0.25 J and 0.41 J µg/L).

The data validator rejected the data for eight of the 12 wet weather surface water samples collected on November 18 and 19, 2014 (Table X-1, Appendix X).[50] Data for 1,4-dioxane was not rejected.

Detections of 1,4-dioxane occurred in samples from all streams in 2014, indicating discharge of contaminated groundwater to the sampled stream reaches. The highest concentrations (21 to 61 µg/L) were in samples ETSW001, ETSW002, and ETSW003 from East Trout Brook where the landfill's GWTP effluent discharges.[51] Figure 2-2a shows surface water sampling locations. Figure 4-7 presents 1,4-dioxane concentrations in surface water.

Along East Trout Brook, 1,4-dioxane concentrations at the most upstream location, closest to the GWTP effluent discharge, were 35 µg/L for both the dry and wet weather samples. The uppermost portion of East Trout Brook is a losing stream while it is a gaining stream near Parker Road. Moving downstream, the results for the dry weather samples were 61 µg/L in the middle section and 40 µg/L at the most downstream location near Parker Road (Figure 4-7). The increase in 1,4-dioxane concentration at the middle section of the stream may indicate an additive contribution from discharge of impacted groundwater to the concentration already present in the discharged effluent upstream. Lower concentrations in wet weather samples at the downstream locations (22 µg/L and 21 µg/L, respectively) signify dilution with storm water runoff entering the stream.

At the Tanners Brook UNT, there were no detections of 1,4-dioxane in the dry weather samples. The two downstream sampling points had reported wet weather 1,4-dioxane concentrations of 4.5 and 35 µg/L, respectively. As storm water runoff should dilute, not increase concentrations, the only plausible explanation for these results would be that groundwater discharges into the Tanners Brook UNT mostly during high water table conditions such as storm events and the local water table is too low during dry weather.

In Trout Brook, 1,4-dioxane was non-detect in the dry weather samples at the most upstream sampling location, and reported at 4.2 µg/L and 9.6 µg/L, respectively, further downstream. The increases in concentration downstream likely result from upward groundwater flow into the streams

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[50] Rejections of several VOC analysis results for CLP case #44845 resulted from the laboratory exceeding the holding time. Receipt of the samples by the laboratory occurred within holding time, but the laboratory analyzed the samples outside of the 7-day holding time. The data validator qualified the non-detected results for this case as rejected and the detected results as estimated (J). The R-qualified data from this case accounts for approximately 70% of rejected VOC results for groundwater and all of the rejected VOC results for surface water.

[51] The November 2014 discharge monitoring report for the treatment plant (NJDEP 2014) showed 29 µg/L of 1,4-dioxane in the effluent for a sample collected the week before the dry weather surface water sample was collected, and 30 µg/L the week after the wet weather surface water sample was collected.

away from the landfill at discharge areas, while downward groundwater flow occurs closest to the landfill at recharge areas. The 1,4-dioxane concentrations for the wet weather samples were lower than the dry weather samples, indicative of the effect of dilution (non-detect, 1.7 and 4.3 µg/L from upstream to downstream locations).

The concentrations of 1,4-dioxane in samples from the Lamington River UNT collected under dry weather conditions decreased from the most upstream sampling point (8.1 µg/L) to the mid-section (4.2 µg/L) and the most downstream location (3.1 µg/L). In the wet weather samples, 1,4-dioxane concentrations slightly increased from the furthest upstream sampling point to the furthest downstream sampling point (0.48 J µg/L, 0.57 J µg/L, and 0.63 µg/L). The change in concentrations from upstream to downstream in the wet weather samples was too insignificant to draw conclusions regarding the cause (Figure 4.7). For the dry weather samples, the decrease in concentrations moving downstream likely results from areas of clean groundwater entering the Lamington River UNT as the distance from the landfill increases.

No SVOCs were above detection limits in the 2014 surface water samples; however, the detection limits for 13 compounds, including several PAHs, exceeded the respective SWQS (Table X-1, Appendix X). There were no rejections of the SVOC laboratory analysis results.

No detections of PCBs were in any surface water samples. Detection limits for PCBs were below SWQS and there were no rejections of the PCB laboratory analysis results.

No pesticide concentrations exceeded SWQS. Alpha chlordane, which has no SWQS, was the only compound reported above detection limits (0.0021 J and 0.0048J µg/L). Detection limits for six pesticide compounds were above the respective SWQS. The only rejection of laboratory analysis results for pesticides was for Endrin, occurring in nine samples (Table X-1, Appendix X).

Comparison of inorganic analyte results to the SWQS is described in Section 4.1. Silver was the only analyte exceeding the SWQS (0.12 µg/L) for total concentrations in two samples (0.46 J and 0.54 J µg/L), and copper, cadmium, and lead were the only analytes exceeding the SWQS for dissolved concentrations (Figure 4-6). Lead is a COC for groundwater and surface water. Silver, copper and cadmium are not groundwater COCs, and the surface water exceedances are less than an order of magnitude above the SWQS. Three of the four copper exceedances in surface water were in samples from East Trout Brook. Both silver exceedances and the single cadmium exceedance were from this stream as well.

Metal	No. of Detections	Range of Detections, µg/L	No. of Exceedances	SWQS, µg/L
Copper, dissolved	4	3.8 J to 6.7 J	4	2.2
Lead, dissolved	17	2.1 J to 9 J	3	5.4
Silver, total	2	0.46 J and 0.54 J	2	0.12
Cadmium, dissolved	1	0.19 J	1	0.056

In addition to these exceedances, detections of several metals (total and dissolved fractions) were below the respective SWQS (Table X-2, Appendix X). The data review further indicated that the detection limits for several metals and cyanide were above the respective SWQS for some or all of the samples reported non-detected.

The 2011 surface water samples underwent tritium analysis. Tritium detection occurred in only two of 26 samples, at low estimated concentrations of 45.5 J and 46.3 J picocuries per liter (piC/L)

(criterion 20,000 piC/L) (Table V-1, Appendix V). The detection limit for the remaining samples was 50 piC/L. Based on these results, the project team determined tritium wasn't a suitable tracer for groundwater originating at CFS and discontinued the analysis for later sampling events.

2017 Sampling of Seeps and Pond Surface Water

In September 2017, HDR conducted sampling of four seeps and a spring (pond) in the area near Schoolhouse Lane. As indicated by the results for the 2014 stream samples and NJDEP analytical results (Section 1.6), impacted groundwater discharges to the Lamington River UNT in this area. Collection of these samples was in support of the SLERA. These samples represent an expression of groundwater at a point where it reaches the surface. Therefore, sample results comparison is to GWQS, not SWQS.

Chloroform was the only VOC other than 1,4-dioxane detected in the 2017 seeps and spring samples. The reported chloroform concentrations of 0.27 J and 0.34 J µg/L (seeps B-1 and B-2) were below the criterion (70 µg/L). The reported concentrations of 1,4-dioxane, 5.9 D µg/L and 3.5 D µg/L (seeps B-1 and B-2), exceeded the 0.4 µg/L GWQS. The samples also had detections of four pesticides (endrin - , alpha-BHC, endosulfan sulfate, and p,p'-DDD) , with all reported concentrations between two and four orders of magnitude below the GWQS. No PCBs were detected in the 2017 seeps and spring samples. The samples also underwent TAL metals analyses (total and dissolved).. Total TAL results for seven metals (aluminum, arsenic, beryllium, iron, lead, magnesium, manganese and mercury) exceeded the GWQS. The highest concentrations for six of the seven metals were reported for seep sample B-2, which was described on the sampling log (Appendix W) as 'very turbid water' with a turbidity field reading of 59.4 NTU. The sample had the only exceedances for five of the seven metals (iron was detected above the GWQS in five and manganese in three samples) and the highest TSS value of the seven aqueous samples collected in 2017, indicating the cause of the high concentrations of the total metals in sample Seep B-2 was entrained sediment. In the dissolved fraction, only iron (five samples) and manganese (three samples) exceeded the GWQS. The data summary table for the 2017 seep and spring samples is in Appendix X.

4.2.2.2.2 Sediment

No VOC concentrations exceeded the LELs in the 2014 sediment samples, and methylene chloride was the only detected VOC, with a concentration of 0.0024 J mg/kg in one sample (LEL: 0.159 mg/kg) (Table Y-1, Appendix Y). The detection limits for bromomethane, which ranged from 0.0048 U mg/kg to 0.016 U mg/kg, exceeded the LEL (0.00137 mg/kg) in all samples.

SVOC LEL exceedances follow:

Compound	No. of Detections	Range of Detections, mg/kg	No. of Exceedances	LEL, mg/kg
Benzo(a)pyrene	4	0.1J to 0.67	3	0.15
Chrysene	4	0.12 J to 1.3	3	0.166
Pyrene	5	0.087 J to 1.7	3	0.195
Benzo(a)anthracene	4	0.092 J to 1.2	3	0.108
Benzo(g,h,i)perylene	3	0.11 J to 0.32 J	2	0.17
Benzo(k)fluoranthene	4	0.11 J to 0.73	2	0.24
Fluoranthene	5	0.11 J to 3.4	2	0.423

Phenanthrene	4	0.12 J to 0.88	2	0.204
Anthracene	2	0.17 J to 0.3 J	2	0.0572
Indeno(1,2,3-cd)pyrene	3	0.099 J to 0.34	2	0.2
Benzyl butyl phthalate	1	6.9	1	1.97
Dibenz(a,h)anthracene	1	0.15 J	1	0.033

SVOCs exceedances were limited to three samples from the Lamington River UNT near Schoolhouse Lane and one sample from the Tanners Brook UNT. Samples from Trout Brook and East Trout Brook did not have SVOC concentrations above the LELs (Figure 4-4).

The samples from the Lamington River UNT that had SVOCs above the LELs were from depositional areas in the central and downstream portions of the stream (sample LUSD0001-SD-AA-AB-RS-0 from the deeper portion of a ponded stream section above a small dam, and sample LUSD0004-SD-AA-AB-RS-0 and its duplicate sample LUSD0004-SD-AA-AB-RS-1 from a bank location). These two locations had several LEL exceedances for SVOCs (mostly PAH compounds) and metals (arsenic, lead, and cadmium). The only sample with exceedances from the Tanners Brook UNT was also from a bank location, and from the most downstream transect on that stream.

SVOCs detected at concentrations below LELs were benzo(b)fluoranthene, DEHP, and di-n-butyl-phthalate. The detection limits for 30 SVOCs exceeded the LELs (Table Y-2, Appendix Y).[52]

Sediment samples did not have detections of PCBs and all detection limits were below the LEL.

Detection of one pesticide, endrin aldehyde, was at a concentration of 0.0026 J mg/kg in one sample (LEL: 0.48 mg/kg). Detection limits for pesticides were below the LELs except for aldrin, dieldrin, endrin, gamma-BHC, heptachlor, heptachlor epoxide, methoxychlor, p,p'-DDD, and p,p'-DDE. There were no rejections of pesticide analytical results.

Among the inorganic compounds, detection limits were below LELs except for cadmium (one sample), mercury (four samples), silver (22 samples), and cyanide in all usable results (cyanide results were rejected for two samples).

The following inorganic compounds had sediment concentrations exceeded the LELs:

Compound	No. of Detections	Range of Detections, mg/kg	No. of Exceedances	LEL, mg/kg
Cadmium	16	0.15 J to 2.6	7	0.6
Arsenic	24	1.6 to 20	6	6
Lead	24	4.7 J to 71.4 J	4	31
Copper	24	1.7 J to 28.2 J	3	16
Manganese	24	12.7 to 1,400	2	630
Mercury	1	0.27	1	0.174
Silver	1	0.56	1	0.5

At least one metal exceeded the LEL concentration at one or more locations on each of the four streams (Figure 4-5). The highest lead (36.4 J to 71.4 J mg/kg) and copper (18.2 J to 28.2 J mg/kg) concentrations were in three samples from the two downstream transects on the Lamington River

[52] The LELs for many of the SVOCs are extremely low and laboratories frequently cannot achieve the detection limits in sediment samples with low percent solids. The range of detection limits for SVOC laboratory results reported as non-detect were 0.18 U mg/kg to 0.84 U mg/kg.

UNT. Sample LUSD0001-SD-AA-AB-RS-0 was from the deeper portion of a ponded stream section above a small dam, and sample LUSD0004-SD-AA-AB-RS-0 and its duplicate sample LUSD0004-SD-AA-AB-RS-1 were from a bank location. The highest concentrations of arsenic were in samples from the Tanners Brook UNT (9.5 mg/kg in sample TUSD001, and 20 mg/kg in the duplicate sample from TUSD002). The highest reported concentrations of cadmium were for East Trout Brook downstream locations, along with the highest results for manganese (the only LEL exceedances for manganese).

Detections of 16 other metals, including chromium, were below the respective LELs (Table Y-2, Appendix Y).

4.2.2.3 Evaluation of Surface Water and Sediment Contamination

Surface Water

The widespread and continuing detections of 1,4-dioxane in the surface water bodies near CFS indicate that contaminated groundwater originating at the landfill is upwelling into these streams, and into seeps (e.g., near Schoolhouse Lane; Figure 4-7). The highest detected concentration of 1,4-dioxane in surface water during the RI (61 µg/L) was from East Trout Brook downstream of the landfill's GWTP effluent discharge. A combination of the concentration in plant effluent concurrently with that in groundwater is one possible explanation for this high result. The highest 1,4-dioxane concentrations at the Tanner's Brook UNT (35 µg/L) and at the Lamington River UNT (44 D µg/L, NJDEP sample) are only one order of magnitude below the highest detected concentration in groundwater of 350 µg/L. This is indicative of limited dilution in surface water and that a significant portion of water in the streams originates in the aquifers as a continuing source. Although the EPA Region 5 ESL of 22,000 µg/L was approved for use as a comparison criterion for 1,4-dioxane in surface water (Section 4.2.1), when local surface waters flow within losing streams, it would be prudent to use the 0.4 µg/L GWQS as the comparison criterion for recharge of surface water to groundwater.

No organic compounds exceeded their comparison criteria. Concentrations of dissolved cadmium, lead, and silver exceeded the comparison criteria in stream samples, but were either not detected or detected below the comparison criteria at the farthest downstream sampling locations on all streams. Therefore, these three metals are delineated in surface water (Figure 4-6). Only dissolved copper exceeded the comparison criterion at the farthest downstream sampling location on East Trout Brook, thus is not delineated (Figure 4-6). Of the 2017 samples collected from seeps and a spring near Schoolhouse Lane, two (seeps B-1 and B-2) exceeded the comparison criterion for 1,4-dioxane for groundwater (the GWQS was applied because seeps and springs are surface expressions of groundwater). The detection of 1-4-dioxane indicates discharge of contaminated groundwater to surface water. Seven metals also exceeded the GWQS in the total fraction, with the highest concentrations for six of the metals occurring in one sample, and exceedances for five of the seven only in this single sample. Concentrations in the dissolved fraction exceeded only for iron and manganese. The exceedances in the total fraction are likely a result of entrained sediment, as indicated by a high turbidity field reading and TSS value for this sample.

Sediment

Of the 12 SVOCs with concentrations exceeding the respective LELs (Figure 4-4), 11 were PAHs, and the other was benzyl butyl phthalate. Neither the PAH compounds nor benzyl butyl phthalate are groundwater COCs. Surface water samples did not have detections of PAHs. The majority of groundwater samples did not have detections of PAHs. However, the PAH detection limits in

groundwater ranged from 5 to 10 µg/L, but the corresponding GWQS ranged from 0.02 to 3 µg/L. Detections of benzyl butyl phthalate in the RI groundwater samples were at a very low frequency and at low concentrations (1.2 J µg/L in one deep groundwater sample, and 4.9 J µg/L in one sample from a previously installed well**).** Benzyl butyl phthalate was also not in any of the surface water samples.

PAHs are ubiquitous contaminants in urban and suburban streams. Although the surrounding area is semi-rural, almost any development with roads and nearby sources of combustion produces sufficient storm water run-off containing PAHs to contaminate sediments at these low concentrations. Storm water run-off likely contributed to the PAH contamination in sediments. However, a significant contributor was likely the landfill prior to capping.

The extent of sediment with concentrations of metals above comparison criteria was not delineated downstream on three of the four investigated stream segments, all of which (East Trout Brook, Lamington River UNT, and Tanners Brook UNT) had at least two metals above the LEL at the furthest downstream sampling location. The metals exceeding the LELs at the downstream locations were arsenic, cadmium, copper, manganese, and lead. Only Trout Brook did not have any metals above the LELs at the furthest downstream sampling location (Figure 4-5).

The highest concentrations exceeding the LELs for all metals except mercury were in sediment samples collected on the stream banks. The comparison of co-located mid-stream sediment and surface water samples indicated that the highest lead concentrations in sediment and in surface water were not co-located (i.e., not occurring at the same sampling locations) on Trout Brook, the Tanners Brook UNT, or the Lamington River UNT. Only on East Trout Brook were the highest lead concentrations in sediment and surface water samples co-located (sediment sample ETSD0001 and surface water sample ETSW001).[53] For arsenic and copper, a comparison of the highest sediment and surface water sample results for co-location could not be made because all but one surface water result for both of these metals were reported as non-detected.

Similar to PAHs, storm water run-off likely contributed to the metals contamination in sediments, but a significant contributor was likely the landfill prior to capping.

4.2.3 Soil

The limited soil investigation completed during the RI consisted of the installation and sampling of five borings at locations on the perimeter of the landfill (Figure 4-3) to determine if remaining source areas within the landfill, such as possible buried drums and the un-remediated portion of the North Waste Cell, impacted soil. Collection of soil samples did not occur outside the landfill property boundary. Table 2-16 presents the soil boring and sampling summary; Appendix Z contains the soil boring logs; and Table AA-1, Appendix AA includes the analytical results summary.

Geophysical surveys for buried drums that may be potentially leaking, contributing to soil impacts, and acting as continuing sources of groundwater contamination (Section 2.1.1.2) took place at two corners of the landfill. The surveys indicated multiple anomalies suggestive of subsurface metals although it was not possible to identify specific targets of interest (i.e., drums). Metal wire present within the gabion wall was a source of interference during data collection. Installation of soil borings occurred in proximity to both of the surveyed areas.

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[53] Distribution of the highest sediment and surface water concentrations of lead on the other streams were as follows: On the Tanners Brook UNT, most downstream/most upstream location, on Trout Brook, mid-stream/most upstream location, and Lamington River UNT, most downstream/midstream location.

Soil boring depths ranged from 18 feet to 72 feet bgs. HDR collected between two and eight samples at approximately 10-foot intervals over the length of the borings. Soil sample analysis consisted of TCL VOCs, SVOCs, pesticides and PCBs; TAL metals, cyanide and TOC. Approximately 20% of the samples also underwent grain size analysis. Because of refusal and low recovered soil volume, the 35 to 36 foot bgs interval at boring CFB002 did not undergo inorganic analysis.

No waste materials were in any of the borings. Wood fragments were at two locations (at 4 to 6 feet bgs at boring CFB002, immediately below the roadway sub-base, and at 8 to 10 feet bgs at boring CFB005, which may also represent a former land surface). Vapor screening of the recovered soil cores did not indicate the presence of elevated organic vapors (PID readings on all cores were zero). Materials observed below the roadway gravel and sub-base consisted of clay, silt, sand, gravel, cobbles, and saprolite. Appendix Z contains the soil boring logs.

4.2.3.1 Soil Borings Investigation Results

Table AA-1 (Appendix AA) presents the analytical data summaries comparing the soil sample results to the NJDEP IGWSSLs and the NJDEP RDCSRS and NRDCSRS. Figure 4-3 depicts results for compounds that exceeded the most conservative comparison criteria.

No VOCs exceeded any of the comparison criteria. Methylene chloride was the only detected VOC in soil samples, with concentrations of 0.0023 J mg/kg and 0.0038 mg/kg. Detections of 1,4-dioxane were not in any soil samples. Detection limits were not met in some samples for benzene, bromodichloromethane, carbon tetrachloride, VC, 1,2-dibromo-3-chloropropane, and 1,2-dichloropropane. The detection limits for these compounds ranged from 0.0047 U to 0.0065 U mg/kg while the most stringent criterion for each of these compounds (IGWSSL) is 0.005 mg/kg.

No SVOCs exceeded any comparison criteria, and only detections of DEHP and di-n-butylphthalate were in soil samples. DEHP (RDCSRS 35 mg/kg) concentrations ranged from 0.071 J to 0.4 mg/kg in five samples and di-n-butylphthalate (IGWSSL criterion of 760 mg/kg) ranged from 0.053 J to 0.089 J mg/kg in three samples. Detection limits were not met for 11 SVOCs in some samples (2,4,6-trichlorophenol, 2,4-dichlorophenol, 2,4-dinitrophenol, 4,6-dinitro-2-methylphenol, benzo(a)pyrene, bis(2-chloroethyl)ether, hexachlorobenzene, hexachloroethane, isophorone, n-nitrosodi-n-propylamine, and pentachlorophenol). The detection limits for these compounds ranged from 0.18 U to 0.47 U mg/kg while the criteria for these compounds (IGWSSL) ranged from 0.2 to 0.3 mg/kg.

No detections of PCBs were in any soil sample, and all detection limits were below the comparison criterion.

Detection limits for pesticides were below all comparison criteria, except for alpha-BHC, beta-BHC, dieldrin, and gamma-BHC (Lindane). No detections of pesticides were in the soil samples that had detection limits below the comparison values. Rejection of endrin results occurred in 16 of the 22 analyzed samples.

Among the inorganic compounds, detection limits were below all comparison criteria except for mercury (18 samples) and silver (2 samples). The following metals concentrations exceeded the comparison values:

Metal	No. of Detections	Range of Detections, mg/kg	No. of Exceedances	Comparison Value[+], mg/kg
Aluminum	21	4,300 to 48,200	20	6,000
Manganese	21	27.7 to 1,320 J	19	65
Beryllium	21	0.27 J to 6.3 J	17	0.7
Cadmium	21	0.14 J to 6.3	7	2
Vanadium	21	5.8 to 217 J	7	78
Nickel	21	0.94 J to 74.6	2	48
Silver	7	0.28 J to 2.9 J	2	1
Arsenic	20	1.1 to 326*	1	19
Cobalt	21	3.4 J to 113 J	1	90

* The arsenic exceedance was in a duplicate sample for which the concentration in the parent sample was 6.1 mg/kg.

[+] IGWSSL, RDCSRS or NRDCSRS whichever is the most conservative if applicable to that sample interval (vadose or saturated zone; refer to Section 4.1.3).

Detected concentrations of fourteen other metals, including lead and chromium, were below comparison criteria. There were no detections of cyanide in any soil samples and the detection limits for all cyanide samples were below the comparison values (Table AA-1, Appendix AA).

4.2.3.2 Evaluation of Soil Contamination

Soil contamination above the comparison criteria was limited to nine metals (Figure 4-3). Among these, aluminum, beryllium, and manganese exceeded the comparison values in samples from all five borings and in at least 75% of the samples, and at least one metal exceeded the comparison values in each sample. Overall, the concentrations of metals were highest in the 20 to 22 foot bgs interval at boring CFB005, which had the highest concentrations for six of the nine metals that exceeded comparison values (aluminum, cobalt, manganese, nickel, silver, and vanadium). A seventh metal, cadmium, exceeded the IGWSSL criterion in the 30 to 32 foot interval at this boring (Figure 4-3). With the exception of the 20 to 22 foot bgs interval at boring CFB005, soil borings CFB001, CFB003, CFB004, and CFB005 had consistent concentrations of metals over their respective lengths, and obvious vertical distribution patterns of metals (e.g., found in specific depth intervals) were not observed. At boring CFB002, the concentrations of some metals were higher in the deeper intervals.

The arsenic concentration in a duplicate sample from the 10 to 12 feet bgs interval at soil boring CFB002 was 326 mg/kg while the concentration in the parent sample was 6.1 mg/kg (the soil criterion for arsenic is 19 mg/kg). EPA inquired to the CLP laboratory that analyzed these samples and after reviewing the results indicated there were no issues with the arsenic analysis. There is no explanation for this duplicate sample result. Additional soil sampling of the 10 to 12 feet bgs sample interval at boring CFB002 for arsenic is necessary to evaluate the prior parent and duplicate sample results.

Based on the absence of organic COCs in soil samples, and the lack of correlation between the groundwater metal COCs and the elevated metals in the soil samples, soils just outside the landfill cap do not appear impacted from remaining source areas within the landfill, such as potentially buried drums and the un-remediated portion of the North Waste Cell.

5 Contaminant Fate and Transport

This section discusses the migration potential and probable environmental fate of the identified COCs in groundwater, surface water, and sediment. First is a discussion of the probable contaminant transport and attenuation mechanisms in the context of overburden and bedrock aquifers, where contaminant behavior is subject to advection, molecular diffusion, dispersion, dilution, sorption, volatilization, and facilitated transport effects. Also discussed are the transformation processes that some COCs may undergo and site-specific conditions governing the fate and transport of the COCs. A presentation of the refined CSM is at the end of this section.

5.1 Contaminant Transport, Attenuation and Transformation Mechanisms

TRANSPORT MECHANISMS

Advection

Advection occurs when a contaminant in groundwater or surface water moves because of fluid flow, but its concentration remains unchanged as it moves, such as a dissolved contaminant or particulate carried along in the direction of (parallel to) fluid flow without changes to the concentration of the contaminant itself. A simple example is a contaminant transported downstream in a river (Williamson and Klamut 2001).

Advection is often the dominant transport process in the movement of chemicals in groundwater, especially where the aquifer material is composed of coarse granular material (Freeze and Cherry 1979).

In a fractured rock setting, advective transport is occurring in a network of fractures and produces an effective porosity of the fracture network generally several orders of magnitude lower than in granular media. The net effect is that the calculated linear groundwater velocity in the fractured media is very high. However, several field studies have shown that the actual rate of advance of the leading edge of the aqueous mass in fractured rock can be lower than the calculated (predicted) value. The ratio between the calculated average linear velocity and the observed advance rate of the leading edge of the aqueous mass is termed plume front retardation (Lipson et al, 2005). The consensus is that it is a result of the net effect of sorption, facilitated transport, dispersion, volatilization, transformational processes, and diffusion (if there is a porous matrix). As the metamorphic bedrock at CFS is not porous, diffusion has little, if any, effect on plume front retardation.

Diffusion

Diffusion occurs when differences in contaminant concentrations drive transport, i.e., when a contaminant moves from a higher concentration area to a lower concentration area by diffusion, similar to a ball rolling down a slope from higher elevation to lower elevation. These concentration gradients produce random motions over time. Within a surface water body, advection and diffusion are the primary modes of transport (Williamson and Klamut 2001).

The traditional understanding of groundwater systems pre-supposed that mass transport due to diffusion was negligible relative to transport due to advection and dispersion. Recent studies have increasingly focused on the importance of matrix diffusion of dissolved contaminants as a transport

process in some fractured rock environments, particularly sedimentary rock; however, as the tight crystalline grain found in the granite and gneiss at CFS is essentially non-porous, mass transport due to diffusion is anticipated to be negligible.

Dispersion

Dispersion in the simplest terms is mixing from variations in water velocity, whether it is surface water or groundwater flow (Williamson and Klamut 2001). In a stream, surface water velocity varies across the channel, with faster moving areas generally in the center and slower moving areas along the banks. Most mixing or dispersion in surface water occurs in the fastest flowing areas.

In groundwater, dispersion is the mixing of dissolved chemicals resulting from differences in groundwater velocity (magnitude and direction) between pores or fractures of varying size and shape. As such, dispersion results in the spreading of dissolved constituents both parallel and perpendicular to groundwater flow.

Dilution

Dilution occurs when an uncontaminated substance added to a contaminated substance makes it less contaminated or no longer contaminated. Dilution can be intentional or unintentional. The phrase “the solution to pollution is dilution” refers to a former “disposal method” that ceased to be effective when the number of polluted sources outweighed the number of clean sources. Rainfall and snowmelt will enter surface water bodies and at least temporarily dilute contaminant concentrations. Groundwater recharge will dilute contaminant concentrations in an aquifer assuming the recharged water is uncontaminated. Similarly, uncontaminated groundwater will dilute contaminated surface water within gaining streams.

ATTENUATION MECHANISMS

Sorption

Sorption occurs when a contaminant attaches or detaches itself from a solid, typically an immobile solid. The process of attachment is adsorption and the process of detachment is desorption. The term sorption refers collectively to both processes. Dissolved substances such as contaminants bind chemically and/or physically to the surface of sediments in a surface water environment, or to aquifer material such as sand in an unconsolidated aquifer or to a fracture surface in a bedrock aquifer (Williamson and Klamut 2001).

Although sorption is reversible, it reduces a compound’s mobility and retards the compound’s rate of migration. Sorption does not alter the total mass of a contaminant, but the associated reduction in mobility may lead to substantial reduction in risk to human and ecological health by limiting the spread of a contaminant.

The characteristics of the contaminant, the solid media, and the fluid media control the degree of sorption (EPA 1990):

	Contaminant Characteristics	Solid Media Characteristics	Fluid Media Characteristics
Ionic or charged species	X		
Uncharged polar species	X		
Uncharged non-polar species	X		
Mineralogy		X	
Permeability/Porosity		X	
Texture		X	
Homogeneity		X	
Organic Carbon Content		X	
Surface Charge		X	
Surface Area		X	
pH			X
Salinity			X
Dissolved Organic Carbon			X

Facilitated Transport

In certain cases, a compound may sorb to a colloid or other mobile solid within an aqueous medium. Colloids are particles of less than 10 micrometers (µm) in diameter and may be organic or inorganic in composition. Organic colloids consist of biocolloids such as bacteria or spores, macromolecules such as humic substances and organic fibers, and non-aqueous phase liquid (NAPL), such as oil droplets and surfactants. Inorganic colloids include clays, metal oxides, and inorganic precipitates, which may or may not be naturally occurring. The most common type of facilitated transport is organic and inorganic compounds sorbing onto and being transported with colloids.

Alternatively, the presence of surfactants or co-solvents may serve to reduce the compound's actual sorption potential. The co-solvent effect occurs when a miscible organic compound such as a chlorinated solvent dense non-aqueous phase liquid (DNAPL) is present in sufficient concentration to reduce the sorption coefficient of a hydrophobic organic compound (HOC) so that it is more soluble in solution. DNAPL is not know or suspected to exist at CFS. Since many sites often have multiple sources, it is common to find strongly sorbing organic compounds and metals along with miscible organic compounds. Surfactants are another class of compounds that act to alter the sorption coefficient of a surface. This may lead to an increase in concentration of a chemical in solution that would typically sorb. Surfactants may occur naturally or originate from an anthropogenic source.

In either case, the theoretical compound mobility (based on advective flow and chemical sorption potential with a particular aquifer material) is less than transport facilitated by the mobile colloids.

TRANSFORMATION MECHANISMS

Volatilization

Volatilization occurs when a contaminant mass transfers from the aqueous phase to the gaseous phase. The aqueous phase may include an immiscible non-aqueous fraction or a compound dissolved in water. The factors that affect a compound's volatilization include the vapor pressure, solubility, and molecular weight. The Henry's Law constant, defined as the vapor pressure divided by the aqueous solubility, characterizes a compound's tendency to volatilize. Compounds with a high Henry's Law constant are more volatile. Volatilization occurs in both surface water and

groundwater. Transfer of mass from the aqueous to gaseous phase reduces contaminant concentrations in surface water and groundwater.

Biodegradation

Biodegradation is a transformation process in which microorganisms break down organic contaminants. Microorganisms can break down contaminants in both aerobic (using oxygen) and anaerobic (using oxygen substitutes) environments. Microorganisms may break down contaminants directly by using them as a food source or indirectly and inadvertently by producing enzymes generated for other purposes. This biological transformation process may convert organic compounds to inorganic compounds, toxic compounds to non-toxic compounds, or non-toxic compounds to toxic compounds (Williamson and Klamut 2001).

In water, organic contaminants in contact with microorganisms produce a demand for oxygen known as biological oxygen demand (BOD). This demand decreases the oxygen available for other uses, such as by plants and fish in surface water. Biodegradation of contaminants in groundwater can occur naturally or be induced by the addition of substrates (food) or non-resident microbes.

Abiotic Transformation

In surface water, sunlight can degrade contaminants. This process is photodegradation or photolysis. Absorption of sunlight causes a chemical reaction resulting in transformation of contaminants to other compounds (Williamson and Klamut 2001).

Hydrolysis is a chemical reaction in which organic contaminants react with water or a hydroxide ion, resulting in replacement of a group (e.g., halides, alcohols, amines) by a hydroxyl ion (OH) and formation of a new carbon-oxygen bond. Hydrolysis breaks down contaminants into smaller molecules. The half-lives of organic contaminants undergoing hydrolysis range from seconds to thousands of years (Liu and Liptak 2000.).

Oxidation-reduction occurs when organic contaminants either gain oxygen and lose hydrogen (oxidation) or gain hydrogen and lose oxygen (reduction). The most significant abiotic transformation processes for contaminants such as TCE, for example, typically occur in the presence of reduced minerals, such as iron sulfide (FeS).

Inorganic compounds are not subject to degradation. However, geochemical conditions such as pH and oxygen reduction potential (ORP) influence the speciation (valence-state) of metals, which may affect both their toxicity and mobility.

5.2 Fate and Transport of Site Contaminants

Discussed below are the expected fate and transport of CFS contaminants in groundwater, air, surface water, and sediment.

5.2.1 Groundwater

Organic Contaminants (VOCs/SVOCs/Pesticides)

Benzene and 1,4-dioxane are soluble, mobile by advection, diffusion, and dispersion, and tend not to sorb to particles. 1,4-dioxane is miscible (completely soluble) and is less likely than benzene to sorb to any particulate matter. Benzene is subject to degradation, and biotic and abiotic transformation processes including volatilization. 1,4-Dioxane on the other hand, is not. Although transport of both

of these VOCs is for the most part, unimpeded, benzene is aerobically degraded en route via several different mechanisms, while 1,4-dioxane migrates unaltered.

At CFS, both benzene and 1,4-dioxane originate in the landfill waste. The highest 1,4-dioxane concentrations originate at the North Waste Cell; in contrast, the highest concentrations of benzene are centered near the northeast corner of the landfill. Both of these high concentration areas are close to the preferential groundwater flow pathways identified via the Willowstick® survey. In overburden and bedrock groundwater, 1,4-dioxane will move with groundwater flow unaffected through pore spaces in the overburden and fractures, joints and preferential flow paths in bedrock and form the leading edge of the plume. Transport mechanisms for benzene will be similar, but some will sorb to organic particulate matter in the overburden, some will volatilize in the presence of oxygen and some will aerobically biodegrade. If released at the same time, benzene will lag behind 1,4-dioxane and concentrations will tend to reduce over time from transformation processes. Reductions in 1,4-dioxane concentrations will generally result from dilution, with limited contributions from transformation mechanisms such as biodegradation, which usually occurs, if at all, via cometabolism.

TCE is a chlorinated ethane and its recent history at CFS has been one of infrequent, low-concentration detections. The highest TCE concentrations occur at the northeast corner of the landfill. The North Waste Cell area is devoid of TCE detections. TCE is highly volatile, only partially soluble, and heavier than water. When released from the landfill waste it will sink in groundwater, although concentrations have never been high enough to suspect a DNAPL pool. Adsorption is not a significant attenuation mechanism and little, if any, adsorption occurs in fractured, metamorphic bedrock. Although TCE is frequently subject to reductive dechlorination, there is little evidence this has occurred at CFS, with very infrequent detections and low concentrations of breakdown contaminants such as DCE and vinyl chloride. It is possible TCE marginally diffused into the non-porous rock matrix decades ago after release from buried waste near the northeast corner of the landfill, which has been acting as a low concentration source area over time.

DEHP, a semi-volatile leaching from many plastics and the enteric-coatings of solid oral drug products in the landfill, sorbs to particulates as the primary means of transport. At CFS, it is as widespread as 1,4-dioxane, but it is present only at very low concentrations. Although DEHP is biodegradable, the plastics buried in the landfill and drug coatings are on-going sources. Its wide extent is likely a result of many decades of continuous leaching rather than site-specific fate and transport mechanisms. It is noteworthy that DEHP can be problematic to delineate and therefore, to theorize site-specific fate and transport processes. DEHP is also a common laboratory contaminant, can be an artifact of sampling and analysis procedures (WIDNR 2002), and may be released from PVC. PVC is one of the primary construction materials for monitoring wells. Petroleum constituents such as benzene can act as solvents for DEHP. In one Wisconsin Department of Natural Resources study, detections of DEHP were associated with well casing degradation, sample tubing degradation by iron bacteria, and well casing abrasion from insertion of sampling equipment (WIDNR 2002).

Alpha-BHC (aka alpha-HCH) is a chlorinated pesticide. Although there is the potential for it to have originated on site, historical agricultural uses of the site and surrounding area are potential sources in addition to the landfilled waste. Alpha-BHC detections are infrequent, and concentrations are minimally above the GWQS of 0.02 µg/L. Its plume footprint at CFS is small relative to the other COCs. Alpha-BHC is not soluble; it is heavier than water and can be present as DNAPL, although there is no suspicion of DNAPL at CFS. It will sorb to particulates, which is likely its means of groundwater transport. It is stable and persistent, with the primary transformation process being hydrolysis. Hydrolysis is significant for alpha-BHC in warm climates, but is insignificant in cold ones.

In a temperate climate such as that at CFS, hydrolysis may play a moderate role in degradation during the warmer months.

Inorganic Contaminants (Metals)

The primary factor influencing the fate and transport of metals is their speciation and adsorption capacity, affected by, and changing with, the geochemistry of the environment. The degree to which a metal will adsorb depends on a complex combination of competing ions, organic carbon content, cation exchange capacity, and metal speciation, which is, in turn affected by such factors as pH and redox potential. In instances where metals are present in solution with other ions, competition for sorption sites on soil particles or on organic material may enhance the mobility of weakly sorbed metals. Because inorganic compounds tend to adsorb to soil, sediment, and/or rock, leaching usually results in transportation only over short distances (EPA 1982; Welch et al. 1988). This is not evident from the extent of the inorganic plumes at CFS.

Arsenic's primary transport mechanism is adsorption to particles in groundwater, although soluble forms of arsenic can advect, diffuse, and disperse. Arsenic concentrations above the 3 µg/L GWQS occur in three separate lobes of a plume at and near CFS, and extend to the investigation boundary. Just as is the case of alpha-BHC, arsenical pesticide use associated with historic agricultural activities may be a contributing source to the widespread but low concentrations of arsenic.

Chromium concentrations exceeding the 70 µg/L GWQS have the narrowest footprint at CFS. Detections and exceedances have no particular trend at any monitoring well locations. Presence along the preferential groundwater flow paths northeast of the landfill is the only commonality with the other COCs. Like arsenic, there are soluble forms of chromium that can advect, diffuse, and disperse, but the primary transport mode is adsorption to particulates in groundwater. Unlike arsenic, chromium exceedances are limited in extent and confined in a narrow band northeast and to the west of the landfill. The narrow chromium plume shape is more representative of advective transport with particulates within major fracture zones rather than a soluble form transported by advection, diffusion, or dispersion.

Lead solubility ranges from 30 µg/L to 500 µg/L, although most transport is as colloidal or undissolved particles. Lead is the only groundwater COC that is also a surface water COC. It is not present in surface water samples collected from background locations. These findings are evidence of groundwater discharge to surface water within each of the streams with headwaters downgradient of CFS. Detections in surface water are likely representative of advective, diffusive, and dispersive transport in groundwater rather than transport on colloids up through sediment to surface water. Further discussion is in Section 5.2.3 below.

Groundwater Fate and Transport Summary

CFS groundwater COCs are rather a unique set. Many Superfund sites, including landfills, have groups of chlorinated solvents or other related classes of compounds like PAHs. At Combe, there are few, if any, relationships between the individual COCs:

COC	Chemical/Element Class	Primary Transport	Primary Fate(s)
1,4-dioxane	Ether	Advection	Recalcitrant
Benzene	Aromatic hydrocarbon	Advection	Volatilization, Biodegradation
TCE	Halogenated hydrocarbon	Advection	Reductive dechlorination
DEHP	Phthalate	Adsorption	Biodegradation
Alpha-BHC	Organochloride isomer of HCH	Adsorption	Recalcitrant, Hydrolysis
Arsenic	Metalloid, member of the phosphorus family	Adsorption	Biotransformation, Oxidation-reduction
Chromium	Refractory metal, member of the transition metals	Adsorption	Reduction from Cr6 to Cr3
Lead	“Other” metal, member of the carbon family	Adsorption	Limited biotransformation

1,4-Dioxane is an ether, benzene is an aromatic hydrocarbon, TCE is a halogenated hydrocarbon, and DEHP is a phthalate. Despite all of their differences, the COC groundwater plumes are similar in shape, position, and extent relative to the landfill except for perhaps chromium having fewer similarities. 1,4-Dioxane concentrations are highest at the North Waste Cell with the plume moving both northeast and southwest. Benzene and TCE concentrations are highest at the northeast corner of the landfill, opposite the location of the North Waste Cell. Both of their plumes move preferentially in the same directions.

It is evident that preferential flow paths comprised of large fracture zones in conjunction with the nature of the bedrock in the valley bisecting CFS, as opposed to that on the parallel ridges, is what defines the shapes and extents of all of the COC plumes. Transformation processes attenuate the extents of individual COC plumes by reducing concentrations and limiting mobility of some COCs. 1,4-Dioxane is limited primarily by dilution at the furthest extents of the plume.

5.2.2 Air

TCE, benzene, and 1,4-dioxane are VOCs. VOCs volatilize to the atmosphere and, in the unsaturated soil zone, to the pore spaces between soil particles. Volatile chemicals dissolved in groundwater volatilize into the overlying unsaturated zone as contaminants move with groundwater flow. Vapors move through the unsaturated zone pore spaces, often along preferential flow pathways such as zones with higher porosity and permeability. As vapors move through the unsaturated zone, they can enter structures, such as homes, potentially affecting air quality. Vapor movement may also be affected by differential pressure gradients, either natural (e.g., caused by weather changes) or manmade (e.g., pressure differences inside and outside structures). 1,4-Dioxane has a moderate vapor pressure but its affinity for water keeps it in solution and makes it less problematic in the vadose zone than other VOCs. It may be non-detect in soil vapor samples (Mohr 2013).

5.2.3 Surface Water/Sediment

The transport processes governing contaminants in surface water are advection, diffusion, and sorption to suspected sediment (Mohr page 129). Groundwater discharge transports organic and inorganic contaminants to surface water in the four investigated streams. Contaminants in sediment

are more likely the result of historic discharges of storm water runoff from the landfill before capping and/or from “urban” storm water runoff. Storm water runoff may contain dissolved contaminants or those adsorbed to particulate matter. At CFS, primary transport of dissolved and adsorbed contaminants is via overland flow to drainage ditches and surface water bodies where the heavier particles may sink and become part of the sediment.

Comparison of the groundwater COCs to the surface water and sediment COCs indicates that 1,4-dioxane is the only organic COC found in both groundwater and surface water. It was absent in sediment. Its presence in surface water is a result of the on-going discharge of 1,4-dioxane-contaminated groundwater to surface water in Trout Brook, Lamington River UNT, and Tanner’s Brook UNT. Its presence in East Trout Brook is also a result of the treatment plant conveyance (discussed in Section 5.4). Because the upper portion of East Trout Brook is a losing stream, treatment plant effluent with elevated concentrations of 1,4-dioxane may at times infiltrate to groundwater in this section of East Trout Brook, as detailed in Section 5.4.2.

The other organic COCs – benzene, TCE, DEHP, and alpha-BHC – are less widespread in groundwater than 1,4-dioxane, are present at very low to relatively low concentrations in groundwater, and were not detected in surface water or sediment.

Lead is the only metal COC in both groundwater (Figure 8-6) and surface water (Figure 4-6 and Table A-2 in Appendix A). Its presence in the furthest upstream surface water samples from the Tanners Brook and Lamington River UNTs may be a result of discharge of lead-contaminated groundwater to these streams. Lead is not present in the sediment samples from these locations.

Lead and arsenic are the only COCs in both groundwater and sediment. Sediment sample locations closest to the landfill in all four streams did not contain lead or arsenic at concentrations exceeding the freshwater LELs. The lead groundwater plume is coincident with three sediment sample locations containing lead above the LELs and the arsenic groundwater plume is coincident with two sediment sample locations containing arsenic above the LELs. It is undetermined if contaminated groundwater discharging to surface water at these separate locations contributed to the sediment contamination. Both lead and arsenic are ubiquitous in the environment, particularly in sediment, and other sources such as agricultural and urban storm water runoff contribute.

Other than groundwater discharge, overland flow (storm water runoff) could transport contaminants as particles or dissolved constituents in runoff and result in surface water and/or sediment impacts. Since the mid-1990s, the landfill cap has eliminated contaminant transport via overland flow from the landfill to the streams. Historic overland flow from the landfill to the streams resulted in sediment impacts, but decades of storm flows in these small streams may have transported historically contaminated sediments further downstream outside the RI study area.

5.3 Conceptual Site Model

The CSM integrates the different types of information collected during the RI, including site background, setting, geology, hydrogeology, and the type and extent of contamination. The CSM “paints a picture” of what is occurring above, at and beneath the surface with respect to contaminants and their movements in relation to CFS. Figure 5-1 provides a graphical representation of the CSM.

5.3.1 Sources of Contamination

In the CSM, the waste buried within the confines of the landfill is the main source of contamination at CFS. The highest concentrations of 1,4-dioxane are at the remaining portion of the former North

Waste Cell. In contrast, the highest concentrations of benzene and TCE are in an area around the northeast corner of the landfill. These source areas are components of the landfill waste that happen to consist of buried materials with slightly different profiles – enough to distinguish between them with analytical data.

Landfill Waste

The landfill was a municipal refuse and solid waste landfill, used for the disposal of household and industrial wastes, animal carcasses, sewage sludge, septic tank wastes, chemicals, and waste oils. Additionally, large amounts of PPCPs wastes were disposed of, most notably in the North Waste Cell area, but not exclusively in that location.

Placement of waste was directly onto fractured bedrock within the landfill and a portion of the waste rests within the unconsolidated aquifer. The landfill cap and groundwater collection and treatment system are operational. The collection system is mostly limited to recovering from the bottom of the overburden (only the screen for recovery well RW-T is in bedrock).

North Waste Cell

The North Waste Cell was an area immediately outside the landfill cap to the north; its presence was unknown at the time of landfill closure with the construction of the cap in late 1995. The date/period over which waste was placed in North Waste Cell area is not known; however, the area existed outside the cap for 11 years after the landfill was closed (i.e., installation of the cap) and was a continuing source of groundwater contamination until it was partially excavated in mid-2006. During the excavation and removal of the North Waste Cell, the section of the shallow groundwater recovery system on the northern perimeter of the landfill was dormant for almost three years, until early 2009.[54]

Reports of the North Waste Cell area cleanup also indicated the presence of additional related waste underneath a portion of the gravel perimeter road adjacent to the North Waste Cell.

Possible Buried Drums within the Capped Landfill

Buried drums potentially exist within portions of the capped landfill, remaining at the time of closure. Drums encountered during early exploratory test trenching may have remained in place during the construction of the landfill cap. The possible drum areas are the northeast and southwest-central corners of the landfill. The geophysical survey (Section 2.1.1.2) did not provide evidence of this, nor were contaminants indicative of buried drums detected in soil samples collected adjacent to these areas. The former North Waste Cell, the North Waste Cell remains, and the potential buried drum areas are former sources and potential existing sources of contamination in addition to the main (capped) landfill body.

5.3.2 Migration Pathways

Two hydraulically connected aquifers, an unconfined overburden/saprolite aquifer and a fractured bedrock aquifer, exist at CFS. The fractured bedrock aquifer is artesian in places. Contamination from the sources identified in the previous section enters either into the overburden/saprolite aquifer and then into the bedrock aquifer, or directly into the fractured bedrock aquifer (placement of waste within the landfill was directly on the fractured bedrock surface, which provides direct conduits for

[54] The original recovery wells in the vicinity were removed in March 2006 and a replacement recovery well and force main became operational in January 2009 (NJDEP 2011a).

leachate and contaminated shallow groundwater into the bedrock aquifer). Transport of COCs is also from groundwater into surface water in gaining stream segments via impacted groundwater discharging to surface water (i.e., Trout Brook, Lamington River UNT, Tanner's Brook UNT, and portions of East Brook Trout). In addition, the GWTF conveys 1,4-dioxane-impacted groundwater to surface water, because the recovered groundwater cannot be treated effectively for 1,4-dioxane (the presence of 1,4-dioxane was not known at the time the treatment system was designed). Discharge of treatment plant effluent containing 1,4-dioxane at concentrations above the previous ISGWQSs and the current GWQS is to the upper portion of East Trout Brook since the plant became operational in 1997.

5.3.2.1 Migration of Groundwater and Contaminants

Since placement of waste materials was in the overburden/saprolite layer and directly on bedrock, investigation of the migration of groundwater contaminants in both the shallow overburden and bedrock aquifers has taken place.

5.3.2.1.1 Overburden Aquifer

As described in Section 3.6.2.1.1, groundwater flow in the shallow, unconsolidated aquifer at CFS has three components:

1. Horizontal flow outward from the landfill (generally following topography towards surface water bodies);
2. Flow along the bedrock surface from higher to lower top of bedrock elevations at the overburden/bedrock interface; and
3. Vertical flow towards the bedrock interface and into mostly steeply dipping bedrock fractures; downward flow near the landfill, and upward flow near the streams.

The horizontal flow direction of shallow groundwater is nearly radial in all directions from higher elevations at and near the landfill, as shown on Figures 3.9 and 5.1. This is the reason for the semi-circular design of the GWTF recovery wells, to capture overburden groundwater and leachate around the landfill perimeter; however, only one recovery well extends into the bedrock aquifer, and the GWTF does not capture all overburden groundwater.

Groundwater flow at the bedrock interface generally follows the elevation of the bedrock surface. Two bedrock surface highs beneath the northwest and southeast portions of the landfill frame the sides of a bedrock surface low that developed at the contact between two rock types and crosses CFS from southwest to northeast (Figures 3-3 and 5-1). The bedrock interface along this low slopes to the northeast and southwest from a divide along the landfill's northern perimeter[55] and marks a major fracture zone. From the divide, groundwater at the overburden-bedrock interface will flow to either the northeast (towards Schoolhouse Lane and the Lamington River UNT) or to the southwest (towards Trout Brook).

Downward flow from the overburden to the bedrock aquifer occurs at the landfill and in the immediate vicinity (Sections 3.6.2.2.1 and 3.6.2.3). Wells further from the landfill, especially in the low-lying area between the landfill and Schoolhouse Lane, and wells closer to discharge features generally demonstrated upward flows, with some wells being artesian (Figure 5.1).

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[55] The exact location of the divide is uncertain because of the lack of borings and depth to bedrock in the east-central portion of the landfill (Figure 3-8). The divide may be further south than determined during the RI.

5.3.2.1.2 Bedrock Aquifer

Once in the bedrock aquifer, groundwater moves downward and horizontally in recharge areas, and predominantly upward and horizontally in discharge areas, emptying into seeps and gaining streams around the landfill (Figures 3-10a through 3-10d, and 5-1); however, these streams are not boundaries to groundwater flow.

Structure, namely fractures, controls groundwater flow in the bedrock aquifer. As the results of the RI activities (including FLUTe™ hydraulic profiling, packer testing, and aquifer and formation characterization, Section 3.6.2.2.2) confirmed, the bedrock fractures are numerous, frequently large, have high (steep) angles and extend to depths of over 600 feet bgs. They act as steeply dipping pipes that transport contaminants in groundwater downward and away from the landfill.

The borehole geophysical investigation (Section 3.4.2.2.2) confirmed the northeast-southwest orientation of the bedrock regional strike that results in predominant flow pathways in those directions. Flow in other directions is less pronounced, but not absent. As bedrock groundwater flows in multiple directions away from the landfill, which is a local topographic high, it transitions from downward flow to predominantly upward flow in proximity to the streams. Outside of the landfill, downward flow from the overburden to the bedrock aquifer is also predominant. Geophysical testing during the RI and previous investigations demonstrated downward flows at wells on and in the immediate vicinity of the landfill. Wells further from the landfill, especially in the low-lying area between the landfill and Schoolhouse Lane, and wells closer to discharge features generally demonstrated upward flows. Two deep boreholes installed during the RI near Schoolhouse Lane and five previously existing wells south of CFS near Parker Road were artesian and discharged above the ground surface.

Streams near CFS are gaining with the possible exception of the upper portion of East Trout Brook, which is a losing stream at times. Discharge of contaminated groundwater to the streams around the landfill is evident due to the presence of 1,4-dioxane in surface water samples. Contaminated groundwater upwells through stream sediment and enters surface water. The only exception is the stream segment where the landfill treatment plant conveys its effluent (Figure 2-2a). In this limited area, at times the stream may lose 1,4-dioxane containing surface water to the shallow aquifer below.

Three preferential flow paths, running southwest to northeast from the northern side of the landfill to Schoolhouse Lane and the Lamington River UNT, were identified as a result of the Willowstick® Electromagnetic Survey (Section 3.6.2.2.3 and Figure 3-11). The flow path numbering order follows the measured electric current intensity as flow paths #1 through #3.

Two of the flow paths are west of the transmission lines (FP #1 and #3) and converge near wells CF-206D and CF-207D. The third flow path (FP #2) is east of the transmission lines and crosses through the former planned Millstone Crossing development (now the Chester Township Parker Preserve) before turning north to converge with the combined west side flow paths near well CF-204D at Schoolhouse Lane and the Lamington River UNT. From there, the combined flow path appears to bend east (continuity to the north was investigated but not found). The three identified preferential flow paths follow nearly vertical fracture zones, tilt downward (i.e., increase in depth) away from the landfill, and have both shallow (near surface) and deep (bedrock) components.

The identified preferential pathways provide conduits for the migration of contaminants from the landfill to the northeast, towards Schoolhouse Lane and the Lamington River UNT. Five monitoring wells (from the landfill to Schoolhouse Lane: CF-209D, CF-227D, CF06D, CF-207D, and CF-204D) are along FP #1. The highest 1,4-dioxane concentrations detected during the RI were for well CF-

209D along FP#1 (350 µg/L), and the other four wells had maximum concentrations of between 35 and 93 µg/L (the latter at well CF-204D, closest to Schoolhouse Lane).

Along FP #2, earlier groundwater investigations of deep boreholes for a planned residential development identified benzene and TCE contamination (1,4-dioxane was not detected at the time, however, the detection limit was elevated to 100 µg/L; Berger 2010; Section 1.6). During the RI, the three wells along FP #2 at the northeast landfill boundary and in the Parker Preserve (CF-2011D, CF-228D, and CF-205D) had maximum 1,4-dioxane concentrations of between 14 and 24 µg/L.

Figure 5-1 provides a conceptual representation of the preferential transport through fracture networks.

Although bedrock groundwater predominantly flows through preferential flow paths along strike NNE towards the Lamington River UNT, it also flows to lesser extents radially from the landfill area, south to East Trout Brook and Trout Brook, and west to the Tanners Brook UNT.

In addition to the natural fracture zone pathways, a number of manmade conduits have facilitated the vertical movement of groundwater and transport of contaminants for over a decade. These include the boreholes for potable wells installed on the property northeast of the landfill in early 2004 which were cased to 200 feet bgs, but are open boreholes from that depth to the bottom (up to 748 feet bgs). Also included are monitoring wells at and near the landfill not constructed according to NJDEP well construction regulations. These may act as conduits for contaminants from the landfill to the overburden and shallow bedrock aquifers. For example, casing not installed into competent bedrock, and/or long, open boreholes serving as direct conduits for vertical movement of groundwater between the overburden and/or bedrock fracture zones.

5.3.2.2 Surface Water Migration

The results of the investigation of groundwater/surface water interaction conducted during the RI indicated that stream segments near CFS are mostly gaining flow from groundwater (Section 3.5). Discharge of contaminated groundwater to the gaining streams around the landfill is also indicated by the presence of 1,4-dioxane and lead in surface water samples. The presence of COCs in surface water confirms upwelling of contaminated groundwater through stream sediment, entering surface water in the streams and in seeps (Section 5.3.3). After the impacted groundwater discharges to surface water, contaminants dilute from sources of clean water entering the streams, such as precipitation and overland flow from storm water runoff, and shallow and deep groundwater originating from areas other than the landfill. The more volatile contaminants will transfer to the atmosphere and less volatile and recalcitrant compounds, especially 1,4-dioxane, will be transported downstream while undergoing dilution. In addition to volatilization, other processes, such as hydrolysis and photolysis are also active for some of the COCs, but not all. Contaminants adsorbed to particles in surface water (e.g., inorganics) can settle out, resulting in sediment impacts. High-velocity flow can scour contaminated sediment, re-suspend the sediment as solids in surface water, and transport it further downstream along the streambed. Refer to Figures 4-6 and 4-7 for the known distribution of metals and 1,4-dioxane in surface water.

5.3.2.3 Impact of Surface Water Infiltration on Groundwater

Surface water infiltrating from losing stream segments during the driest times of the year may recharge groundwater. In the case of uncontaminated surface water, infiltration and recharge would result in dilution of groundwater contaminants. If surface water is contaminated, it may have an additive, but insignificant effect on already impacted groundwater. As stated in Section 4.2.2.1, East

Trout Brook samples had 1,4-dioxane concentrations ranging from 21 µg/L to 61 µg/L. The concentrations at the most upstream location, closest to the treatment plant effluent discharge[56], were 35 µg/L for both the dry and wet weather samples, and 1,4-dioxane concentrations increased to 61 µg/L in the middle section and to 40 µg/L further downstream at the sampling location near Parker Road. The increase in concentration at the middle section of the stream may indicate discharge of impacted groundwater to this stream segment. Lower concentrations in wet weather samples at the downstream locations (22 µg/L and 21 µg/L, respectively), may be attributed to dilution with storm water runoff entering the stream.

5.3.3 Receptors

A summary of the potential risks to the current and future adult and child residents and current/future adult and child recreational users is included in Section 6 of this report. Also addressed are the risks of exposure to COPCs in groundwater used by residences and recreational exposure to COPCs in surface water. Section 7 provides a summary of ecological receptors and associated exposure risks.

5.4 Fate and Transport Summary

Fate and Transport Summary for CFS COCs				
Contaminant	Advection/Diffusion/ Dispersion/Dilution	Sorption/Facilitated Transport	Biodegradation	Abiotic Transformation/ Volatilization/ Photolysis/Hydrolysis
Recalcitrant Organics				
1,4-Dioxane	Miscible (completely soluble) in water. Will readily dilute, advect, diffuse and disperse	Migrates rapidly in groundwater. Prefers not to sorb	Cometabolism may be effective. In theory directly metabolized by indigenous microbes, but insignificant	Highly soluble therefore less likely to volatilize. Photolysis not expected to occur. Resistant to hydrolysis
alpha-BHC/alpha-HCH	Not soluble. Not expected to advect, diffuse or disperse. Heavier than water, can occur as DNAPL	Will sorb to particulates	Stable and persistent in the environment	Not volatile. Resistant to photolysis. Hydrolysis occurs; more prevalent in warmer climates
Organics				

[56] The November 2014 discharge monitoring report for the treatment plant (NJDEP 2014) showed 29 µg/L 1,4-dioxane in the effluent for a sample collected the week before collection of the dry weather surface water sample, and 30 µg/L the week after collection of the wet weather surface water sample.

Fate and Transport Summary for CFS COCs				
Contaminant	Advection/Diffusion/ Dispersion/Dilution	Sorption/Facilitated Transport	Biodegradation	Abiotic Transformation/ Volatilization/ Photolysis/Hydrolysis
Benzene	Moderately soluble in water. Dissolved portion will dilute, advect, diffuse and disperse. Soluble in oil. Lighter than water. Can be present as LNAPL (not known or expected at CFS)	Does not readily sorb to sediments or suspended solids in surface water (WebWiser 2018). Tendency to adsorb to organic aquifer solids (ATSDR 2007b)	Can be completely biodegraded aerobically in water, but not anaerobically	Highly volatile. Volatilization ½ life in model river is 1 hour. Hydroxyl radical reaction ½ life of 103 days in aqueous media (WebWiser). Subject to indirect photolysis (ATSDR 2007b)
TCE	Low solubility. Dissolved portion will dilute, advect, diffuse and disperse. Heavier than water. Can be present as DNAPL (not known or expected at CFS)	Weakly sorbed	Reductive dechlorination to other toxic compounds, usually incomplete. Degradation product of PCE	Highly volatile. Photolysis not significant. No hydrolysis.
DEHP (ATSDR 2002)	Dissolved portion will dilute, advect, diffuse and disperse. Presence of fulvic acid increases solubility and mobility	Most of it sorbs to particulates which provide transport	Biodegradation under aerobic conditions, ½ life in river water of 1 month	Not volatile. Photolysis and hydrolysis insignificant
Inorganics				
Arsenic (ATSDR 2007a)	Soluble forms move with water. Dissolved portion will dilute, advect, diffuse and disperse. Transport in storm water runoff to surface water and suspended sediment	Can be absorbed onto clays, Fe oxides, Al hydroxides, Mn compounds and organic material. Groundwater concentrations typically controlled by adsorption	Biotransform-ation by aquatic microorganisms from arsenate to arsenite, and in sediments methylate As under aerobic and anaerobic conditions	Oxidation-reduction reactions, ligand exchange, precipitation. Arsenical pesticides not degraded by photolysis or hydrolysis

Fate and Transport Summary for CFS COCs				
Contaminant	Advection/Diffusion/ Dispersion/Dilution	Sorption/Facilitated Transport	Biodegradation	Abiotic Transformation/ Volatilization/ Photolysis/Hydrolysis
Chromium	Soluble forms move with water. Dissolved portion will dilute, advect, diffuse and disperse. Transport in storm water runoff to surface water and suspended sediment	Suspended solids absorbed to clay, organics or Fe oxide in water	Possible microbial reduction from Cr6 to Cr3	A few inorganic and organic substances reduce Cr6 to Cr3. Aerobic reduction from Cr6 to Cr3 in water by Fe+2 ions and organic matter. Oxidizing conditions for Cr6 in shallow groundwater
Lead	Most transported as colloidal or undissolved particles in flowing water or in storm water runoff. Solubility from 30 µg/L to 500 µg/L. Dissolved portion will dilute, advect, diffuse and disperse	Sorbs to polar particulate matter in surface water	Biotransform-ation to tetraethyl lead via alkylation of organic and inorganic lead in anaerobic sediments	Some forms subject to photolysis and volatilization in water, degrading to more persistent forms

Contamination originating at CFS enters the overburden and bedrock aquifers, shallow and deep groundwater flows transport it outward, and it predominantly discharges to surface water in the surrounding area, although some portion of the contamination remains in the bedrock aquifer. Along the migration pathways, benzene undergoes biodegradation and volatilization from the groundwater table and surface water, while 1,4-dioxane, which is less volatile, does not biodegrade, or sorb to organic matter, does not. Transport of 1,4-dioxane is with minimal attenuation through these migration pathways. TCE is subject to reductive dechlorination, which is not evident at CFS. DEHP tends to sorb strongly to particulates, has low solubility, and will biodegrade in both water and soil under aerobic conditions. Transport of inorganics such as arsenic, chromium and lead, will be via adsorption to particles along the groundwater pathway and will have the potential to accumulate in stream sediments.

Contaminant transport pathways at CFS are complete if humans come into contact with contaminated ground and surface waters or if wildlife comes into contact with contaminated surface water and sediment. Humans previously ingested contaminants when consuming water from potable wells, and inhaled and contacted contaminants when showering. However, connection of affected residences to a municipal water supply severed this pathway. Wildlife ingests contaminated surface water and to a lesser extent, sediment when drinking or feeding on aquatic species.

The soil and soil vapor pathways at CFS are incomplete. The landfill and perimeter road act as a cap on the contaminated soil, preventing direct contact, ingestion, and inhalation. The NJDEP and EPA vapor intrusion investigations found an incomplete soil vapor pathway and no impacts from vapor intrusion to indoor air at residences in areas of contaminated groundwater.

6 Summary of Baseline Human Health Risk Assessment

The BHHRA is summarized in this section, which includes a description of the approach, receptors and results. The BHHRA report text, tables, and figures are in Appendix CC; the attachments are in the full report submitted to EPA separately.

Note that in the RI for purposes of delineation, the acronym "COC" is used to identify constituents exceeding promulgated standards or other criteria at a frequency of five percent or greater of the total number of samples. In the BHHRA, the constituent of potential concern (COPC) acronym is used to describe those constituents identified in the Pathway Analysis Report (PAR) whose maximum detected concentrations are greater than applicable human health risk-based screening levels or for which a risk-based screening level does not exist. The BHHRA further evaluates these COPCs to determine how many of the COPCs actually contribute to an excess lifetime cancer risk (ELCR) or HI exceeding acceptable levels, in accordance with EPA guidance.

6.1 Introduction

The BHHRA was conducted in accordance with the scope provided in Subtask 7.1 of the original RI/FS Work Plan (HDR 2011b), EPA *Risk Assessment Guidance for Superfund* (RAGS, EPA 1989 and EPA 1991) and other applicable guidance. In preparation for the BHHRA, a PAR was prepared to identify the potential exposure points and routes of exposure for each exposure pathway, as well as parameters regarding human receptor characteristics and behavior (e.g., body weight, ingestion rate, and exposure frequency) and toxicity criteria (HDR 2015b).

6.2 Data Refinements

Section 2 of the RI report describes the collection and analysis of samples. HDR reviewed and compiled the groundwater, surface water, sediment, and soil data in the DER[57], to determine whether the data met the data quality indicators of the QAPP, to identify data gaps, and determine the usability of the data before conducting the BHHRA.

The BHHRA excludes certain groundwater data to meet the requirements in the EPA memorandum titled *Determining Groundwater Exposure Point Concentrations, Supplemental Guidance*, OSWER Directive 9283.1-42 (EPA 2014a). This memorandum specifies which groundwater data are acceptable for calculating the exposure point concentrations based on the type of well sample (e.g., monitoring well) and data quality (e.g., low turbidity).

6.3 Exposure Assessment

6.3.1 Human Health CSM

The BHHRA includes a human health CSM to identify each human receptor population and the exposure pathways potentially present at the Site. Figure 4-1 in Appendix CC is a schematic presentation of the CSM.

[57] The text, tables, and figures of the DER are in Appendix B. The full report was provided to EPA separately.

Current land-use consists primarily of low-density residential (lot sizes are generally more than two acres) amidst large parcels of cleared or forested rolling hills. Use of some of the larger parcels is for agricultural purposes. Expectations of future land use are the same - to remain predominantly residential with limited agriculture. Therefore, HDR identified the following potential receptors and exposure pathways: current/future adult and child resident's exposure to COPCs in groundwater via drinking water ingestion, dermal contact, and inhalation of shower water pathways, and current/future adult and child recreational user's exposure to COPCs in surface water via incidental water ingestion and dermal contact.

Section 5 describes the fate and transport of COPCs for the exposure pathways in the CSM.

6.3.2 Exposure Point Concentrations

Estimates of COPC concentrations at points of potential human exposure are necessary for evaluating chemical intakes by potentially exposed individuals. The concentrations of chemicals in the exposure medium at the exposure point are termed "exposure point concentrations" (EPC).

The EPC for the BHHRA is the 95 percent upper confidence limit (UCL) of the arithmetic mean or maximum observed concentration of an individual COPC, whichever is lower, per media. Calculation of the UCL is conducted in accordance with EPA guidance (EPA 2002, 2016). HDR used the ProUCL software package, version 5.1 (EPA 2016) to determine the underlying statistical distributions and the EPCs.

The BHHRA evaluated the groundwater data in two ways:

1. Groundwater EPCs using site-wide groundwater data for the COPCs, and
2. A sensitivity analysis calculating groundwater EPCs for a subset of data with the 10 highest concentrations of the eight COPCs with exceedance counts greater than or equal to five percent: 1,4-dioxane, benzene, TCE, DEHP, alpha-BHC, lead, arsenic, and chromium (EPA 2015g).

The BHHRA also evaluated the surface water data in two ways:

1. Surface water EPCs using data from three local surface water bodies: Trout Brook, the Lamington River UNT and Tanners Brook UNT, and
2. Surface water EPCs using data from East Trout Brook for potential impacts downstream of the GWTP effluent discharge.

6.3.3 Chemical Exposure Intake

The BHHRA uses EPCs in combination with exposure factors from EPA guidance and standard default parameters (EPA 2011), including updated values (EPA 2014b, 2018b) to estimate chemical intake via each exposure pathway for each receptor.

Each of the intake variables in the above equation consists of a range of values taken from RAGS, Part A through F (EPA 1989, 2004, 2009) and other applicable risk guidance, e.g., the Exposure Factors Handbook (EPA 2011). Appendix CC provides further discussion on the exposure equations and exposure factor values for each exposure pathway.

The basis for the lead exposure evaluation is blood lead concentrations instead of calculation of chemical intakes and subsequent risk estimates. Assessment of blood lead concentrations uses

the EPA blood lead model Integrated Exposure and Uptake Biokinetic (IEUBK, EPA 2010b), discussed further in Appendix CC.

6.4 Toxicity Assessment

The toxicity assessment provides a framework for characterizing the relationship between the magnitude of exposure to a COPC and the nature and likelihood of adverse health effects that may result from such exposure. For all exposure pathways, there are two approaches for deriving toxicity values. One involves the derivation of a noncancer reference value, i.e., an oral or dermal reference dose (RfD) and inhalation reference concentration (RfC), while the other involves derivation of a predictive cancer risk estimate, i.e., an oral or dermal cancer slope factor (SF) and inhalation unit risk (IUR).

Pertinent toxicological information on COPCs was selected using a standard hierarchy that is incorporated in the EPA Regional Screening Level (RSL) tables; therefore, the May 2018 RSL summary table (EPA 2018b) is used as the source of toxicity values for this BHHRA. Refer to Appendix CC for further toxicity assessment details.

6.5 Risk Characterization

The evaluation of potential non-cancer hazards and cancer risks to residents and recreational users from exposure to COPCs in groundwater and surface water indicates several COPCs whose concentrations in environmental media contribute to the hazard and risk estimates. See Appendix CC for details of the methodology to calculate non-cancer hazards and cancer risks.

6.5.1 Resident Exposure

For a resident's exposure to site-wide groundwater, chromium, 1,4-dioxane, arsenic, benzene, DEHP, chloroform, vinyl chloride, 1,4-dichlorobenzene and 1,2-dichloroethane contribute the most to the ELCR of 1.2E-03; alpha-BHC and TCE also contribute in the Core of the Plume evaluation that has an ELCR of 6.9E-03.

For non-cancer, several COPCs contribute to total HIs greater than one, 4.0E+00 for an adult and 4.9E+00 for a child, but none of the individual HQs for these COPCs are greater than one (arsenic, chromium, cobalt, iron, manganese, benzene, DEHP and TCE), except for 1,4-dioxane with HQs of 1.4E+00 and 1.2E+00 for an adult's and child's inhalation route, respectively. For the Core of the Plume evaluation, chromium, 1,4-dioxane, DEHP, TCE and benzene have HQs greater than one, which contribute to total HIs of 1.3E+01 for an adult and 1.5E+01 for a child. Several constituents are COPCs for site-wide groundwater, but not for Core of the Plume groundwater. The Core of the Plume evaluation included only the eight COCs identified in the RI.

Evaluation of total chromium assumes it is hexavalent chromium in both scenarios; an evaluation of chromium as trivalent chromium in the Uncertainty section of Appendix CC indicates that chromium is no longer a contributor to the hazard and risks, which have decreased, but the hazards and risks remain in the same orders of magnitude.

While the initial findings indicated a potential VI concern, residents are unlikely exposed to contaminants through the VI pathway. TCE in indoor air likely originates from sources unrelated to VI, as TCE is not detected in any of the sub-slab soil gas samples nor are there TCE

concentrations in groundwater exceeding the groundwater screening level of 2 ug/L within a quarter mile or more of residences or any other structure.

A child resident's exposure to lead in site-wide groundwater was evaluated separately using the integrated exposure uptake biokinetic (IEUBK) model. The model predicted 22% of the population of children between the ages of one and six years old would be expected to have a blood lead concentration above 5 ug/dL, which is greater than the regional threshold of 5%. For the Core of the Plume evaluation, the model predicted 68% of the population.

6.5.2 Recreational User Exposure

For a recreational user's exposure to surface water from Trout Brook, Lamington River UNT, and Tanners Brook UNT, consumption of fish with arsenic contributes the most to the ELCR of 5.7E-06. The non-cancer HIs for an adult and child are below one.

For a recreational user's exposure to surface water from East Trout Brook, downstream from the GWTP permitted discharge, arsenic and 1,4-dioxane contribute most to the ELCR of 8.4E-06. The non-cancer HIs are below one.

The ELCRs calculated for exposure to COPCs are within EPA's acceptable risk range for surface waters within Trout Brook, Lamington River UNT, Tanners Brook UNT, and East Trout Brook.

For a child recreator's exposure to lead in surface water, the IEUBK model predicted 16% of the population of children between the ages of one and six years old would be expected to have a blood lead concentration above 5 ug/dL.

6.6 Uncertainty Analysis

Uncertainty is inherent in the methods, inputs, and conclusions of any BHHRA. This uncertainty results because most every step in the risk assessment process involves assumptions and unknowns, contributing to the total uncertainty in the conclusions. Appendix CC provides further discussion on uncertainties.

Appendix CC also includes an evaluation of PPCPs. HDR reviewed the TIC analytical data to determine what PPCPs were present in groundwater and surface water. Of the approximately 100 TICs detected in the groundwater and surface water, 36 of them are PPCPs or related to the manufacture and degradation of PPCPs. The impact the presence of PPCPs may have on human health risk, particularly as endocrine hormone disruptors, is included in the BHHRA report in a qualitative manner as part of the risk assessment.

7 Summary of Screening Level Ecological Risk Assessment

The SLERA is summarized in this section, which includes a description of the approach, receptors and results. The SLERA report text, tables and figures are in Appendix DD; the attachments are in the full SLERA report submitted to EPA separately.

7.1 Introduction

The SLERA was conducted in accordance with the scope provided in Subtask 7.2 of the original RI/FS Work Plan (HDR 2011b) and current Superfund ecological risk assessment guidance (EPA 1997, EPA 1998a). The SLERA characterizes the exposure setting and ecological receptor characteristics for the Site. It identifies the pathways by which populations may be exposed to contaminants identified in surface water and sediments, based on consideration of the sources and locations of contaminants, their likely environmental fate, and the potentially exposed populations.

7.2 Environmental Setting, Receptors and Exposure Pathways

7.2.1 Environmental Setting

The ecological characteristics of the Site are presented in the Wildlife Technical Memorandum in Appendix P and the Wetland Technical Memorandum – Wetland Delineation Report and Wetlands Functions and Values Assessment in Appendix Q. The physical characteristics of the Site are discussed in Section 3 of the RI report.

The SLERA evaluated surface water and sediment data from the four surface water bodies with headwaters near the landfill, i.e., Trout Brook, East Trout Brook, the Lamington River UNT, and Tanners Brook UNT. Evaluation of East Trout Brook data is separate from that for the other surface water data to determine if there are any impacts to surface water quality from the GWTP effluent discharge into this stream. The SLERA also evaluated seeps/springs water as there is evidence that groundwater is discharging to seeps and springs near the Site.

The usability of the surface water, seeps/springs water and sediment data was evaluated in the DER, which is provided in Appendix B, prior to conducting the SLERA.

7.2.2 Ecological CSM

The SLERA includes an ecological CSM to identify each ecological receptor group and the exposure pathways potentially present at the Site. Figure 4-1 in Appendix DD is a diagram of the ecological CSM. The fate and transport of COPCs for the exposure pathways in the CSM are described in Section 5 of the RI.

7.2.3 Assessment and Measurement Endpoints

Assessment and measurement endpoints are chosen as to adequately protect the local populations at the Site and those identified in the ecological CSM.

The assessment endpoints for this SLERA include:

- Reproduction, growth and survival of aquatic biota, benthic invertebrates, amphibians and plants; and

- Reproduction, growth and survival of aquatic herbivores, invertivores and piscivores.

Selection of assessment endpoints leads to the development of measurement endpoints, used to identify if any potential threats to the assessment endpoints exist.

The measurement endpoints for this SLERA include:

- Comparison of surface water and seep water/spring water concentrations, as expressions of exposure, to surface water ecological benchmarks to represent potential adverse effects to aquatic biota and amphibians;
- Comparison of sediment concentrations to sediment ecological benchmarks to represent potential adverse effects to benthic invertebrates, amphibians and plants; and
- Calculation of HQ in wildlife food chain modeling by calculating exposure doses and comparing the doses to toxicity values for aquatic herbivores, invertivores and piscivores.

7.3 Risk Characterization

7.3.1 Aquatic Biota, Invertebrates, Amphibians and Plants Evaluation

The quantitative evaluation indicates that potential adverse impacts to aquatic biota, benthic invertebrates, amphibians and plants may be associated with the surface water, seeps/springs water and sediment exposure pathways because of exposure to VOCs, pesticides and inorganics in surface water and PAHs and inorganics in sediment.

A literature review for 1,4-dioxane was performed to evaluate potential adverse effects in lieu of a quantitative evaluation, as there is a lack of tissue data, representative species with pertinent exposure factors and toxicity reference values for the COPCs. The maximum detected concentrations of 1,4-dioxane in surface water are well below the literature-derived toxicity values in the SLERA.

7.3.2 Wildlife Food Chain Modeling Evaluation

Wildlife food chain modeling, performed using maximum detected concentrations, indicates that potential adverse impacts to mammalian herbivores, avian invertivores and mammalian piscivores may be associated with exposure to aluminum, copper, lead, mercury, selenium and vanadium in the surface water and sediment from Trout Brook, the Lamington River UNT and Tanners Brook UNT. The highest No Observed Adverse Effect Level (NOAEL)-based HQ is 25 for an American mink's exposure to aluminum; the remaining NOAEL-based HQs are less than four. Potential adverse impacts to avian herbivores, mammalian invertivores and avian piscivores from exposure to the COPCs in these three water bodies are unlikely as the NOAEL-based HQs are less than one.

Evaluation of the COPCs in the surface water and sediment of East Trout Brook indicates potential adverse impacts to mammalian herbivores and avian invertivores; the highest NOAEL-based HQ is four for a spotted sandpiper's exposure to vanadium. Potential adverse impacts to avian herbivores, mammalian invertivores, avian piscivores and mammalian piscivores from exposure to COPCs in East Trout Brook are not likely as the NOAEL-based HQs are less than one.

Additional evaluation was performed to determine if COPCs would vary if more realistic assumptions were used in a Step 3A analysis. The refinements in the Step 3A analysis included 1) using 95% UCLs of the mean in the wildlife food chain modeling, 2) comparing the data to background threshold values (BTVs) and 3), using additional ecological benchmarks to determine whether or not COPCs can be eliminated from the SLERA. The Step 3A process was performed for six COPCs: aluminum, copper, lead, mercury, selenium and vanadium.

The results of Step 3A indicate that for wildlife exposure via bioaccumulation in the four local streams (Trout Brook, Lamington River UNT, and Tanners Brook UNT and East Trout Brook), the LOAEL-based HQs are less than one for all receptor groups. The one exception, the spotted sandpiper, representing avian invertivores, assuming exposure to vanadium in East Trout Brook results in a HQ of 1.7.

7.4 SLERA Summary

The evaluation of surface water and sediment exposure pathways from local streams and seep/spring pathways indicates that aquatic biota, benthic invertebrates, amphibians and plants may potentially be adversely impacted by inorganics, PAHs, 2,3,4,6-tetrachlorophenol, and alpha-chlordane.

Step 3A of the wildlife food chain modeling indicates LOAEL-based HQs less than one, except for one species, for which the result is just above one.

There is uncertainty inherent in the conclusions of any SLERA. This level of uncertainty results from the fact that most every step in the risk assessment process involves assumptions and unknowns, contributing to the total uncertainty in the final conclusions. Uncertainties and further discussion is provided in Appendix DD.

8 Summary and Conclusions

This report presents the findings of the EPA RI undertaken at the CFS Landfill Superfund Site, located in Chester and Washington Townships, Morris County, New Jersey, and a summary of the findings of previous and concurrent investigation/monitoring activities conducted by NJDEP.

CFS was a municipal refuse and solid waste landfill that accepted waste from the 1940s to 1981. Most notably, the landfill accepted chemicals, off-spec PPCPs, and pharmaceutical wastes from the pharmaceutical and PCPs industry in northern New Jersey. About five million cubic yards (5,000,000 cy) of waste material buried in the landfill sit directly on fractured bedrock. The source of contamination is leachate that originates at the landfill and migrates both vertically and horizontally, resulting in impacts to both the overburden and bedrock aquifers, and surface water in the local streams.

EPA listed CFS on the NPL on September 1, 1983. NJDEP's 1986 RI/ FS identified a wide range of COCs consistent with known past disposal practices at the landfill. The remedy selected in the 1986 ROD (EPA 1986) consisted of:

1. An alternate water supply for impacted homes;
2. Capping of the landfill in accordance with RCRA requirements;
3. An active collection and treatment system for landfill gases;[58]
4. Pumping and on-site treatment of shallow groundwater and leachate with discharge of treated water to East Trout Brook; and
5. Surface water controls; security fencing; and environmental monitoring.

Despite the 1986 ROD and subsequent closure of the landfill via capping and on-site groundwater treatment in 1995 to 1997, it was necessary to conduct additional investigations due to continuing and persistent levels of groundwater contamination. Beginning in the early 1990s, NJDEP installed, maintained, and monitored POETS as an interim remedial measure at residences in Chester and Washington Townships, pending design and construction of a public water supply system. NJDEP also established a groundwater CKE.

A 2004 soil investigation conducted by NJDEP at the northern perimeter of the landfill revealed an area outside of the landfill cap containing a significant volume of pharmaceutical wastes, personal care products, and containers. NJDEP excavated this area known as the North Waste Cell in 2006 and disposed of about 27,300 tons of non-hazardous soil and debris off-site. Construction of a landfill cap extension over this area occurred in 2008.

NJDEP's investigation of the deep bedrock aquifer began after the discovery of the North Waste Cell. In 2009, this investigation transitioned from NJDEP to EPA. The deep bedrock aquifer is the major source of potable water in the area; however, the recent (July 2015) completion of a municipal water line provides an alternate source of drinking water to impacted properties.[59] The field activities undertaken to prepare this RI took place between 2010 and 2017. The field component included the

[58] After additional sampling indicated landfill gas was not amenable to active treatment (composition and quantity), EPA revised the landfill gas system from an active to a passive system, and issued an Explanation of Significant Differences (ESD) (EPA 2006).

[59] Some property owners within the service area decided to not connect to the new municipal water supply..

installation of 19 bedrock monitoring wells, nine pairs of piezometers and stream gauges, and five soil borings. Samples collected for laboratory analysis included over 200 groundwater samples, 22 soil samples, 40 surface water samples, 53 potable well water samples, and 34 sediment samples, plus the required duplicate and quality assurance/quality control samples for each medium. Monitoring wells underwent short- and long-term water level monitoring. The field investigation also included several types of geophysical surveys – resistivity, Willowstick® electromagnetic, magnetic gradient and electromagnetic terrain conductivity to locate preferential flow pathways in bedrock and also possible buried drums in two locations at the landfill. Downhole investigations incorporated FLUTe™ hydraulic profiling, packer testing, and downhole geophysical surveys including single-point resistivity, long normal resistivity and short normal resistivity; fluid temperature; fluid resistivity; caliper; natural gamma; heat pulse flow meter; and acoustic televiewer. To inform the FS, additional field activities included a hydrogeological assessment consisting of an aquifer pump test, and a 1,4-dioxane treatment pilot test.

Because the landfill is a continuing source of groundwater contamination both inside and outside the landfill property boundary, the RI includes review and integration of NJDEP's analytical data for both groundwater and surface water.

Also included in the RI were a wetland delineation, wildlife surveys, well condition surveys and land surveys (topographic, boundary, stream cross sections, and well/piezometer horizontal and vertical locations) in support of the field investigation activities.

The CSM incorporates the results of the field surveys, field investigations, and laboratory analysis of samples to describe the nature and extent of groundwater, surface water, and sediment contamination, as well as the human and ecological risks at locations of complete pathways.

Multiple lines of evidence indicate the landfill, including the North Waste Cell, is a continuing source of groundwater contamination that is discharging to surface water. These lines of evidence include:

1. The historic waste burial practice of direct placement on fractured rock;
2. Historic and recent groundwater analytical data for the landfill and surrounding area indicating COC concentrations above standards and criteria;
3. Concentrations of three COCs - 1,4-dioxane, benzene, and TCE - were higher within the landfill property during the period of the RI (2010 through 2015) than in the surrounding area; the highest 1,4-dioxane concentrations originating at wells at the North Waste Cell, and the highest concentrations of benzene and TCE originating near the northeastern corner of the landfill;
4. Mostly different contaminants in background surface water and sediment data from locations outside the landfill's influence as compared to surface water and sediment data from within OU2;
5. Nearly radial and generally downward groundwater flow near the landfill;
6. Generally upward and sometimes artesian groundwater flow near the headwaters of several streams;
7. Detections of 1,4-dioxane in surface water;
8. Three distinct preferential groundwater flow paths in bedrock from the landfill to the northeast towards Schoolhouse Lane; and

9. Both the North Waste Cell and northeastern corner of the landfill are along the three preferential groundwater flow paths.

8.1 Nature and Extent of Contamination

The COCs for purposes of delineation in this RI are those that exceeded promulgated standards or interim groundwater quality criteria at a frequency of five percent or greater of the total number of samples, with the exception of sediment for which only screening criteria exist. Metals with aqueous standards based on secondary characteristics (i.e. appearance, odor and taste; i.e., aluminum, iron and manganese) are not treated as COCs for purposes of delineation in groundwater or surface water although these metals are evaluated in the risk assessments as COPCs.

8.1.1 Groundwater

Eight target contaminants exceeded the GWQS or IGGWQC at a frequency of five percent or greater of the total number of samples: 1,4-dioxane , benzene, TCE, DEHP, alpha-BHC, lead, arsenic, and chromium. Two TICs, phenobarbital, and TAME, exceeded the generic criteria for SOCs.

1,4-dioxane exceeded the 0.4 µg/L GWQS at 20 locations[60] in 101 samples, with concentrations up to 290 J µg/L. 1,4-dioxane is present above the GWQS in groundwater in all directions from the landfill with the exception of north. Because the criterion decreased from 10 µg/L to 0.4 µg/L subsequent to collection and analysis of the samples during Phases I through III of the RI, the reporting limit of the analytical method used at the time was greater than the current standard (0.5 µg/L vs. 0.4 µg/L). During Phase IV, the reporting limit of the analytical method was 0.1 µg/L.

HDR prepared an interpreted horizontal extent of groundwater contaminated with 1,4-dioxane above the new standard using sample locations that were non-detect and extrapolation of detected results at various distances from the landfill (Figure 8-1). The horizontal extent of 1,4-dioxane-contaminated groundwater is roughly three times longer than it is wide, and is oriented in a northeast-southwest direction. The contamination extends from the overhead transmission lines that run perpendicular to Parker Road southwest of the landfill, to County Route 513 aka Washington Turnpike to the northeast. To the west, the contamination extends to the southeastern portion of the horse farm, and to the east, it extends to Parker Road. The basis for the Parker Road limit is the lack of 1,4-dioxane contamination in the majority of potable wells along Parker Road prior to connection of Parker Road to the municipal water supply.

1,4-Dioxane was detected in the deepest intervals in many of the multi-level wells and in several conventional (single-depth screened wells); detections at 20 of 26 bedrock monitoring wells exceeded the criterion in the deepest sample interval. Vertical migration of 1,4-dioxane extends to the limits of bedrock transmissivity within each bedrock borehole evaluated, with an average depth of roughly 454 feet bgs.

As indicated on Figure 4-1C, based on analytical results for the landfill wells sampled by NJDEP, the highest 1,4-dioxane concentrations at CFS are in overburden groundwater in the former North Waste Cell area (PZ-21R, 45-95 feet bgs, 510 µg/L; Figure 1-6A). The highest concentrations in bedrock were at nearby RI well CF-209D (150-160 feet bgs), and four landfill bedrock monitoring wells with open intervals between 45 and 175 bgs exceeding 100 µg/L (Figure 1-6C).

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[60] Monitoring wells CF-209D (until January 2017) and CF-209D-R (from March 2017) are at the same location since completion of both occurred in the same borehole.

The 100 µg/L 1,4-dioxane isoconcentration line is long and narrow; it's hot spot is centered at the North Waste Cell extending northeast and southwest from this source area (Figure 8-1). To the southwest, it ends just outside the landfill cap, outside the perimeter fence. To the northeast, it is depicted as ending near well CF-227D; however, it more likely ends near well CF-204D (93 µg/L) where the three preferential flow paths merge before encountering the Lamington River UNT and groundwater flow is artesian.

Benzene exceeded the 1 µg/L criterion at six locations in 27 RI samples with concentrations up to 90 J µg/L and at maximum concentrations of 980 D µg/L in the NJDEP samples, though this is thought to be an outlier as concentrations from that well are typically much lower. The second highest concentration in NJDEP samples is 110 µg/L. The benzene plume (Figure 8-2) is roughly half the size of the 1,4-dioxane plume, but has the same general shape. Unlike the 1,4-dioxane plume, the benzene plume appears to originate near the northeast corner of the landfill, following a portion of the central preferential flow path to an area with the highest concentrations (to 110 µg/L, NJDEP samples) in wells D-2 and CF-204D. The horizontal extent is generally within the landfill footprint and the area between the landfill and Schoolhouse Lane.

Benzene exceedances were deeper than 600 feet at one location. Although most exceedances were in the shallower depth intervals, the transmissivities of bedrock fractures control the vertical extent which varies across the site at an average depth of roughly 454 feet bgs. As depicted on Figures 4-1A and 4-1B, benzene concentrations exceeded the GWQS in the deepest interval at four monitoring wells during the RI (two wells to the northeast of the landfill, near Schoolhouse Lane, and one well each to the east and west). During a 2007/2008 packer test sampling investigation at the Millstone Crossing wells northeast of the landfill (Berger 2010), well 22.12 had a benzene concentration of 9.2 µg/L at 660 to 685 feet bgs. Open boreholes drilled for potable use in this area continue to act as vertical conveyance for contaminants from shallower to deeper fracture intervals.

Review of the NJDEP PCEM analytical results indicated that high benzene concentrations also exist in the overburden aquifer in two areas; to the west side of the landfill (CF-28S and MW-1, with 18 D µg/L and 22 D µg/L. respectively) and along Schoolhouse Lane (CF-14S and CF-27S, with 27 D µg/L and 37 D µg/L, respectively; Figure 1-6A). There are high benzene concentrations in the bedrock aquifer on the eastern landfill perimeter, where two wells (CF-15D, 145-190 feet bgs, and MW-19D, 71-107 feet bgs) had concentrations of 110 D and 980 D µg/L, respectively (Figure 1-6C). Note, however, the very high MW-19D result is anomalous with other, very low benzene results from this well.

TCE exceeded the 1 µg/L criterion at five locations in nine samples with concentrations up to 4 J µg/L. Based on RI data, the TCE plume is largely confined to the footprint of the landfill with the exception of a finger extending northeast from the landfill to Schoolhouse Lane (Figure 8-3). No TCE exceedances were deeper than 215 to 220 feet (with the exception of one duplicate result of 1.1 µg/L from the 409 to 419 foot interval). Compliant intervals below the exceedances ranged in depth from 360 to 409 feet bgs. When considering the supplemental NJDEP PCEM analytical results, the TCE plume in the bedrock aquifer is slightly larger and has higher core concentrations above the GWQS (7.2 to 12 µg/L, centered on three wells in the eastern portion of the landfill; Figure 1-6C) than based on RI data alone (1.1 to 4 J µg/L). The highest concentration of TCE in the NJDEP samples from the overburden wells was 4.3 JD µg/L (MW-1, west of the landfill; Figure 1-6A).

DEHP exceeded the 3 µg/L GWQS at seven locations in 11 samples with concentrations up to 15 µg/L. The DEHP plume has two separate, far-reaching lobes. One lobe extends to the southwest and south towards the transmission lines perpendicular to Parker Road all the way to the WRA

series wells on either side of Trout Brook (Figure 8-4). The other lobe is to the northeast, where a narrow finger of the plume follows the Lamington River UNT, extending past County Route 513 to the confluence of the tributary with the Lamington River. The highest concentrations (30 to 33 µg/L) are in the area where the preferential flow paths converge near well CF-204D and groundwater flow is artesian.

DEHP exceeded the GWQS at 558 feet in one location - the deepest interval in that well (CF-206D). In the supplemental NJDEP PCEM analytical results, DEHP concentrations above the GWQS in the bedrock aquifer (3.2 JB µg/L – 7.5 B µg/L; Figure 1-6C) were below the RI results and did not contribute to the extent of the DEHP plume. In the overburden aquifer, DEHP exceeded the GWQS at only one location (MW-7, 9 B µg/L; Figure 1-6A).

Alpha-BHC exceeded the 0.02 µg/L criterion at four locations in nine samples with concentrations up to 0.073 µg/L. The bulk of the plume is generally within the landfill footprint. A portion outside the landfill to the northeast extends almost halfway to Schoolhouse Lane and a portion outside the landfill to the west extends to the southern corner of the horse farm around well CF-216D (Figure 8-5). Only the samples collected in June 2014 had alpha-BHC detections. The deepest alpha-BHC exceedance was 365 ft. bgs, the deepest interval at that location.

NJDEP does not analyze samples for pesticides as part of the PCEM sampling program. Therefore, the status of alpha-BHC in overburden groundwater is unknown.

Lead exceeded the 5 µg/L criterion at seven locations outside the landfill footprint in 11 RI samples with concentrations up to 175 µg/L. . The locations with the highest concentrations are to the northeast (Figure 8-6). This plume begins near the northeastern landfill perimeter boundary, occupies the area up to Schoolhouse Lane, and constrained in width by the confining ridges. From Schoolhouse Lane, a narrow finger of the plume follows the Lamington River UNT continuing to County Route 513 where it appears to terminate. The deepest lead exceedance was 438 ft. bgs, which was the deepest interval at that location. At the two locations to the south and southwest of the landfill where the GWQS was exceeded (CF-223D and CF-225D), the concentrations (5.2 µg/L to 6.1 J µg/L) were only slightly above the standard.

NJDEP's analytical results indicate that lead concentrations in the bedrock aquifer (concentrations up to 13 µg/L) also exceed the GWQS inside the CFS landfill, along its western perimeter, to the south, and between the landfill and Schoolhouse Lane (Figure 1-6D). As such, the lead plume in the bedrock aquifer is more extensive than based on the RI data alone. In the NJDEP overburden aquifer samples, exceedance of the GWQS was at landfill wells and wells in all directions from the landfill (Figure 1-6B). The highest concentrations were for wells in the central and northeastern sections of the landfill (11.5 and 11.7 µg/L) and at Schoolhouse Lane (13.6 µg/L).

Arsenic exceeded the 3 µg/L criterion at six locations in eight samples with concentrations up to 6.4 J µg/L. Based on the RI results, the arsenic plume (Figure 8-7) has two sections – a detached, narrow section to the northeast of the landfill beginning roughly half-way between the northeast perimeter of the landfill and Schoolhouse Lane and ending with a very narrow finger at County Route 513, and the main section roughly matching the landfill footprint in size and shape, but with a location offset from the landfill to the southwest. The deepest arsenic exceedance was 362 ft. bgs, which was the deepest interval at that location.

NJDEP's PCEM analytical results indicate that arsenic concentrations in the bedrock aquifer (to 11.1 µg/L) also exceed the GWQS inside the CFS landfill, along its western perimeter, and to the south and between the landfill and Schoolhouse Lane (Figure 1-6D). As such, the arsenic plume in the bedrock aquifer is more extensive than based on the RI data alone. In NJDEP's overburden aquifer

samples, arsenic exceeded the GWQS only marginally (5.8 J to 6.2 J µg/L) with the exception of one location that had concentrations of 11.2 to 44.5 µg/L (MW-4, west of the landfill; Figure 1-6B).

Chromium exceeded the 70 µg/L criterion at five locations in seven RI samples with concentrations up to 262 J µg/L. The chromium plume (Figure 8-8) is very narrow and extends west to northeast from well CF-212D to well CF-201D. The deepest exceedance was at well CF-206D at 558 ft. bgs in the central section of the plume. The vertical extent has not been determined in this location as the exceedance was at the bottom of the well. There is also an isolated exceedance at well CF-224D near the southeastern corner of the landfill, in the 145 to 160 feet bgs interval. The vertical extent of chromium contamination at this well has not been determined in this location as the exceedance was at the bottom of the well. Chromium did not exceed the GWQS in any of the NJDEP PCEM samples.

Phenobarbital exceeded the criterion of 5 µg/L in NJDEP samples from seven overburden wells with concentrations of up to 36 JN µg/L (well PTO-2) and in 15 bedrock wells with concentrations of up to 37 JN µg/L (well D-7). In the EPA RI samples (all from bedrock wells), it was detected at concentrations of up to 19 JN µg/L (well CF-224D), with exceedances at six wells or open boreholes (i.e., in packer testing samples prior to well completion). In the overburden wells, the criterion was exceeded at three wells within the landfill, two wells outside the southwest perimeter of the landfill, and at two wells to the northeast at Schoolhouse Lane. The alignment of these wells is southwest to northeast – the same as the other COCs. In the bedrock aquifer, phenobarbital contamination above the criterion was found at 15 wells, including within the landfill, on its perimeter and further to the south than in the overburden (CF-218D), as well as at wells to the northeast of the landfill up to Schoolhouse Lane. The deepest interval that exceeded the criterion was from 432 to 442 feet at well CF-205D to the northeast of the landfill.

TAME, aka 2-methyoxy-2-methylbutane, exceeded the criterion of 100 µg/L in the NJDEP samples from 11 overburden and 11 bedrock wells. The highest concentrations were 380 JN µg/L in the overburden wells (MW-6 on the landfill's southern perimeter) and 480 JN µg/L in the bedrock wells (CF-11D on Schoolhouse Lane). The EPA RI samples, all of which were collected from bedrock wells, did not have TAME reported as a TIC.

In overburden groundwater, the TAME criterion was exceeded at five wells inside the landfill and five wells to the north, west and south of the landfill, as well as at one well on Schoolhouse Lane. In the bedrock aquifer, the criterion was exceeded at one NJDEP well within the landfill, seven wells on the landfill perimeter or near the landfill, and one well each at a considerable distance to the south and on Schoolhouse Lane. The deepest interval with an exceedance for TAME was reported for the 244 to 254 foot interval at well WRA-3-1 to the south of the landfill, south of Parker Road.

8.1.2 Surface Water and Sediment

Surface Water

Surface water samples from the four streams around the landfill and the seeps and springs met the SWQS for VOCs, SVOCs, pesticides and PCBs . Four metals – copper (dissolved), lead (dissolved), silver (total) and cadmium (dissolved) - were at concentrations exceeding the SWQS in the streams (Figure 4-6). Note that some SWQS only pertain to dissolved concentrations of contaminants while others apply only to total concentrations.

Copper (dissolved) concentrations exceeded the criterion of 2.2 µg/L at all three sampling locations on East Trout Brook where concentrations ranged from 5 J to 6.7 J µg/L. On Trout Brook, only one location had an exceedance of dissolved copper. Upstream and downstream locations that did not have exceedances bound this location; therefore, copper is delineated for this stream (although the detection limits for the samples were above the criterion). The Lamington River and Tanners Brook UNTs did not have any dissolved copper exceedances.

Lead (dissolved) concentrations exceeded the criterion of 5.4 µg/L at two locations on the Tanners Brook UNT where concentrations ranged from 6 J to 9 J µg/L, but the dissolved lead concentration at a downstream location was below the criterion. The area upstream of this location is a wetland (headwaters) adjacent to the landfill; therefore, lead is delineated along the Tanners Brook UNT between the headwaters and the downstream compliant location. Dissolved lead marginally exceeded the criterion only at the most upstream location on the Lamington River UNT (5.8 J µg/L). As the downstream location concentrations were below the SWQS for dissolved lead, the Lamington River UNT is delineated for lead.

Silver (total) concentrations exceeded the criterion of 0.12 µg/L at two locations on East Trout Brook (0.46 J and 0.54 J µg/L). The downstream location did not have a silver detection, although the detection limit was above the criterion. Silver was not detected in the other streams, but the detection limits were all above the criterion. East Trout Brook is delineated for silver.

Cadmium (dissolved) concentrations exceeded the criterion of 0.056 µg/L at one location on East Trout Brook (0.19 J µg/L). Cadmium was not detected in surface water samples from locations upstream and downstream of the sample with the exceedance, although the detection limits were above the criterion. East Trout Brook is delineated for cadmium.

Though widespread in surface water near CFS (Figure 4-7), 1,4-dioxane did not exceed the comparison criterion value (22,000 µg/L). Its presence in streams and seeps indicates that contaminated groundwater originating at the landfill is upwelling into the streams and seeps. The highest concentration of 1,4-dioxane at the Tanner's Brook UNT (35 µg/L) as well as in a sample collected by NJDEP on the Lamington River UNT north of Schoolhouse Lane (44 D µg/L) are only one order of magnitude below the highest detected concentration in the RI bedrock groundwater samples (350 µg/L), indicating that there is little dilution in surface water and that a significant portion of water in the streams originates in the aquifers. This assessment is supported by the presence of high concentrations of TAME (150 JN µg/L to 410 JN µg/L; SWQS not established) in NJDEP surface water samples from the Lamington River UNT north of Schoolhouse Lane. The surface water sampling locations are close to the monitoring well with the highest concentration of TAME (CF-11D, 480 JN µg/L).

In sediment, the PAHs anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene, along with benzyl butyl phthalate in various combinations were detected at concentrations above the freshwater LELs at two locations on the Lamington River UNT and at one location on the Tanners Brook UNT. These same PAHs were not detected at intervening sediment sample locations between the landfill and the stream headwaters. PAHs and benzyl butyl phthalate are not groundwater COCs for CFS (Section 8.1.1) although reporting limits for some PAHs exceeded GWQS.

Copper exceeded the freshwater sediment LEL of 16 mg/kg at three locations on two streams with concentrations ranging from 18.2 J to 28.2 J mg/kg. The location on Tanners Brook UNT was the furthest upstream location (closest to the landfill) and bounded by locations downstream where the

concentrations of copper were below the LEL. The two locations on the Lamington River UNT are downstream of an intervening location between the landfill and the headwaters of the Lamington River UNT where the concentration of copper was below the LEL. Copper exceedances in sediment were not co-located with surface water exceedances.

Lead exceeded the freshwater LEL of 31 mg/kg at three locations with concentrations ranging from 36.4 J to 71.4 J mg/kg. All three locations are located on the Lamington River UNT, which are downstream of an intervening location between the landfill and the headwaters of the Lamington River UNT where the concentration of lead was below the LEL. Lead exceedances were not co-located with surface water exceedances from these same three locations; however, the lead concentration in the upstream surface water sample marginally exceeded the SWQS.

Silver marginally exceeded the freshwater LEL of 0.5 mg/kg in only one sediment sample where the concentration was 0.56 mg/kg. This sample was from the furthest upstream location on the Lamington River UNT. Silver was not detected in the surface water sample from this location, but the detection limit was above the criterion.

Cadmium exceeded the freshwater LEL of 0.6 mg/kg at seven locations (concentration range of 0.94 J to 2.6 mg/kg), five of which are along East Trout Brook; two are along the Lamington River UNT. One of the sample locations on East Trout Brook also had cadmium in surface water (0.19 J µg/L) above the SWQS. Cadmium is not a groundwater COC (Section 8.1.1). Cadmium in sediment is not delineated along East Trout Brook or downstream of the impacted sample location on the Lamington River UNT.

Arsenic exceeded the freshwater LEL of 6 mg/kg at five locations with concentrations ranging from 6.3 J to 9.5 mg/kg. Distribution of these locations was amongst all streams except Trout Brook; none was from an upstream location close to the landfill. Arsenic did not exceed the SWQS in any of the surface water samples.

Mercury marginally exceeded the freshwater LEL of 0.17 mg/kg at one location on Trout Brook (0.27 mg/kg). Mercury was not detected in the sediment sample from Trout Brook closest to the landfill. Mercury did not exceed the SWQS in any of the surface water samples.

Manganese exceeded the freshwater LEL of 630 mg/kg at two downstream locations on East Trout Brook (concentrations of 785 and 1,400 mg/kg). The manganese concentrations at the upstream locations closer to the landfill were below the freshwater LEL. Manganese did not exceed the SWQS in any of the surface water samples.

8.1.3 Soil

Soil samples collected along the landfill perimeter road did not contain concentrations of VOCs, SVOCs, pesticides or PCBs above the applicable criteria. Nine metals - aluminum, arsenic, beryllium, cadmium, cobalt, manganese, nickel, silver, and vanadium - were detected at concentrations exceeding criteria in various combinations at all five soil boring locations along the landfill perimeter road. Arsenic, which exceeded applicable criteria in a duplicate sample only, is the only metal in soil that is also a groundwater COC.

8.2 Contaminant Fate and Transport

Contamination originating at the landfill enters the overburden and bedrock aquifers, shallow and deep groundwater flows transport it outward, and it predominantly discharges to surface water in the surrounding area, although some portion of the contamination remains in the bedrock aquifer. Along

the migration pathways, benzene undergoes biodegradation and volatilization from the groundwater table and surface water, while 1,4-dioxane, which is less volatile, does not biodegrade, or sorb to organic matter, does not. Transport of 1,4-dioxane is via advection with minimal attenuation through these migration pathways. Although TCE is subject to reductive dechlorination, this is not evident at CFS. DEHP tends to sorb strongly to particulates, has low solubility, and will biodegrade in both water and soil under aerobic conditions. It is widespread, but at low concentrations. Transport of inorganics such as arsenic, chromium and lead, will be via adsorption to particles along the groundwater pathway and will have the potential to accumulate in stream sediments, although evidence of this mechanism is indeterminate.

The horizontal extents of the COC plumes are similar in shape, with the most predominant lobe extending from the landfill perimeter to well CF-201D to the northeast. This particular component of the plumes follows the three preferential flow pathways from the landfill to Schoolhouse Lane, then bends eastward, then north following the Lamington River UNT. This portion of groundwater contamination originating at CFS is well-defined. Transport of each COC is via the preferential flow paths in the bedrock between the two confining ridges primarily via advection, diffusion and dispersion. Because of the strong evidence of the preferential pathways and the predominant southwest-northeast groundwater flow, for areas with data gaps, it is reasonable to assume that the same transport mechanisms play a similar role throughout the site.

The vertical extents of the COCs in groundwater are highly variable and controlled by the transmissivities of individual fractures and groups of fractures. Vertical transport is through fractures, primarily via advection, downward to the limit of transmissivity at locations near the landfill, and upward at locations near surface water bodies. At depth, few, if any, transformation processes influence the concentrations of the COCs.

Transport of contaminants to surface water is from groundwater discharge to gaining streams. The continual presence of surface water contamination is evidence of a substantial mass of contaminants in overburden and shallow bedrock groundwater, continually feeding the headwaters of the streams around CFS.

Contaminant transport pathways at CFS are complete if humans come into contact with contaminated ground and surface waters or if wildlife comes into contact with contaminated surface water and sediment. Humans previously ingested contaminants when consuming water from potable wells, and inhaled and contacted contaminants when showering. However, connection of affected residences to a municipal water supply severed this pathway. Wildlife ingests contaminated surface water and to a lesser extent, sediment when drinking or feeding on aquatic species.

The soil and soil vapor pathways at CFS are incomplete. The landfill and perimeter road act as a cap on the contaminated soil, preventing direct contact, ingestion, and inhalation. The NJDEP and EPA vapor intrusion investigations found an incomplete soil vapor pathway and no impacts from vapor intrusion to indoor air at residences in areas of contaminated groundwater.

8.3 Risk Assessment Summary

8.3.1 Human Health Risk Assessment

For recreational users exposed to surface water in the streams within the investigation area, the non-cancer HIs for an adult and child are below one, and the ELCRs calculated for exposure to COPCs are within EPA’s acceptable risk range.

For a resident's exposure to groundwater within the investigation area, for non-cancer, several COPCs contribute to an adult HI of 4.0E+00 and child HI of 2.3E+00, but none of the individual HQs for these COPCs are greater than one, except for 1,4-dioxane with HQs of 1.4E+00 and 1.2E+00 for an adult and child's inhalation route, respectively. For cancer, chromium, 1,4-dioxane, arsenic, benzene, DEHP, chloroform, vinyl chloride, 1,4-dichlorobenzene and 1,2-dichloroethane contribute the most to the ELCR of 1.2E-03.

Actual exposure to these COCs in groundwater is expected to be limited, as the 1986 ROD called for an alternate water supply (HDR 2011b) and a municipal water supply has been constructed to serve properties impacted by groundwater contamination (EPA 2015d).

Residents are unlikely to be exposed to contaminants through the VI pathway. TCE in indoor air likely originates from sources unrelated to VI, as TCE is not detected in any of the sub-slab soil gas samples nor are there TCE concentrations in groundwater exceeding the groundwater screening level within a quarter mile or more of residences or any other structure.

8.3.2 Ecological Risk Evaluation

The evaluation of surface water and sediment exposure pathways indicates that aquatic biota, benthic invertebrates, amphibians, and plants may potentially be adversely impacted by inorganics, PAHs, 2,3,4,6-tetrachlorophenol, and alpha-chlordane.

For wildlife exposure via bioaccumulation of COPCs in the food chain, the evaluation of surface water and sediment exposure pathways have LOAEL-based HQs less than one for all receptor groups, with one exception - the spotted sandpiper. This species, representing avian invertivores, has exposure to vanadium in East Trout Brook with a HQ of 1.7, which is slightly above the acceptable limit of one.

8.4 Conclusions

Eight target COCs exceeded the GWQS at a frequency of five percent or greater of the total number of samples: 1,4-dioxane, benzene, TCE, DEHP, alpha-BHC, lead, arsenic, and chromium, in addition to two TICs, phenobarbital, and TAME, exceeding the IGGWQC. It is evident from isoconcentration maps, that the source of these contaminants is the landfill itself, with two locations within the landfill predominant – the North Waste Cell at the northern corner of the landfill and the northeast corner.

1,4-Dioxane is the contaminant most frequently detected and frequently elevated above the criterion in groundwater. Because 1,4-dioxane is miscible, readily transported via advection, and is recalcitrant to transformation processes, it is the most prevalent and problematic COC. The plumes associated with each groundwater COC have many similarities and all follow preferential flow paths in bedrock to the northeast of the landfill, with a similar, but less documented pattern to the southwest. Few, if any, transformation processes reduce contaminant concentrations or the spread of contamination in the bedrock aquifer.

Surface water contamination is a result of contaminated groundwater discharging to surface water. 1,4-Dioxane is prevalent in surface water, but poses little human health or ecological risks. Low concentrations of sediment contamination with PAHs and metals do not appear to be landfill related, and the FS will not address sediments based on the results of the SLERA.

Construction of a municipal water supply in 2015 eliminated the pathway for humans to ingest and contact contaminated groundwater. However, as the existing GWTP cannot treat for 1,4-dioxane nor is it sufficiently capturing contaminants leaching from the landfill, groundwater contamination remains an issue should the COC plumes increase in extent beyond the water supply boundary where private wells are still in use.

8.5 Recommendations

The data collected during the RI by both EPA and NJDEP are sufficient to support development of remedial alternatives in the FS and preparation of a ROD. Additional data are required to support remedial design, however, and may be incorporated into a Pre-Design Investigation (PDI), including:

- Further assessment of preferential flow paths in bedrock at areas other than to the northeast of the landfill. This may include additional Willowstick surveys or the equivalent to the southwest and west;
- Long-term pump tests at deep bedrock wells to the southwest and west to determine drawdown and yield in these areas;
- Groundwater sampling and analysis for naturally-occurring microbes, enzymes, and other analytes indicative of transformation processes to confirm the contribution, if any, to contaminant reduction;
- Continued periodic sampling of EPA bedrock wells to monitor performance and inform the pre-design and design phases with current information; and
- Bench-scale or pilot test evaluation of 1,4-dioxane treatment alternatives as an add-on to the existing GWTP.

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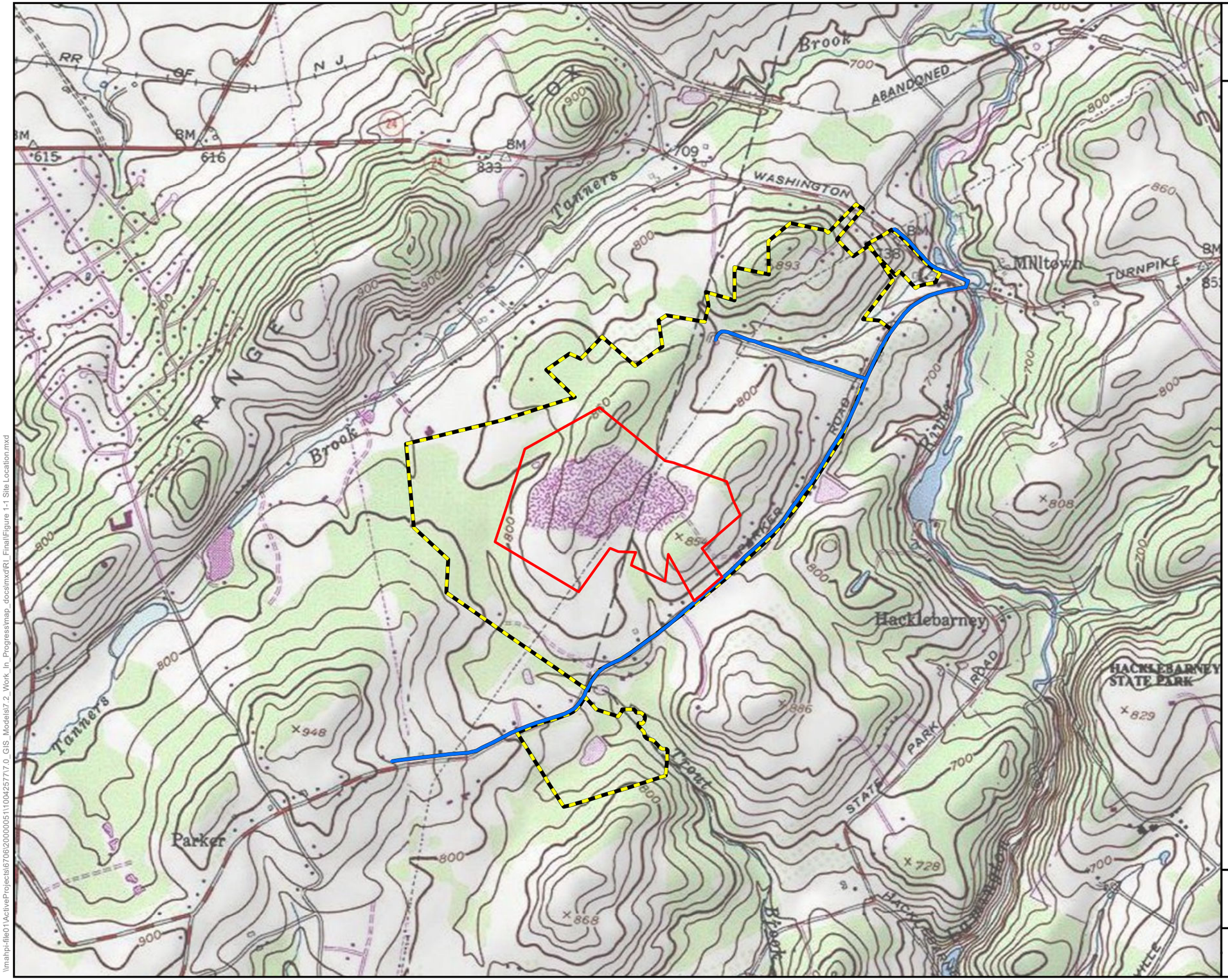
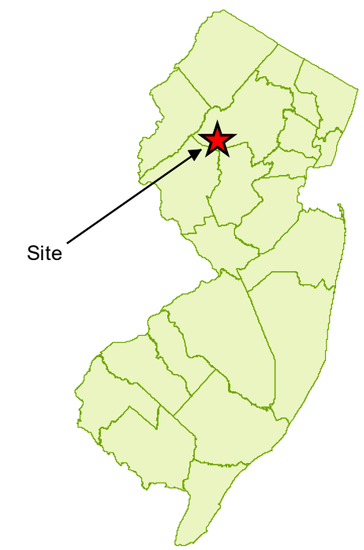
FIGURES



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US



Legend

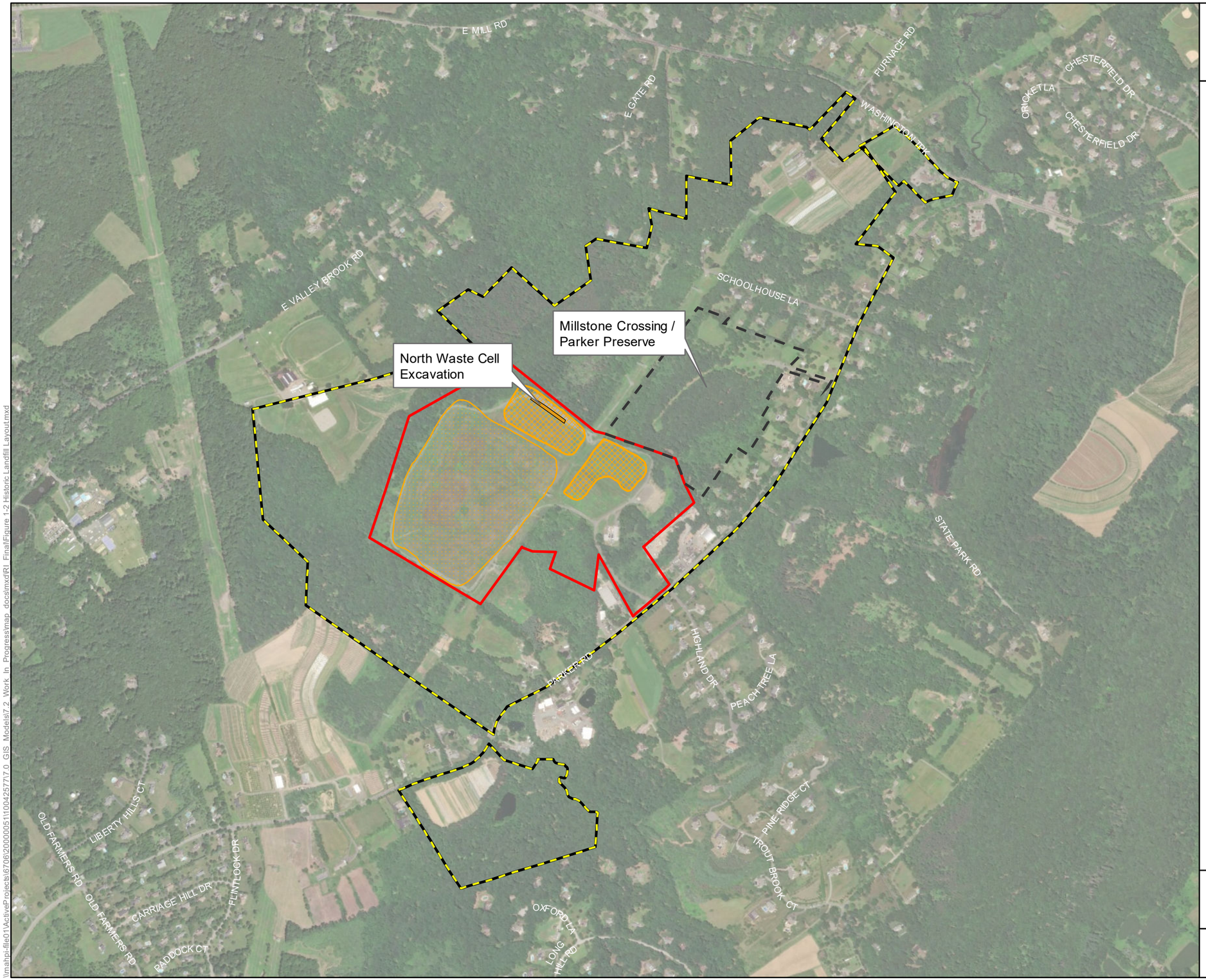
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Approximate Extent of 2015 Water Main Extension

0 0.25 Miles

Site Location and Overview

Figure 1-1
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005111\0042577\7.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-1 Site Location.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Millstone Crossing / Parker Preserve

Historic Landfill Activity Areas

- Pre 1972
- Post 1972
- North Waste Cell Excavation

Notes

Historic landfill activity areas mapped by geo-reference of Figure 1-4 of the 1986 LMS RI/FS Report.

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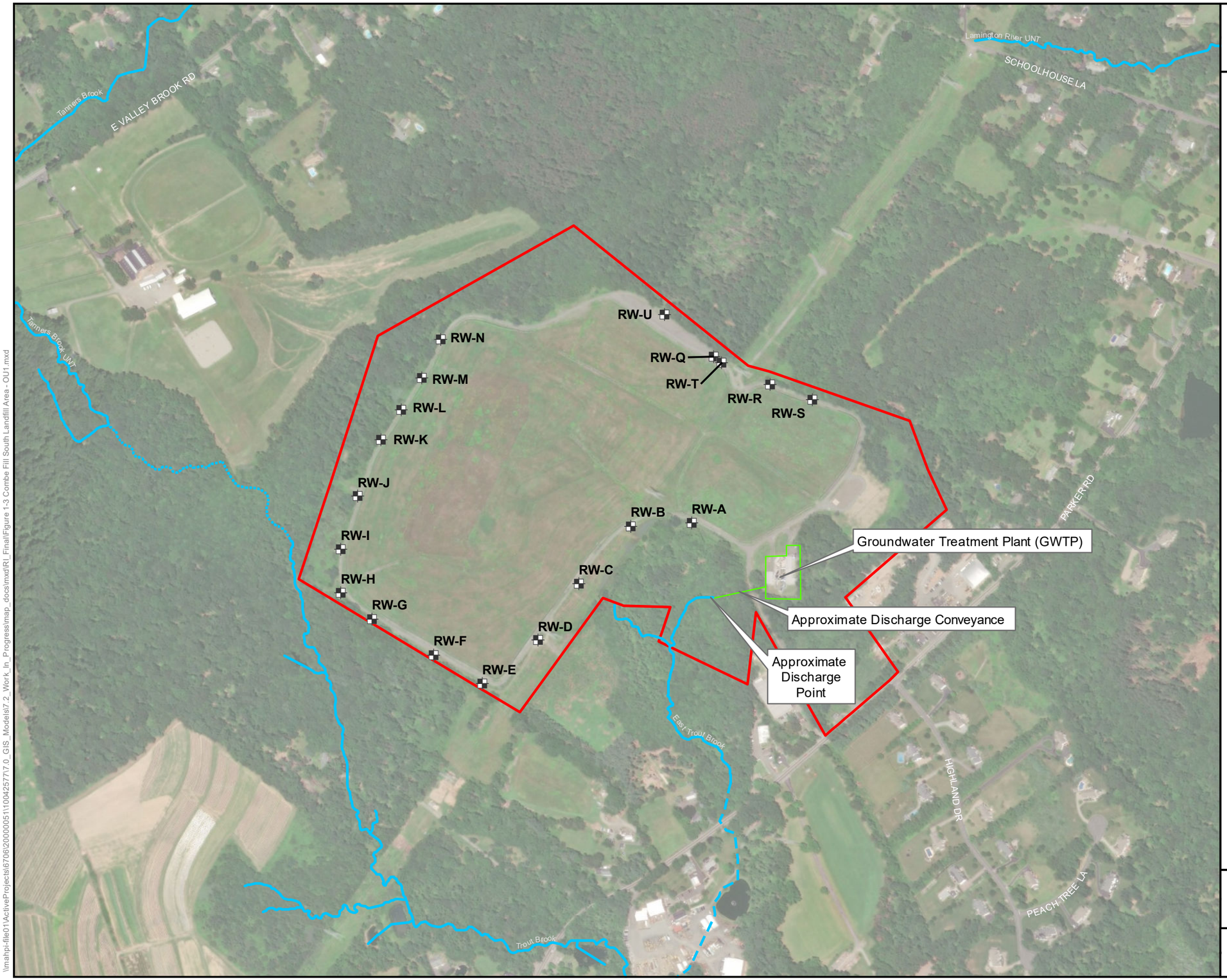
0 500 1,000 Feet

Approximate Historic Landfill Activity Areas

Figure 1-2
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005110\042577\7.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 1-2 Historic Landfill Layout.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Extraction Well
- Treatment Plant
- Surface Water
- East Trout Brook culvert

UNT = Unnamed Tributary

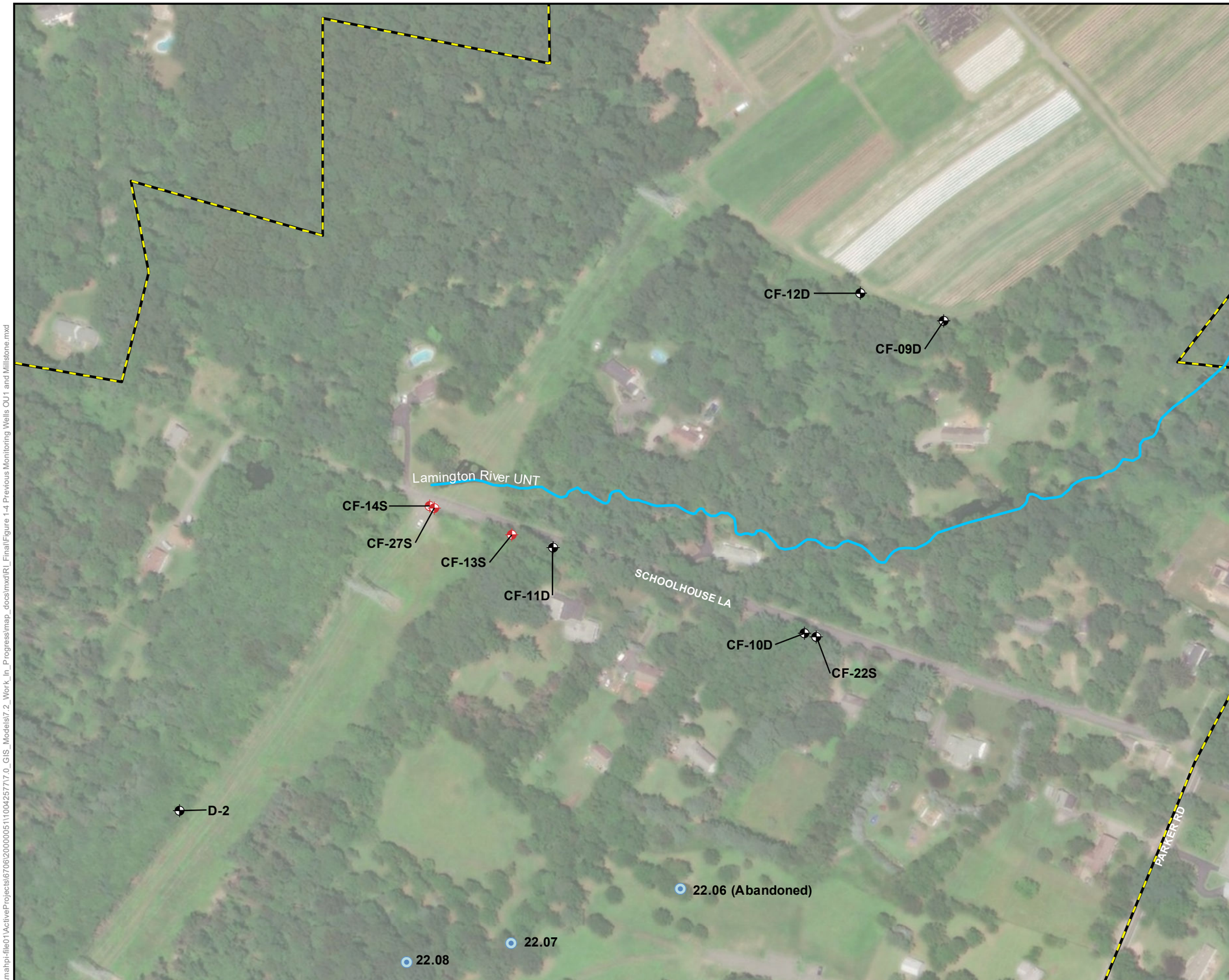
Note:
Two recovery wells on the northern perimeter of the landfill (RW-O and RW-P) were abandoned during the removal of the North Waste Cell in 2006. The replacement well for this area, RW-U, came online in 2009.

0 250 500 Feet

Combe Fill South Landfill Area (OU1)

Figure 1-3
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1100425771\0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-3 Combe Fill South Landfill Area - OU1.mxd



Combe Fill South Landfill Superfund Site RI/FS

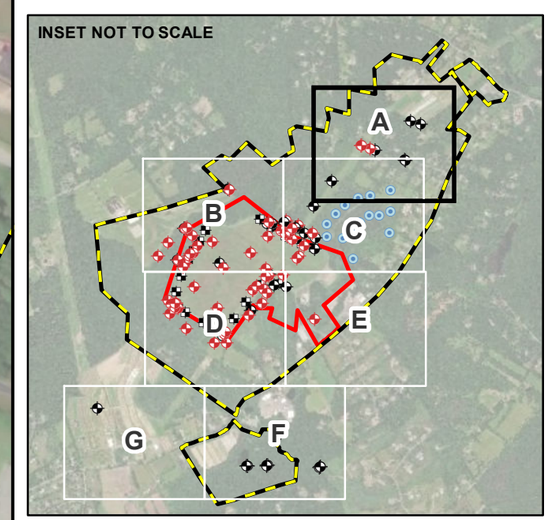
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Overburden Well
- Bedrock Well
- Millstone Crossing Open Boreholes
- OU1 Groundwater Treatment Extraction Wells
- Treatment Plant
- Surface Water

UNT = Unnamed Tributary



0 100 200 Feet

Previously Existing Monitoring Wells, Recovery Wells, and Millstone Crossing Open Boreholes

Figure 1-4A
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\100425777\0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-4 Previous Monitoring Wells OU1 and Millstone.mxd

Combe Fill South Landfill Superfund Site RI/FS

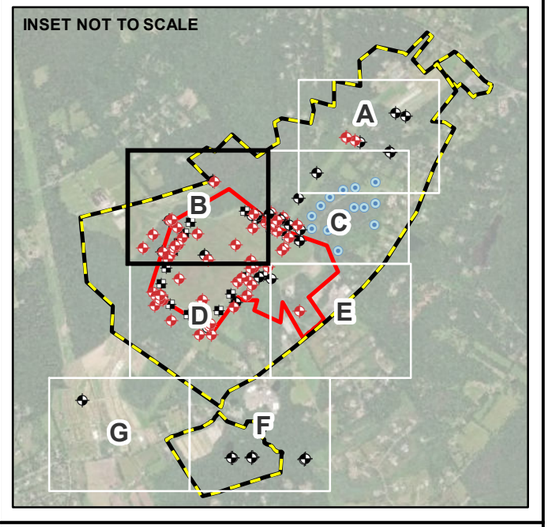
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Overburden Well
- Bedrock Well
- Millstone Crossing Open Boreholes
- OU1 Groundwater Treatment Extraction Wells
- Treatment Plant
- Surface Water

UNT = Unnamed Tributary

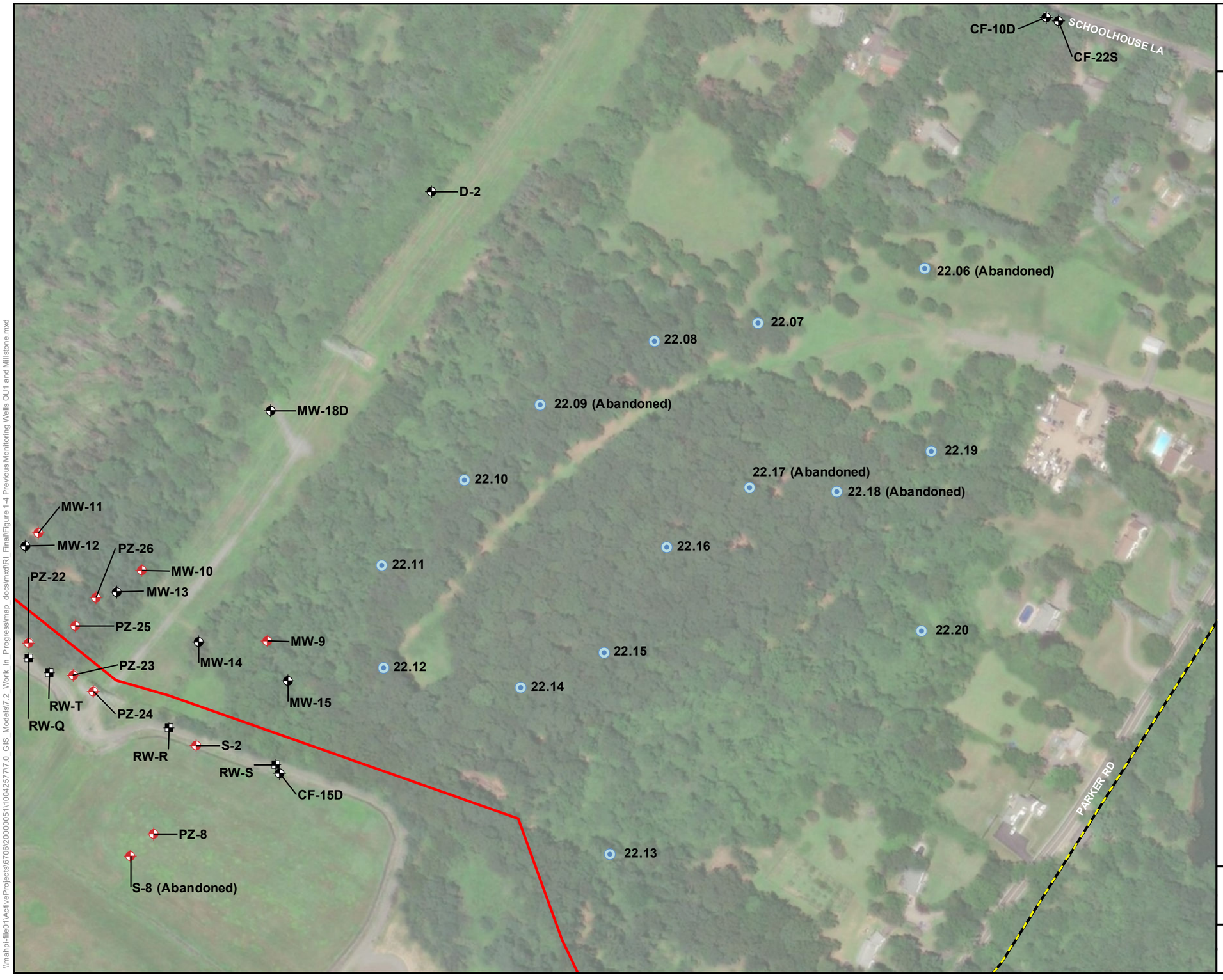


0 100 200 Feet

Previously Existing Monitoring Wells, Recovery Wells, and Millstone Crossing Open Boreholes

Figure 1-4B
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1100425717\0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-4 Previous Monitoring Wells OU1 and Millstone.mxd



Combe Fill South Landfill Superfund Site RI/FS

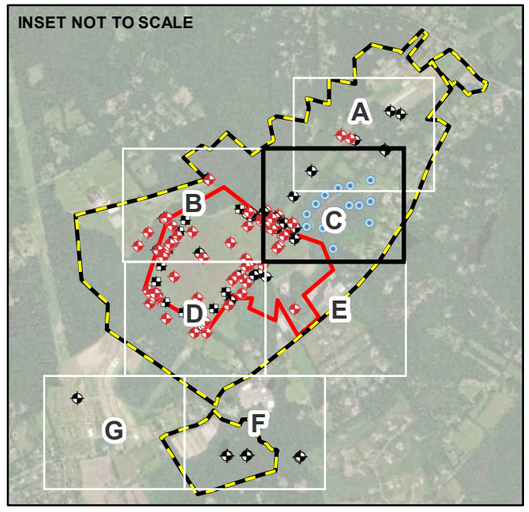
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Overburden Well
- Bedrock Well
- Millstone Crossing Open Boreholes
- OU1 Groundwater Treatment Extraction Wells
- Treatment Plant
- Surface Water

UNT = Unnamed Tributary

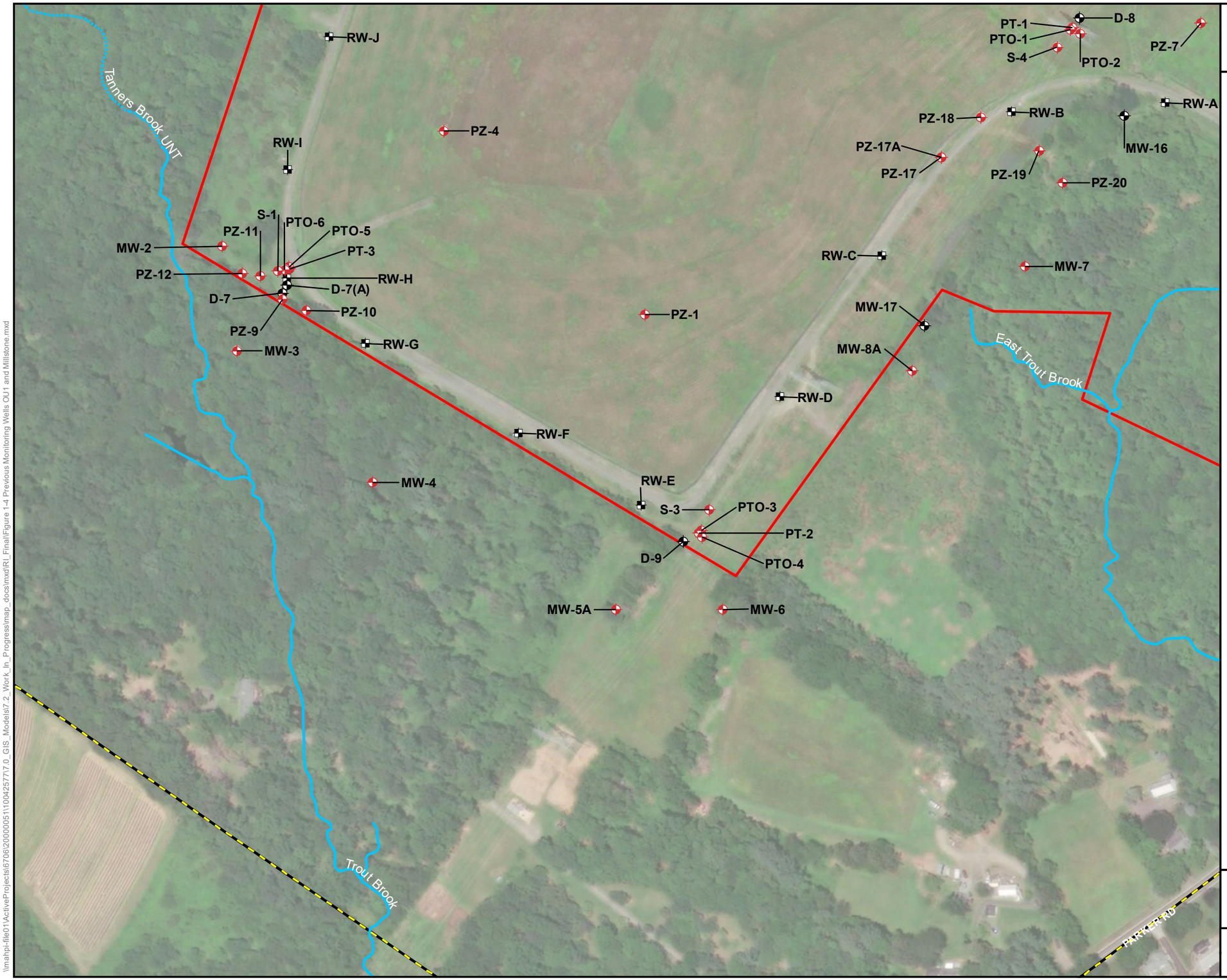


0 100 200 Feet

Previously Existing Monitoring Wells, Recovery Wells, and Millstone Crossing Open Boreholes

Figure 1-4C
June, 2018

\\mahpi-file01\ActiveProjects\67062000000511\1004257717.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-4 Previous Monitoring Wells OU1 and Millstone.mxd



Combe Fill South Landfill Superfund Site RI/FS

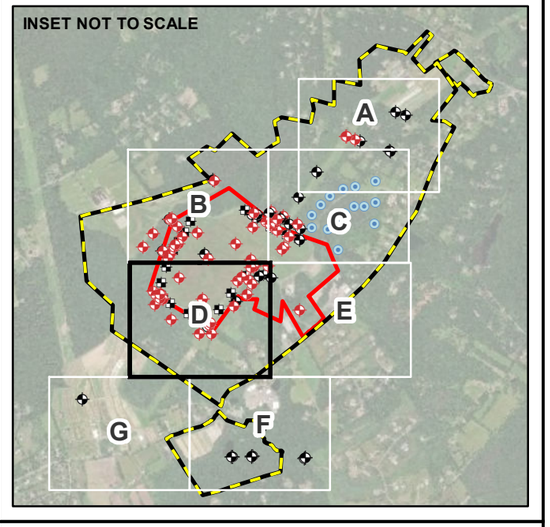
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Overburden Well
- Bedrock Well
- Millstone Crossing Open Boreholes
- OU1 Groundwater Treatment Extraction Wells
- Treatment Plant
- Surface Water

UNT = Unnamed Tributary



0 100 200 Feet

Previously Existing Monitoring Wells, Recovery Wells, and Millstone Crossing Open Boreholes

Figure 1-4D
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005111004257 7\0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-4 Previous Monitoring Wells OU1 and Millstone.mxd

Combe Fill South Landfill Superfund Site RI/FS

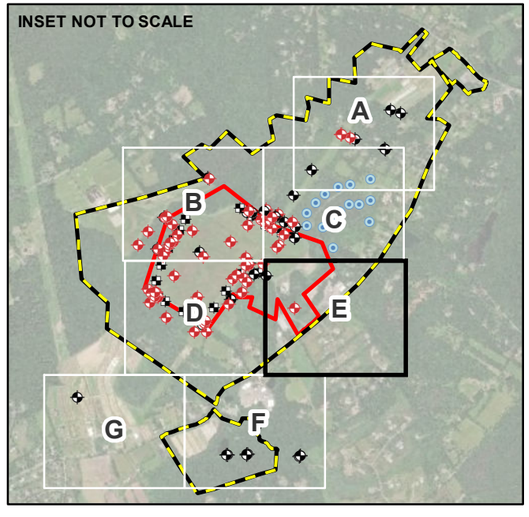
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Overburden Well
- Bedrock Well
- Millstone Crossing Open Boreholes
- OU1 Groundwater Treatment Extraction Wells
- Treatment Plant
- Surface Water

UNT = Unnamed Tributary

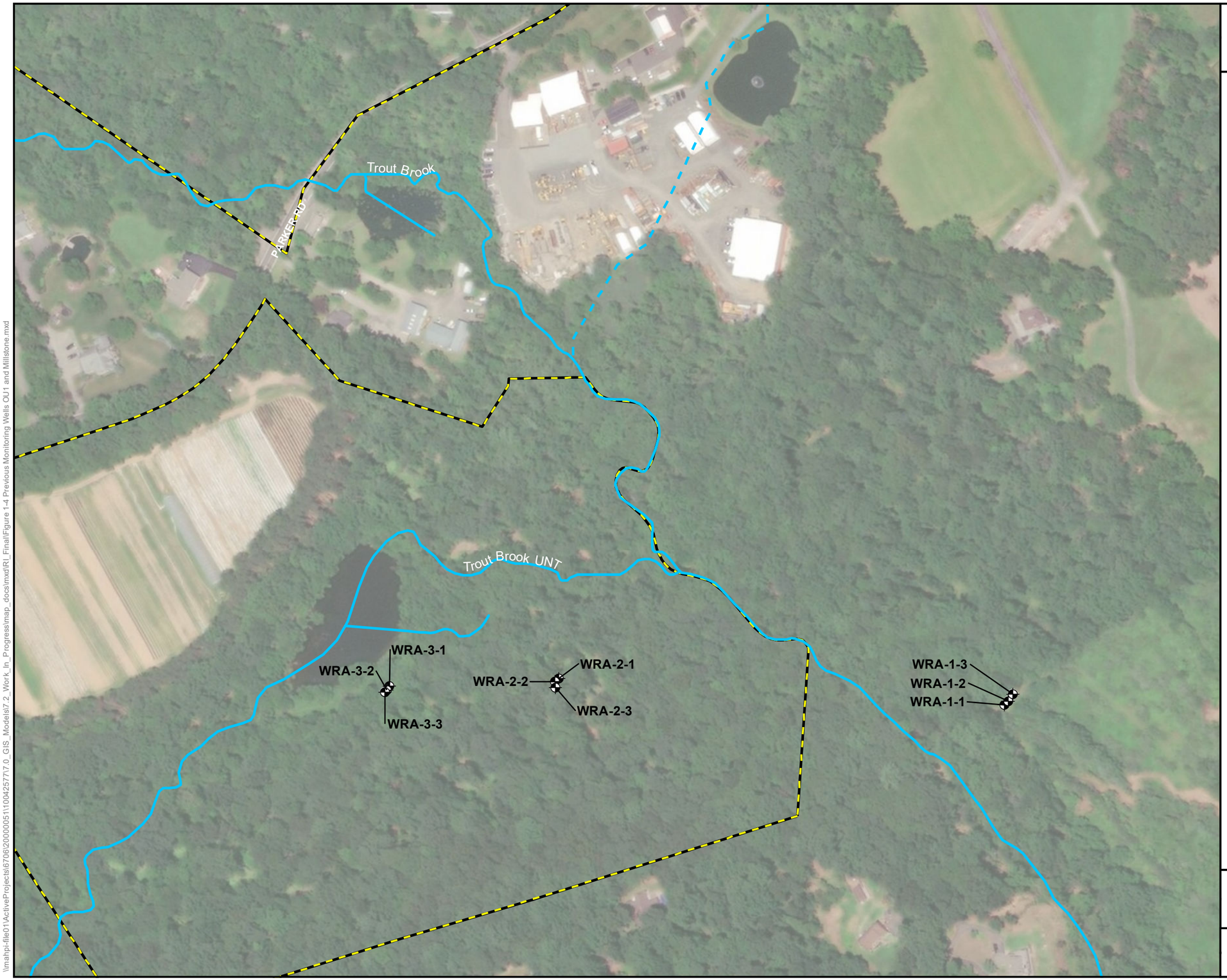


0 100 200 Feet

Previously Existing Monitoring Wells, Recovery Wells, and Millstone Crossing Open Boreholes

Figure 1-4E
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\100425777.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-4 Previous Monitoring Wells OU1 and Millstone.mxd



Combe Fill South Landfill Superfund Site RI/FS

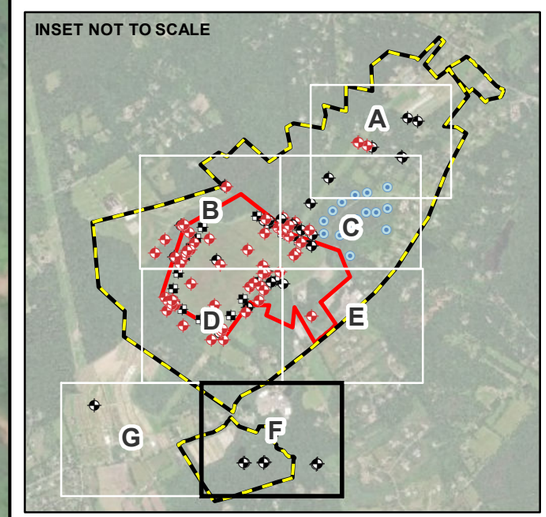
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Overburden Well
- Bedrock Well
- Millstone Crossing Open Boreholes
- OU1 Groundwater Treatment Extraction Wells
- Treatment Plant
- Surface Water

UNT = Unnamed Tributary



0 100 200 Feet

Previously Existing Monitoring Wells, Recovery Wells, and Millstone Crossing Open Boreholes

Figure 1-4F
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005111004257\7.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-4 Previous Monitoring Wells OU1 and Millstone.mxd

Combe Fill South Landfill Superfund Site RI/FS

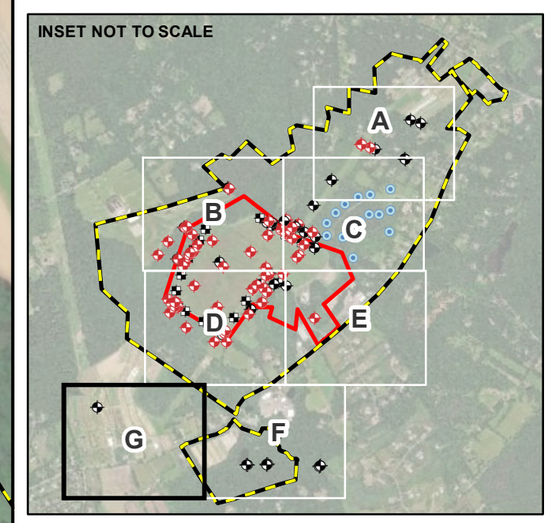
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Overburden Well
- Bedrock Well
- Millstone Crossing Open Boreholes
- OU1 Groundwater Treatment Extraction Wells
- Treatment Plant
- Surface Water

UNT = Unnamed Tributary



0 100 200 Feet

Previously Existing Monitoring Wells, Recovery Wells, and Millstone Crossing Open Boreholes

Figure 1-4G
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\100425717\0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-4 Previous Monitoring Wells OU1 and Millstone.mxd

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

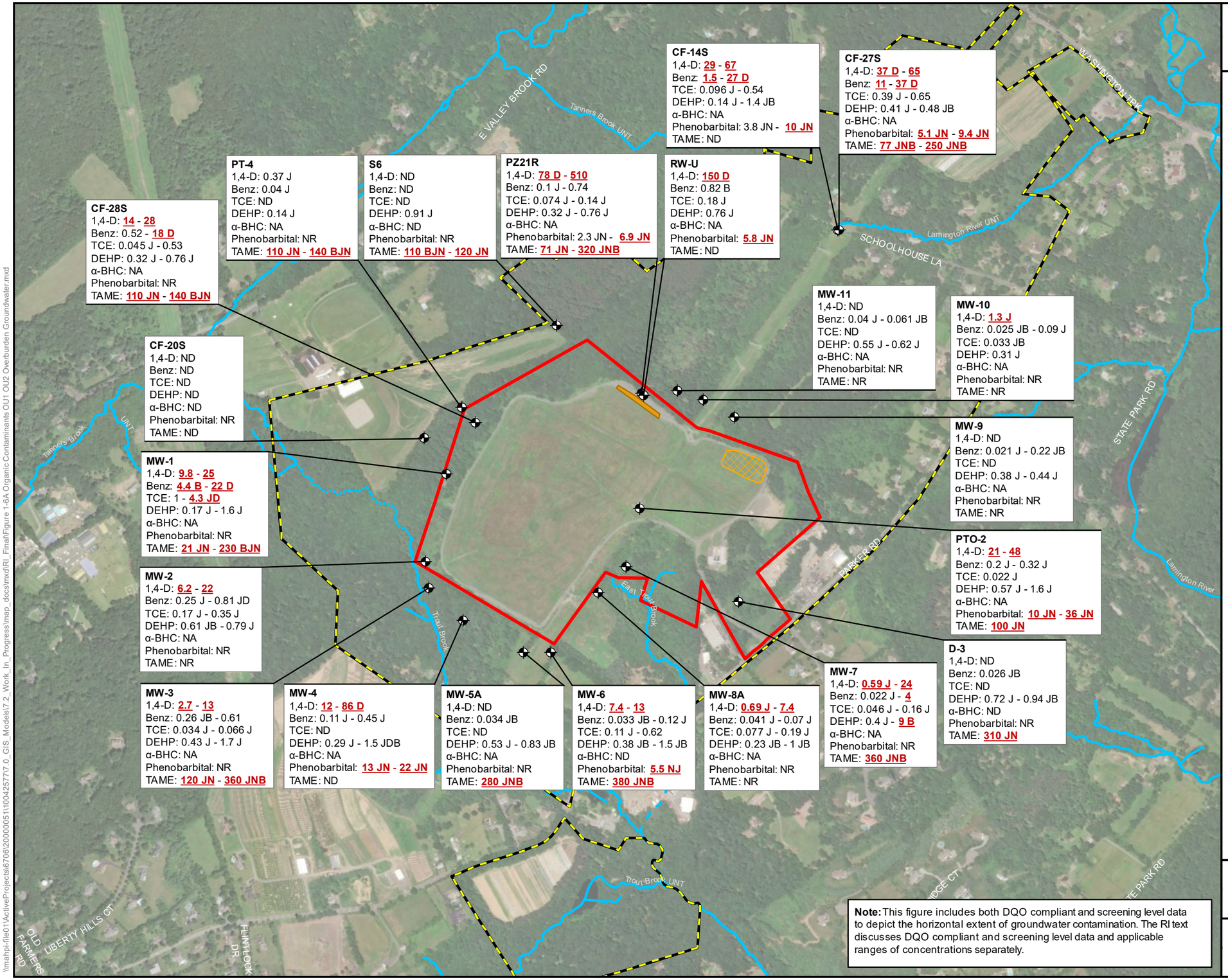
- OU2 Investigation Area
- Tax Parcel

0 100 200 Feet

Schoolhouse Lane Parcels

Figure 1-5
June, 2018

\\mahpi-file01\ActiveProjects\67060200000511\00425771\7.0 GIS Models\7.2 Work In Progressmap docs\mxd\RI FinalFigure 1-5 Schoolhouse Lane Parcels.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- Overburden Monitoring Well (NJDEP)
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water

DATA BOX EXAMPLE

Well ID — Detected Concentration Range (Min - Max) If only detected once, a single value is shown.

PTO-2
1,4-D: 21 - 72
Benz: 0.2 J - 0.32 J
TCE: 0.022 J
DEHP: 0.57 J - 1.6 J
α-BHC: NA
Phenobarbital: 10 JN - 36 JN
TAME: 100 JN

Exceedance of NJDEP GWQS indicated by **Bold, Red, and Underline**

Abbreviation	Compound	GWQS
1,4-D	1,4-Dioxane	0.4
Benz	Benzene	1
TCE	Trichloroethylene	1
DEHP	di (2-ethylhexyl) phthalate	3
α-BHC	alpha-BHC	0.02
	Phenobarbital*	5
TAME	Tert-amyl methyl ether*	100

GWQS - NJDEP Groundwater Quality Standards (N.J.A.C. 7:9C, 2018)

NOTES

- Concentrations are in ug/L and are detected results from the applicable time range. Databoxes are not depth discrete and intended to conceptualize the extent of detections.
- ND = Analyte analyzed for but not detected above reporting limits.
- NA = Not analyzed for (see PCEMP note below).
- NR = Not Reported (see note related to TICs below).
- di(2-ethylhexyl) phthalate synonym: bis(2-ethylhexyl) phthalate).
- tert-amyl methyl ether synonym: butane, 2-methoxy-2-methyl-
- alpha-BHC: alpha-benzenehexachloride

*Tentatively Identified Compound (TIC). Interim generic groundwater quality criteria for synthetic organic chemicals (SOCs) applied. The criteria for individual carcinogenic SOCs is 5 ug/l and non-carcinogenic SOCs is 100 ug/l. TICs are not reported by the analytical laboratory unless there is sufficient presumptive evidence for their presence. Phenobarbital is classified as a possible human carcinogen by IARC. TAME is not listed by IARC and presumed non-carcinogenic. Both chemicals are non-target analytes and reported as TICs.

Analytical Data Sources

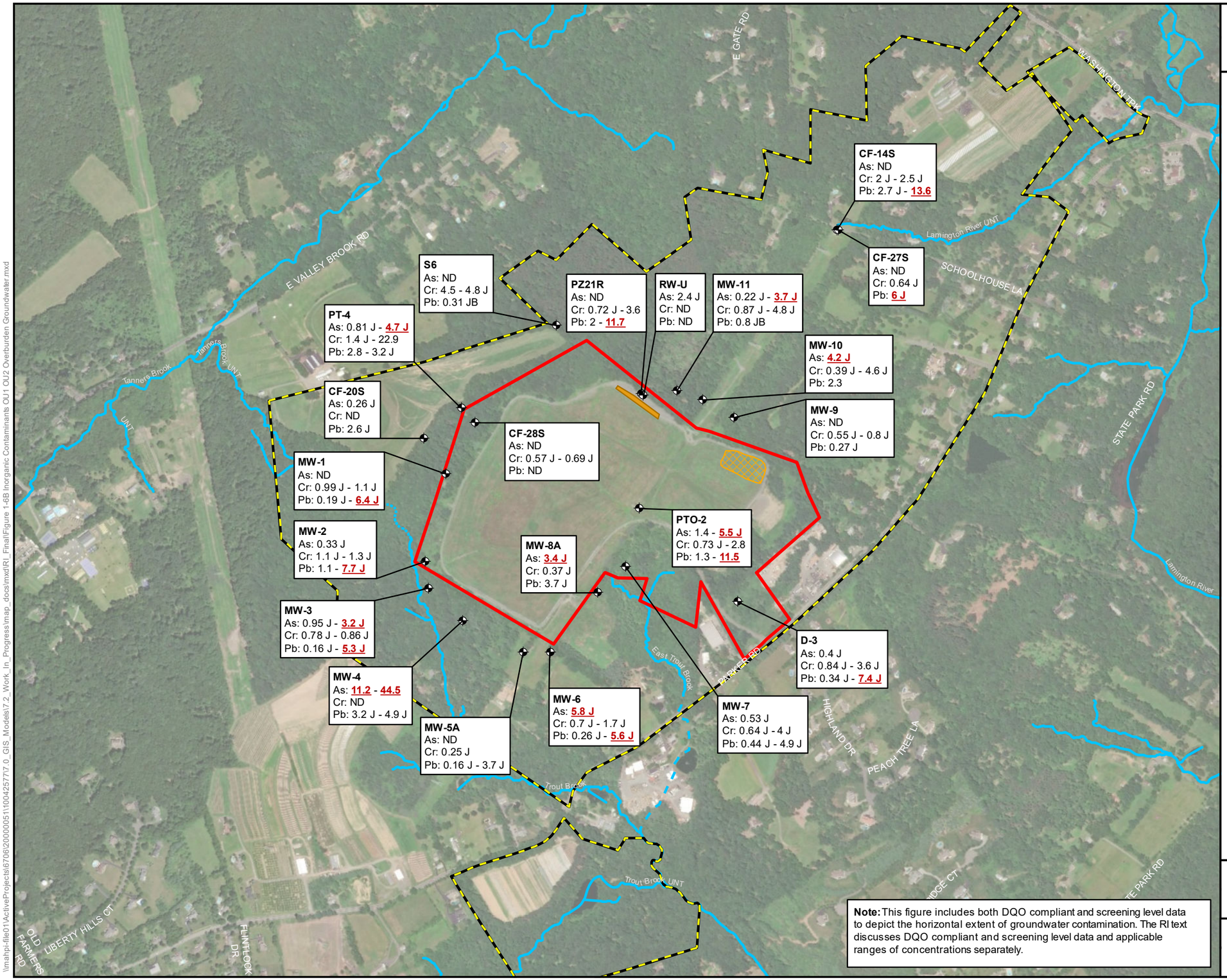
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

0 400 800 Feet

OU2 Organic Contaminants of Concern in Overburden Groundwater

Figure 1-6A
August, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1\00425777.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-6A Organic Contaminants OU1 OU2 Overburden Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- Overburden Monitoring Well (NJDEP)
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water

DATA BOX EXAMPLE

Well ID — Detected Concentration Range (Min - Max). If only detected once, a single value is shown.

MW-11
As: 0.22 J - **3.7 J**
Cr: 0.87 J - 4.8 J
Pb: 0.8 JB

Exceedance of NJDEP GWQS indicated by **Bold Red Underline**

Abbrev.	Compound	GWQS
As	Arsenic	3 ug/L
Cr	Chromium	70 ug/L
Pb	Lead	5 ug/L

GWQS - NJDEP Groundwater Quality Standards (N.J.A.C. 7:9C, 2018)

NOTES

- Concentrations are in ug/L and are detected results from the applicable time range. Databoxes are not depth discrete and intended to conceptualize the extent of detections.
- ND = Analyte not detected.
- UNT = Unnamed tributary

Analytical Data Sources

- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

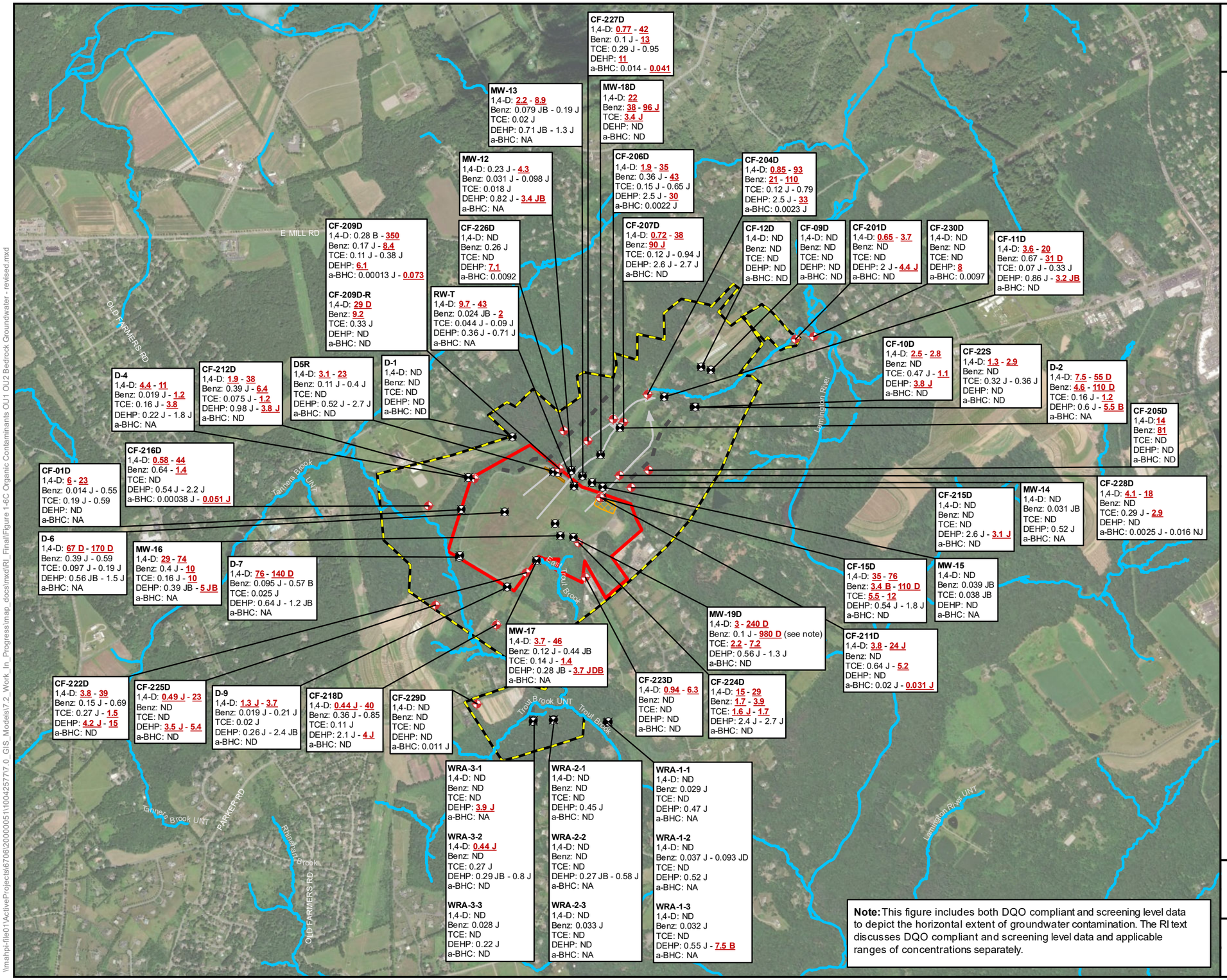
NJDEP PCEMP periodically analyzes metals using the ICP-MS method in addition to the ICP-AES method typically reported. The maximum concentration of the two methods is shown. This is applicable to samples collected in 2012 only.

0 400 800 Feet

OU2 Inorganic Contaminants of Concern in Overburden Groundwater

Figure 1-6B
August, 2018

\\mahpi-file01\ActiveProjects\6706\200000511\00425777.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-6B Inorganic Contaminants OU1 OU2 Overburden Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 Bedrock Monitoring Well (NJDEP)
- OU2 Bedrock Monitoring Well (HDR)
- OU1 - Landfill Property Boundary
- OU2 Investigation
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

DATA BOX EXAMPLE

Well ID — Detected Concentration Range (Min - Max) If only detected once, a single value is shown.

D-2
1,4-D: 7.5 - 55 D
Benz: 4.6 - 110 D
TCE: 0.16 J - 1.2
DEHP: 0.6 J - 5.5 B
α-BHC: NA

Exceedance of NJDEP GWQS indicated by **Bold Red Underline**

Abbrev.	Compound	GWQS
1,4-D	1,4-Dioxane	0.4 ug/L
Benz	Benzene	1 ug/L
TCE	Trichloroethylene	1 ug/L
DEHP	di (2-ethylhexyl) phthalate	3 ug/L
α-BHC	alpha-BHC	0.02 ug/L

GWQS - NJDEP Groundwater Quality Standards (N.J.A.C. 7:9C, 2018)

NOTES

- Concentrations are in ug/L and are detected results from the applicable time range. Databoxes are not depth discrete and intended to conceptualize the extent of detections.
- ND = Analyte analyzed for but not detected above reporting limits.
- NA = Not analyzed for (see PCEMP note below).
- HDR also sampled wells: WRA-2-1, WRA-3-2, WRA-3-3, and CF-11D (shown as NJDEP wells on map).
- di(2-ethylhexyl) phthalate synonym: bis(2-ethylhexyl) phthalate)
- alpha-BHC: alpha-benzenehexachloride

** MW-19D: Max detection of 980 ug/l from spring 2012 is anomalous. The second highest concentration was 14 ug/l detected in the fall of 2012.

Analytical Data Sources

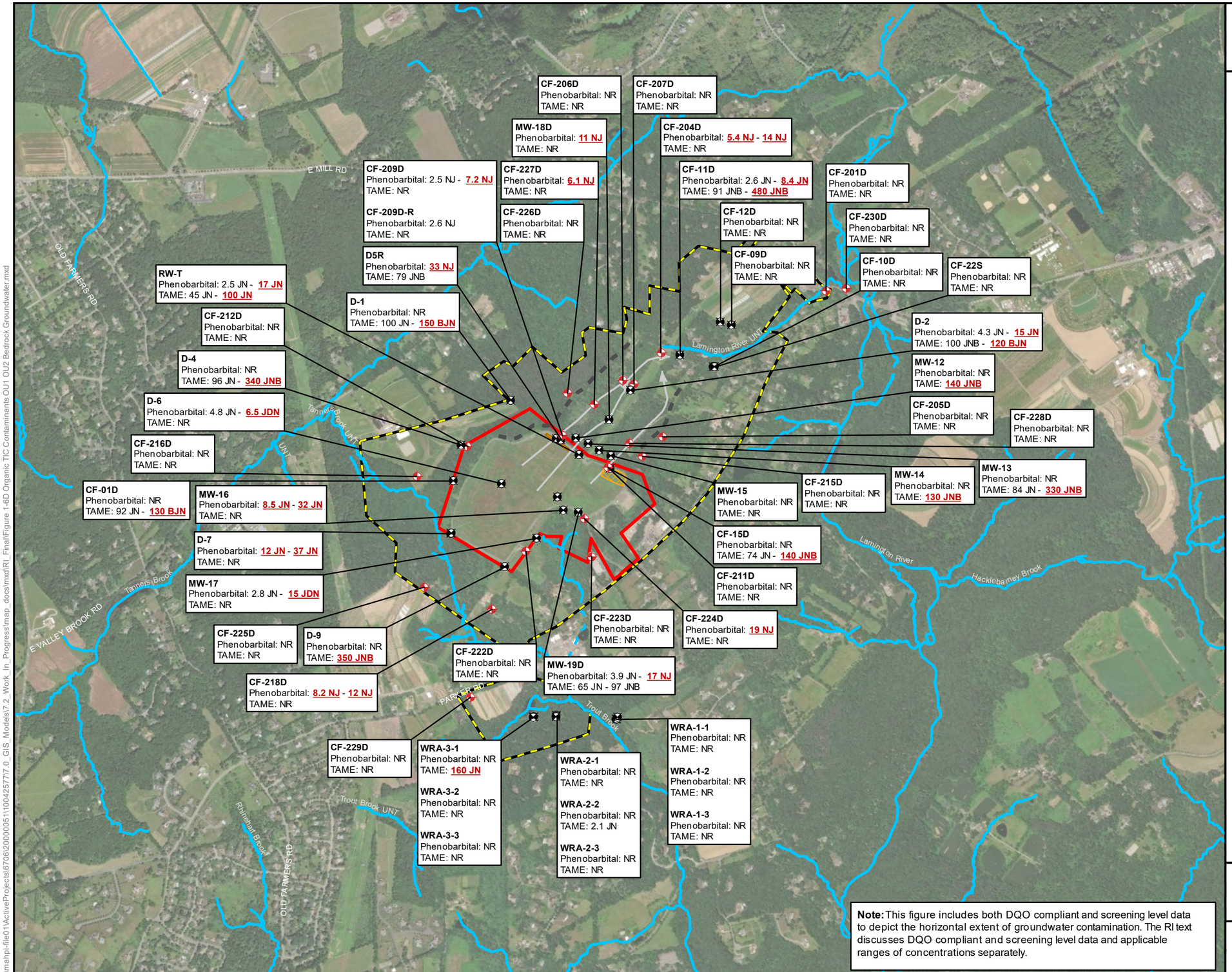
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)
- NJDEP PCEMP does not include analysis of pesticides; therefore, alpha BHC is shown as "not analyzed" in the data boxes.

0 500 1,000 Feet
NOT TO SCALE

OU2 Organic Contaminants of Concern in Bedrock Groundwater

Figure 1-6C
August, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1\00425777.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-6C Organic Contaminants OU1 OU2 Bedrock Groundwater - revised.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 Bedrock Monitoring Well (NJDEP)
- OU2 Bedrock Monitoring Well (HDR)
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

DATA BOX EXAMPLE

Well ID — Detected Concentration Range (Min - Max)
If only detected once, a single value is shown.

D-2
Phenobarbital: 4.3 JN - 15 JN D
TAME: 100 - 120 BJN

Exceedance of NJDEP IGGWQC indicated by **Bold Red Underline**

Abbrev.	Compound	IGGWQC
	Phenobarbital (1)	5
TAME	Tert-amyl-methyl-ether (2)	100

GWQS - NJDEP Groundwater Quality Standards Table 2 Interim Generic Ground Water Quality Criteria (IGGWQC) (N.J.A.C. 7:9C, 2018)

NOTES

- Concentrations are in ug/L and are detected results from the applicable time range. Databoxes are not depth discrete and intended to conceptualize the extent of detections.
- HDR also sampled wells: WRA-2-1, WRA-3-2, WRA-3-3, and CF-11D (shown as NJDEP wells on map).
- NR = Not reported (see TIC note below)
- Tert-amyl-methyl-ether synonym: butane,2-methyoxy-2-methyl-

*Tentatively Identified Compounds (TICs). Interim groundwater quality criteria for synthetic organic chemicals (SOCs) applied. The critera for carcinogenic SOCs is 5 ug/l and non-carcinogenic SOCs is 100 ug/l for individual chemicals. TICs are not reported by the analytical laboratory unless there is sufficient presumptive evidence for their presence.
(1) Classified as a possible human carcinogen by IARC.
(2) Not listed by IARC. Presumed non-carcinogen.
Phenobarbital and TAME are non-target analytes and reported as TICs.

Analytical Data Sources

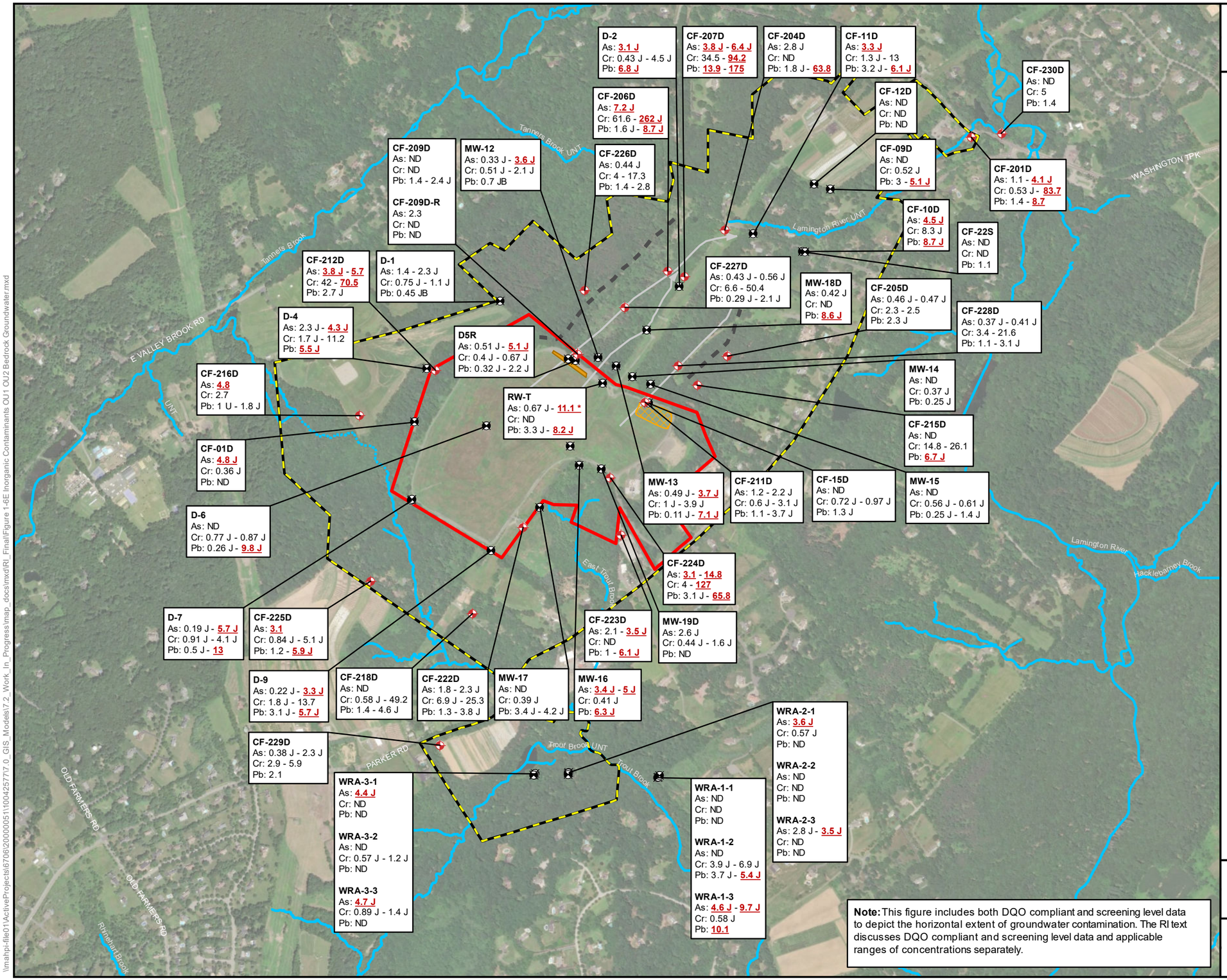
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

0 500 1,000 Feet
NOT TO SCALE

OU2 Organic TIC Contaminants of Concern in Bedrock Groundwater

Figure 1-6D
August, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1\004257\7.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-6D Organic TIC Contaminants OU1 OU2 Bedrock Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 Bedrock Monitoring Well (NJDEP)
- OU2 Bedrock Monitoring Well (HDR)
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

DATA BOX EXAMPLE

Well ID — Detected Concentration Range (Min - Max)
If only detected once, a single value is shown.

D-2
As: **3.1 J**
Cr: 0.43 J - 4.5 J
Pb: **6.8 J** - **6.8 J**

Exceedance of NJDEP GWQS indicated by **Bold Red Underline**

Abbrev.	Compound	GWQS
As	Arsenic	3 ug/L
Cr	Chromium	70 ug/L
Pb	Lead	5 ug/L

GWQS - NJDEP Groundwater Quality Standards (N.J.A.C. 7:9C, 2018)

NOTES
- Concentrations are in ug/L and are detected results from the applicable time range. Databoxes are not depth discrete and intended to conceptualize the extent of detections.
- ND = Analyte not detected.
- UNT = Unnamed tributary
- HDR also sampled wells: WRA-2-1, WRA-3-2, WRA-3-3, and CF-11D (shown as NJDEP wells on map)

Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

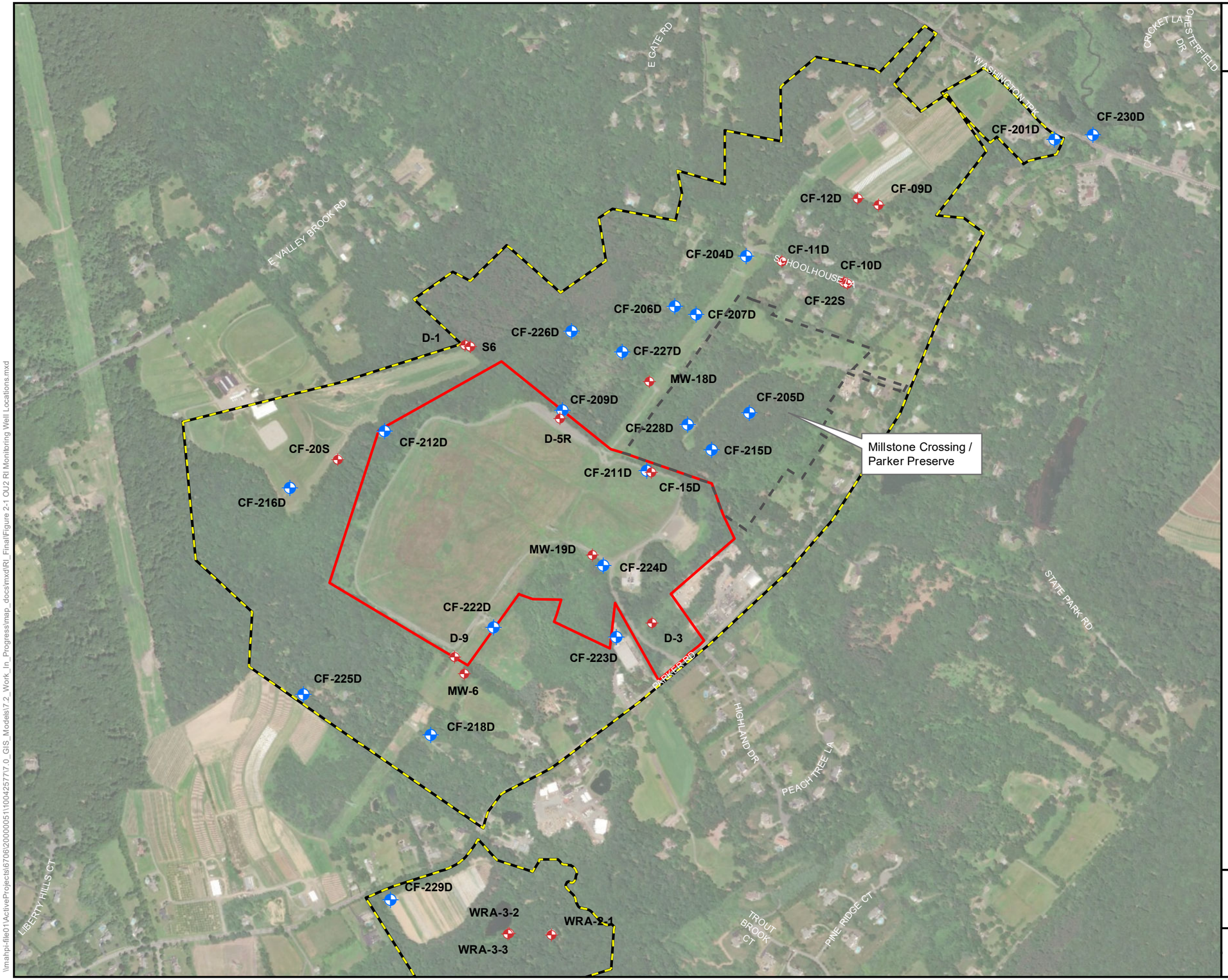
NJDEP PCEMP periodically analyzes metals using the ICP-MS method in addition to the ICP-AES method typically reported. The maximum concentration between the two methods is shown. This is applicable to samples collected in 2012.

0 500 1,000 Feet

OU2 Inorganic Contaminants of Concern in Bedrock Groundwater

Figure 1-6E
August, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1\004257\7.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 1-6E Inorganic Contaminants OU1 OU2 Bedrock Groundwater.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- OU2 RI Bedrock Monitoring Wells
- NJDEP Subset Monitoring Wells
- Millstone Crossing / Parker Preserve

Notes

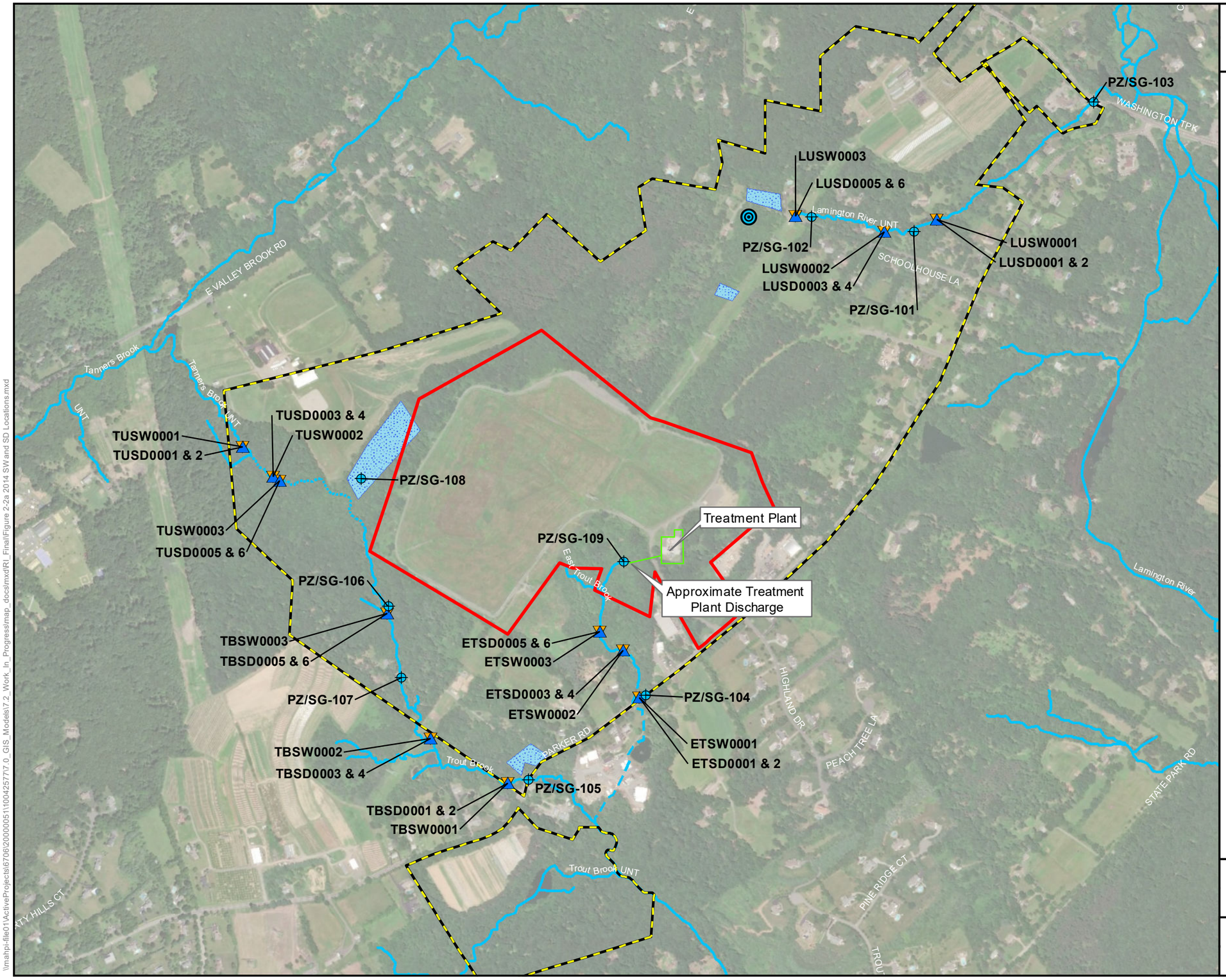
CF-215D: Monitoring well not constructed at borehole due to low yield as determined during packer testing. This borehole was samples during packer testing and subsequently abandoned. CF-205D monitoring well used to provide delineation in the area of the ridge to the northeast.

0 400 800 Feet

OU2 RI Monitoring Well Locations (Sampled Wells Only)

Figure 2-1
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1\00425771\7.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 2-1 OU2 RI Monitoring Well Locations.mxd



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Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation
- Surface Water Samples
- Sediment Samples
- Stream Gauge / Piezometer
- Surface Water
- Undefined Surface Water
- East Trout Brook culvert
- Springs
- Seeps

UNT = Unnamed Tributary

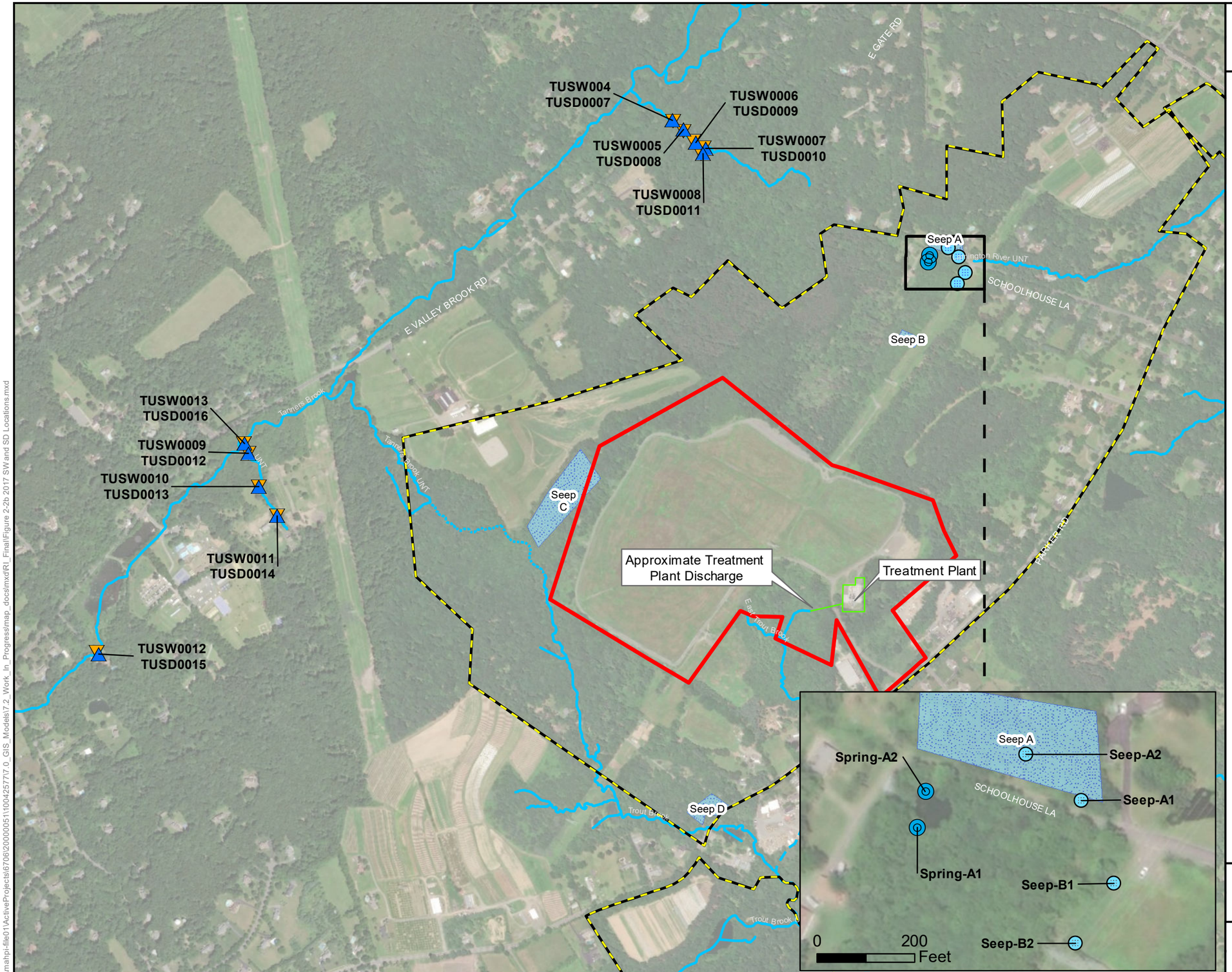
Note
Samples collected in November, 2014.

0 400 800 Feet

2014 Surface Water Sample, Sediment Sample, Stream Gauge, and Piezometer Locations

Figure 2-2a
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\100425777.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 2-2a 2014 SW and SD Locations.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Surface Water Samples
- Sediment Samples
- Seeps
- Springs
- Surface Water
- Undefined Surface Water
- East Trout Brook culvert

UNT = Unnamed Tributary

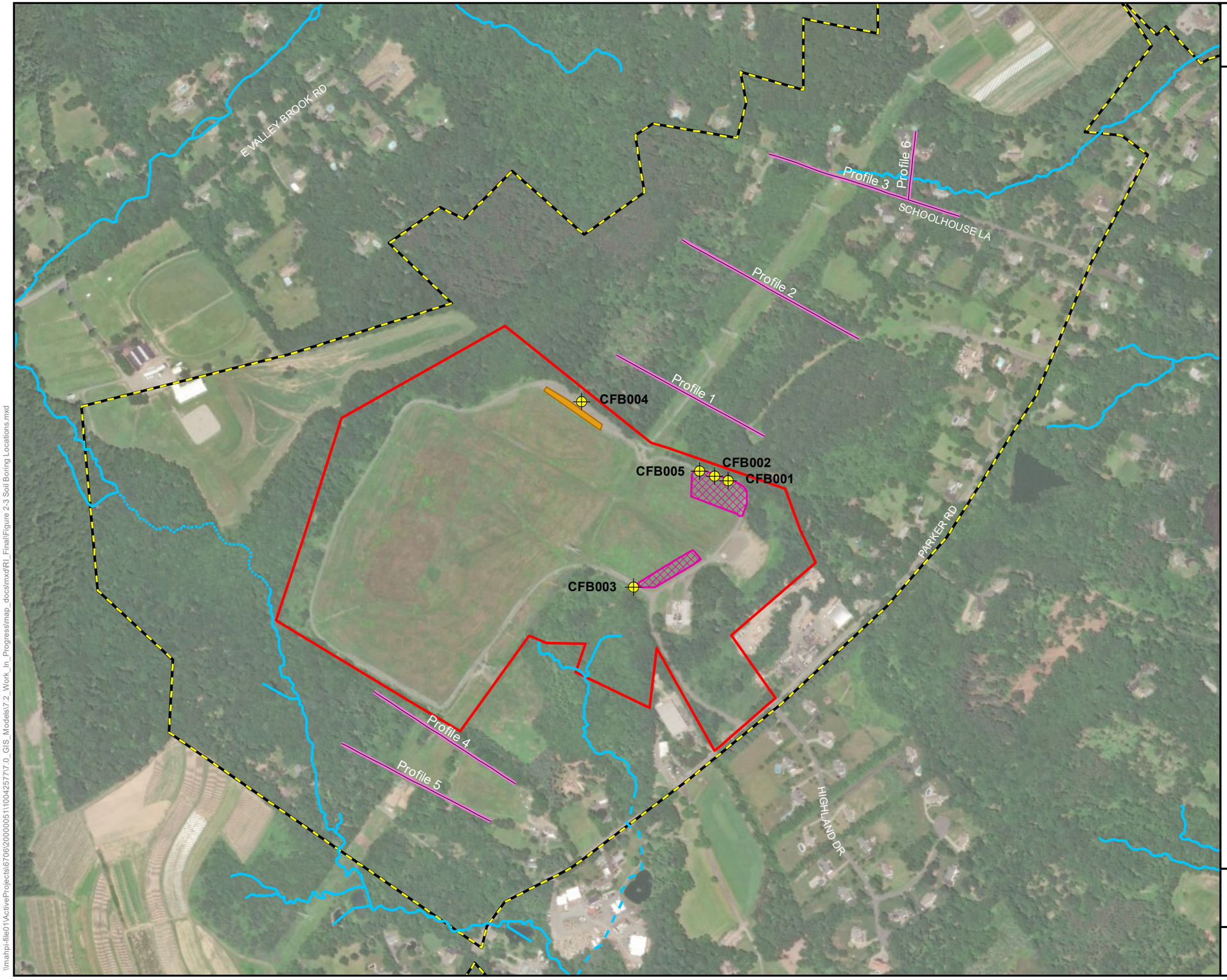
Note
Samples collected in September, 2017.

0 400 800 Feet

2017 Spring, Seep, Background Surface Water and Sediment Sampling Locations

Figure 2-2b
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\100425717.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 2-2b 2017 SW and SD Locations.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

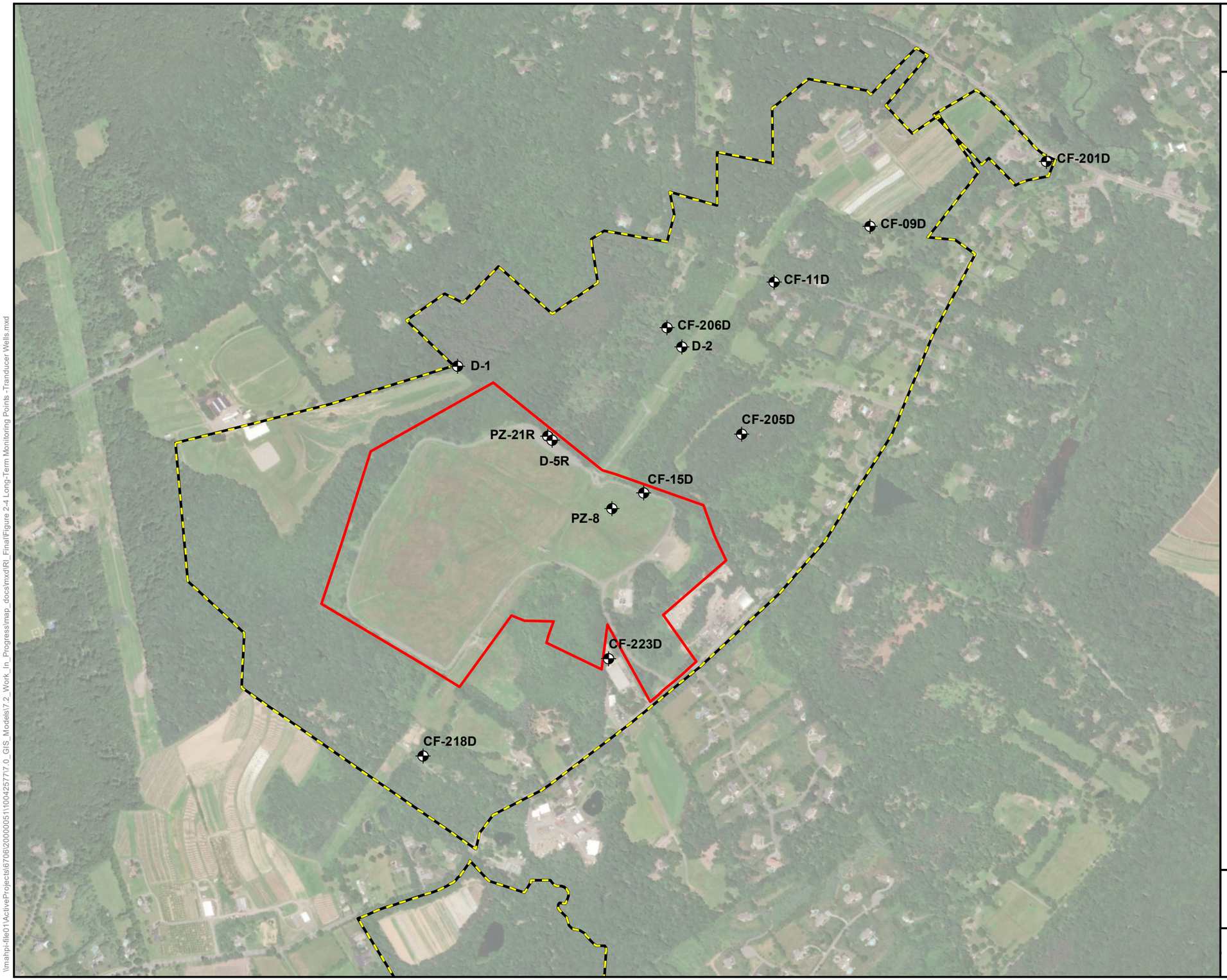
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Soil Borings
- 2011 Buried Drum Delineation Report Geophysical Investigation Areas (Delta Geophysics - See Appendix D)
- 2011 Geophysical Cross Section Profile Lines (Delta Geophysics - See Appendix C)
- North Waste Cell Excavation
- Surface Water
- Undefined Surface Water
- East Trout Brook culvert

0 300 600 Feet

Soil Borings and Geophysical Survey Locations

Figure 2-3
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1\00425777.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 2-3 Soil Boring Locations.mxd



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Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

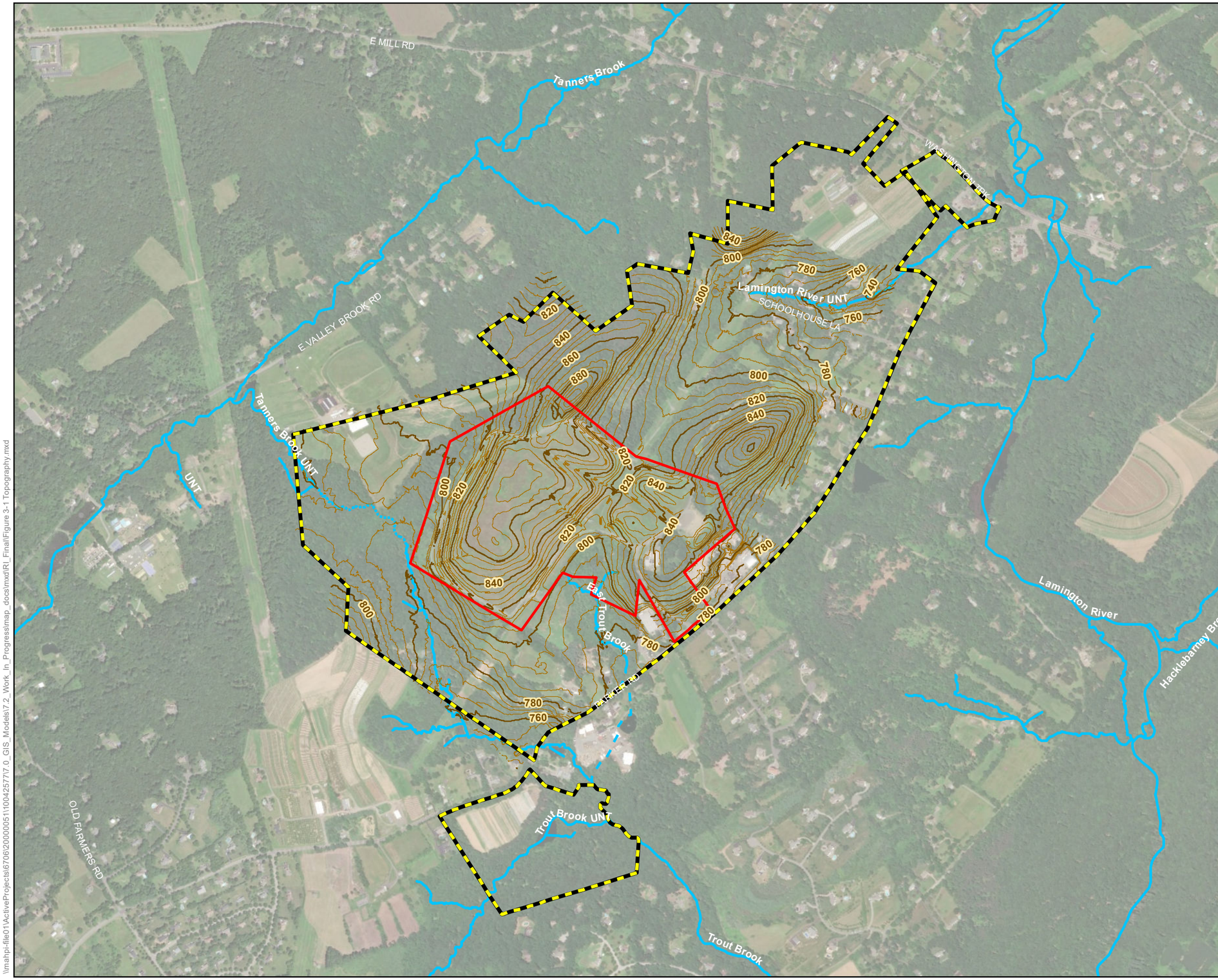
- Transducer Study Well
- OU1 - Landfill Property Boundary
- OU2 Investigation Area

0 400 800 Feet

Long-term Water Elevation Monitoring Points (Transducer Wells)

Figure 2-4
June, 2018

\\mahpl-file01\ActiveProjects\67061200000511\00425777\7.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 2-4 Long-Term Monitoring Points -Tranducer Wells.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
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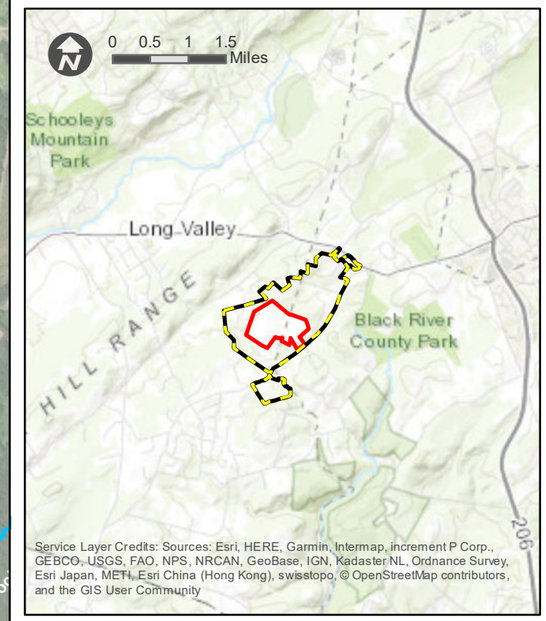
Units: Foot US



Legend

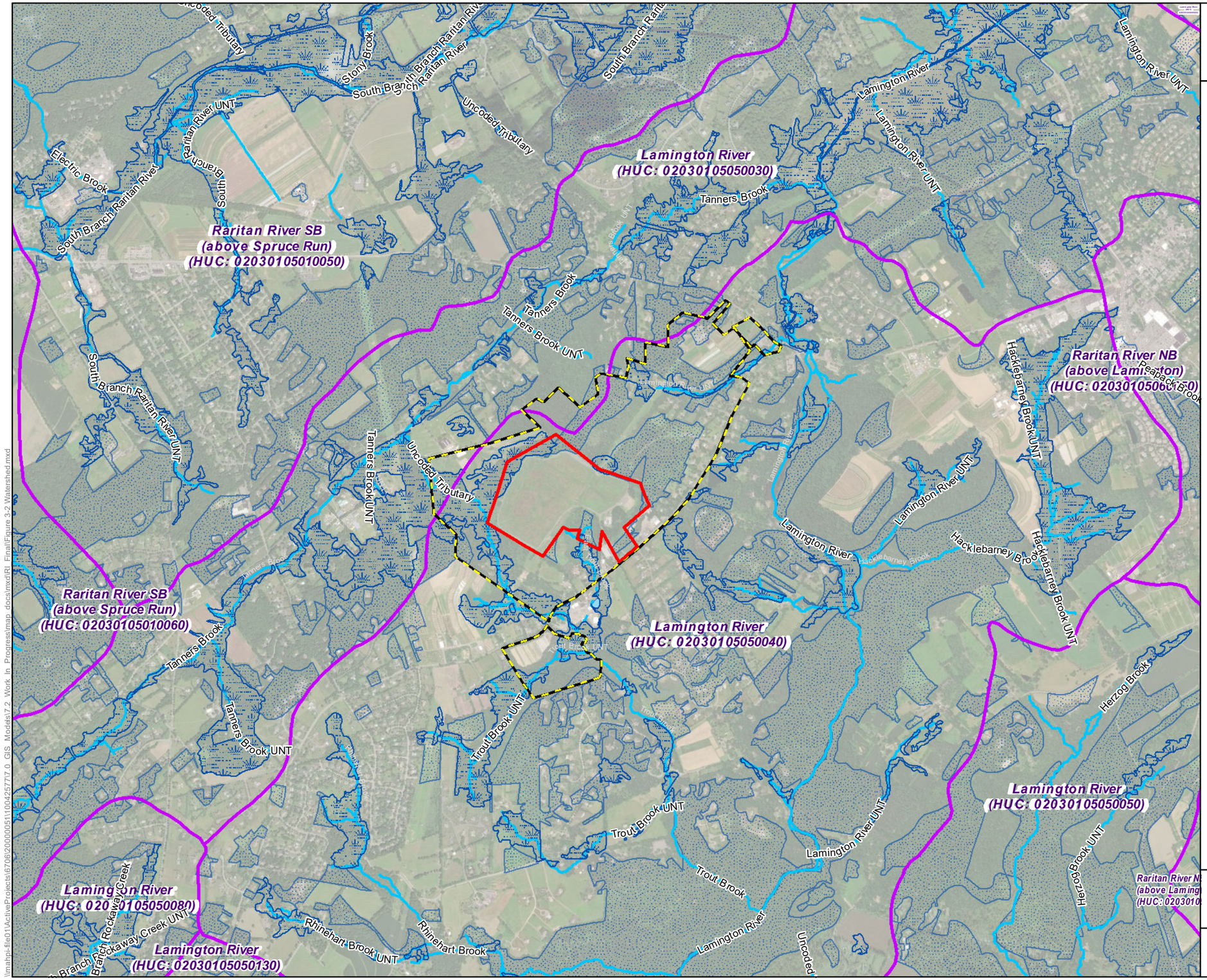
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- 5 ft Elevation Contour
- 20 ft Elevation Contour
- Surface Water

0 500 1,000 Feet

Site Topography

Figure 3-1
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\100425777.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_FinalFigure 3-1 Topography.mxd



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Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

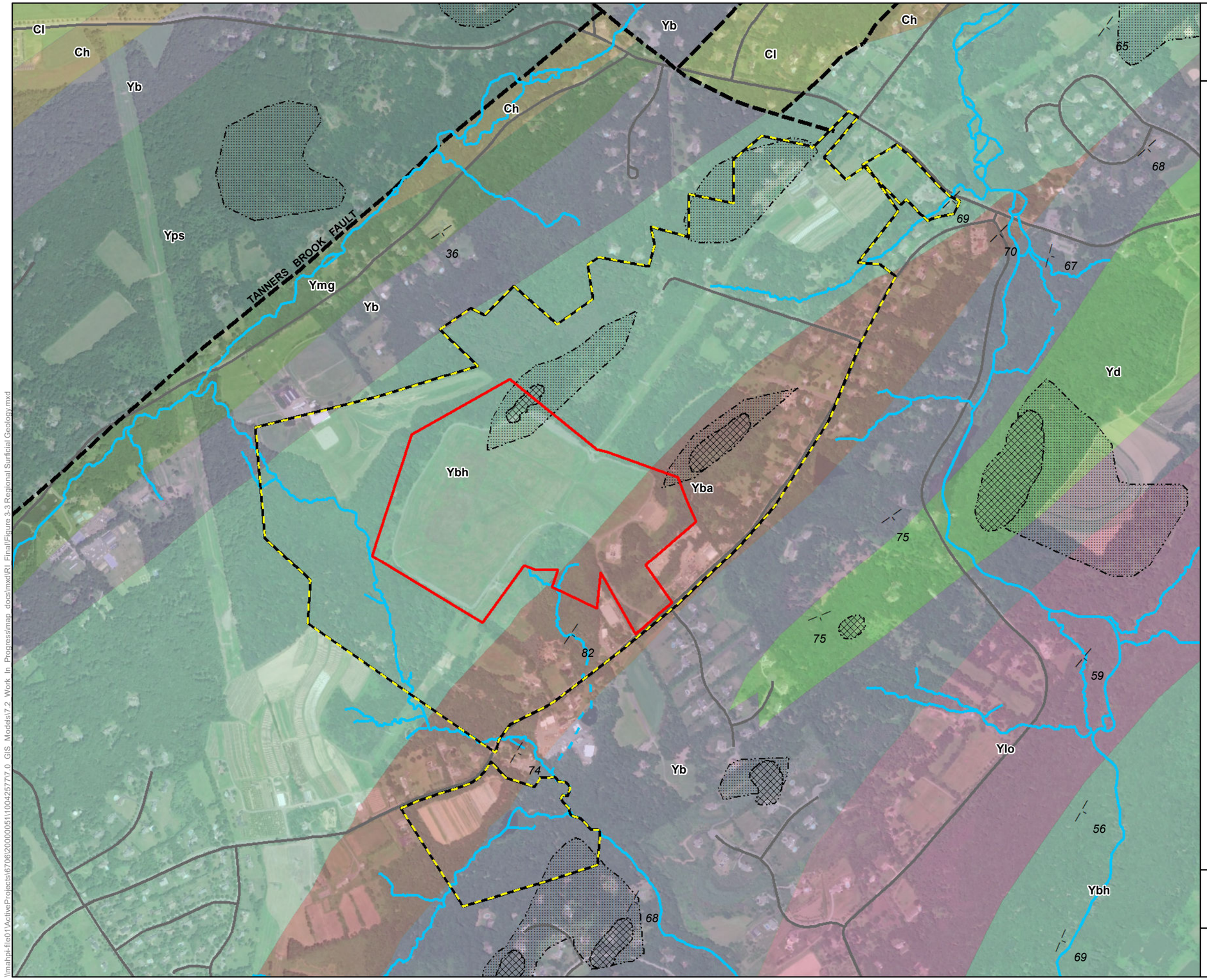
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Hydrologic Unit Boundaries (HUC 14)
- Wetlands
- Surface Water
- Undefined Surface Water
- Streams
- East Trout Brook culvert
- Ponds
- Highlands Groundwater Recharge Areas

0 1,000 2,000 Feet

Watersheds

Figure 3-2
June, 2018

\\mahpi-file01\ActiveProjects\6706\200000511\00425717.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 3-2 Watershed.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Streets
- Surface Water
- East Trout Brook culvert

Bedrock Geology

Name, Symbol

- Microantiperthite Alaskite, Yma
- Biotite-Quartz-Feldspar Gneiss, Yb
- Diorite, Yd
- Hardyston Quartzite, Ch
- Hornblende Granite, Ybh
- Leithsville Formation, Cl
- Microperthite Alaskite, Yba
- Monazite Gneiss, Ymg
- Pyroxene Syenite, Yps
- Quartz-Oligoclase Gneiss, Ylo
- Tanners Brook Fault
- Approximate strike and dip of inclined planar bedding features.

Bedrock Outcrops

- Scattered
- Extensive

Strike and data is approximate. Data geoferenced based on data obtained from the *Bedrock Geologic Map of the Chester Quadrangle, Morris County, NewJersey* .

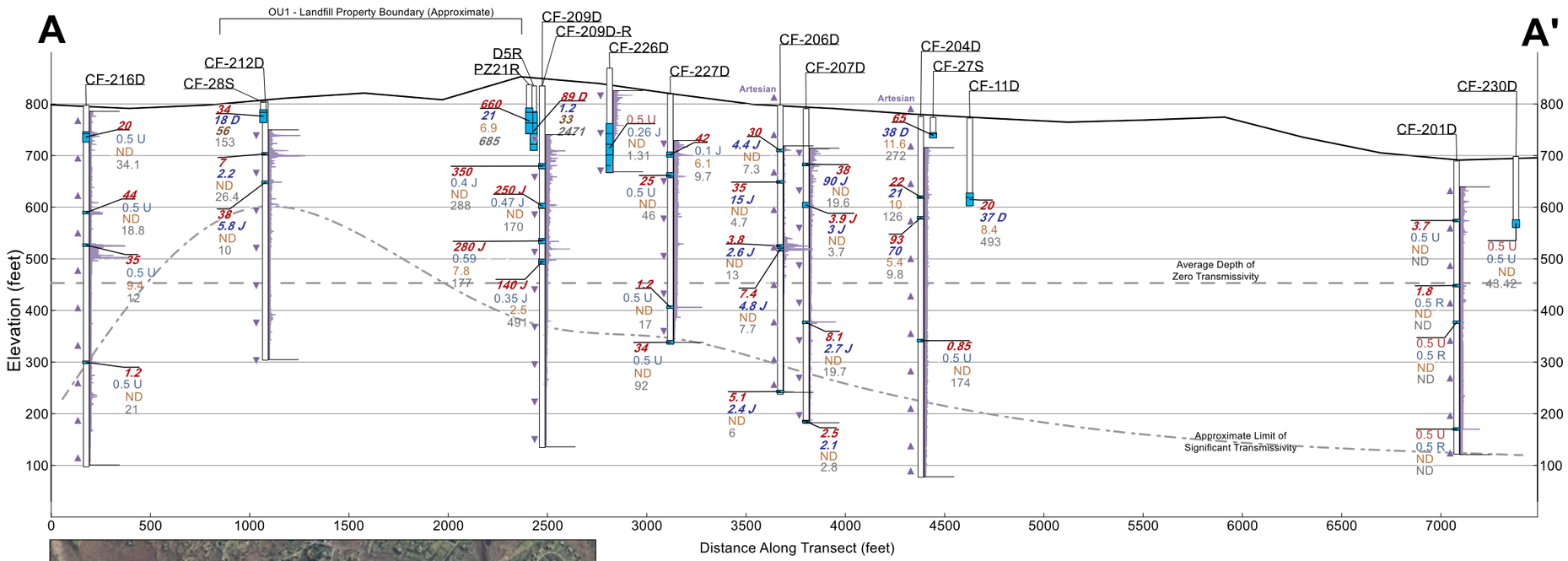
Volkert, Richard A.; Markewicz Frank J.; Drake, Avery A. *Bedrock Geologic Map of the Chester Quadrangle, Morris County, New Jersey [map]* 1:24,000 New Jersey Department of Environmental Protection Division of Water Resources; New Jersey Geological Survey. 1990

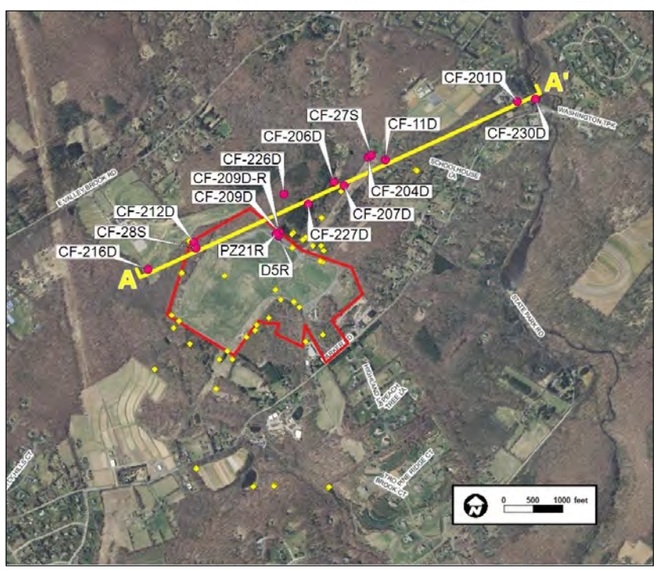
0 500 1,000 Feet

Local Surficial Bedrock Geology

Figure 3-3
June, 2018

\\mahpi-file01\ActiveProjects\67062000005\1100425777.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 3-3 Regional Surficial Geology.mxd





Analytical Data Sources:
HDR OU2 Remedial Investigation Groundwater Samples (2011 to 2015, 2017)
NJDEP Post-Construction Environmental Monitoring (PCEM) Program Samples (Q4 2011 to Q4 2015)

Approximate Limit of Significant Transmissivity Notes:
CF-204D excluded from interpolation due to artesian nature of aquifer unit at this location.
CF-226D excluded from interpolation due to shallow installation depth.

Average site-wide depth of zero transmissivity calculated using OU2 RI geophysical data.

Geophysical Data Source:
Downhole Geophysical Report (see RI Appendix K)
(NOTE: Downhole geophysical survey not completed at CF-230D.)

Transmissivity Data Source:
FLUTe Hydraulic Profiling Report (see RI Table 4-1 and RI Appendix T)

Well	Total Depth (ft bgs)	Depth to Competent Rock (ft bgs)	Maximum Depth of Liner Eversion (ft bgs)	Vertical Flow Direction
CF-201D	571	30	570	Upwards
CF-204D	700	56	205	Artesian
CF-206D	561	70	561	Artesian
CF-207D	561	40	490	Down or none
CF-209D	700	65	480	Down or none
CF-212D	500	50	220	Down or none
CF-216D	700	0	539	Upwards
CF-226D	200	3	94	Down or none
CF-227D	480	75	480	Down or none

Combe Fill South Landfill
Superfund Site RI/FS

Legend (Inset Map)

- Well Location On Section
- Other Well Location
- OU1 - Landfill Property Boundary

Cross Section Legend

- *20* — 1,4-Dioxane
- *37 D* — Benzene
- 8.4 — Total Carcinogenic TICs
- 493 — Total Non-Carcinogenic TICs

Generalized Vertical Flow Direction
Well Casing
Borehole Caliper Reading (Relative Width of Hole) Spikes indicate potential fracture zones.
Well Screen or Sample Port Zone

Notes:

Constituents are presented in the same order adjacent to the sample location.

Concentrations shown in ug/L.

Bold Italics indicates exceedance of applicable NJGWQS.

Constituent	GWQS
1,4-Dioxane	0.4
Benzene	1
Total Carcinogenic SOCs *	25
Total Non-Carcinogenic SOCs *	500

NJAC 7:9C Ground Water Quality Standards, Tables 1 & 2
** Interim Generic Criteria for Synthetic Organic Chemicals*

Synthetic Organic Chemicals (SOCs) are purposefully produced organic chemical compounds defined in NJAC 7:9C-1.4. SOCs do not have a specific groundwater quality criterion. Criteria for individual carcinogenic and non-carcinogenic are 5 ug/L and 100 ug/L respectively. The criteria for totals of each are 25 ug/L and 500 ug/L respectively.

Tentatively Identified Compounds (TICs) are non-target analytes for which there is presumptive evidence of their presence. Some TICs are unidentifiable and reported as unknowns. SOC TICs were grouped based on their carcinogenicity listed by the International Agency for Research on Cancer (IARC, March 2018).

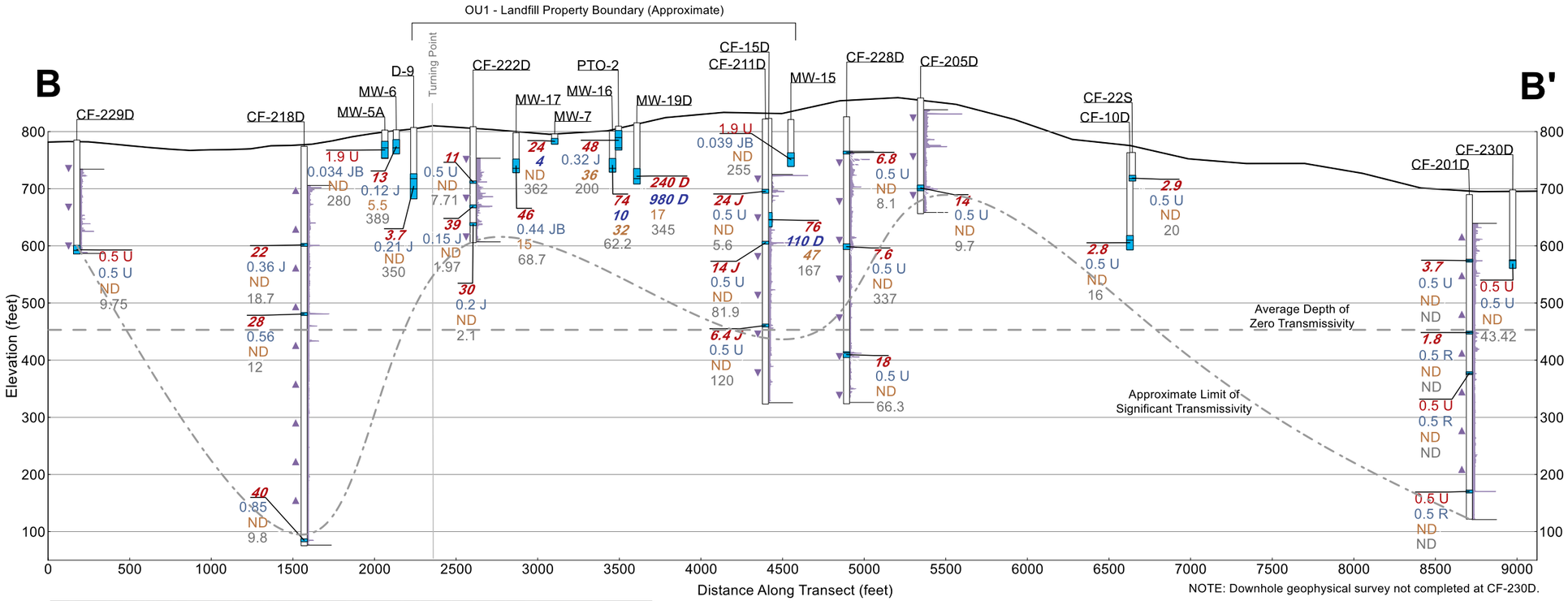
Unknown TICs, non-SOCs, and TICs for which there is a promulgated standard in Table 1 of NJAC 7:9C are excluded from summations.

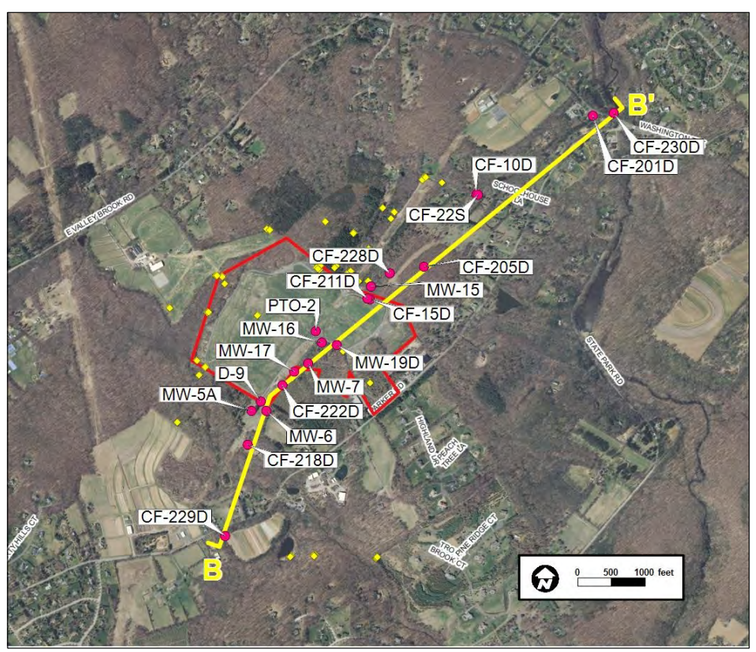
Maximum detected concentration occurring within the study duration is shown. Sample dates range from 4th Quarter 2011 through 4th Quarter 2015; and 1st Quarter 2017 (CF-209D and CF-209D-R). Samples collected by NJDEP and HDR.

CROSS SECTION A - A'

Figure 3-4
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\10042577\7.0 GIS Models\7.2 Work In Progress\EnviroInsite\Cross Sections\Figure 3-4 Transect A.vizx





Analytical Data Sources:
HDR OU2 Remedial Investigation Groundwater Samples (2011 to 2015, 2017)
NJDEP Post-Construction Environmental Monitoring (PCEM) Program Samples (Q4 2011 to Q4 2015)

Average site-wide depth of zero transmissivity calculated using OU2 RI geophysical data.

Geophysical Data Source:
Downhole Geophysical Report (see RI Appendix K)
(NOTE: Downhole geophysical survey not completed at CF-230D.)

Transmissivity Data Source:
FLUTe Hydraulic Profiling Report (see RI Table 4-1 and RI Appendix T)

Well	Total Depth (ft bgs)	Depth to Competent Rock (ft bgs)	Maximum Depth of Liner Eversion (ft bgs)	Vertical Flow Direction
CF-201D	571	30	570	Upwards
CF-205D	198	6	173	Down or none
CF-211D	499	87	359	Down or none
CF-218D	700	67	698	Upwards
CF-222D	200	60	200	Down or none
CF-228D	499	35	428	Down or none
CF-229D	197	35	197	Down or none

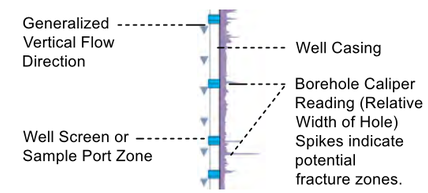
Combe Fill South Landfill
Superfund Site RI/FS

Legend (Inset Map)

- Well Location On Section
- Other Well Location
- OU1 - Landfill Property Boundary

Cross Section Legend

- 20 — 1,4-Dioxane
- 37 D — Benzene
- 8.4 — Total Carcinogenic TICs
- 493 — Total Non-Carcinogenic TICs



Notes:

Constituents are presented in the same order adjacent to the sample location.

Concentrations shown in ug/L.

Bold Italics indicates exceedance of applicable NJGWQS.

Constituent	GWQS
1,4-Dioxane	0.4
Benzene	1
Total Carcinogenic SOCs *	25
Total Non-Carcinogenic SOCs *	500

NJAC 7:9C Ground Water Quality Standards, Tables 1 & 2
** Interim Generic Criteria for Synthetic Organic Chemicals*

Synthetic Organic Chemicals (SOCs) are purposefully produced organic chemical compounds defined in NJAC 7:9C-1.4. SOCs do not have a specific groundwater quality criterion. Criteria for individual carcinogenic and non-carcinogenic are 5 ug/L and 100 ug/L respectively. The criteria for totals of each are 25 ug/L and 500 ug/L respectively.

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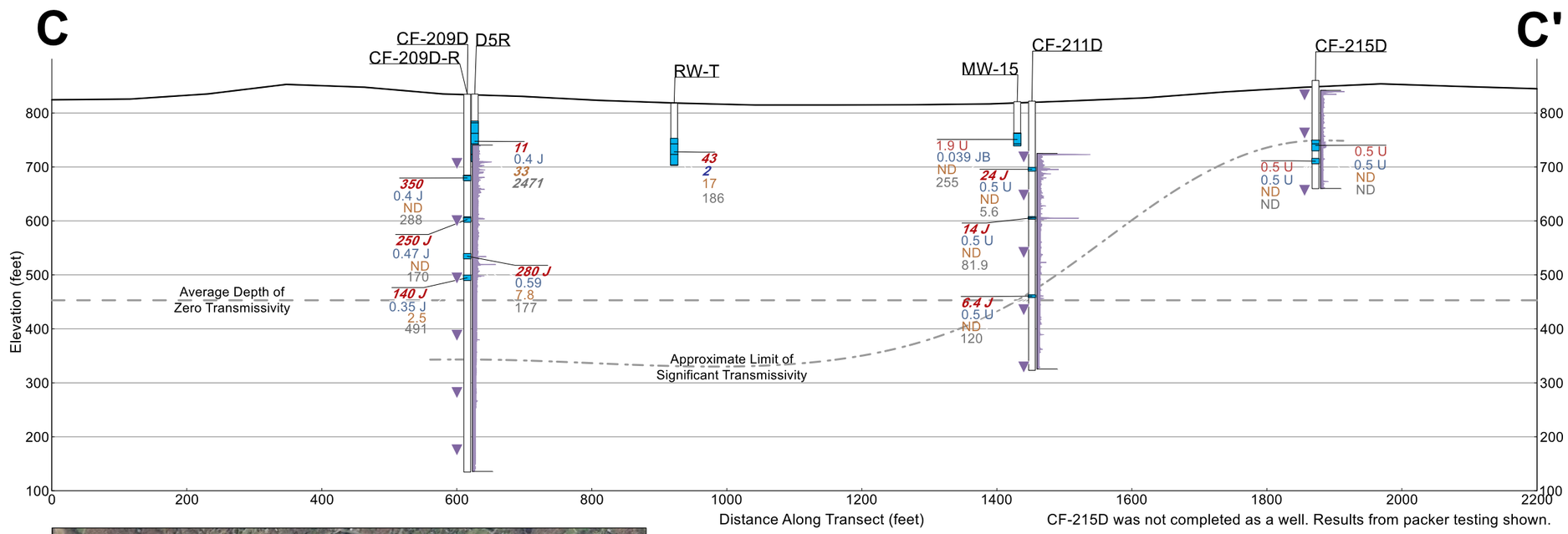
Unknown TICs, non-SOCs, and TICs for which there is a promulgated standard in Table 1 of NJAC 7:9C are excluded from summations.

Maximum detected concentration occurring within the study duration is shown. Sample dates range from 4th Quarter 2011 through 4th Quarter 2015; and 1st Quarter 2017 (CF-209D and CF-209D-R). Samples collected by NJDEP and HDR.

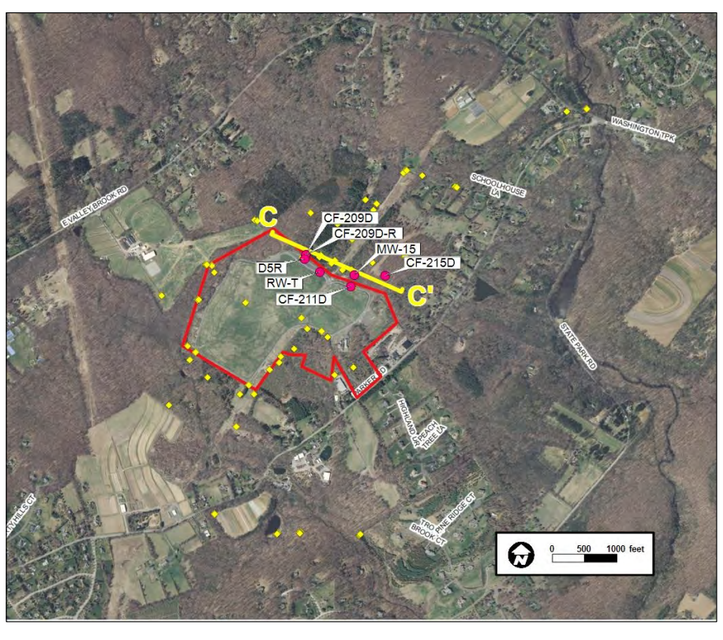
CROSS SECTION B - B'

Figure 3-5
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\10042577\7.0 GIS Models\7.2 Work In Progress\EnviroInsite\Cross Sections\Figure 3-5 to 3-7 Transects B-D.vizx



CF-215D was not completed as a well. Results from packer testing shown.



Analytical Data Sources:
HDR OU2 Remedial Investigation Groundwater Samples (2011 to 2015, 2017)
NJDEP Post-Construction Environmental Monitoring (PCEM) Program Samples (Q4 2011 to Q4 2015)

Average site-wide depth of zero transmissivity calculated using OU2 RI geophysical data.

Geophysical Data Source:
Downhole Geophysical Report (see RI Appendix K)

Transmissivity Data Source:
FLUTe Hydraulic Profiling Report (see RI Table 4-1 and RI Appendix T)

Well	Total Depth (ft bgs)	Depth to Competent Rock (ft bgs)	Maximum Depth of Liner Eversion (ft bgs)	Vertical Flow Direction
CF-209D	700	65	480	Down or none
CF-211D	499	87	359	Down or none
CF-215D	200	15	68	Down or none

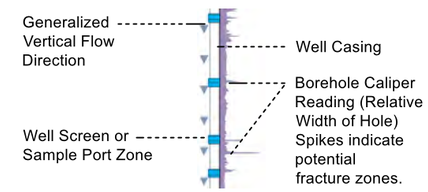
Combe Fill South Landfill
Superfund Site RI/FS

Legend (Inset Map)

- Well Location On Section
- Other Well Location
- OU1 - Landfill Property Boundary

Cross Section Legend

- 20 — 1,4-Dioxane
- 37 D — Benzene
- 8.4 — Total Carcinogenic TICs
- 493 — Total Non-Carcinogenic TICs



Notes:

Constituents are presented in the same order adjacent to the sample location.

Concentrations shown in ug/L.

Bold Italics indicates exceedance of applicable NJGWQS.

Constituent	GWQS
1,4-Dioxane	0.4
Benzene	1
Total Carcinogenic SOCs *	25
Total Non-Carcinogenic SOCs *	500

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** Interim Generic Criteria for Synthetic Organic Chemicals*

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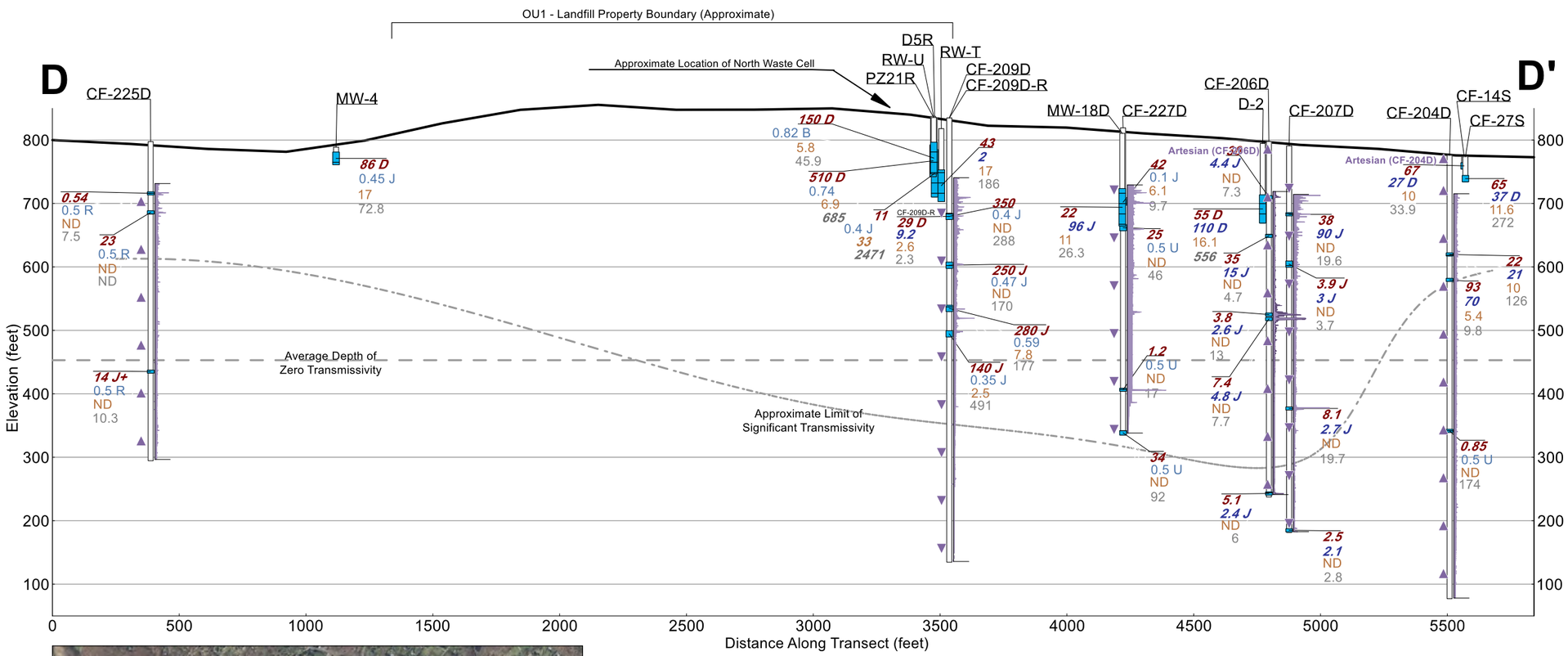
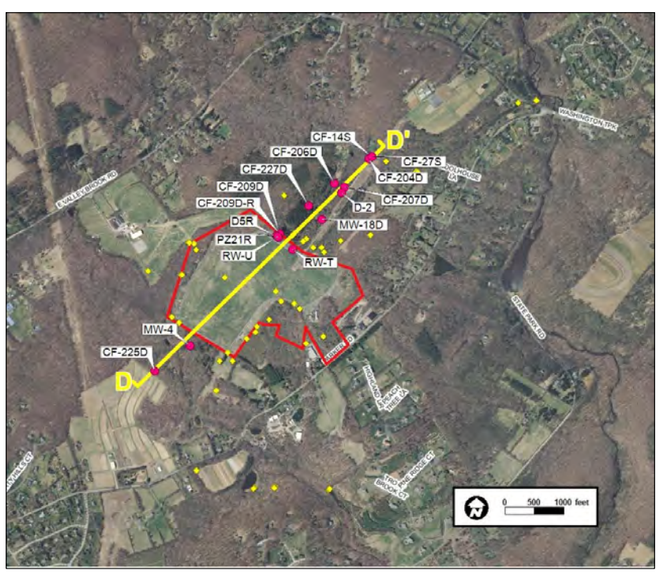
Maximum detected concentration occurring within the study duration is shown. Sample dates range from 4th Quarter 2011 through 4th Quarter 2015; and 1st Quarter 2017 (CF-209D and CF-209D-R). Samples collected by NJDEP and HDR.

CROSS SECTION C - C'

Figure 3-6
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\10042577\7.0_GIS_Models\7.2_Work_In_Progress\EnviroInsite\Cross Sections\Figure 3-5 to 3-7 Transects B-D.vizx





Analytical Data Sources:
HDR OU2 Remedial Investigation Groundwater Samples (2011 to 2015, 2017)
NJDEP Post-Construction Environmental Monitoring (PCEM) Program Samples (Q4 2011 to Q4 2015)

Average site-wide depth of zero transmissivity calculated using OU2 RI geophysical data.

Geophysical Data Source:
Downhole Geophysical Report (see RI Appendix K)

Transmissivity Data Source:
FLUTe Hydraulic Profiling Report (see RI Table 4-1 and RI Appendix T)

Well	Total Depth (ft bgs)	Depth to Competent Rock (ft bgs)	Maximum Depth of Liner Eversion (ft bgs)	Vertical Flow Direction
CF-204D	700	56	205	Artesian
CF-206D	561	70	561	Artesian
CF-207D	561	40	490	Down or none
CF-209D	700	65	480	Down or none
CF-225D	500	45	177	Upwards
CF-227D	480	75	480	Down or none

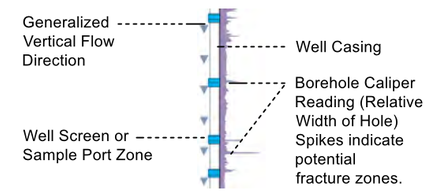
Combe Fill South Landfill
Superfund Site RI/FS

Legend (Inset Map)

- Well Location On Section
- Other Well Location
- OU1 - Landfill Property Boundary

Cross Section Legend

- 20 — 1,4-Dioxane
- 37 D — Benzene
- 8.4 — Total Carcinogenic TICs
- 493 — Total Non-Carcinogenic TICs



Notes:

Constituents are presented in the same order adjacent to the sample location.

Concentrations shown in ug/L.

Bold Italics indicates exceedance of applicable NJGWQS.

Constituent	GWQS
1,4-Dioxane	0.4
Benzene	1
Total Carcinogenic SOCs *	25
Total Non-Carcinogenic SOCs *	500

NJAC 7:9C Ground Water Quality Standards, Tables 1 & 2
** Interim Generic Criteria for Synthetic Organic Chemicals*

Synthetic Organic Chemicals (SOCs) are purposefully produced organic chemical compounds defined in NJAC 7:9C-1.4. SOCs do not have a specific groundwater quality criterion. Criteria for individual carcinogenic and non-carcinogenic are 5 ug/L and 100 ug/L respectively. The criteria for totals of each are 25 ug/L and 500 ug/L respectively.

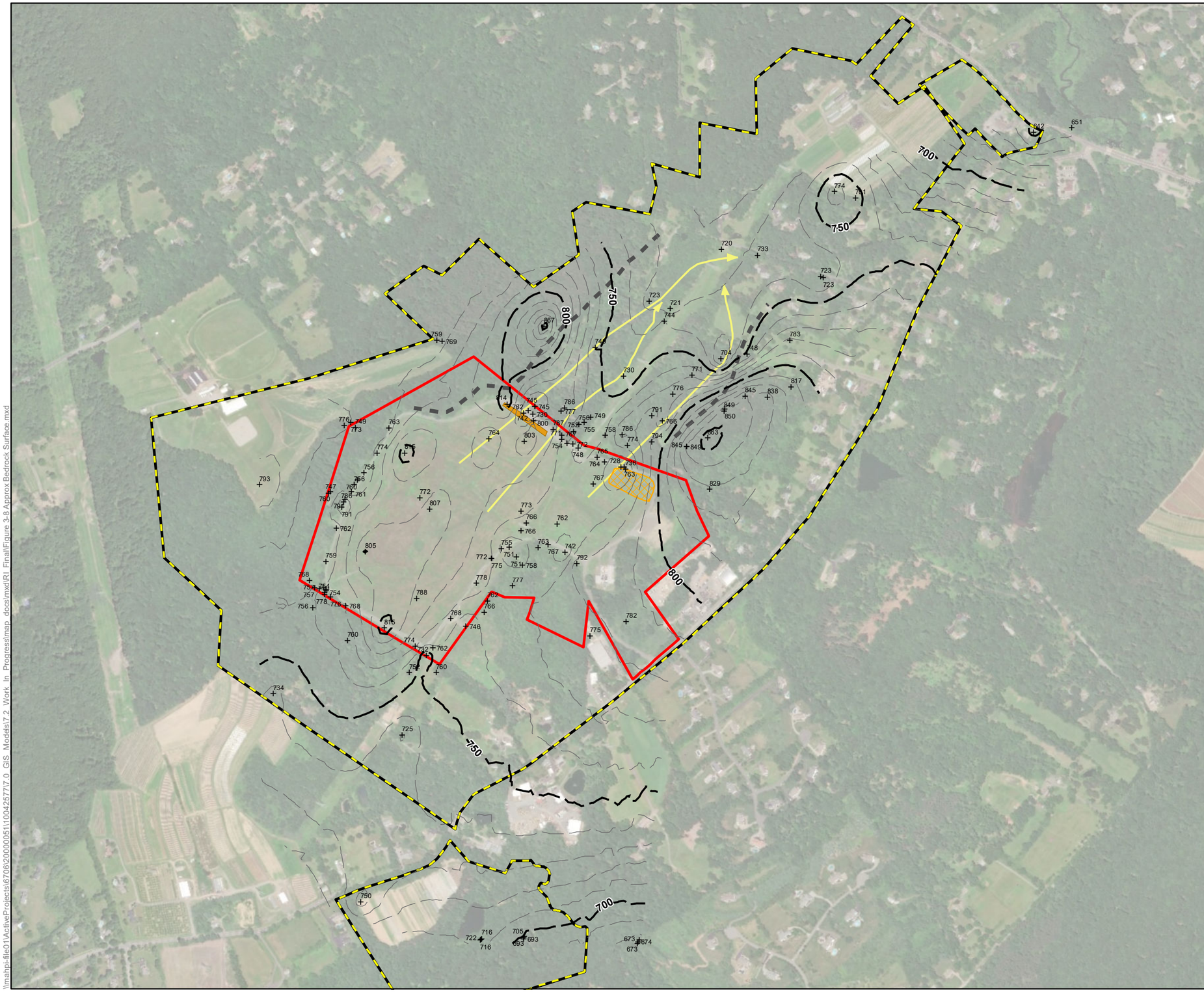
Tentatively Identified Compounds (TICs) are non-target analytes for which there is presumptive evidence of their presence. Some TICs are unidentifiable and reported as unknowns. SOC TICs were grouped based on their carcinogenicity listed by the International Agency for Research on Cancer (IARC, March 2018).

Unknown TICs, non-SOCs, and TICs for which there is a promulgated standard in Table 1 of NJAC 7:9C are excluded from summations.

Maximum detected concentration occurring within the study duration is shown. Sample dates range from 4th Quarter 2011 through 4th Quarter 2015; and 1st Quarter 2017 (CF-209D and CF-209D-R). Samples collected by NJDEP and HDR.

CROSS SECTION D - D'

Figure 3-7
June, 2018



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- North Waste Cell Excavation Area
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Geologic Data Point
- Approximate Bedrock Elevation Contour (10 ft)
- Approximate Bedrock Elevation Contour (50 ft)
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Geologic data collected from both HDR and NJDEP installed monitoring wells as well as well records for private irrigation and potable wells. Interpolation developed using Kriging.

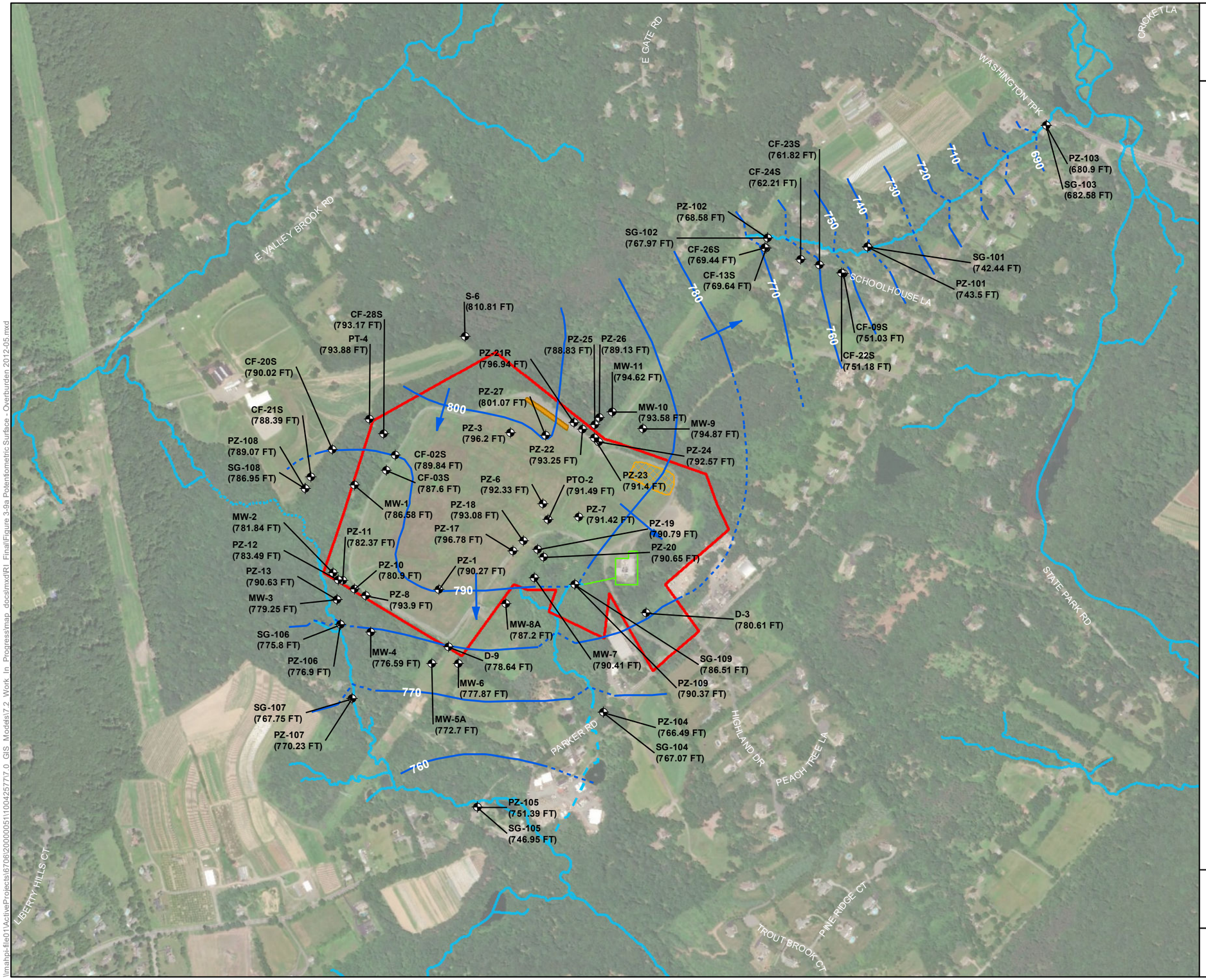
Elevations in feet above mean sea level (ft amsl).

0 400 800 Feet

Approximate Bedrock Surface Elevation

Figure 3-8
June, 2018

\\mahpi-file01\ActiveProjects\670\120000051\100425777.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 3-8 Approx Bedrock Surface.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Well location used for interpretation of potentiometric surface
- Potentiometric Surface Elevation Contour
- Contour dashed where inferred.
- Groundwater Flow Direction
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Treatment Plant
- Surface Water

Notes

Potentiometric surface elevation contours based on measurements of groundwater depth collected in May, 2012.

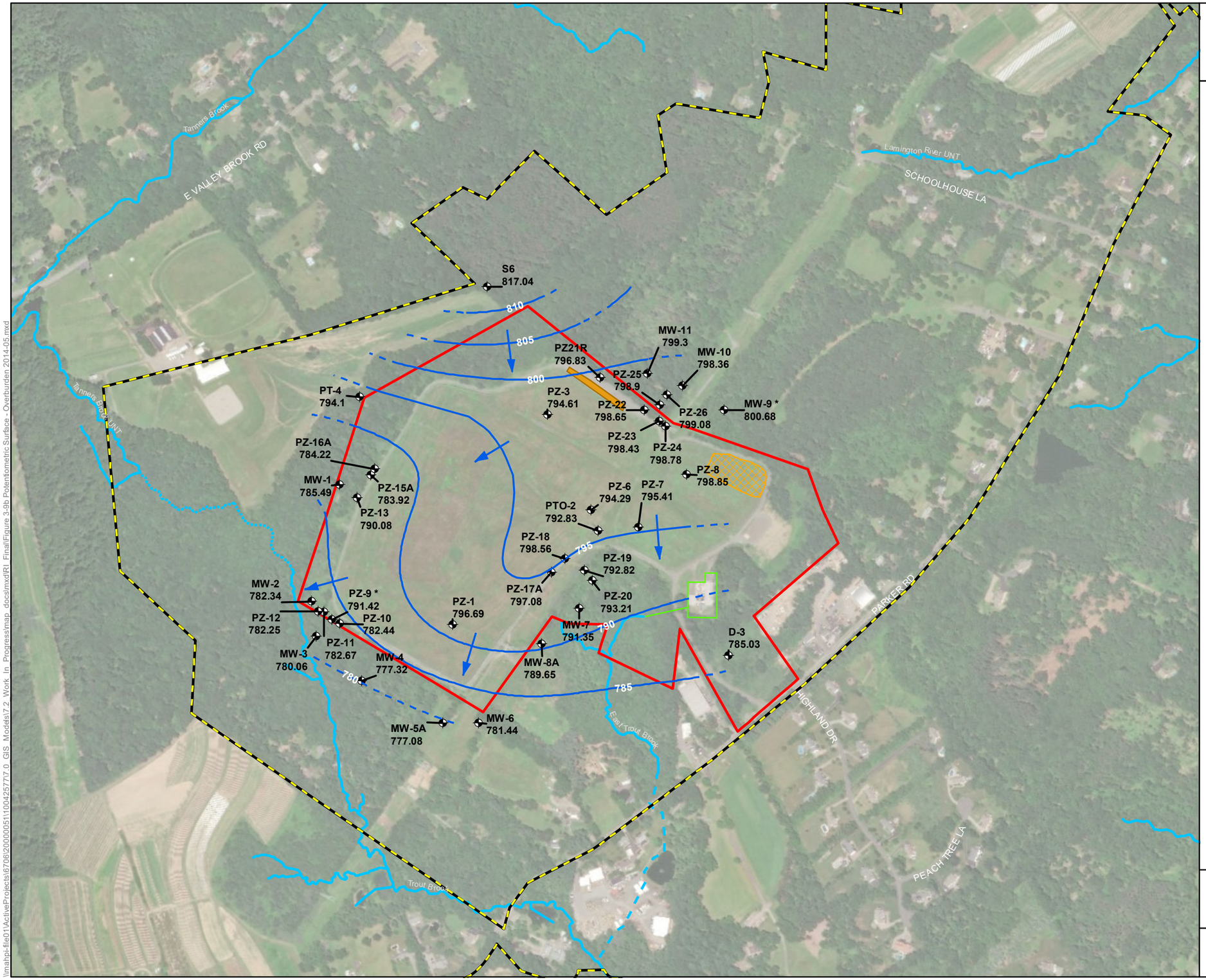
Elevations shown in feet above mean sea level (ft amsl).

0 400 800 Feet

Potentiometric Surface Elevation Overburden Aquifer (May, 2012)

Figure 3-9A
June, 2018

\\mahpi-file01\ActiveProjects\670\0\20000051\100425777.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 3-9a Potentiometric Surface - Overburden 2012-05.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill PropertyBoundary
- OU2 Investigation Area
- Monitor well location used for interpretation of potentiometric surface
- Potentiometric Surface Elevation Contour
- Contour dashed where inferred.
- Groundwater Flow Direction
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Treatment Plant & Conveyance
- Surface Water

Notes

Potentiometric surface elevation contours based on measurements of depth to groundwater collected in May, 2014 by NJDEP.

* Indicates location not used for contouring. PZ-27 (not shown) excluded.

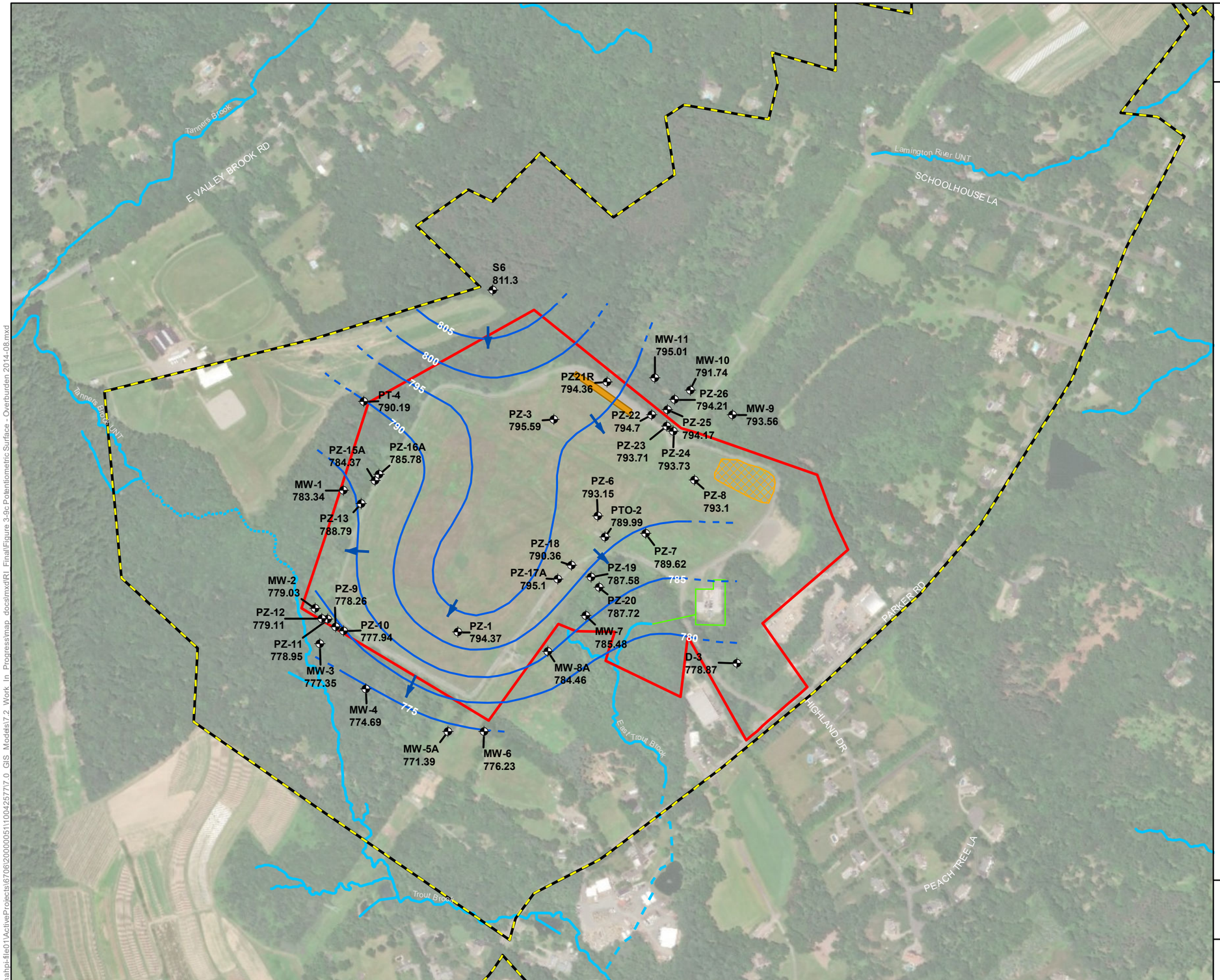
Elevations shown in feet above mean sea level (ft amsl).

0 300 600 Feet

Potentiometric Surface Elevation Overburden Aquifer (May, 2014)

Figure 3-9B
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\110042577\7.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 3-9b Potentiometric Surface - Overburden 2014-05.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Monitor well location used for interpretation of potentiometric surface
- Potentiometric Surface Elevation Contour
- Contour dashed where inferred
- Groundwater Flow Direction
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Treatment Plant & Conveyance
- Surface Water

Notes

Potentiometric surface elevation contours based on measurements of depth to groundwater collected in August, 2014 by NJDEP.

* Indicates location not used for contouring. PZ-27 (not shown) excluded.

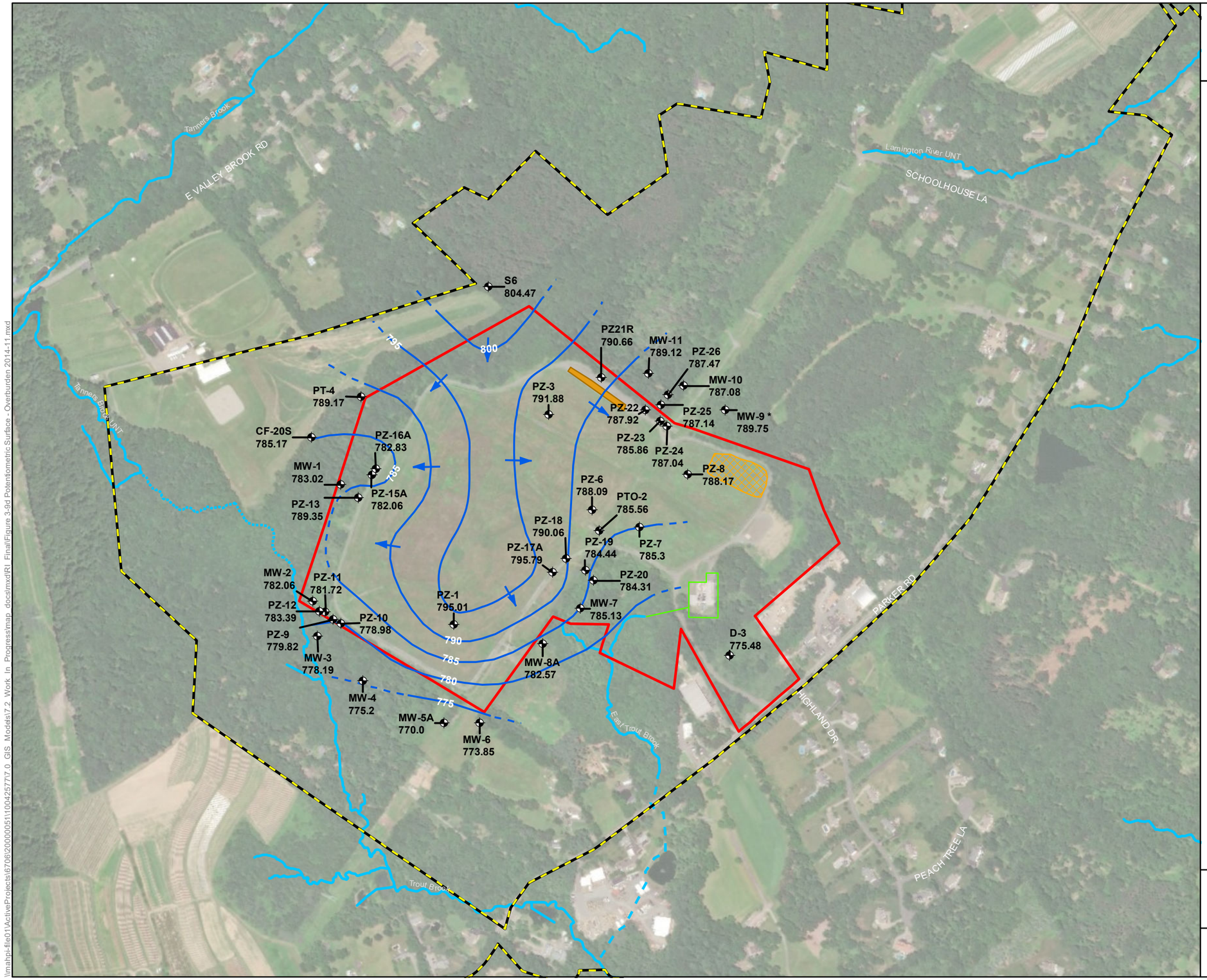
Elevations shown in feet above mean sea level (ft amsl).

0 300 600 Feet

Potentiometric Surface Elevation Overburden Aquifer (August, 2014)

Figure 3-9C
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\110042577\7.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 3-9c Potentiometric Surface - Overburden 2014-08.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- Landfill Boundary
- OU2 Investigation Area
- Monitor well location used for interpretation of potentiometric surface
- Potentiometric Surface Elevation Contour
- Contour dashed where inferred
- Groundwater Flow Direction
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Treatment Plant & Conveyance
- Surface Water

Notes

Potentiometric surface elevation contours based on measurements of depth to groundwater collected in November, 2014 by NJDEP.

* Indicates location not used for contouring. PZ-27 (not shown) excluded.

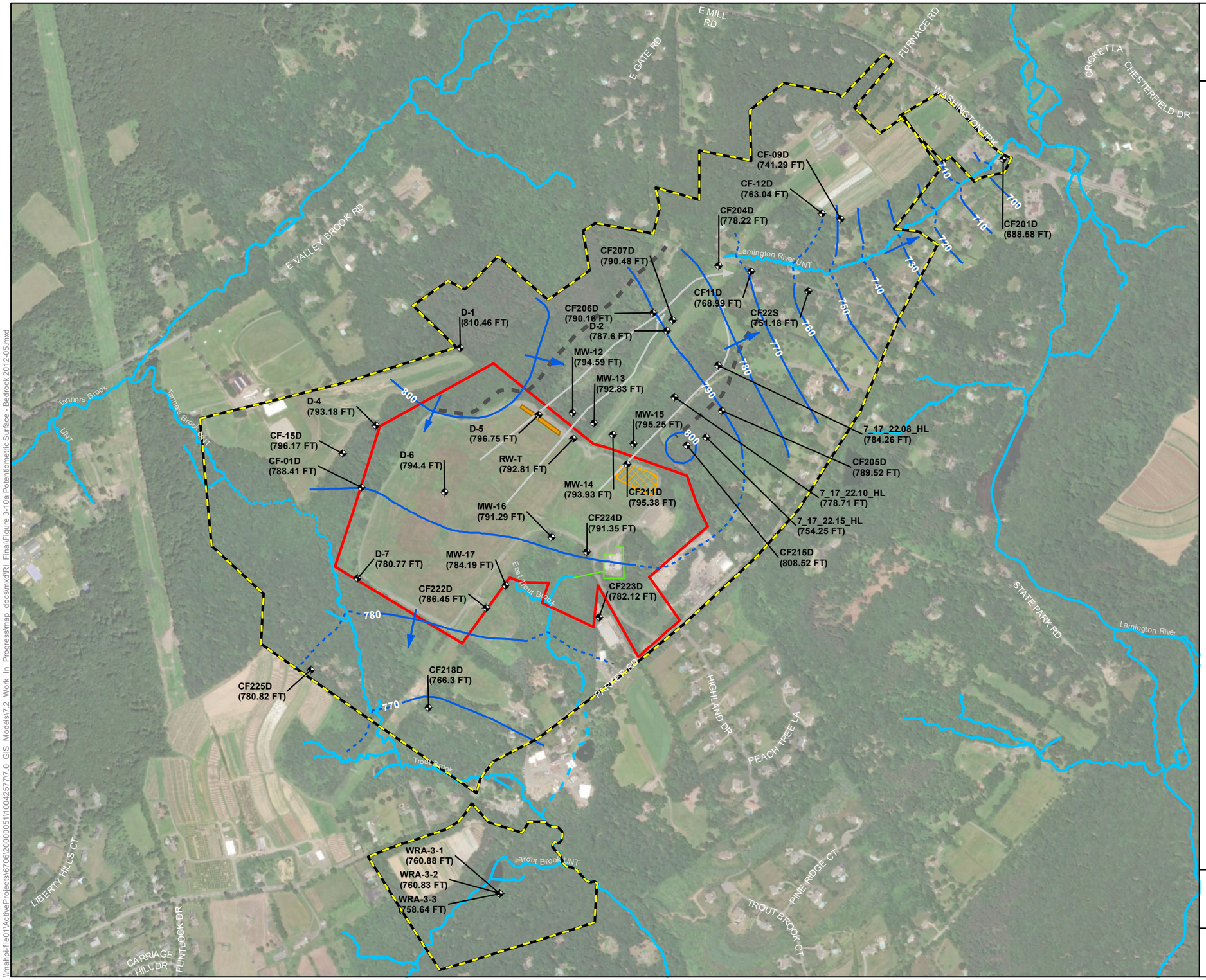
Elevations shown in feet above mean sea level (ft amsl).

0 300 600 Feet

Potentiometric Surface Elevation Overburden Aquifer (November, 2014)

Figure 3-9D
June, 2018

\\mahpi-file01\ActiveProjects\67060200000511\00425777.0 GIS Models\7.2 Work In Progressmap docs\mxd\RI Final\Figure 3-9d Potentiometric Surface - Overburden 2014-11.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Monitor well location used for interpretation of potentiometric surface
- Potentiometric Surface Elevation Contour
- Contour dashed where inferred
- Groundwater Flow Direction
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Treatment Plant & Conveyance
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes

Potentiometric surface elevation contours based on measurements of groundwater depth collected in May, 2012.

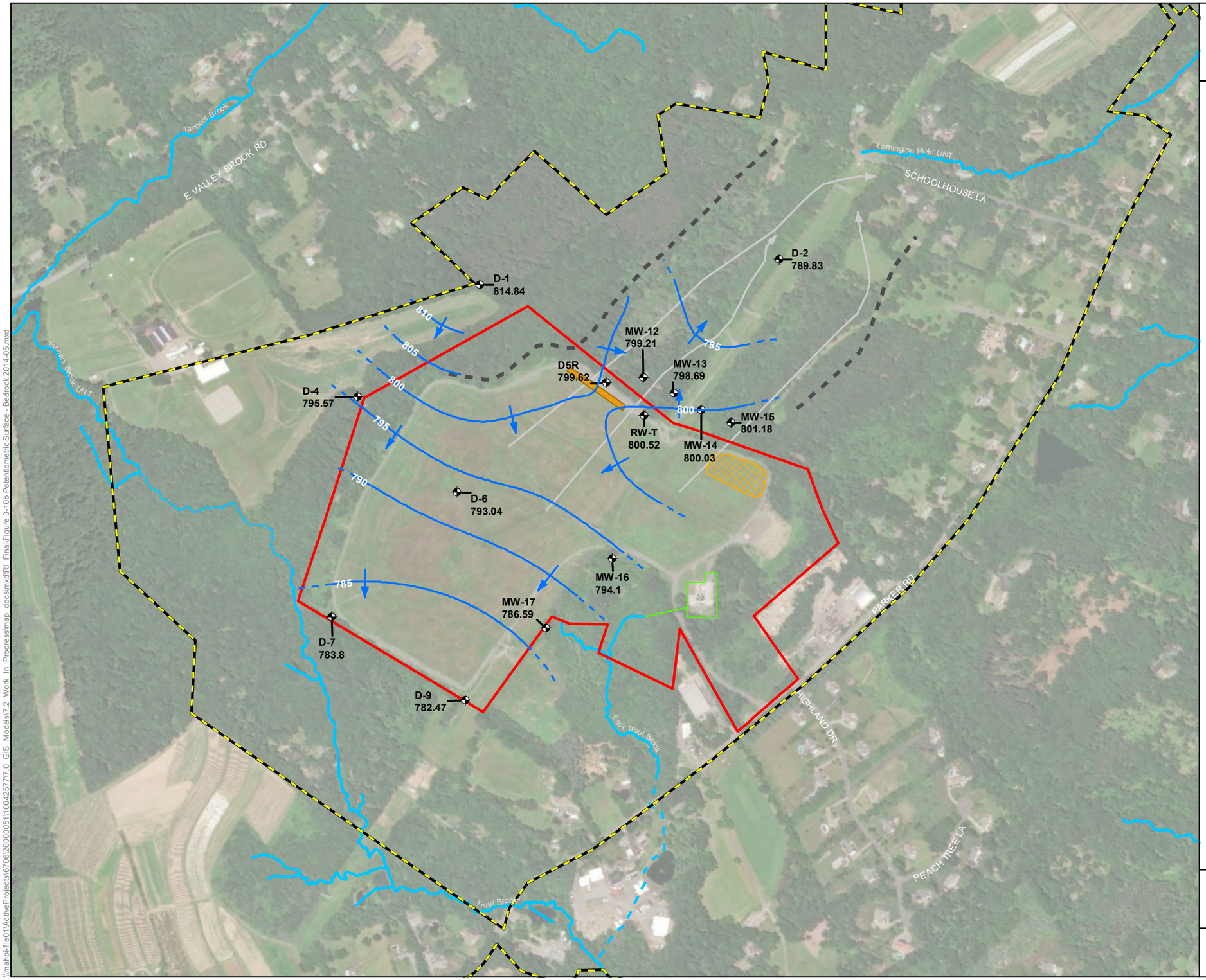
Elevations shown in feet above mean sea level (ft amsl).

0 400 800 Feet

Potentiometric Surface Elevation Bedrock Aquifer (May, 2012)

Figure 3-10A
June, 2018

\\mahpi-file01\ActiveProjects\67062000005\1100425777.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 3-10a Potentiometric Surface - Bedrock 2012-05.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Monitor well location used for interpretation of potentiometric surface
- Potentiometric Surface Elevation Contour
- Contour dashed where inferred
- Groundwater Flow Direction
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Treatment Plant & Conveyance
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes

Potentiometric surface elevation contours based on measurements of depth to groundwater collected in May, 2014 by NJDEP.

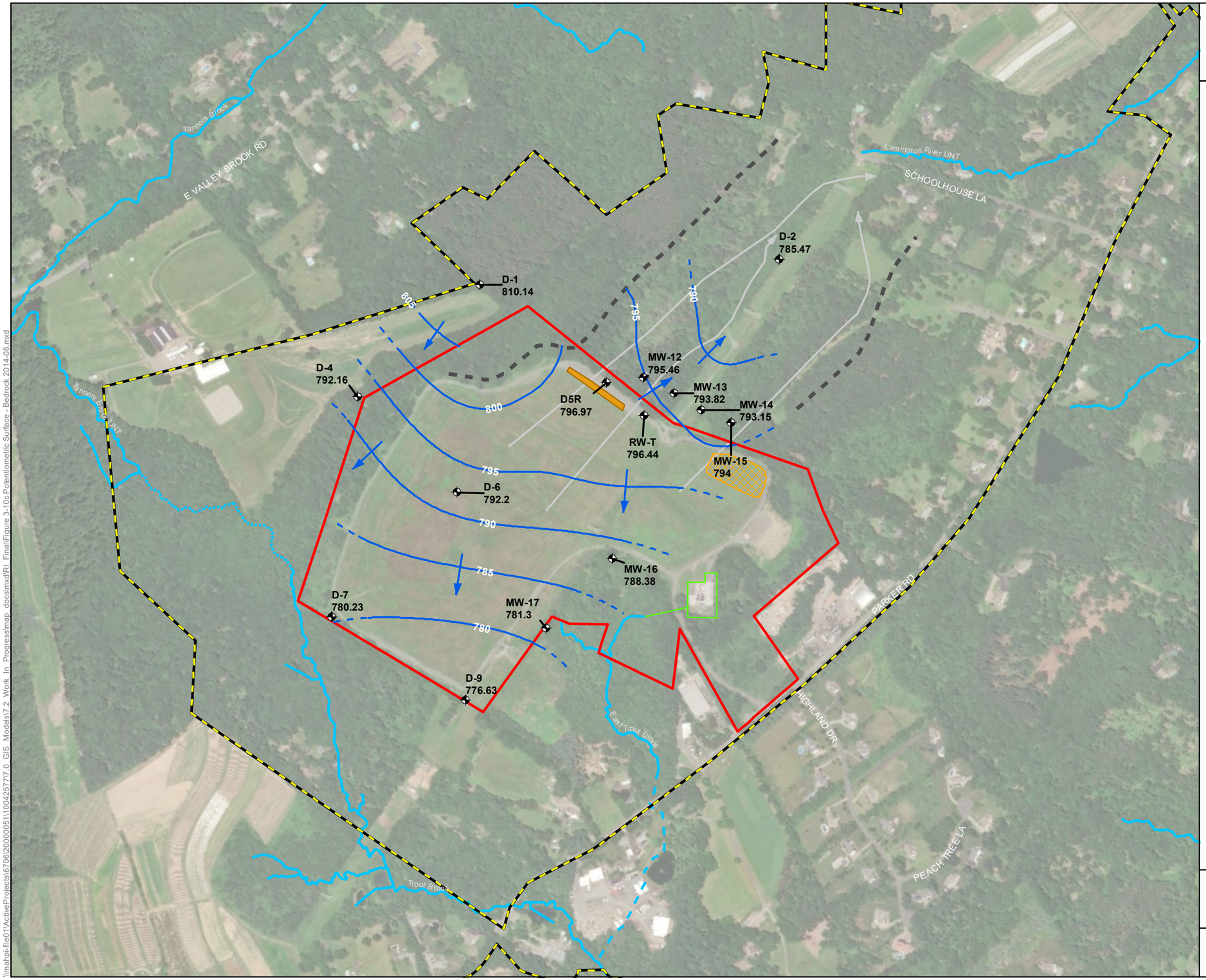
Elevations shown in feet above mean sea level (ft amsl).

0 300 600 Feet

Potentiometric Surface Elevation Bedrock Aquifer (May, 2014)

Figure 3-10B
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1100425777.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI FinalFigure 3-10b Potentiometric Surface - Bedrock 2014-05.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Monitor well location used for interpretation of potentiometric surface
- Potentiometric Surface Elevation Contour
- Contour dashed where inferred
- Groundwater Flow Direction
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes

Potentiometric surface elevation contours based on measurements of depth to groundwater collected in August, 2014 by NJDEP.

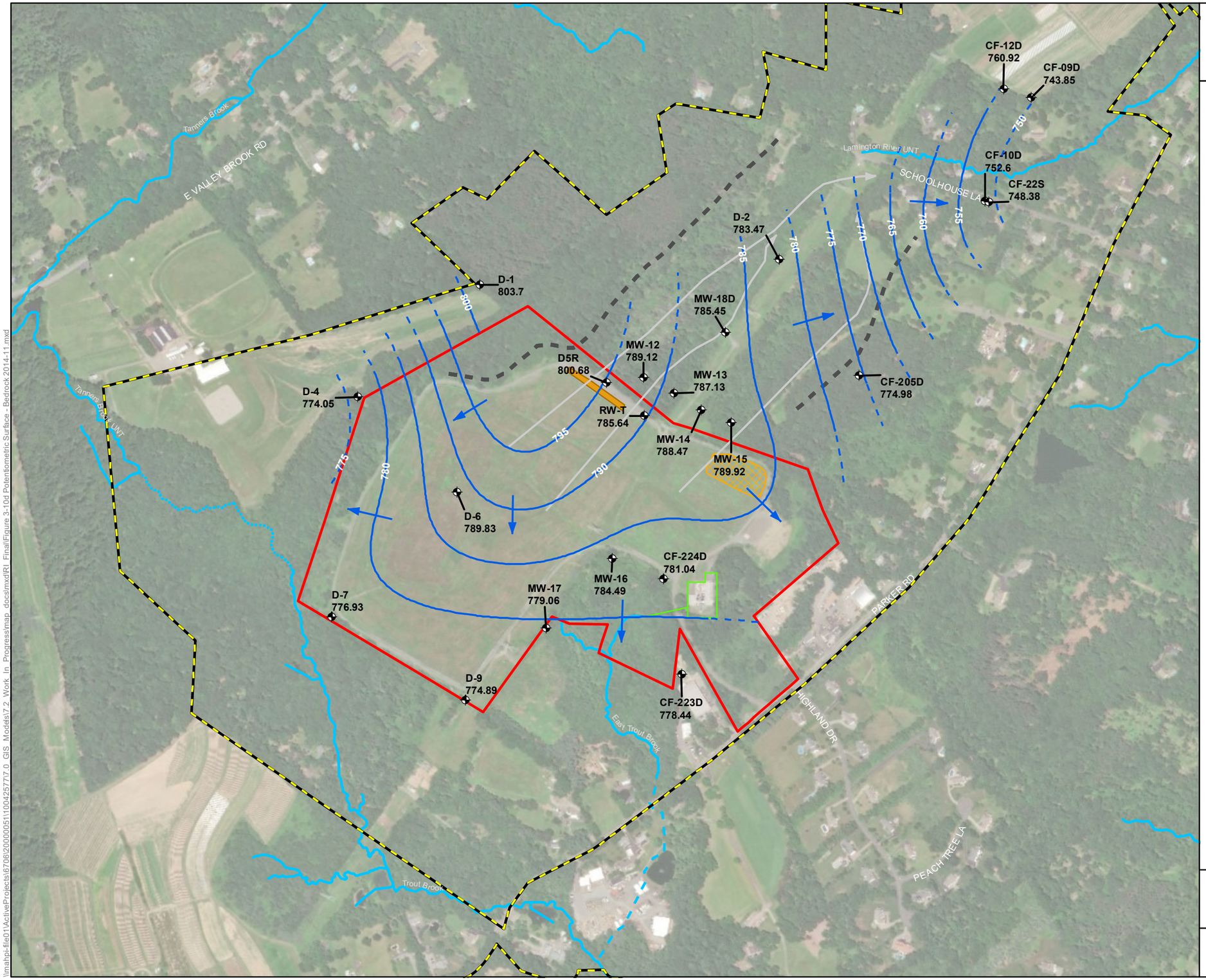
Elevations shown in feet above mean sea level (ft amsl).

0 300 600 Feet

Potentiometric Surface Elevation Bedrock Aquifer (August, 2014)

Figure 3-10C
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1100425717.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 3-10c Potentiometric Surface - Bedrock 2014-08.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- Landfill Boundary
- OU2 Investigation Area
- Monitor well location used for interpretation of potentiometric surfaec
- Potentiometric Surface Contour (ft amsl)
- Contour dashed where inferred
- Groundwater Flow Direction
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Treatment Plant & Conveyance
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes
Potentiometric surface elevation contours based on measurements of depth to groundwater collected in November, 2014 by NJDEP and HDR.

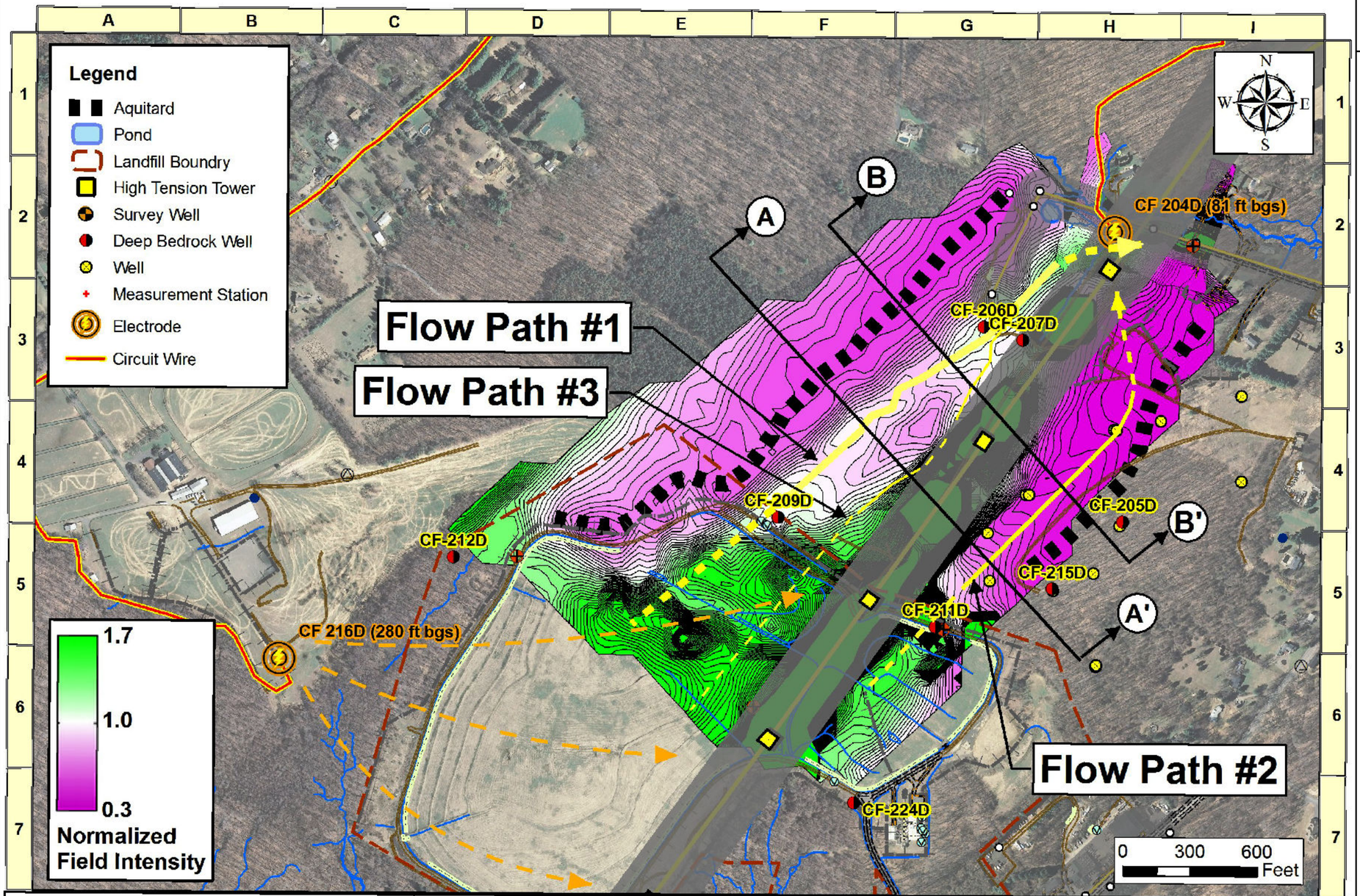
Elevations shown in feet above mean sea level (ft amsl).

0 300 600 Feet

Potentiometric Surface Elevation Bedrock Aquifer (November, 2014)

Figure 3-10D
June, 2018

\\mahpi-file01\ActiveProjects\67060200000511\00425777.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 3-10d Potentiometric Surface - Bedrock 2014-11.mxd



WILLOWSTICK TECHNOLOGIES, LLC. Groundwater Mapping Services 11814 Election Road, Suite 100 Draper, Utah 84020 TEL: (801) 984-9850 FAX: (801) 984-9851	willowstick	HDR Combe Fill South Landfill, NJ Figure S1 – Summary of Investigation	PROJECT #: 13157 DATE: 17-Jul-2013 SCALE: 1:7,200

Combe Fill South Landfill Superfund Site RI/FS

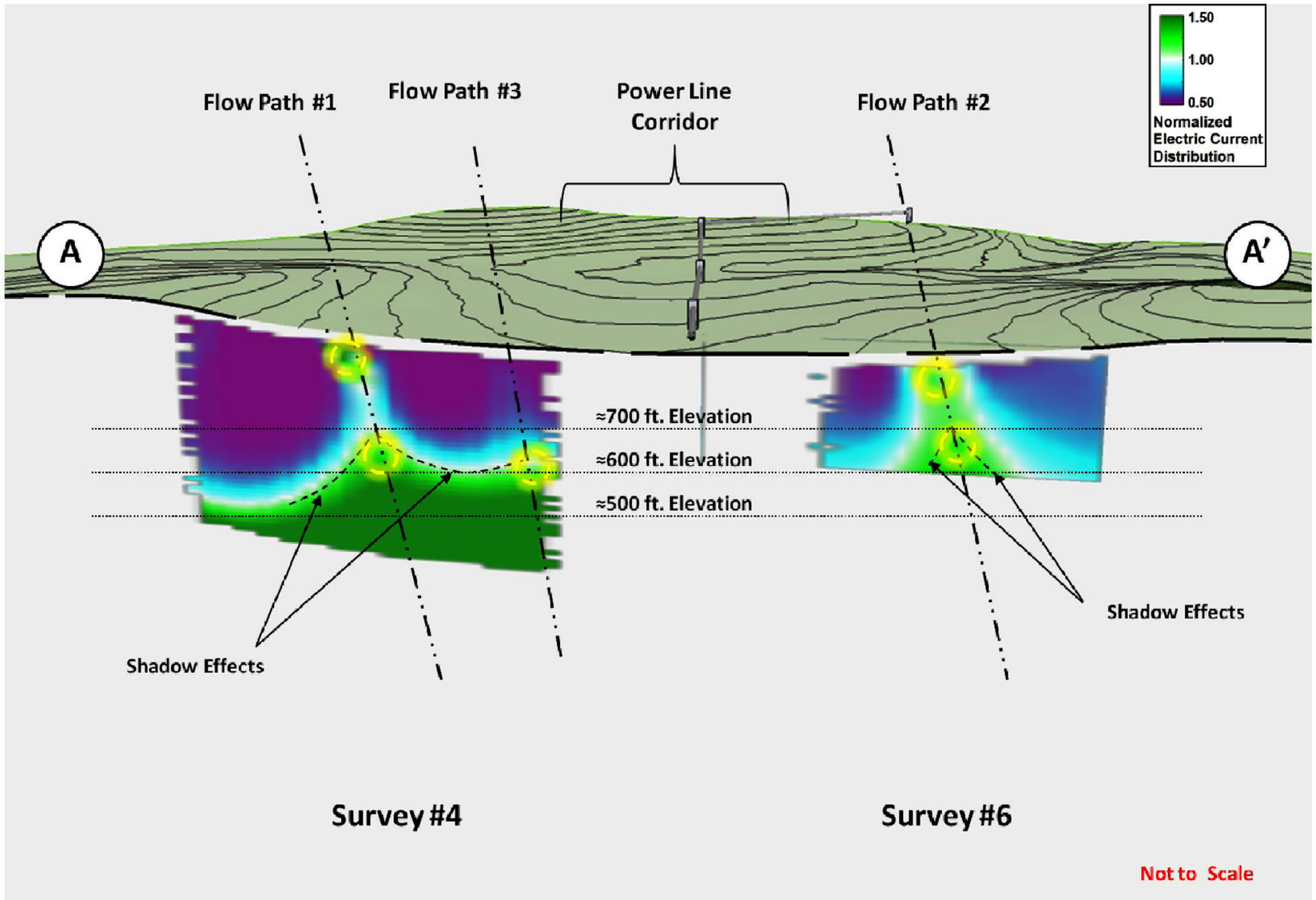
Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Original figure from *Willowstick Investigation of Combe Fill South Landfill* as prepared by Willowstick Technologies, LLC. Original report dated July 31st, 2013.
(See Remedial Investigation Report Appendix E)

Preferential Flow Paths from Combe Landfill to the Northeast (Plan View)

Figure 3-11
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\110042577\0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 3-11\Willowstick S-1.mxd



WILLOWSTICK TECHNOLOGIES, LLC. Groundwater Mapping Services 11814 Election Road, Suite 100 Draper, Utah 84020 TEL: (801) 984-9850 FAX: (801) 984-9851	willowstick	HDR Combe Fill South Landfill, NJ Figure S2 ECD Model Cross Section A-A' (X=800m)	PROJECT #: 13157 DATE: 17-Jul-2013 SCALE: N/A

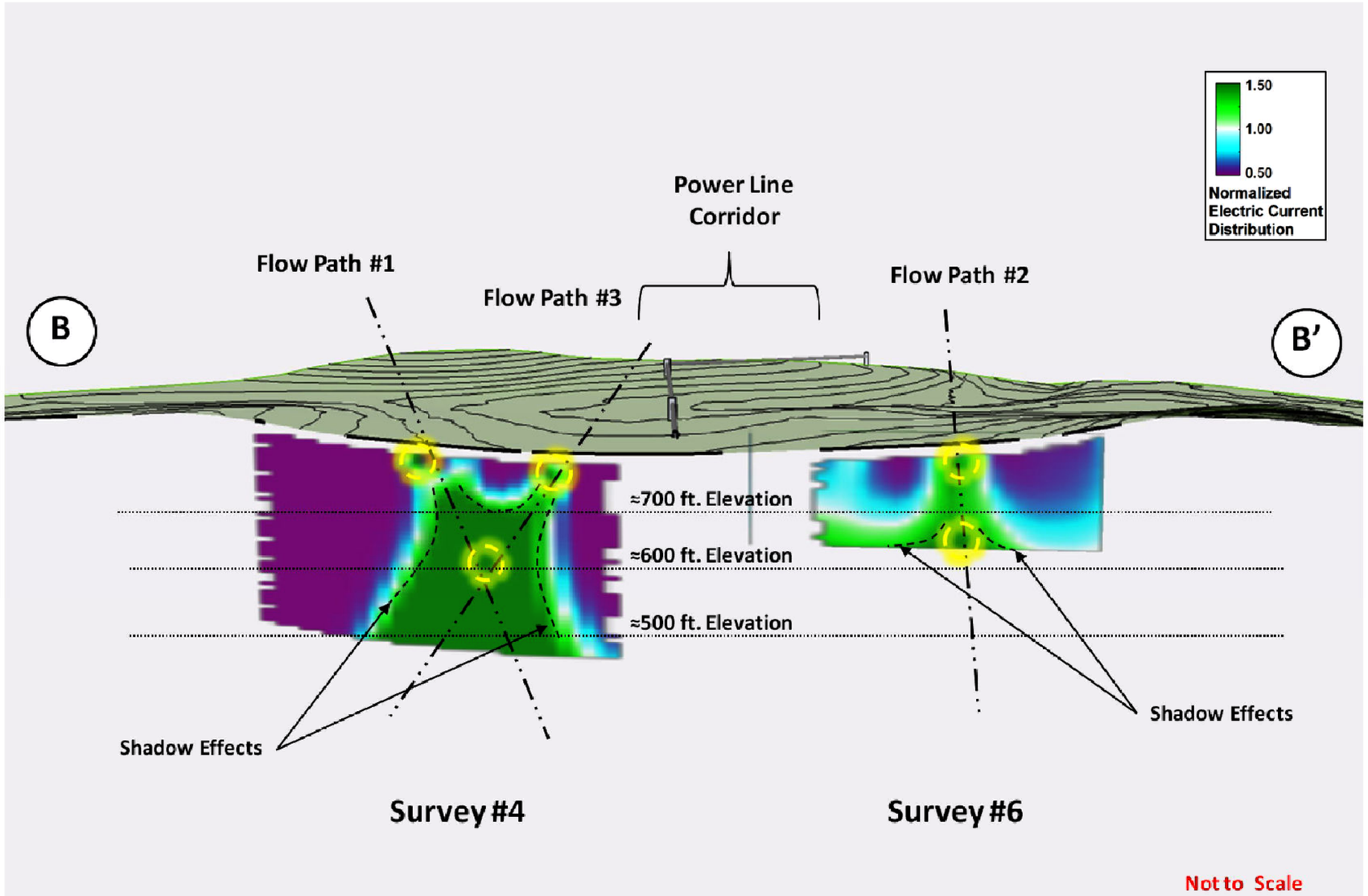
Combe Fill South Landfill Superfund Site RI/FS

Original figure from *Willowstick Investigation of Combe Fill South Landfill* as prepared by Willowstick Technologies, LLC. Original report dated July 31st, 2013.
(See Remedial Investigation Report Appendix E)

Preferential Groundwater Flow Paths Cross Section A-A'

Figure 3-12
June, 2018

\\mahpi-file01\ActiveProjects\67062000000511\0042577\7.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 3-12 Willowstick S-2.mxd



WILLOWSTICK TECHNOLOGIES, LLC.
Groundwater Mapping Services
11814 Election Road, Suite 100
Draper, Utah 84020
TEL: (801) 984-9850 FAX: (801) 984-9851

willowstick

HDR
Combe Fill South Landfill, NJ

Figure S3
ECD Model Cross Section B-B' (X=950m)

PROJECT #:	13157
DATE:	17-Jul-2013
SCALE:	N/A

HDR

Combe Fill South Landfill Superfund Site RI/FS

Original figure from *Willowstick Investigation of Combe Fill South Landfill* as prepared by Willowstick Technologies, LLC. Original report dated July 31st, 2013.
(See Remedial Investigation Report Appendix E)

Preferential Groundwater Flow Paths Cross Section B-B'

Figure 3-13
June, 2018

\\mahpi-file01\ActiveProjects\67062000005\1100425777.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 3-13 Willowstick S-3.mxd

Combe Fill South Landfill Superfund Site RI/FS

THE LEGEND ITEMS AND NOTES CONTAINED IN THIS FIGURE ARE BASED ON FIGURE 3 FROM THE 2011 HANDEX PUMP TEST SUMMARY REPORT.

HANDEX 2011. Handex Consulting and Remediation, LLC. Pump Test Summary NJDEP - Combe Fill South, Chester, Morris County, NJ. September 2010 - March 2011. Prepared for New Jersey Department of Environmental Protection.

Elevation Difference

- 5ft - 10ft
- 10ft - 15ft
- 15ft - 20ft
- > 20ft

Dashed lines are inferred.

- Gas Sampling Location
- Monitoring Well Location
- Recovery Well Location
- Chain Link Fence
- Approximate Landfill Boundary
- Stream / River

PZ-27 was not used in the contours.

NOTES:

1. HORIZONTAL DATUM - NORTH AMERICAN DATUM 1983 (NAD1983) FROM CONTROL MONUMENTS "A" AND "B" PROVIDED BY LJCE SURVEY CREW IN THE FIELD (IN NAD27 DATUM) AND CONVERTED TO NAD83 USING CORPSCON6.

2. VERTICAL DATIUM - NATIONAL GEODETIC VERTICAL DATUM 1927 (NGVD27). FROM CONTROL MONUMENTS PROVIDED TO LJCE SURVEY CREW IN THE FIELD. MONUMENT "A" ELEV. = 817.61. MONUMENT "B" ELEV.=877.31.

3. WELL LOCATION AS SHOWN IN THE WELL TABLE WERE LOCATED BY LJCE SURVEY CREW ON MAY 6, 2011.

4. ALL WELLS SHOWN ON THIS PLAN THAT ARE NOT IN THE WELL TABLE ARE GRAPHICALLY FROM INFORMATION PROVIDED TO LJCE FROM HANDEX. THIS PLAN DOES NOT CERTIFY TO THE LOCATION OF ANY WELL NOT SHOWN IN THE WELL TABLE.

5. THE BOUNDARY SHOWNON THIS PLAN WAS TAKEN FROM INFORMATION PROVIDED TO LJCE FROM HANDEX. LJCE MAKES NO CLAIMS AS TO THE ACCURACY OF THE BOUNDARY SHOWN HEREIN. THIS IS NOT A SURVEY CONVEYANCE.

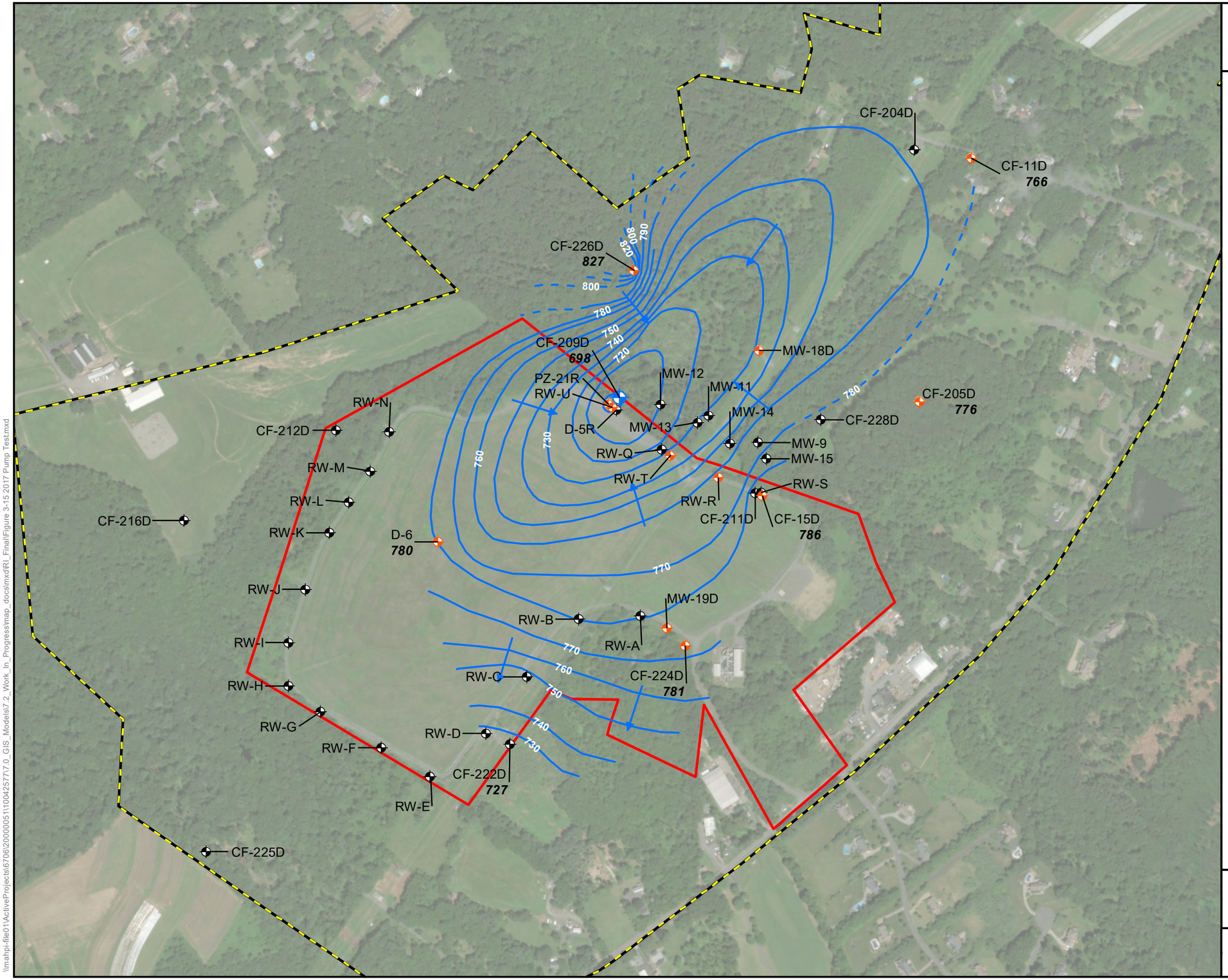
6. MW6 AND MW-8A ARE APPROXIMATE LOCATIONS BASED ON MAP PROVIDED BY THE LOUIS BERGER GROUP, INC. MAP.

0 125 250 Feet

2011 Pump Test Drawdown

Figure 3-14
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000005\1100425777.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 3-14 2011 Pump Test Drawdown.mxd



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Pumping Well
- Transducer Wells
- Wells

Groundwater Contours

- Contour (10ft Interval)
- Contour Dashed where Inferred
- Groundwater Flow Direction

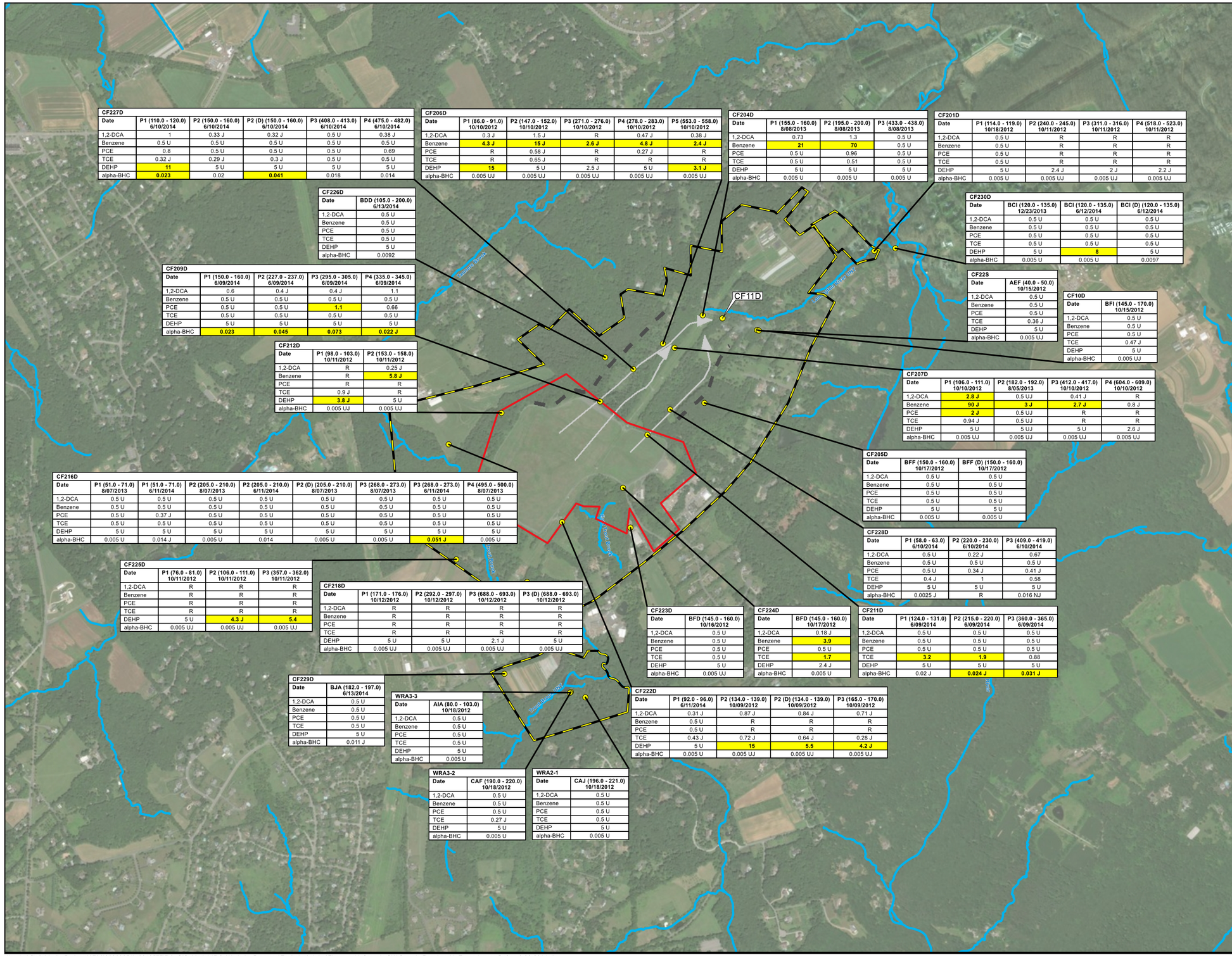
Note:
The groundwater elevations shown are for February 24, 2017, after 22 days of constant rate (70 gallons per minute) pumping. Treatment system recovery wells were not in operation during the pump test period.

0 250 500 Feet

2017 Pump Test Drawdown
Deep Bedrock Wells (Screens > 100ft)

Figure 3-15
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1\0042577\7.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 3-15 2017 Pump Test.mxd



CF227D

Date	P1 (110.0 - 120.0) 6/10/2014	P2 (150.0 - 160.0) 6/10/2014	P2 (D) (150.0 - 160.0) 6/10/2014	P3 (408.0 - 413.0) 6/10/2014	P4 (475.0 - 482.0) 6/10/2014
1,2-DCA	1	0.33 J	0.32 J	0.5 U	0.38 J
Benzene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
PCE	0.8	0.5 U	0.5 U	0.5 U	0.69
TCE	0.32 J	0.29 J	0.3 J	0.5 U	0.5 U
DEHP	**11**	5 U	5 U	5 U	5 U
alpha-BHC	**0.023**	0.02	**0.041**	0.018	0.014

CF206D

Date	P1 (86.0 - 91.0) 10/10/2012	P2 (147.0 - 152.0) 10/10/2012	P3 (271.0 - 276.0) 10/10/2012	P4 (278.0 - 283.0) 10/10/2012	P5 (553.0 - 558.0) 10/10/2012
1,2-DCA	0.3 J	1.5 J	R	0.47 J	0.38 J
Benzene	**4.3 J**	**15 J**	**2.6 J**	**4.8 J**	**2.4 J**
PCE	R	0.58 J	R	0.27 J	R
TCE	R	0.65 J	R	R	R
DEHP	**15**	5 U	2.5 J	5 U	**3.1 J**
alpha-BHC	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ

CF204D

Date	P1 (155.0 - 160.0) 8/08/2013	P2 (195.0 - 200.0) 8/08/2013	P3 (433.0 - 438.0) 8/08/2013
1,2-DCA	0.73	1.3	0.5 U
Benzene	**21**	**70**	0.5 U
PCE	0.5 U	0.96	0.5 U
TCE	0.5 U	0.51	0.5 U
DEHP	5 U	5 U	5 U
alpha-BHC	0.005 U	0.005 U	0.005 U

CF201D

Date	P1 (114.0 - 119.0) 10/18/2012	P2 (240.0 - 245.0) 10/11/2012	P3 (311.0 - 316.0) 10/11/2012	P4 (518.0 - 523.0) 10/11/2012
1,2-DCA	0.5 U	R	R	R
Benzene	0.5 U	R	R	R
PCE	0.5 U	R	R	R
TCE	0.5 U	R	R	R
DEHP	5 U	2.4 J	2 J	2.2 J
alpha-BHC	0.005 U	0.005 UJ	0.005 UJ	0.005 UJ

CF226D

Date	BDD (105.0 - 200.0) 6/13/2014
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.5 U
DEHP	5 U
alpha-BHC	0.0092

CF230D

Date	BCI (120.0 - 135.0) 12/23/2013	BCI (120.0 - 135.0) 6/12/2014	BCI (D) (120.0 - 135.0) 6/12/2014
1,2-DCA	0.5 U	0.5 U	0.5 U
Benzene	0.5 U	0.5 U	0.5 U
PCE	0.5 U	0.5 U	0.5 U
TCE	0.5 U	0.5 U	0.5 U
DEHP	5 U	**8**	5 U
alpha-BHC	0.005 U	0.005 U	0.0097

CF209D

Date	P1 (150.0 - 160.0) 6/09/2014	P2 (227.0 - 237.0) 6/09/2014	P3 (295.0 - 305.0) 6/09/2014	P4 (335.0 - 345.0) 6/09/2014
1,2-DCA	0.6	0.4 J	0.4 J	1.1
Benzene	0.5 U	0.5 U	0.5 U	0.5 U
PCE	0.5 U	0.5 U	**1.1**	0.66
TCE	0.5 U	0.5 U	0.5 U	0.5 U
DEHP	5 U	5 U	5 U	5 U
alpha-BHC	**0.023**	**0.045**	**0.073**	**0.022 J**

CF22S

Date	AEF (40.0 - 50.0) 10/15/2012
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.36 J
DEHP	5 U
alpha-BHC	0.005 UJ

CF10D

Date	BFI (145.0 - 170.0) 10/15/2012
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.47 J
DEHP	5 U
alpha-BHC	0.005 UJ

CF212D

Date	P1 (98.0 - 103.0) 10/11/2012	P2 (153.0 - 158.0) 10/11/2012
1,2-DCA	R	0.25 J
Benzene	R	**5.8 J**
PCE	R	R
TCE	0.9 J	R
DEHP	**3.8 J**	5 U
alpha-BHC	0.005 UJ	0.005 UJ

CF207D

Date	P1 (106.0 - 111.0) 10/10/2012	P2 (182.0 - 192.0) 8/05/2013	P3 (412.0 - 417.0) 10/10/2012	P4 (604.0 - 609.0) 10/10/2012
1,2-DCA	**2.8 J**	0.5 UJ	0.41 J	R
Benzene	**90 J**	**3 J**	**2.7 J**	0.8 J
PCE	**2 J**	0.5 UJ	R	R
TCE	0.94 J	0.5 UJ	R	R
DEHP	5 U	5 UJ	5 U	2.6 J
alpha-BHC	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ

CF205D

Date	BFF (150.0 - 160.0) 10/17/2012	BFF (D) (150.0 - 160.0) 10/17/2012
1,2-DCA	0.5 U	0.5 U
Benzene	0.5 U	0.5 U
PCE	0.5 U	0.5 U
TCE	0.5 U	0.5 U
DEHP	5 U	5 U
alpha-BHC	0.005 U	0.005 U

CF216D

Date	P1 (51.0 - 71.0) 8/07/2013	P1 (51.0 - 71.0) 6/11/2014	P2 (205.0 - 210.0) 8/07/2013	P2 (205.0 - 210.0) 6/11/2014	P2 (D) (205.0 - 210.0) 8/07/2013	P3 (268.0 - 273.0) 8/07/2013	P3 (268.0 - 273.0) 6/11/2014	P4 (495.0 - 500.0) 8/07/2013
1,2-DCA	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Benzene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
PCE	0.5 U	0.37 J	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
TCE	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
DEHP	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
alpha-BHC	0.005 U	0.014 J	0.005 U	0.014	0.005 U	0.005 U	**0.051 J**	0.005 U

CF228D

Date	P1 (58.0 - 63.0) 6/10/2014	P2 (220.0 - 230.0) 6/10/2014	P3 (409.0 - 419.0) 6/10/2014
1,2-DCA	0.5 U	0.22 J	0.67
Benzene	0.5 U	0.5 U	0.5 U
PCE	0.5 U	0.34 J	0.41 J
TCE	0.4 J	1	0.58
DEHP	5 U	5 U	5 U
alpha-BHC	0.0025 J	R	0.016 NJ

CF225D

Date	P1 (76.0 - 81.0) 10/11/2012	P2 (106.0 - 111.0) 10/11/2012	P3 (357.0 - 362.0) 10/11/2012
1,2-DCA	R	R	R
Benzene	R	R	R
PCE	R	R	R
TCE	R	R	R
DEHP	5 U	**4.3 J**	**5.4**
alpha-BHC	0.005 UJ	0.005 UJ	0.005 UJ

CF218D

Date	P1 (171.0 - 176.0) 10/12/2012	P2 (292.0 - 297.0) 10/12/2012	P3 (688.0 - 693.0) 10/12/2012	P3 (D) (688.0 - 693.0) 10/12/2012
1,2-DCA	R	R	R	R
Benzene	R	R	R	R
PCE	R	R	R	R
TCE	R	R	R	R
DEHP	5 U	5 U	2.1 J	5 U
alpha-BHC	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ

CF223D

Date	BFD (145.0 - 160.0) 10/16/2012
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.5 U
DEHP	5 U
alpha-BHC	0.005 UJ

CF224D

Date	BFD (145.0 - 160.0) 10/17/2012
1,2-DCA	0.18 J
Benzene	**3.9**
PCE	0.5 U
TCE	**1.7**
DEHP	2.4 J
alpha-BHC	0.005 U

CF211D

Date	P1 (124.0 - 131.0) 6/09/2014	P2 (215.0 - 220.0) 6/09/2014	P3 (360.0 - 365.0) 6/09/2014
1,2-DCA	0.5 U	0.5 U	0.5 U
Benzene	0.5 U	0.5 U	0.5 U
PCE	0.5 U	0.5 U	0.5 U
TCE	**3.2**	**1.9**	0.88
DEHP	5 U	5 U	5 U
alpha-BHC	0.02 J	**0.024 J**	**0.031 J**

CF229D

Date	BJA (182.0 - 197.0) 6/13/2014
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.5 U
DEHP	5 U
alpha-BHC	0.011 J

WRA3-3

Date	AIA (80.0 - 103.0) 10/18/2012
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.5 U
DEHP	5 U
alpha-BHC	0.005 U

CF222D

Date	P1 (92.0 - 96.0) 6/11/2014	P2 (134.0 - 139.0) 10/09/2012	P2 (D) (134.0 - 139.0) 10/09/2012	P3 (165.0 - 170.0) 10/09/2012
1,2-DCA	0.31 J	0.87 J	0.84 J	0.71 J
Benzene	0.5 U	R	R	R
PCE	0.5 U	R	R	R
TCE	0.43 J	0.72 J	0.64 J	0.28 J
DEHP	5 U	**15**	**5.5**	**4.2 J**
alpha-BHC	0.005 U	0.005 UJ	0.005 UJ	0.005 UJ

WRA3-2

Date	CAF (190.0 - 220.0) 10/18/2012
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.27 J
DEHP	5 U
alpha-BHC	0.005 U

WRA2-1

Date	CAJ (196.0 - 221.0) 10/18/2012
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.5 U
DEHP	5 U
alpha-BHC	0.005 U

HDR

Combe Fill South Landfill
Superfund Site RI/FS

Aerial Background Credits: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IGN, and the GIS User Community.

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

Legend

- Groundwater Sample Location
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Surface Water
- Aquitard (Source: Willowstick Report)
- Preferential Flow Path (Source: Willowstick Report)

CONSTITUENT	CRITERION (1)
1,2-DCA (1,2-Dichloroethane)	2
Benzene	1
PCE (Tetrachloroethene)	1
TCE (Trichloroethene)	1
DEHP (bis-2(ethylhexyl)phthalate)	3
alpha-BHC	0.02

Exceedances indicated by yellow highlighting.

Notes
- Results shown in ug/L.
- UNT = Unnamed Tributary

- Field duplicate samples are indicated by (D).
- 1,4-Dioxane depicted on separate figure.
- Locations shown without a databox were not sampled within the time frame depicted on the figure.

1. New Jersey Department of Environmental Protection (NJDEP) NJAC 7:9C Ground Water Quality Standards (updated January 16, 2018).

Wells identified as CF### (example CF209D) were installed for the OU2 RI/FS. Others predate this RI/FS.

Well CF-209D was a multi-port FLUTe well constructed in 2014 and decomissioned in January, 2017. It was replaced in March, 2017 with a conventional well screened from 150 to 160 feet bgs that was constructed in the same borehole. Samples from CF-209D collected in February, 2017 were collected from the open borehole during a pumping test.

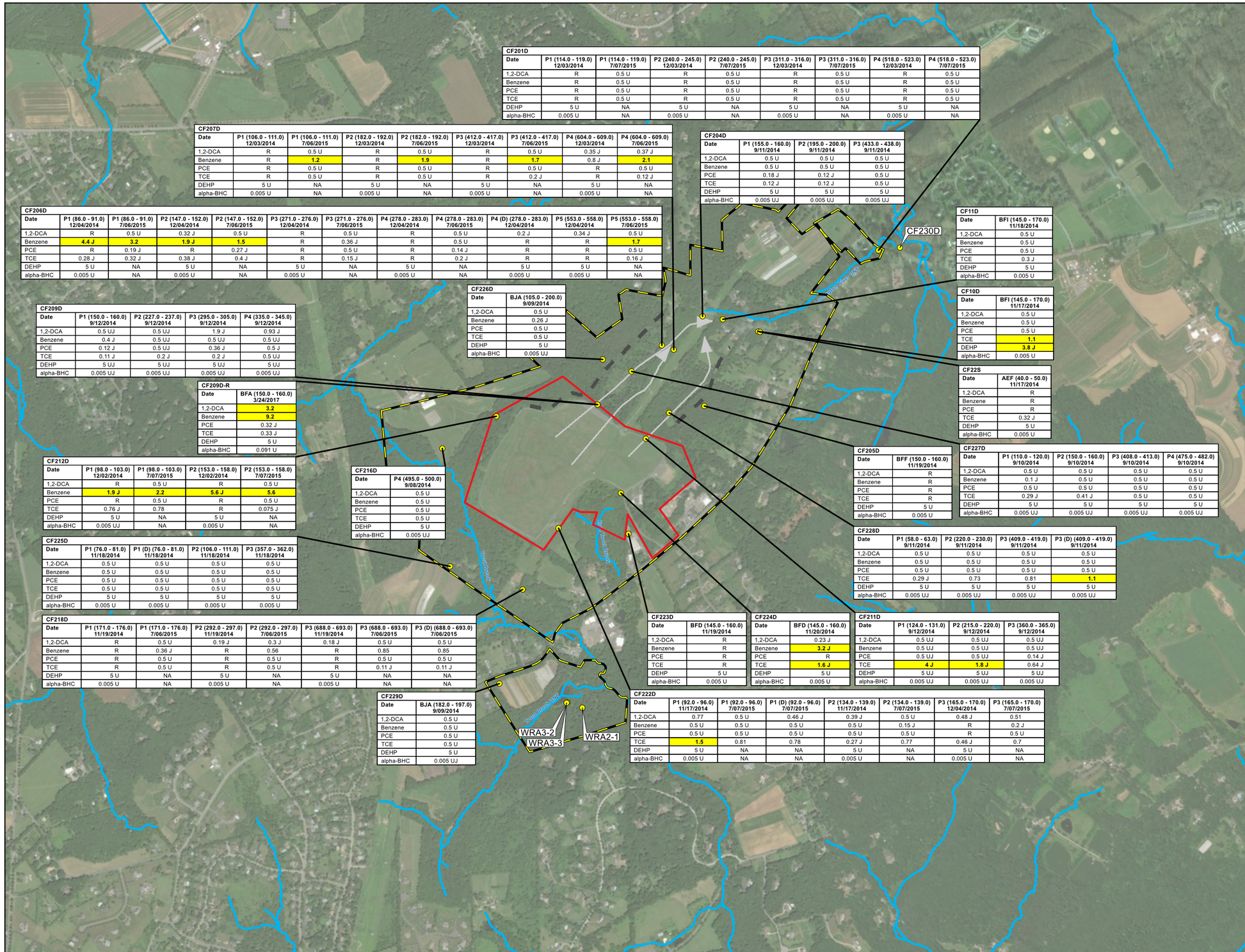
Sample intervals in databox are indicated by sample port number (P#) or using sample depth codes (A=0, B=1, C=2, etc.).

0 500 1000 feet
Not To Scale

Organic Groundwater Sample Results Exceeding Criteria (Prior to 6/30/14) OU2 RI Samples

Figure 4-1A
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\10042577\7.0_GIS_Models\7.2_Work_In_Progress\EnviroInsite\vizx\Figure 4-1A Organic GW Sample Results with Exceedances Before 6-30-2014.vizx



CF201D

Date	P1 (114.0 - 119.0) 12/03/2014	P1 (114.0 - 119.0) 7/07/2015	P2 (240.0 - 245.0) 12/03/2014	P2 (240.0 - 245.0) 7/07/2015	P3 (311.0 - 316.0) 12/03/2014	P3 (311.0 - 316.0) 7/07/2015	P4 (518.0 - 523.0) 12/03/2014	P4 (518.0 - 523.0) 7/07/2015
1,2-DCA	R	0.5 U	R	0.5 U	R	0.5 U	R	0.5 U
Benzene	R	0.5 U	R	0.5 U	R	0.5 U	R	0.5 U
PCE	R	0.5 U	R	0.5 U	R	0.5 U	R	0.5 U
TCE	R	0.5 U	R	0.5 U	R	0.5 U	R	0.5 U
DEHP	5 U	NA	5 U	NA	5 U	NA	5 U	NA
alpha-BHC	0.005 U	NA	0.005 U	NA	0.005 U	NA	0.005 U	NA

CF207D

Date	P1 (106.0 - 111.0) 12/03/2014	P1 (106.0 - 111.0) 7/06/2015	P2 (182.0 - 192.0) 12/03/2014	P2 (182.0 - 192.0) 7/06/2015	P3 (412.0 - 417.0) 12/03/2014	P3 (412.0 - 417.0) 7/06/2015	P4 (604.0 - 609.0) 12/03/2014	P4 (604.0 - 609.0) 7/06/2015
1,2-DCA	R	0.5 U	R	0.5 U	R	0.5 U	0.35 J	0.37 J
Benzene	R	1.2	R	1.9	R	1.7	0.8 J	2.1
PCE	R	0.5 U	R	0.5 U	R	0.5 U	R	0.5 U
TCE	R	0.5 U	R	0.5 U	R	0.2 J	R	0.12 J
DEHP	5 U	NA	5 U	NA	5 U	NA	5 U	NA
alpha-BHC	0.005 U	NA	0.005 U	NA	0.005 U	NA	0.005 U	NA

CF204D

Date	P1 (155.0 - 160.0) 9/11/2014	P2 (195.0 - 200.0) 9/11/2014	P3 (433.0 - 438.0) 9/11/2014
1,2-DCA	0.5 U	0.5 U	0.5 U
Benzene	0.5 U	0.5 U	0.5 U
PCE	0.18 J	0.12 J	0.5 U
TCE	0.12 J	0.12 J	0.5 U
DEHP	5 U	5 U	5 U
alpha-BHC	0.005 UJ	0.005 UJ	0.005 UJ

CF206D

Date	P1 (86.0 - 91.0) 12/04/2014	P1 (86.0 - 91.0) 7/06/2015	P2 (147.0 - 152.0) 12/04/2014	P2 (147.0 - 152.0) 7/06/2015	P3 (271.0 - 276.0) 12/04/2014	P3 (271.0 - 276.0) 7/06/2015	P4 (278.0 - 283.0) 12/04/2014	P4 (278.0 - 283.0) 7/06/2015	P4 (D) (278.0 - 283.0) 12/04/2014	P5 (553.0 - 558.0) 12/04/2014	P5 (553.0 - 558.0) 7/06/2015
1,2-DCA	R	0.5 U	0.32 J	0.5 U	R	0.5 U	R	0.5 U	0.2 J	0.34 J	0.5 U
Benzene	4.4 J	3.2	1.9 J	1.5	R	0.36 J	R	0.5 U	R	R	1.7
PCE	R	0.19 J	R	0.27 J	R	0.5 U	R	0.14 J	R	R	0.5 U
TCE	0.28 J	0.32 J	0.38 J	0.4 J	R	0.15 J	R	0.2 J	R	R	0.16 J
DEHP	5 U	NA	5 U	NA	5 U	NA	5 U	NA	5 U	5 U	NA
alpha-BHC	0.005 U	NA	0.005 U	NA	0.005 U	NA	0.005 U	NA	0.005 U	0.005 U	NA

CF11D

Date	BFI (145.0 - 170.0) 11/18/2014
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.3 J
DEHP	5 U
alpha-BHC	0.005 U

CF226D

Date	BJA (105.0 - 200.0) 9/09/2014
1,2-DCA	0.5 U
Benzene	0.26 J
PCE	0.5 U
TCE	0.5 U
DEHP	5 U
alpha-BHC	0.005 UJ

CF10D

Date	BFI (145.0 - 170.0) 11/17/2014
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	1.1
DEHP	3.8 J
alpha-BHC	0.005 U

CF209D

Date	P1 (150.0 - 160.0) 9/12/2014	P2 (227.0 - 237.0) 9/12/2014	P3 (295.0 - 305.0) 9/12/2014	P4 (335.0 - 345.0) 9/12/2014
1,2-DCA	0.5 UJ	0.5 UJ	1.9 J	0.93 J
Benzene	0.4 J	0.5 UJ	0.5 UJ	0.5 UJ
PCE	0.12 J	0.5 UJ	0.36 J	0.5 J
TCE	0.11 J	0.2 J	0.2 J	0.5 UJ
DEHP	5 UJ	5 UJ	5 UJ	5 UJ
alpha-BHC	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ

CF22S

Date	AEF (40.0 - 50.0) 11/17/2014
1,2-DCA	R
Benzene	R
PCE	R
TCE	0.32 J
DEHP	5 U
alpha-BHC	0.005 U

CF209D-R

Date	BFA (150.0 - 160.0) 3/24/2017
1,2-DCA	3.2
Benzene	9.2
PCE	0.32 J
TCE	0.33 J
DEHP	5 U
alpha-BHC	0.091 U

CF205D

Date	BFF (150.0 - 160.0) 11/19/2014
1,2-DCA	R
Benzene	R
PCE	R
TCE	R
DEHP	5 U
alpha-BHC	0.005 U

CF227D

Date	P1 (110.0 - 120.0) 9/10/2014	P2 (150.0 - 160.0) 9/10/2014	P3 (408.0 - 413.0) 9/10/2014	P4 (475.0 - 482.0) 9/10/2014
1,2-DCA	0.5 U	0.5 U	0.5 U	0.5 U
Benzene	0.1 J	0.5 U	0.5 U	0.5 U
PCE	0.5 U	0.5 U	0.5 U	0.5 U
TCE	0.29 J	0.41 J	0.5 U	0.5 U
DEHP	5 U	5 U	5 U	5 U
alpha-BHC	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ

CF212D

Date	P1 (98.0 - 103.0) 12/02/2014	P1 (98.0 - 103.0) 7/07/2015	P2 (153.0 - 158.0) 12/02/2014	P2 (153.0 - 158.0) 7/07/2015
1,2-DCA	R	0.5 U	R	0.5 U
Benzene	1.9 J	2.2	5.6 J	5.6
PCE	R	0.5 U	R	0.5 U
TCE	0.76 J	0.78	R	0.075 J
DEHP	5 U	NA	5 U	NA
alpha-BHC	0.005 UJ	NA	0.005 U	NA

CF216D

Date	P4 (495.0 - 500.0) 9/08/2014
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.5 U
DEHP	5 U
alpha-BHC	0.005 UJ

CF228D

Date	P1 (58.0 - 63.0) 9/11/2014	P2 (220.0 - 230.0) 9/11/2014	P3 (409.0 - 419.0) 9/11/2014	P3 (D) (409.0 - 419.0) 9/11/2014
1,2-DCA	0.5 U	0.5 U	0.5 U	0.5 U
Benzene	0.5 U	0.5 U	0.5 U	0.5 U
PCE	0.5 U	0.5 U	0.5 U	0.5 U
TCE	0.29 J	0.73	0.81	1.1
DEHP	5 U	5 U	5 U	5 U
alpha-BHC	0.005 UJ	0.005 UJ	0.005 UJ	0.005 UJ

CF225D

Date	P1 (76.0 - 81.0) 11/18/2014	P1 (D) (76.0 - 81.0) 11/18/2014	P2 (106.0 - 111.0) 11/18/2014	P3 (357.0 - 362.0) 11/18/2014
1,2-DCA	0.5 U	0.5 U	0.5 U	0.5 U
Benzene	0.5 U	0.5 U	0.5 U	0.5 U
PCE	0.5 U	0.5 U	0.5 U	0.5 U
TCE	0.5 U	0.5 U	0.5 U	0.5 U
DEHP	5 U	5 U	5 U	5 U
alpha-BHC	0.005 U	0.005 U	0.005 U	0.005 U

CF218D

Date	P1 (171.0 - 176.0) 11/19/2014	P1 (171.0 - 176.0) 7/06/2015	P2 (292.0 - 297.0) 11/19/2014	P2 (292.0 - 297.0) 7/06/2015	P3 (688.0 - 693.0) 11/19/2014	P3 (688.0 - 693.0) 7/06/2015	P3 (D) (688.0 - 693.0) 7/06/2015
1,2-DCA	R	0.5 U	0.19 J	0.3 J	0.18 J	0.5 U	0.5 U
Benzene	R	0.36 J	R	0.56	R	0.85	0.85
PCE	R	0.5 U	R	0.5 U	R	0.5 U	0.5 U
TCE	R	0.5 U	R	0.5 U	R	0.11 J	0.11 J
DEHP	5 U	NA	5 U	NA	5 U	NA	NA
alpha-BHC	0.005 U	NA	0.005 U	NA	0.005 U	NA	NA

CF223D

Date	BFD (145.0 - 160.0) 11/19/2014
1,2-DCA	R
Benzene	R
PCE	R
TCE	R
DEHP	5 U
alpha-BHC	0.005 U

CF224D

Date	BFD (145.0 - 160.0) 11/20/2014
1,2-DCA	0.23 J
Benzene	3.2 J
PCE	R
TCE	1.6 J
DEHP	5 U
alpha-BHC	0.005 U

CF211D

Date	P1 (124.0 - 131.0) 9/12/2014	P2 (215.0 - 220.0) 9/12/2014	P3 (360.0 - 365.0) 9/12/2014
1,2-DCA	0.5 UJ	0.5 UJ	0.5 UJ
Benzene	0.5 UJ	0.5 UJ	0.5 UJ
PCE	0.5 UJ	0.5 UJ	0.14 J
TCE	4 J	1.8 J	0.64 J
DEHP	5 UJ	5 UJ	5 UJ
alpha-BHC	0.005 UJ	0.005 UJ	0.005 UJ

CF229D

Date	BJA (182.0 - 197.0) 9/09/2014
1,2-DCA	0.5 U
Benzene	0.5 U
PCE	0.5 U
TCE	0.5 U
DEHP	5 U
alpha-BHC	0.005 UJ

CF222D

Date	P1 (92.0 - 96.0) 11/17/2014	P1 (92.0 - 96.0) 7/07/2015	P1 (D) (92.0 - 96.0) 7/07/2015	P2 (134.0 - 139.0) 11/17/2014	P2 (134.0 - 139.0) 7/07/2015	P3 (165.0 - 170.0) 12/04/2014	P3 (165.0 - 170.0) 7/07/2015
1,2-DCA	0.77	0.5 U	0.46 J	0.39 J	0.5 U	0.48 J	0.51
Benzene	0.5 U	0.5 U	0.5 U	0.5 U	0.15 J	R	0.2 J
PCE	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	R	0.5 U
TCE	1.5	0.81	0.78	0.27 J	0.77	0.46 J	0.7
DEHP	5 U	NA	NA	5 U	NA	5 U	NA
alpha-BHC	0.005 U	NA	NA	0.005 U	NA	0.005 U	NA

Combe Fill South Landfill
Superfund Site RI/FS

Aerial Background Credits: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IGN, and the GIS User Community.

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

Legend

- Groundwater Sample Location
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Surface Water
- Aquitard (Source: Willowstick Report)
- Preferential Flow Path (Source: Willowstick Report)

CONSTITUENT	CRITERION (1)
1,2-DCA (1,2-Dichloroethane)	2
Benzene	1
PCE (Tetrachloroethene)	1
TCE (Trichloroethene)	1
DEHP (bis-2(ethylhexyl)phthalate)	3
alpha-BHC	0.02

Exceedances indicated by yellow highlighting.

Notes

- Results shown in ug/L.
- UNT = Unnamed Tributary

- Field duplicate samples are indicated by (D).
- 1,4-Dioxane depicted on separate figure.
- Locations shown without a databox were not sampled within the time frame depicted on the figure.

1. New Jersey Department of Environmental Protection (NJDEP) NJAC 7:9C Ground Water Quality Standards (updated January 16, 2018).

Wells identified as CF### (example CF209D) were installed for the OU2 RI/FS. Others predate this RI/FS.

Well CF-209D was a multi-port FLUTe well constructed in 2014 and decomissioned in January, 2017. It was replaced in March, 2017 with a conventional well screened from 150 to 160 feet bgs that was constructed in the same borehole. Samples from CF-209D collected in February, 2017 were collected from the open borehole during a pumping test.

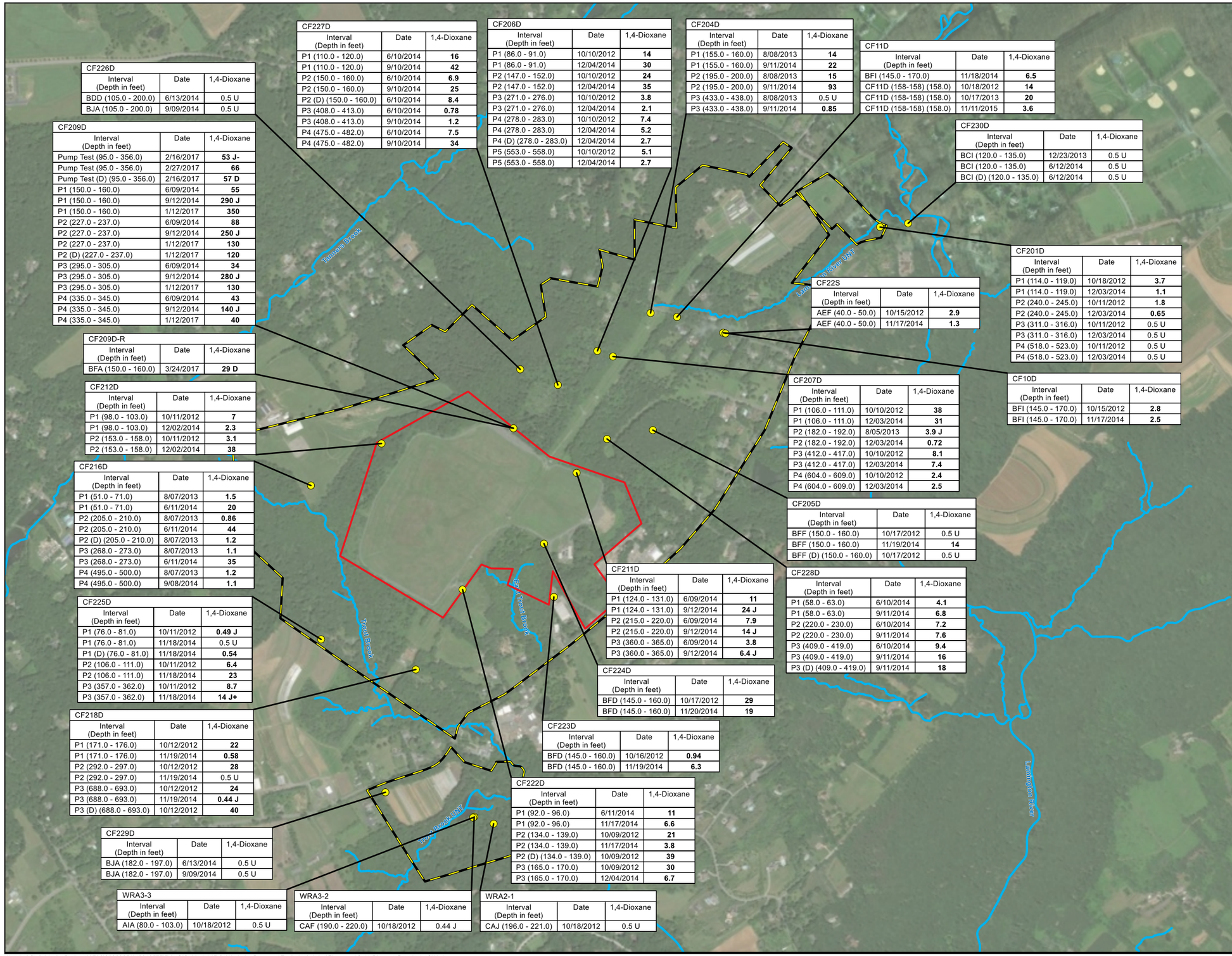
Sample intervals in databox are indicated by sample port number (P#) or using sample depth codes (A=0, B=1, C=2, etc.).

0 500 1000 feet
Not To Scale

Organic Groundwater Sample Results Exceeding Criteria (After 6/30/14) OU2 RI Samples

Figure 4-1B
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\10042577\7.0_GIS_Models\7.2_Work_In_Progress\EnviroInsite\vizx\Figure 4-1B Organic GW Sample Results with Exceedances After 6-30-2014.vizx



CF226D		
Interval (Depth in feet)	Date	1,4-Dioxane
BDD (105.0 - 200.0)	6/13/2014	0.5 U
BJA (105.0 - 200.0)	9/09/2014	0.5 U

CF209D		
Interval (Depth in feet)	Date	1,4-Dioxane
Pump Test (95.0 - 356.0)	2/16/2017	**53 J-**
Pump Test (95.0 - 356.0)	2/27/2017	**66**
Pump Test (D) (95.0 - 356.0)	2/16/2017	**57 D**
P1 (150.0 - 160.0)	6/09/2014	**55**
P1 (150.0 - 160.0)	9/12/2014	**290 J**
P1 (150.0 - 160.0)	1/12/2017	**350**
P2 (227.0 - 237.0)	6/09/2014	**88**
P2 (227.0 - 237.0)	9/12/2014	**250 J**
P2 (227.0 - 237.0)	1/12/2017	**130**
P2 (D) (227.0 - 237.0)	1/12/2017	**120**
P3 (295.0 - 305.0)	6/09/2014	**34**
P3 (295.0 - 305.0)	9/12/2014	**280 J**
P3 (295.0 - 305.0)	1/12/2017	**130**
P4 (335.0 - 345.0)	6/09/2014	**43**
P4 (335.0 - 345.0)	9/12/2014	**140 J**
P4 (335.0 - 345.0)	1/12/2017	**40**

CF209D-R		
Interval (Depth in feet)	Date	1,4-Dioxane
BFA (150.0 - 160.0)	3/24/2017	**29 D**

CF212D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (98.0 - 103.0)	10/11/2012	**7**
P1 (98.0 - 103.0)	12/02/2014	**2.3**
P2 (153.0 - 158.0)	10/11/2012	**3.1**
P2 (153.0 - 158.0)	12/02/2014	**38**

CF216D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (51.0 - 71.0)	8/07/2013	**1.5**
P1 (51.0 - 71.0)	6/11/2014	**20**
P2 (205.0 - 210.0)	8/07/2013	**0.86**
P2 (205.0 - 210.0)	6/11/2014	**44**
P2 (D) (205.0 - 210.0)	8/07/2013	**1.2**
P3 (268.0 - 273.0)	8/07/2013	**1.1**
P3 (268.0 - 273.0)	6/11/2014	**35**
P4 (495.0 - 500.0)	8/07/2013	**1.2**
P4 (495.0 - 500.0)	9/08/2014	**1.1**

CF225D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (76.0 - 81.0)	10/11/2012	**0.49 J**
P1 (76.0 - 81.0)	11/18/2014	0.5 U
P1 (D) (76.0 - 81.0)	11/18/2014	**0.54**
P2 (106.0 - 111.0)	10/11/2012	**6.4**
P2 (106.0 - 111.0)	11/18/2014	**23**
P3 (357.0 - 362.0)	10/11/2012	**8.7**
P3 (357.0 - 362.0)	11/18/2014	**14 J+**

CF218D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (171.0 - 176.0)	10/12/2012	**22**
P1 (171.0 - 176.0)	11/19/2014	**0.58**
P2 (292.0 - 297.0)	10/12/2012	**28**
P2 (292.0 - 297.0)	11/19/2014	0.5 U
P3 (688.0 - 693.0)	10/12/2012	**24**
P3 (688.0 - 693.0)	11/19/2014	**0.44 J**
P3 (D) (688.0 - 693.0)	10/12/2012	**40**

CF229D		
Interval (Depth in feet)	Date	1,4-Dioxane
BJA (182.0 - 197.0)	6/13/2014	0.5 U
BJA (182.0 - 197.0)	9/09/2014	0.5 U

WRA3-3		
Interval (Depth in feet)	Date	1,4-Dioxane
AIA (80.0 - 103.0)	10/18/2012	0.5 U

WRA3-2		
Interval (Depth in feet)	Date	1,4-Dioxane
CAF (190.0 - 220.0)	10/18/2012	0.44 J

WRA2-1		
Interval (Depth in feet)	Date	1,4-Dioxane
CAJ (196.0 - 221.0)	10/18/2012	0.5 U

CF227D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (110.0 - 120.0)	6/10/2014	**16**
P1 (110.0 - 120.0)	9/10/2014	**42**
P2 (150.0 - 160.0)	6/10/2014	**6.9**
P2 (150.0 - 160.0)	9/10/2014	**25**
P2 (D) (150.0 - 160.0)	6/10/2014	**8.4**
P3 (408.0 - 413.0)	6/10/2014	**0.78**
P3 (408.0 - 413.0)	9/10/2014	**1.2**
P4 (475.0 - 482.0)	6/10/2014	**7.5**
P4 (475.0 - 482.0)	9/10/2014	**34**

CF206D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (86.0 - 91.0)	10/10/2012	**14**
P1 (86.0 - 91.0)	12/04/2014	**30**
P2 (147.0 - 152.0)	10/10/2012	**24**
P2 (147.0 - 152.0)	12/04/2014	**35**
P3 (271.0 - 276.0)	10/10/2012	**3.8**
P3 (271.0 - 276.0)	12/04/2014	**2.1**
P4 (278.0 - 283.0)	10/10/2012	**7.4**
P4 (278.0 - 283.0)	12/04/2014	**5.2**
P4 (D) (278.0 - 283.0)	12/04/2014	**2.7**
P5 (553.0 - 558.0)	10/10/2012	**5.1**
P5 (553.0 - 558.0)	12/04/2014	**2.7**

CF204D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (155.0 - 160.0)	8/08/2013	**14**
P1 (155.0 - 160.0)	9/11/2014	**22**
P2 (195.0 - 200.0)	8/08/2013	**15**
P2 (195.0 - 200.0)	9/11/2014	**93**
P3 (433.0 - 438.0)	8/08/2013	0.5 U
P3 (433.0 - 438.0)	9/11/2014	**0.85**

CF11D		
Interval (Depth in feet)	Date	1,4-Dioxane
BFI (145.0 - 170.0)	11/18/2014	**6.5**
CF11D (158-158) (158.0)	10/18/2012	**14**
CF11D (158-158) (158.0)	10/17/2013	**20**
CF11D (158-158) (158.0)	11/11/2015	**3.6**

CF230D		
Interval (Depth in feet)	Date	1,4-Dioxane
BCI (120.0 - 135.0)	12/23/2013	0.5 U
BCI (120.0 - 135.0)	6/12/2014	0.5 U
BCI (D) (120.0 - 135.0)	6/12/2014	0.5 U

CF201D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (114.0 - 119.0)	10/18/2012	**3.7**
P1 (114.0 - 119.0)	12/03/2014	**1.1**
P2 (240.0 - 245.0)	10/11/2012	**1.8**
P2 (240.0 - 245.0)	12/03/2014	**0.65**
P3 (311.0 - 316.0)	10/11/2012	0.5 U
P3 (311.0 - 316.0)	12/03/2014	0.5 U
P4 (518.0 - 523.0)	10/11/2012	0.5 U
P4 (518.0 - 523.0)	12/03/2014	0.5 U

CF22S		
Interval (Depth in feet)	Date	1,4-Dioxane
AEF (40.0 - 50.0)	10/15/2012	**2.9**
AEF (40.0 - 50.0)	11/17/2014	**1.3**

CF10D		
Interval (Depth in feet)	Date	1,4-Dioxane
BFI (145.0 - 170.0)	10/15/2012	**2.8**
BFI (145.0 - 170.0)	11/17/2014	**2.5**

CF207D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (106.0 - 111.0)	10/10/2012	**38**
P1 (106.0 - 111.0)	12/03/2014	**31**
P2 (182.0 - 192.0)	8/05/2013	**3.9 J**
P2 (182.0 - 192.0)	12/03/2014	**0.72**
P3 (412.0 - 417.0)	10/10/2012	**8.1**
P3 (412.0 - 417.0)	12/03/2014	**7.4**
P4 (604.0 - 609.0)	10/10/2012	**2.4**
P4 (604.0 - 609.0)	12/03/2014	**2.5**

CF205D		
Interval (Depth in feet)	Date	1,4-Dioxane
BFF (150.0 - 160.0)	10/17/2012	0.5 U
BFF (150.0 - 160.0)	11/19/2014	**14**
BFF (D) (150.0 - 160.0)	10/17/2012	0.5 U

CF228D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (58.0 - 63.0)	6/10/2014	**4.1**
P1 (58.0 - 63.0)	9/11/2014	**6.8**
P2 (220.0 - 230.0)	6/10/2014	**7.2**
P2 (220.0 - 230.0)	9/11/2014	**7.6**
P3 (409.0 - 419.0)	6/10/2014	**9.4**
P3 (409.0 - 419.0)	9/11/2014	**16**
P3 (D) (409.0 - 419.0)	9/11/2014	**18**

CF211D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (124.0 - 131.0)	6/09/2014	**11**
P1 (124.0 - 131.0)	9/12/2014	**24 J**
P2 (215.0 - 220.0)	6/09/2014	**7.9**
P2 (215.0 - 220.0)	9/12/2014	**14 J**
P3 (360.0 - 365.0)	6/09/2014	**3.8**
P3 (360.0 - 365.0)	9/12/2014	**6.4 J**

CF224D		
Interval (Depth in feet)	Date	1,4-Dioxane
BFD (145.0 - 160.0)	10/17/2012	**29**
BFD (145.0 - 160.0)	11/20/2014	**19**

CF223D		
Interval (Depth in feet)	Date	1,4-Dioxane
BFD (145.0 - 160.0)	10/16/2012	**0.94**
BFD (145.0 - 160.0)	11/19/2014	**6.3**

CF222D		
Interval (Depth in feet)	Date	1,4-Dioxane
P1 (92.0 - 96.0)	6/11/2014	**11**
P1 (92.0 - 96.0)	11/17/2014	**6.6**
P2 (134.0 - 139.0)	10/09/2012	**21**
P2 (134.0 - 139.0)	11/17/2014	**3.8**
P2 (D) (134.0 - 139.0)	10/09/2012	**39**
P3 (165.0 - 170.0)	10/09/2012	**30**
P3 (165.0 - 170.0)	12/04/2014	**6.7**

HDR

Combe Fill South Landfill
Superfund Site RI/FS

Aerial Background Credits: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IGN, and the GIS User Community.

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

Legend

- Groundwater Sample Location
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Surface Water
- Aquitard (Source: Willowstick Report)
- Preferential Flow Path (Source: Willowstick Report)

CONSTITUENT	CRITERION (1)
1,4-Dioxane	0.4

Notes

- Results shown in ug/L.
- UNT = Unnamed Tributary

1. New Jersey Department of Environmental Protection (NJDEP) NJAC 7:9C Ground Water Quality Standards (updated January 16, 2018).

Wells identified as CF### (example CF209D) were installed for this RI/FS. Others predate this RI/FS.

Well CF-209D was a multi-port FLUTe well constructed in 2014 and decomissioned in January, 2017. It was replaced in March, 2017 with a conventional well screened from 150 to 160 feet bgs that was constructed in the same borehole.

Samples from CF-209D collected in February, 2017 were collected from the open borehole during a pumping test.

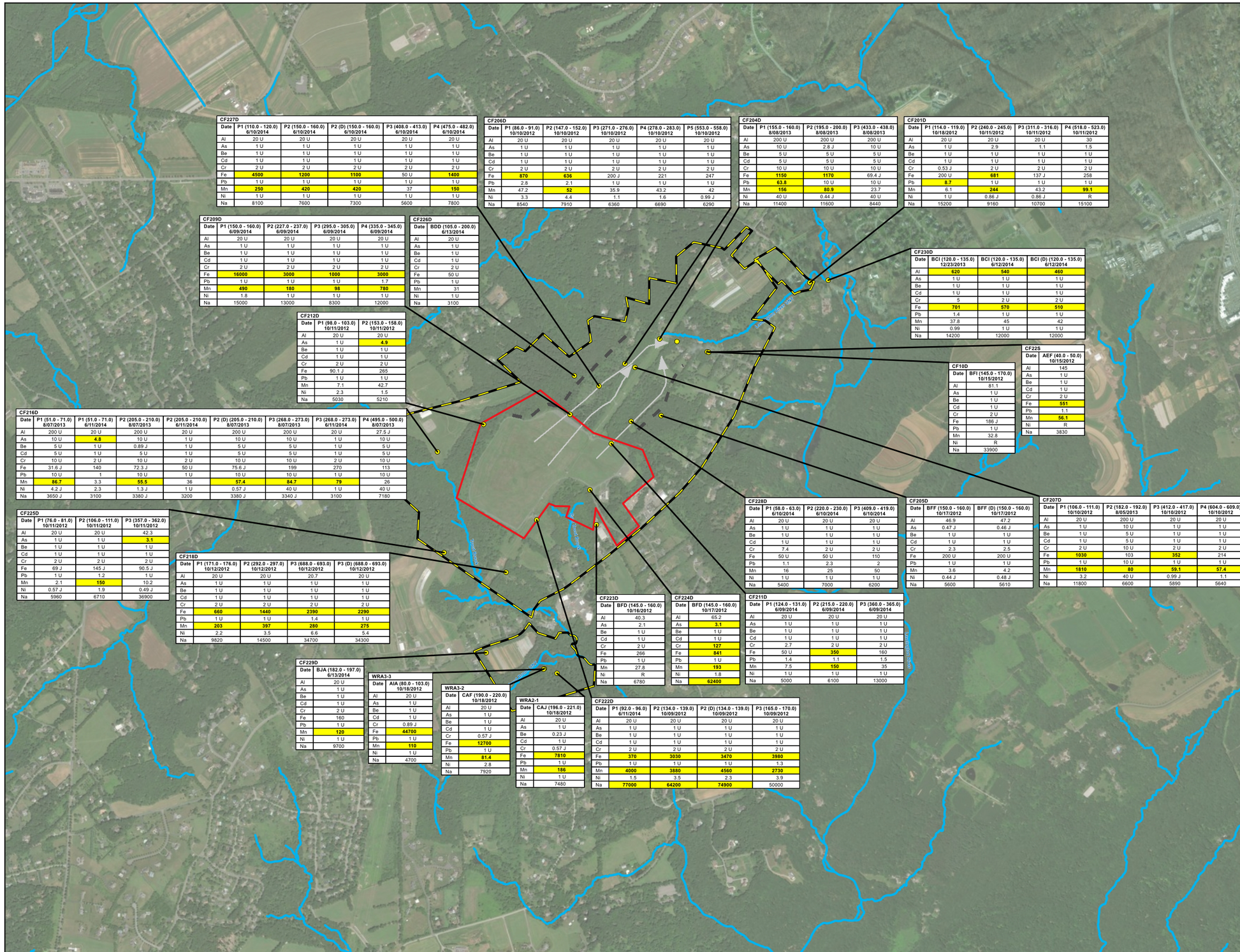
Sample intervals in databox are indicated by sample port number (P#) or using sample depth codes (A=0, B=1, C=2, etc.).

0 500 1000 feet
Not To Scale

1,4-Dioxane Results in Groundwater
OU2 RI Samples (2011 - 2015, 2017)

Figure 4-1C
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\10042577\7.0_GIS_Models\7.2_Work_In_Progress\EnviroInsite\vizx\Figure 4-1C 14-Dioxane Results in GW.vizx



CF227D

Date	P1 (110.0 - 120.0) 6/10/2014	P2 (150.0 - 160.0) 6/10/2014	P2 (D) (150.0 - 160.0) 6/10/2014	P3 (408.0 - 413.0) 6/10/2014	P4 (475.0 - 482.0) 6/10/2014
Al	20 U	20 U	20 U	20 U	20 U
As	1 U	1 U	1 U	1 U	1 U
Be	1 U	1 U	1 U	1 U	1 U
Cd	1 U	1 U	1 U	1 U	1 U
Cr	2 U	2 U	2 U	2 U	2 U
Fe	4500	1200	1100	50 U	1400
Pb	1 U	1 U	1 U	1 U	1 U
Mn	250	420	420	37	150
Ni	1 U	1 U	1 U	1 U	1 U
Na	8100	7600	7300	5600	7800

CF206D

Date	P1 (86.0 - 91.0) 10/10/2012	P2 (147.0 - 152.0) 10/10/2012	P3 (271.0 - 276.0) 10/10/2012	P4 (278.0 - 283.0) 10/10/2012	P5 (553.0 - 558.0) 10/10/2012
Al	20 U	20 U	20 U	20 U	20 U
As	1 U	1 U	1 U	1 U	1 U
Be	1 U	1 U	1 U	1 U	1 U
Cd	1 U	1 U	1 U	1 U	1 U
Cr	2 U	2 U	2 U	2 U	2 U
Fe	870	636	200 J	221	247
Pb	2.8	2.1	1 U	1 U	1 U
Mn	47.2	52	35.9	43.2	42
Ni	3.3	4.4	1.1	1.6	0.99 J
Na	8540	7910	6360	6690	6290

CF204D

Date	P1 (155.0 - 160.0) 8/08/2013	P2 (195.0 - 200.0) 8/08/2013	P3 (433.0 - 438.0) 8/08/2013
Al	200 U	200 U	200 U
As	10 U	2.8 J	10 U
Be	5 U	5 U	5 U
Cd	5 U	5 U	5 U
Cr	10 U	10 U	10 U
Fe	1150	1170	69.4 J
Pb	63.8	10 U	10 U
Mn	156	80.9	23.7
Ni	40 U	0.44 J	40 U
Na	11400	11600	8440

CF201D

Date	P1 (114.0 - 119.0) 10/18/2012	P2 (240.0 - 245.0) 10/11/2012	P3 (311.0 - 316.0) 10/11/2012	P4 (518.0 - 523.0) 10/11/2012
Al	20 U	20 U	20 U	30
As	1 U	2.9	1.1	1.5
Be	1 U	1 U	1 U	1 U
Cd	1 U	1 U	1 U	1 U
Cr	0.53 J	2 U	2 U	2 U
Fe	200 U	681	137 J	258
Pb	8.7	1 U	1 U	1 U
Mn	6.1	244	43.2	99.1
Ni	1 U	0.86 J	0.86 J	R
Na	15200	9160	10700	15100

CF209D

Date	P1 (150.0 - 160.0) 6/09/2014	P2 (227.0 - 237.0) 6/09/2014	P3 (295.0 - 305.0) 6/09/2014	P4 (335.0 - 345.0) 6/09/2014
Al	20 U	20 U	20 U	20 U
As	1 U	1 U	1 U	1 U
Be	1 U	1 U	1 U	1 U
Cd	1 U	1 U	1 U	1 U
Cr	2 U	2 U	2 U	2 U
Fe	16000	3000	1000	3000
Pb	1 U	1 U	1 U	1.7
Mn	490	180	98	780
Ni	1.8	1 U	1 U	1 U
Na	15000	13000	8300	12000

CF226D

Date	BDD (105.0 - 200.0) 6/13/2014
Al	20 U
As	1 U
Be	1 U
Cd	1 U
Cr	2 U
Fe	50 U
Pb	1 U
Mn	31
Ni	1 U
Na	3100

CF230D

Date	BCI (120.0 - 135.0) 12/23/2013	BCI (120.0 - 135.0) 6/12/2014	BCI (D) (120.0 - 135.0) 6/12/2014
Al	620	540	460
As	1 U	1 U	1 U
Be	1 U	1 U	1 U
Cd	1 U	1 U	1 U
Cr	5	2 U	2 U
Fe	701	570	510
Pb	1.4	1 U	1 U
Mn	37.8	45	42
Ni	0.99	1 U	1 U
Na	14200	12000	12000

CF212D

Date	P1 (98.0 - 103.0) 10/11/2012	P2 (153.0 - 158.0) 10/11/2012
Al	20 U	20 U
As	1 U	4.9
Be	1 U	1 U
Cd	1 U	1 U
Cr	2 U	2 U
Fe	90.1 J	265
Pb	1 U	1 U
Mn	7.1	42.7
Ni	2.3	1.5
Na	5030	5210

CF22S

Date	AEF (40.0 - 50.0) 10/15/2012
Al	145
As	1 U
Be	1 U
Cd	1 U
Cr	2 U
Fe	551
Pb	1.1
Mn	56.1
Ni	R
Na	3830

CF10D

Date	BFI (145.0 - 170.0) 10/15/2012
Al	81.1
As	1 U
Be	1 U
Cd	1 U
Cr	2 U
Fe	186 J
Pb	1 U
Mn	32.8
Ni	R
Na	33900

CF216D

Date	P1 (51.0 - 71.0) 8/07/2013	P1 (51.0 - 71.0) 6/11/2014	P2 (205.0 - 210.0) 8/07/2013	P2 (205.0 - 210.0) 6/11/2014	P2 (D) (205.0 - 210.0) 8/07/2013	P3 (268.0 - 273.0) 8/07/2013	P3 (268.0 - 273.0) 6/11/2014	P4 (495.0 - 500.0) 8/07/2013
Al	200 U	20 U	200 U	20 U	200 U	200 U	20 U	27.5 J
As	10 U	4.8	10 U	1 U	10 U	10 U	1 U	10 U
Be	5 U	1 U	0.89 J	1 U	5 U	5 U	1 U	5 U
Cd	5 U	1 U	5 U	1 U	5 U	5 U	1 U	5 U
Cr	10 U	2 U	10 U	2 U	10 U	10 U	2 U	10 U
Fe	31.6 J	140	72.3 J	50 U	75.6 J	199	270	113
Pb	10 U	1	10 U	1 U	10 U	10 U	1 U	10 U
Mn	86.7	3.3	55.5	36	57.4	84.7	79	26
Ni	4.2 J	2.3	1.3 J	1 U	0.57 J	40 U	1 U	40 U
Na	3650 J	3100	3380 J	3200	3380 J	3340 J	3100	7180

CF228D

Date	P1 (58.0 - 63.0) 6/10/2014	P2 (220.0 - 230.0) 6/10/2014	P3 (409.0 - 419.0) 6/10/2014
Al	20 U	20 U	20 U
As	1 U	1 U	1 U
Be	1 U	1 U	1 U
Cd	1 U	1 U	1 U
Cr	7.4	2 U	2 U
Fe	50 U	50 U	110
Pb	1.1	2.3	2
Mn	16	25	50
Ni	1 U	1 U	1 U
Na	5400	7000	6200

CF205D

Date	BFF (150.0 - 160.0) 10/17/2012	BFF (D) (150.0 - 160.0) 10/17/2012
Al	46.9	47.2
As	0.47 J	0.46 J
Be	1 U	1 U
Cd	1 U	1 U
Cr	2.3	2.5
Fe	200 U	200 U
Pb	1 U	1 U
Mn	3.6	4.2
Ni	0.44 J	0.48 J
Na	5600	5610

CF207D

Date	P1 (106.0 - 111.0) 10/10/2012	P2 (182.0 - 192.0) 8/05/2013	P3 (412.0 - 417.0) 10/10/2012	P4 (604.0 - 609.0) 10/10/2012
Al	20 U	200 U	20 U	20 U
As	1 U	10 U	1 U	1 U
Be	1 U	5 U	1 U	1 U
Cd	1 U	5 U	1 U	1 U
Cr	2 U	10 U	2 U	2 U
Fe	1030	103	352	214
Pb	1 U	10 U	1 U	1 U
Mn	1810	80	59.1	57.4
Ni	3.2	40 U	0.99 J	1.1
Na	11800	6600	5890	5640

CF225D

Date	P1 (76.0 - 81.0) 10/11/2012	P2 (106.0 - 111.0) 10/11/2012	P3 (357.0 - 362.0) 10/11/2012
Al	20 U	20 U	42.3
As	1 U	1 U	3.1
Be	1 U	1 U	1 U
Cd	1 U	1 U	1 U
Cr	2 U	2 U	2 U
Fe	69 J	145 J	90.5 J
Pb	1 U	1.2	1 U
Mn	2.1	150	10.2
Ni	0.57 J	1.9	0.49 J
Na	5960	6710	36900

CF218D

Date	P1 (171.0 - 176.0) 10/12/2012	P2 (292.0 - 297.0) 10/12/2012	P3 (688.0 - 693.0) 10/12/2012	P3 (D) (688.0 - 693.0) 10/12/2012
Al	20 U	20 U	20.7	20 U
As	1 U	1 U	1 U	1 U
Be	1 U	1 U	1 U	1 U
Cd	1 U	1 U	1 U	1 U
Cr	2 U	2 U	2 U	2 U
Fe	660	1440	2390	2290
Pb	1 U	1 U	1.4	1 U
Mn	203	397	280	275
Ni	2.2	3.5	6.6	5.4
Na	9820	14500	34700	34300

CF223D

Date	BFD (145.0 - 160.0) 10/16/2012
Al	40.3
As	2.1
Be	1 U
Cd	1 U
Cr	2 U
Fe	266
Pb	1 U
Mn	27.8
Ni	R
Na	6780

CF224D

Date	BFD (145.0 - 160.0) 10/17/2012
Al	65.2
As	3.1
Be	1 U
Cd	1 U
Cr	127
Fe	841
Pb	1 U
Mn	193
Ni	1.8
Na	62400

CF211D

Date	P1 (124.0 - 131.0) 6/09/2014	P2 (215.0 - 220.0) 6/09/2014	P3 (360.0 - 365.0) 6/09/2014
Al	20 U	20 U	20 U
As	1 U	1 U	1 U
Be	1 U	1 U	1 U
Cd	1 U	1 U	1 U
Cr	2.7	2 U	2 U
Fe	50 U	350	160
Pb	1.4	1.1	1.5
Mn	7.5	150	35
Ni	1 U	1 U	1 U
Na	5000	6100	13000

CF229D

Date	BJA (182.0 - 197.0) 6/13/2014
Al	20 U
As	1 U
Be	1 U
Cd	1 U
Cr	2 U
Fe	160
Pb	1 U
Mn	120
Ni	1 U
Na	9700

WRA3-3

Date	AIA (80.0 - 103.0) 10/18/2012
Al	20 U
As	1 U
Be	1 U
Cd	1 U
Cr	0.89 J
Fe	44700
Pb	1 U
Mn	110
Ni	1 U
Na	4700

WRA3-2

Date	CAF (190.0 - 220.0) 10/18/2012
Al	20 U
As	1 U
Be	1 U
Cd	1 U
Cr	0.57 J
Fe	12700
Pb	1 U
Mn	81.4
Ni	2.8
Na	7920

WRA2-1

Date	CAJ (196.0 - 221.0) 10/18/2012
Al	20 U
As	1 U
Be	0.23 J
Cd	1 U
Cr	0.57 J
Fe	7810
Pb	1 U
Mn	186
Ni	1 U
Na	7480

CF222D

Date	P1 (92.0 - 96.0) 6/11/2014	P2 (134.0 - 139.0) 10/09/2012	P2 (D) (134.0 - 139.0) 10/09/2012	P3 (165.0 - 170.0) 10/09/2012
Al	20 U	20 U	20 U	20 U
As	1 U	1 U	1 U	1 U
Be	1 U	1 U	1 U	1 U
Cd	1 U	1 U	1 U	1 U
Cr	2 U	2 U	2 U	2 U
Fe	370	3030	3470	3980
Pb	1 U	1 U	1 U	1.3
Mn	4000	3880	4560	2730
Ni	1.5	3.5	2.3	3.9
Na	77000	64200	74900	50000

HDR

Combe Fill South Landfill
Superfund Site RI/FS

Aerial Background Credits: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IGN, and the GIS User Community.

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

Legend

- Groundwater Sample Location
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Surface Water
- Aquitard (Source: Willowstick Report)
- Preferential Flow Path (Source: Willowstick Report)

CONSTITUENT	CRITERION (1)
Aluminum (Al)	200
Arsenic (As)	3
Beryllium (Be)	1
Cadmium (Cd)	4
Chromium, Total (Cr)	70
Iron (Fe)	300
Lead (Pb)	5
Manganese (Mn)	50
Nickel (Ni)	100
Sodium (Na)	50,000

Exceedances indicated by yellow highlighting.

Notes
- Results shown in ug/L.
- UNT = Unnamed Tributary

- Field duplicate samples are indicated by (D).
- Locations shown without a databox were not sampled within the time frame depicted on the figure.

1. New Jersey Department of Environmental Protection (NJDEP) NJAC 7:9C Ground Water Quality Standards (updated January 16, 2018).

Wells identified as CF### (example CF209D) were installed for the OU2 RI/FS. Others predate this RI/FS.

Well CF-209D was a multi-port FLUTe well constructed in 2014 and decomissioned in January, 2017. It was replaced in March, 2017 with a conventional well screened from 150 to 160 feet bgs that was constructed in the same borehole. Samples from CF-209D collected in February, 2017 were collected from the open borehole during a pumping test.

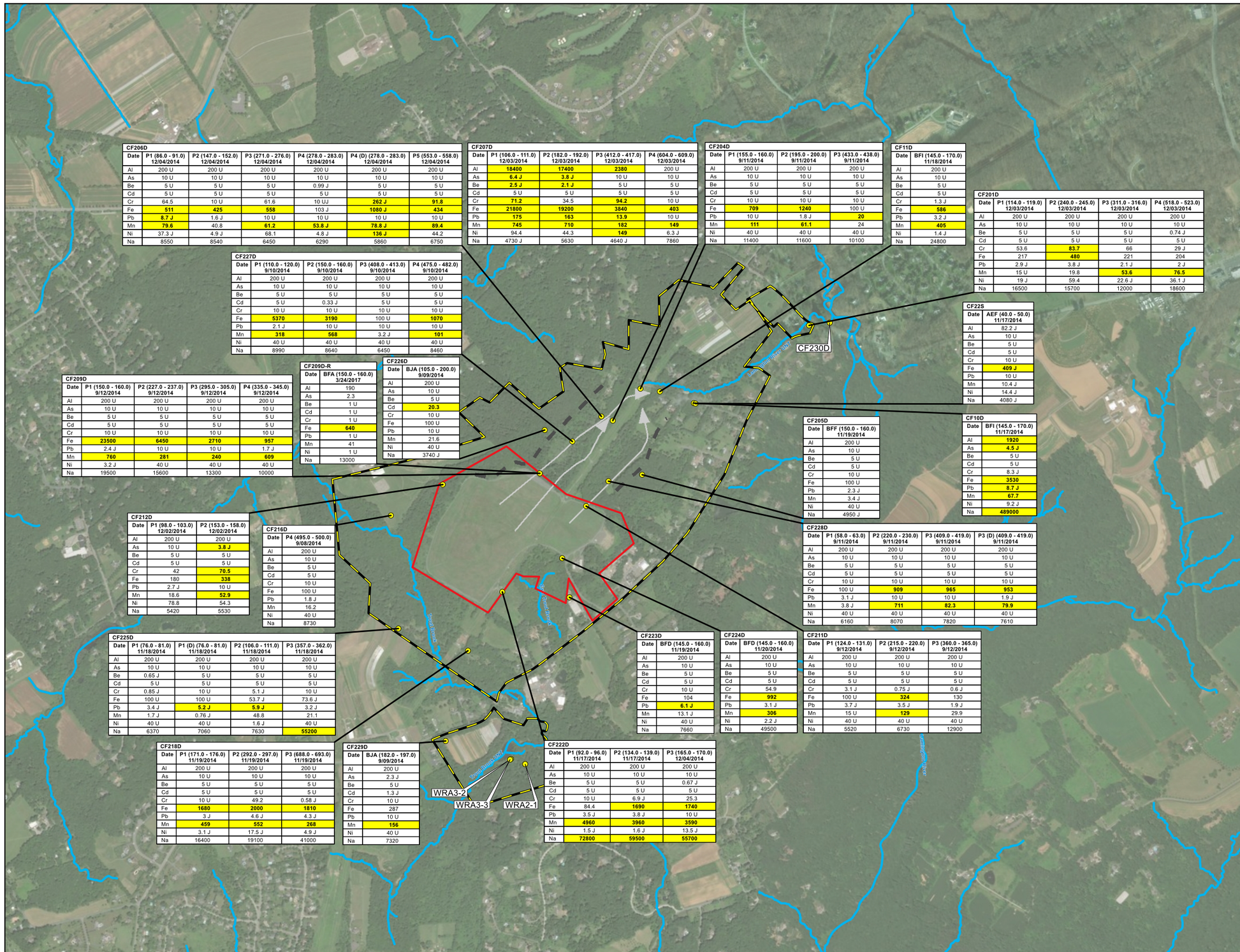
Sample intervals in databox are indicated by sample port number (P#) or using sample depth codes (A=0, B=1, C=2, etc.).

0 500 1000 feet
Not To Scale

Inorganic Groundwater Sample Results Exceeding Criteria (Prior to 6/30/14) OU2 RI Samples

Figure 4-2A
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\10042577\7.0_GIS_Models\7.2_Work_In_Progress\EnviroInsite\vizx\Figure 4-2A Inorganic GW Sample Results with Exceedances Before 6-30-2014.vizx



CF206D

Date	P1 (86.0 - 91.0) 12/04/2014	P2 (147.0 - 152.0) 12/04/2014	P3 (271.0 - 276.0) 12/04/2014	P4 (278.0 - 283.0) 12/04/2014	P4 (D) (278.0 - 283.0) 12/04/2014	P5 (553.0 - 558.0) 12/04/2014
Al	200 U	200 U	200 U	200 U	200 U	200 U
As	10 U	10 U	10 U	10 U	10 U	10 U
Be	5 U	5 U	5 U	0.99 J	5 U	5 U
Cd	5 U	5 U	5 U	5 U	5 U	5 U
Cr	64.5	10 U	61.6	10 UJ	262 J	91.8
Fe	511	425	558	103 J	1080 J	434
Pb	8.7 J	1.6 J	10 U	10 U	10 U	10 U
Mn	79.6	40.8	61.2	53.8 J	78.8 J	89.4
Ni	37.3 J	4.9 J	68.1	4.8 J	136 J	44.2
Na	8550	8540	6450	6290	5860	6750

CF207D

Date	P1 (106.0 - 111.0) 12/03/2014	P2 (182.0 - 192.0) 12/03/2014	P3 (412.0 - 417.0) 12/03/2014	P4 (604.0 - 609.0) 12/03/2014
Al	18400	17400	2380	200 U
As	6.4 J	3.8 J	10 U	10 U
Be	2.5 J	2.1 J	5 U	5 U
Cd	5 U	5 U	5 U	5 U
Cr	71.2	34.5	94.2	10 U
Fe	21800	19200	3840	403
Pb	175	163	13.9	10 U
Mn	745	710	182	149
Ni	94.4	44.3	149	6.3 J
Na	4730 J	5630	4640 J	7860

CF204D

Date	P1 (155.0 - 160.0) 9/11/2014	P2 (195.0 - 200.0) 9/11/2014	P3 (433.0 - 438.0) 9/11/2014
Al	200 U	200 U	200 U
As	10 U	10 U	10 U
Be	5 U	5 U	5 U
Cd	5 U	5 U	5 U
Cr	10 U	10 U	10 U
Fe	709	1240	100 U
Pb	10 U	1.8 J	20
Mn	111	61.1	24
Ni	40 U	40 U	40 U
Na	11400	11600	10100

CF11D

Date	BFI (145.0 - 170.0) 11/18/2014
Al	200 U
As	10 U
Be	5 U
Cd	5 U
Cr	1.3 J
Fe	586
Pb	3.2 J
Mn	405
Ni	1.4 J
Na	24800

CF201D

Date	P1 (114.0 - 119.0) 12/03/2014	P2 (240.0 - 245.0) 12/03/2014	P3 (311.0 - 316.0) 12/03/2014	P4 (518.0 - 523.0) 12/03/2014
Al	200 U	200 U	200 U	200 U
As	10 U	10 U	10 U	10 U
Be	5 U	5 U	5 U	0.74 J
Cd	5 U	5 U	5 U	5 U
Cr	53.6	83.7	66	29 J
Fe	217	480	221	204
Pb	2.9 J	3.8 J	2.1 J	2 J
Mn	15 U	19.8	53.6	76.5
Ni	19 J	59.4	22.6 J	36.1 J
Na	16500	15700	12000	18600

CF227D

Date	P1 (110.0 - 120.0) 9/10/2014	P2 (150.0 - 160.0) 9/10/2014	P3 (408.0 - 413.0) 9/10/2014	P4 (475.0 - 482.0) 9/10/2014
Al	200 U	200 U	200 U	200 U
As	10 U	10 U	10 U	10 U
Be	5 U	5 U	5 U	5 U
Cd	5 U	0.33 J	5 U	5 U
Cr	10 U	10 U	10 U	10 U
Fe	5370	3190	100 U	1070
Pb	2.1 J	10 U	10 U	10 U
Mn	318	568	3.2 J	101
Ni	40 U	40 U	40 U	40 U
Na	8990	8640	6450	8460

CF22S

Date	AEF (40.0 - 50.0) 11/17/2014
Al	82.2 J
As	10 U
Be	5 U
Cd	5 U
Cr	10 U
Fe	409 J
Pb	10 U
Mn	10.4 J
Ni	14.4 J
Na	4080 J

CF209D

Date	P1 (150.0 - 160.0) 9/12/2014	P2 (227.0 - 237.0) 9/12/2014	P3 (295.0 - 305.0) 9/12/2014	P4 (335.0 - 345.0) 9/12/2014
Al	200 U	200 U	200 U	200 U
As	10 U	10 U	10 U	10 U
Be	5 U	5 U	5 U	5 U
Cd	5 U	5 U	5 U	5 U
Cr	10 U	10 U	10 U	10 U
Fe	23500	6450	2710	957
Pb	2.4 J	10 U	10 U	1.7 J
Mn	760	281	240	609
Ni	3.2 J	40 U	40 U	40 U
Na	19500	15600	13300	10000

CF209D-R

Date	BFA (150.0 - 160.0) 3/24/2017
Al	190
As	2.3
Be	1 U
Cd	1 U
Cr	1 U
Fe	640
Pb	1 U
Mn	41
Ni	1 U
Na	13000

CF226D

Date	BJA (105.0 - 200.0) 9/09/2014
Al	200 U
As	10 U
Be	5 U
Cd	20.3
Cr	10 U
Fe	100 U
Pb	10 U
Mn	21.6
Ni	40 U
Na	3740 J

CF205D

Date	BFF (150.0 - 160.0) 11/19/2014
Al	200 U
As	10 U
Be	5 U
Cd	5 U
Cr	10 U
Fe	100 U
Pb	2.3 J
Mn	3.4 J
Ni	40 U
Na	4950 J

CF10D

Date	BFI (145.0 - 170.0) 11/17/2014
Al	1920
As	4.5 J
Be	5 U
Cd	5 U
Cr	8.3 J
Fe	3530
Pb	8.7 J
Mn	67.7
Ni	9.2 J
Na	489000

CF212D

Date	P1 (98.0 - 103.0) 12/02/2014	P2 (153.0 - 158.0) 12/02/2014
Al	200 U	200 U
As	10 U	3.8 J
Be	5 U	5 U
Cd	5 U	5 U
Cr	42	70.5
Fe	160	338
Pb	2.7 J	10 U
Mn	18.6	52.9
Ni	78.8	54.3
Na	5420	5530

CF216D

Date	P4 (495.0 - 500.0) 9/08/2014
Al	200 U
As	10 U
Be	5 U
Cd	5 U
Cr	10 U
Fe	100 U
Pb	1.8 J
Mn	16.2
Ni	40 U
Na	8730

CF228D

Date	P1 (58.0 - 63.0) 9/11/2014	P2 (220.0 - 230.0) 9/11/2014	P3 (409.0 - 419.0) 9/11/2014	P3 (D) (409.0 - 419.0) 9/11/2014
Al	200 U	200 U	200 U	200 U
As	10 U	10 U	10 U	10 U
Be	5 U	5 U	5 U	5 U
Cd	5 U	5 U	5 U	5 U
Cr	10 U	10 U	10 U	10 U
Fe	100 U	909	965	953
Pb	3.1 J	10 U	10 U	1.9 J
Mn	3.8 J	711	82.3	79.9
Ni	40 U	40 U	40 U	40 U
Na	6160	8070	7820	7610

CF225D

Date	P1 (76.0 - 81.0) 11/18/2014	P1 (D) (76.0 - 81.0) 11/18/2014	P2 (106.0 - 111.0) 11/18/2014	P3 (357.0 - 362.0) 11/18/2014
Al	200 U	200 U	200 U	200 U
As	10 U	10 U	10 U	10 U
Be	0.65 J	5 U	5 U	5 U
Cd	5 U	5 U	5 U	5 U
Cr	0.85 J	10 U	5.1 J	10 U
Fe	100 U	100 U	53.7 J	73.6 J
Pb	3.4 J	5.2 J	5.9 J	3.2 J
Mn	1.7 J	0.76 J	48.8	21.1
Ni	40 U	40 U	1.6 J	40 U
Na	6370	7060	7630	55200

CF223D

Date	BFD (145.0 - 160.0) 11/19/2014
Al	200 U
As	10 U
Be	5 U
Cd	5 U
Cr	10 U
Fe	104
Pb	6.1 J
Mn	13.1 J
Ni	40 U
Na	7660

CF224D

Date	BFD (145.0 - 160.0) 11/20/2014
Al	200 U
As	10 U
Be	5 U
Cd	5 U
Cr	54.9
Fe	992
Pb	3.1 J
Mn	306
Ni	2.2 J
Na	49500

CF211D

Date	P1 (124.0 - 131.0) 9/12/2014	P2 (215.0 - 220.0) 9/12/2014	P3 (360.0 - 365.0) 9/12/2014
Al	200 U	200 U	200 U
As	10 U	10 U	10 U
Be	5 U	5 U	5 U
Cd	5 U	5 U	5 U
Cr	3.1 J	0.75 J	0.6 J
Fe	100 U	324	130
Pb	3.7 J	3.5 J	1.9 J
Mn	15 U	129	29.9
Ni	40 U	40 U	40 U
Na	5520	6730	12900

CF218D

Date	P1 (171.0 - 176.0) 11/19/2014	P2 (292.0 - 297.0) 11/19/2014	P3 (688.0 - 693.0) 11/19/2014
Al	200 U	200 U	200 U
As	10 U	10 U	10 U
Be	5 U	5 U	5 U
Cd	5 U	5 U	5 U
Cr	10 U	49.2	0.58 J
Fe	1680	2000	1810
Pb	3 J	4.6 J	4.3 J
Mn	459	552	268
Ni	3.1 J	17.5 J	4.9 J
Na	16400	19100	41000

CF229D

Date	BJA (182.0 - 197.0) 9/09/2014
Al	200 U
As	2.3 J
Be	5 U
Cd	1.3 J
Cr	10 U
Fe	287
Pb	10 U
Mn	156
Ni	40 U
Na	7320

CF222D

Date	P1 (92.0 - 96.0) 11/17/2014	P2 (134.0 - 139.0) 11/17/2014	P3 (165.0 - 170.0) 12/04/2014
Al	200 U	200 U	200 U
As	10 U	10 U	10 U
Be	5 U	5 U	0.67 J
Cd	5 U	5 U	5 U
Cr	10 U	6.9 J	25.3
Fe	84.4	1690	1740
Pb	3.5 J	3.8 J	10 U
Mn	4960	3960	3590
Ni	1.5 J	1.6 J	13.5 J
Na	72800	59500	55700

Combe Fill South Landfill
Superfund Site RI/FS

Aerial Background Credits: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IGN, and the GIS User Community.

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

Legend

- Groundwater Sample Location
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Surface Water
- Aquitard (Source: Willowstick Report)
- Preferential Flow Path (Source: Willowstick Report)

CONSTITUENT	CRITERION (1)
Aluminum (Al)	200
Arsenic (As)	3
Beryllium (Be)	1
Cadmium (Cd)	4
Chromium, Total (Cr)	70
Iron (Fe)	300
Lead (Pb)	5
Manganese (Mn)	50
Nickel (Ni)	100
Sodium (Na)	50,000

Exceedances indicated by yellow highlighting.

Notes
- Results shown in ug/L.
- UNT = Unnamed Tributary

- Field duplicate samples are indicated by (D).
- Locations shown without a databox were not sampled within the time frame depicted on the figure.

1. New Jersey Department of Environmental Protection (NJDEP) NJAC 7:9C Ground Water Quality Standards (updated January 16, 2018).

Wells identified as CF### (example CF209D) were installed for the OU2 RI/FS. Others predate this RI/FS.

Well CF-209D was a multi-port FLUTe well constructed in 2014 and decomissioned in January, 2017. It was replaced in March, 2017 with a conventional well screened from 150 to 160 feet bgs that was constructed in the same borehole. Samples from CF-209D collected in February, 2017 were collected from the open borehole during a pumping test.

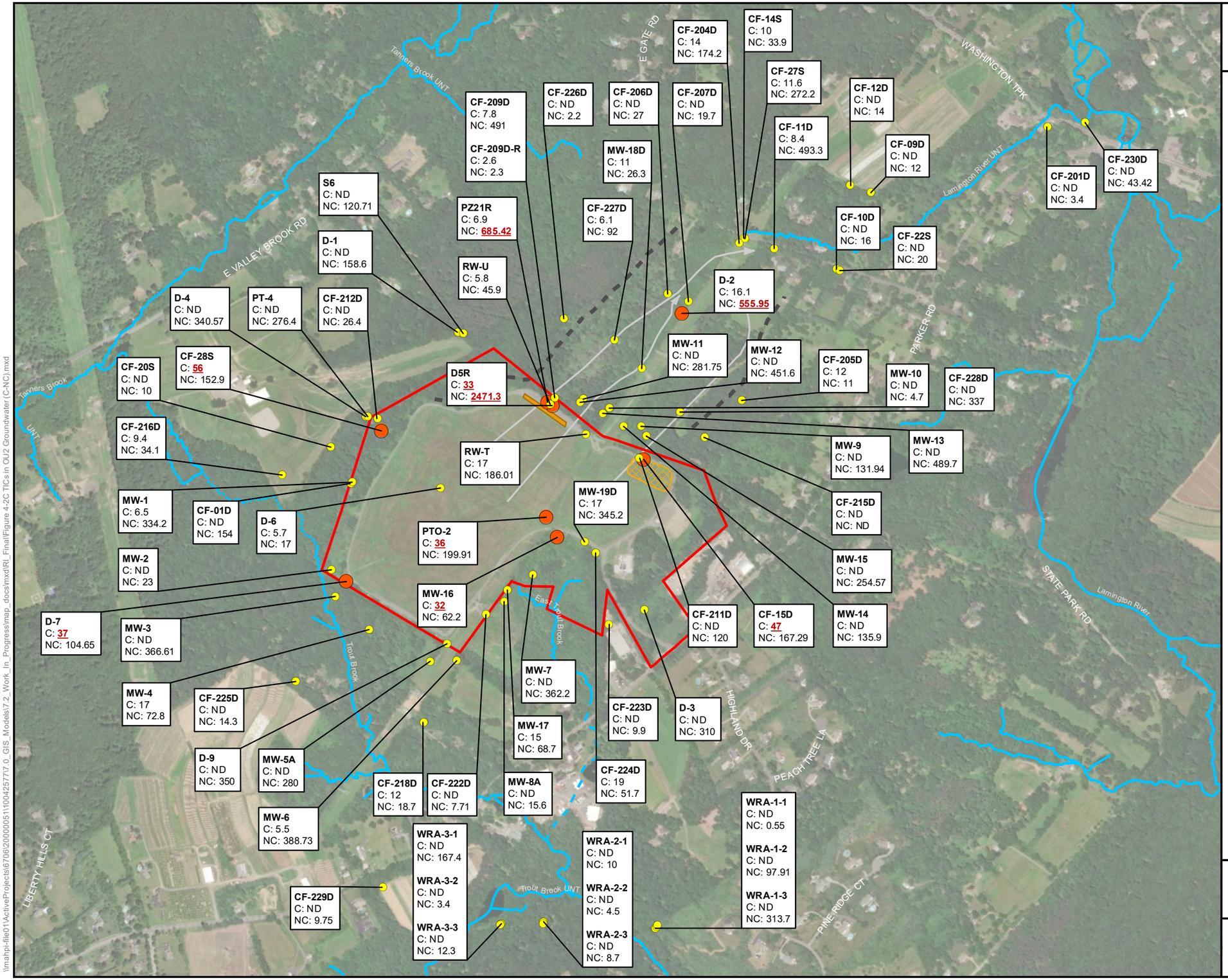
Sample intervals in databox are indicated by sample port number (P#) or using sample depth codes (A=0, B=1, C=2, etc.).

0 500 1000 feet
Not To Scale

Inorganic Groundwater Sample Results Exceeding Criteria (After 6/30/14) OU2 RI Samples

Figure 4-2B
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\10042577\7.0_GIS_Models\7.2_Work_In_Progress\EnviroInsite\vizx\Figure 4-2B Inorganic GW Sample Results with Exceedances After 6-30-2014.vizx



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- Monitor well without exceedance of IGGWQC
- Monitor well with exceedance of carcinogenic or non-carcinogenic IGGWQC
- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

DATA BOX EXAMPLE

D-2 — Well ID
C: 16.1
NC: **555.95** — Exceedance of NJDEP IGGWQC indicated by **Bold Red Underline**

Abbrev.	Compound	IGGWQC
C	Sum of Carcinogenic SOCs (1)	25
NC	Sum of Non-Carcinogenic SOCs (2)	500

GWQS - NJDEP Groundwater Quality Standards Table 2 Interim Generic Ground Water Quality Criteria (IGGWQC) (N.J.A.C. 7:9C, 2018)

NOTES

Concentrations shown in ug/L.
TIC = Tentatively Identified Compound
SOC = Synthetic Organic Chemical
ND = No detected SOC TICs for this group (C or NC).

Maximum sum of carcinogenic and non-carcinogenic SOC TICs shown by location regardless of depth or sample date to visualize approximate extent of landfill related impacts to groundwater.

Carcinogenicity based on classifications published by the International Agency for Research on Cancer (IARC. March, 2018). SOCs not listed by IARC are assumed to be non-carcinogenic. Summations exclude chemicals with promulgated specific groundwater quality standards and unknown TICs.

Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

0 400 800 Feet

Tentatively Identified Sythetic Organic Compounds (TICs) in Groundwater

Figure 4-2C
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1\004257\7.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 4-2C TICs in OU2 Groundwater (C-NC).mxd

CFB005

	4 - 6	10 - 12	20 - 22	30 - 32	40 - 42
Aluminum	4300	**11200**	**48200 J**	**30800**	**42300**
Arsenic	12.9	4.3	4.1	3	2.5 J
Beryllium	0.65	**0.86**	**5.7 J**	**2.8**	**2.9**
Cadmium	0.46	0.37 J	1.6 J	**6.3**	**3.6 J**
Cobalt	10.5	7.9	**113 J**	63.6	46.3 J
Manganese	**167**	**118**	**1320 J**	**758**	**861**
Nickel	12.7	9	**74.6**	**54**	29.8
Silver	0.46 J	0.34 J	**2.9 J-**	**1.1 U**	**1 UJ**
Vanadium	18.1	20.2	**217 J**	**125**	**123**

CFB005

	50 - 52	60 - 62	70 - 72
Aluminum	38100	25900	34900
Arsenic	2.5	2.5 N	2.5
Beryllium	3.8	1.8	2
Cadmium	6	3.6	4.4
Cobalt	62.8	26.1	48.3
Manganese	978	396	909
Nickel	33.4	26.3	47.2
Silver	**1.1 U**	**1 U**	**1 U**
Vanadium	**151**	**93.1**	**113**

CFB004

	10 - 12	20 - 22	32 - 34	32 - 34	40 - 42
Aluminum	**11500**	**16100**	**11200**	**9600**	**7230 J**
Arsenic	5.4	1.1	**0.88 U**	**0.81 U**	1.1 J-
Beryllium	0.27 J	**1.2**	**0.83**	**0.72**	0.68 J-
Cadmium	**2.6**	1.4	0.26 J	0.24	0.69 J
Cobalt	22.6	14.6	2.7 J	3.4 J	7.7
Manganese	**397**	**145**	27.7	25.1	59.4 J
Nickel	26.4	23	4.4	4.5	7.8
Silver	**0.8 U**	**0.89 U**	**0.88 U**	**0.81 U**	**0.85 UJ**
Vanadium	72.7	27.7	5.8	4.6	7 J-

CFB001

	4 - 6	14 - 16
Aluminum	**16700**	**13700**
Arsenic	7.1	2.6
Beryllium	**1.1**	**1**
Cadmium	0.64	0.14 J
Cobalt	13.5	7.2
Manganese	**136**	**77.6**
Nickel	5.7	2.6 J
Silver	0.28 J	**0.84 U**
Vanadium	17.3	6.6

CFB002

	4 - 6	4 - 6	10 - 12	20 - 22	30 - 32
Aluminum	**6850 J**	**7110**	**19900**	**16600**	**30900**
Arsenic	6.1	**326**	4.4	1.7	3.5
Beryllium	0.51 J-	0.59	**0.78**	**1.1**	**5.2**
Cadmium	1.1 J	1.4	1.6	0.74	0.96
Cobalt	8.3	13.8	9.7	8.5	30.4
Manganese	**126 J**	**120**	**90.8**	**125**	**241**
Nickel	10.1	13.5	7.3	1.9 J	20
Silver	**0.88 UJ**	**0.86 U**	**0.8 U**	**0.87 U**	**1.6**
Vanadium	18.9	21.9	29.8	11	**97.7**

CFB003

	2 - 4	10 - 12	20 - 22
Aluminum	**15300**	**26200**	**21100 J**
Arsenic	3.8	7.5	4.4 J-
Beryllium	**0.82**	**1.1**	**6.3 J-**
Cadmium	0.99	1.5	**5.7 J**
Cobalt	11.5	18.9	38.3
Manganese	**208**	**171**	**380 J-**
Nickel	10.3	9.1	0.94 J
Silver	0.8	0.83	R
Vanadium	36	38.4	45.1 J-

Combe Fill South Landfill
Superfund Site RI/FS

Aerial Background Credits: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IGN, and the GIS User Community.

Coordinate System: NAD 1983 New Jersey State Plane FIPS 2900 (Feet)

Legend

- Soil Boring Location
- OU2 Boundary
- Landfill Boundary
- Stream

Constituent	Unsaturated Zone (1)	Saturated Zone (2)
Aluminum	6,000	78,000
Arsenic	19	19
Beryllium	0.7	16
Cadmium	2	78
Cobalt	90	590
Manganese	65	5,900
Nickel	48	1,600
Silver	1	390
Vanadium	78	78

Notes

- All concentrations shown in mg/kg.
- Only constituents exceeding the applicable criterion in any given sample are shown.
- Samples collected in November, 2014.

Exceedance Highlighting

Yellow - Exceeds Unsaturated Zone Criterion (1)

Orange - Exceeds Saturated Zone Criterion (2)

(1) - For evaluation of soil samples collected in the unsaturated zone above the water table, the most conservative value of the Residential Direct Contact Soil Remediation Standard (RDCSRS), Non-Residential Direct Contact Soil Remediation Standard (NRDCSRS), and the Impact to Groundwater Soil Screening Level (IGWSSL) is used for comparison.
NOTE - All samples except for those listed in note (2) were collected from the unsaturated zone. These samples are presented in a separate data box.

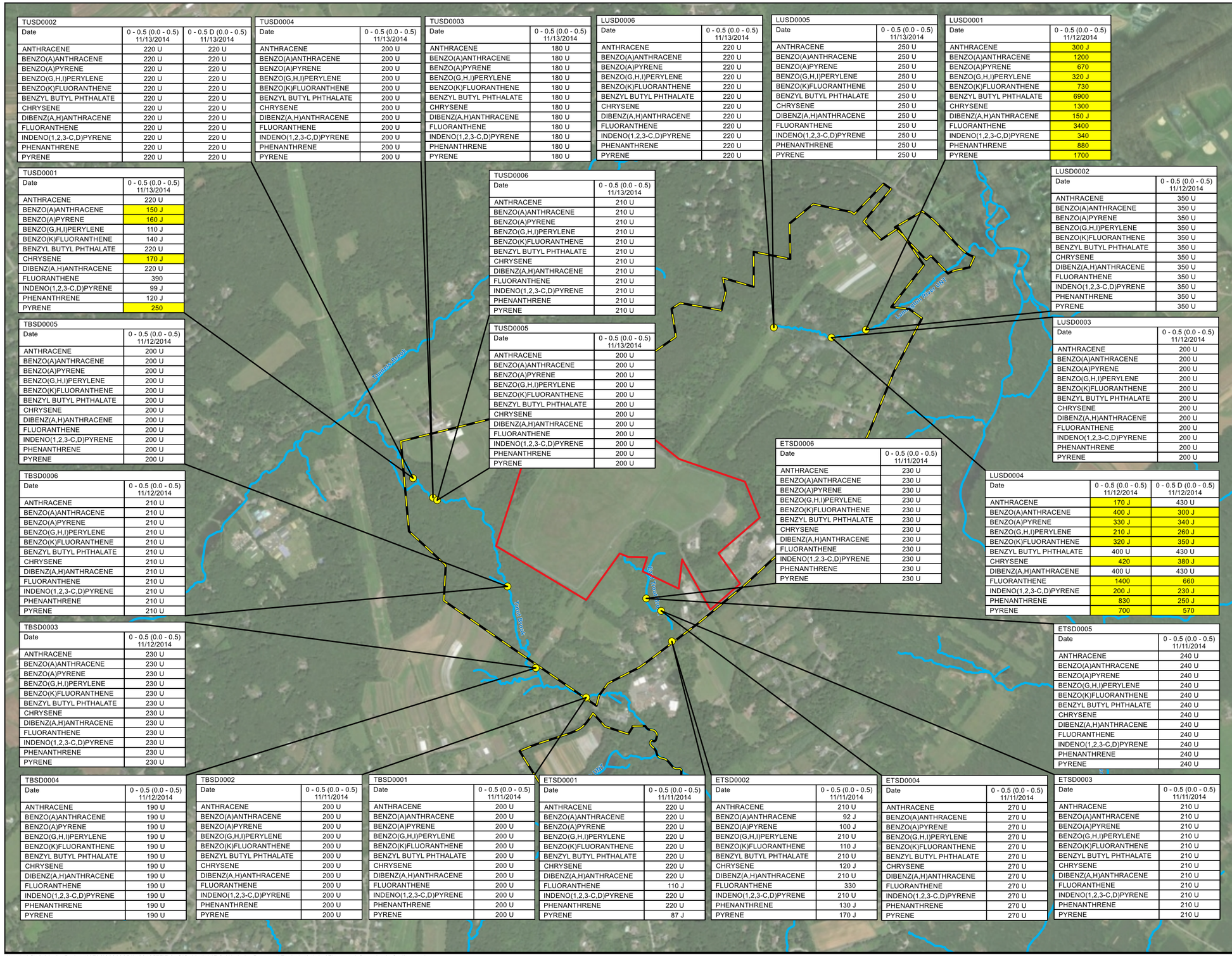
(2) For evaluation of soil samples collected in the saturated zone below the water table, the most conservative value of the Residential Direct Contact Soil Remediation Standard (RDCSRS), Non-Residential Direct Contact Soil Remediation Standard (NRDCSRS) is used for comparison.
NOTE: Samples from CFB005 from 50 - 52 feet, 60 - 62 feet, and 70 - 72 feet deep were collected below the water table in the saturated zone.

RDCSRS & NRDCSRS: NJAC 7:26D Remediation Standards (Last amended September 18, 2017).
IGWSSL: NJDEP Development of Impact to Ground Water Soil Remediation Standards Using the Soil-Water Partition Equation Version 2.0 (November, 2013).

0 500 1000 feet
NOT TO SCALE

Inorganic Soil Sample Results Exceeding Criteria

Figure 4-3
June, 2018



TUSD0002		
Date	0 - 0.5 (0.0 - 0.5) 11/13/2014	0 - 0.5 D (0.0 - 0.5) 11/13/2014
ANTHRACENE	220 U	220 U
BENZO(A)ANTHRACENE	220 U	220 U
BENZO(A)PYRENE	220 U	220 U
BENZO(G,H,I)PERYLENE	220 U	220 U
BENZO(K)FLUORANTHENE	220 U	220 U
BENZYL BUTYL PHTHALATE	220 U	220 U
CHRYSENE	220 U	220 U
DIBENZ(A,H)ANTHRACENE	220 U	220 U
FLUORANTHENE	220 U	220 U
INDENO(1,2,3-C,D)PYRENE	220 U	220 U
PHENANTHRENE	220 U	220 U
PYRENE	220 U	220 U

TUSD0004	
Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ANTHRACENE	200 U
BENZO(A)ANTHRACENE	200 U
BENZO(A)PYRENE	200 U
BENZO(G,H,I)PERYLENE	200 U
BENZO(K)FLUORANTHENE	200 U
BENZYL BUTYL PHTHALATE	200 U
CHRYSENE	200 U
DIBENZ(A,H)ANTHRACENE	200 U
FLUORANTHENE	200 U
INDENO(1,2,3-C,D)PYRENE	200 U
PHENANTHRENE	200 U
PYRENE	200 U

TUSD0003	
Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ANTHRACENE	180 U
BENZO(A)ANTHRACENE	180 U
BENZO(A)PYRENE	180 U
BENZO(G,H,I)PERYLENE	180 U
BENZO(K)FLUORANTHENE	180 U
BENZYL BUTYL PHTHALATE	180 U
CHRYSENE	180 U
DIBENZ(A,H)ANTHRACENE	180 U
FLUORANTHENE	180 U
INDENO(1,2,3-C,D)PYRENE	180 U
PHENANTHRENE	180 U
PYRENE	180 U

LUSD0006	
Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ANTHRACENE	220 U
BENZO(A)ANTHRACENE	220 U
BENZO(A)PYRENE	220 U
BENZO(G,H,I)PERYLENE	220 U
BENZO(K)FLUORANTHENE	220 U
BENZYL BUTYL PHTHALATE	220 U
CHRYSENE	220 U
DIBENZ(A,H)ANTHRACENE	220 U
FLUORANTHENE	220 U
INDENO(1,2,3-C,D)PYRENE	220 U
PHENANTHRENE	220 U
PYRENE	220 U

LUSD0005	
Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ANTHRACENE	250 U
BENZO(A)ANTHRACENE	250 U
BENZO(A)PYRENE	250 U
BENZO(G,H,I)PERYLENE	250 U
BENZO(K)FLUORANTHENE	250 U
BENZYL BUTYL PHTHALATE	250 U
CHRYSENE	250 U
DIBENZ(A,H)ANTHRACENE	250 U
FLUORANTHENE	250 U
INDENO(1,2,3-C,D)PYRENE	250 U
PHENANTHRENE	250 U
PYRENE	250 U

LUSD0001	
Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ANTHRACENE	300 J
BENZO(A)ANTHRACENE	1200
BENZO(A)PYRENE	670
BENZO(G,H,I)PERYLENE	320 J
BENZO(K)FLUORANTHENE	730
BENZYL BUTYL PHTHALATE	6900
CHRYSENE	1300
DIBENZ(A,H)ANTHRACENE	150 J
FLUORANTHENE	3400
INDENO(1,2,3-C,D)PYRENE	340
PHENANTHRENE	880
PYRENE	1700

TUSD0001	
Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ANTHRACENE	220 U
BENZO(A)ANTHRACENE	150 J
BENZO(A)PYRENE	160 J
BENZO(G,H,I)PERYLENE	110 J
BENZO(K)FLUORANTHENE	140 J
BENZYL BUTYL PHTHALATE	220 U
CHRYSENE	170 J
DIBENZ(A,H)ANTHRACENE	220 U
FLUORANTHENE	390
INDENO(1,2,3-C,D)PYRENE	99 J
PHENANTHRENE	120 J
PYRENE	250

TUSD0006	
Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ANTHRACENE	210 U
BENZO(A)ANTHRACENE	210 U
BENZO(A)PYRENE	210 U
BENZO(G,H,I)PERYLENE	210 U
BENZO(K)FLUORANTHENE	210 U
BENZYL BUTYL PHTHALATE	210 U
CHRYSENE	210 U
DIBENZ(A,H)ANTHRACENE	210 U
FLUORANTHENE	210 U
INDENO(1,2,3-C,D)PYRENE	210 U
PHENANTHRENE	210 U
PYRENE	210 U

LUSD0002	
Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ANTHRACENE	350 U
BENZO(A)ANTHRACENE	350 U
BENZO(A)PYRENE	350 U
BENZO(G,H,I)PERYLENE	350 U
BENZO(K)FLUORANTHENE	350 U
BENZYL BUTYL PHTHALATE	350 U
CHRYSENE	350 U
DIBENZ(A,H)ANTHRACENE	350 U
FLUORANTHENE	350 U
INDENO(1,2,3-C,D)PYRENE	350 U
PHENANTHRENE	350 U
PYRENE	350 U

TBSD0005	
Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ANTHRACENE	200 U
BENZO(A)ANTHRACENE	200 U
BENZO(A)PYRENE	200 U
BENZO(G,H,I)PERYLENE	200 U
BENZO(K)FLUORANTHENE	200 U
BENZYL BUTYL PHTHALATE	200 U
CHRYSENE	200 U
DIBENZ(A,H)ANTHRACENE	200 U
FLUORANTHENE	200 U
INDENO(1,2,3-C,D)PYRENE	200 U
PHENANTHRENE	200 U
PYRENE	200 U

TUSD0005	
Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ANTHRACENE	200 U
BENZO(A)ANTHRACENE	200 U
BENZO(A)PYRENE	200 U
BENZO(G,H,I)PERYLENE	200 U
BENZO(K)FLUORANTHENE	200 U
BENZYL BUTYL PHTHALATE	200 U
CHRYSENE	200 U
DIBENZ(A,H)ANTHRACENE	200 U
FLUORANTHENE	200 U
INDENO(1,2,3-C,D)PYRENE	200 U
PHENANTHRENE	200 U
PYRENE	200 U

LUSD0003	
Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ANTHRACENE	200 U
BENZO(A)ANTHRACENE	200 U
BENZO(A)PYRENE	200 U
BENZO(G,H,I)PERYLENE	200 U
BENZO(K)FLUORANTHENE	200 U
BENZYL BUTYL PHTHALATE	200 U
CHRYSENE	200 U
DIBENZ(A,H)ANTHRACENE	200 U
FLUORANTHENE	200 U
INDENO(1,2,3-C,D)PYRENE	200 U
PHENANTHRENE	200 U
PYRENE	200 U

ETSD0006	
Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ANTHRACENE	230 U
BENZO(A)ANTHRACENE	230 U
BENZO(A)PYRENE	230 U
BENZO(G,H,I)PERYLENE	230 U
BENZO(K)FLUORANTHENE	230 U
BENZYL BUTYL PHTHALATE	230 U
CHRYSENE	230 U
DIBENZ(A,H)ANTHRACENE	230 U
FLUORANTHENE	230 U
INDENO(1,2,3-C,D)PYRENE	230 U
PHENANTHRENE	230 U
PYRENE	230 U

LUSD0004		
Date	0 - 0.5 (0.0 - 0.5) 11/12/2014	0 - 0.5 D (0.0 - 0.5) 11/12/2014
ANTHRACENE	170 J	430 U
BENZO(A)ANTHRACENE	400 J	300 J
BENZO(A)PYRENE	330 J	340 J
BENZO(G,H,I)PERYLENE	210 J	260 J
BENZO(K)FLUORANTHENE	320 J	350 J
BENZYL BUTYL PHTHALATE	400 U	430 U
CHRYSENE	420	380 J
DIBENZ(A,H)ANTHRACENE	400 U	430 U
FLUORANTHENE	1400	660
INDENO(1,2,3-C,D)PYRENE	200 J	230 J
PHENANTHRENE	830	250 J
PYRENE	700	570

TBSD0006	
Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ANTHRACENE	210 U
BENZO(A)ANTHRACENE	210 U
BENZO(A)PYRENE	210 U
BENZO(G,H,I)PERYLENE	210 U
BENZO(K)FLUORANTHENE	210 U
BENZYL BUTYL PHTHALATE	210 U
CHRYSENE	210 U
DIBENZ(A,H)ANTHRACENE	210 U
FLUORANTHENE	210 U
INDENO(1,2,3-C,D)PYRENE	210 U
PHENANTHRENE	210 U
PYRENE	210 U

TBSD0003	
Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ANTHRACENE	230 U
BENZO(A)ANTHRACENE	230 U
BENZO(A)PYRENE	230 U
BENZO(G,H,I)PERYLENE	230 U
BENZO(K)FLUORANTHENE	230 U
BENZYL BUTYL PHTHALATE	230 U
CHRYSENE	230 U
DIBENZ(A,H)ANTHRACENE	230 U
FLUORANTHENE	230 U
INDENO(1,2,3-C,D)PYRENE	230 U
PHENANTHRENE	230 U
PYRENE	230 U

ETSD0005	
Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ANTHRACENE	240 U
BENZO(A)ANTHRACENE	240 U
BENZO(A)PYRENE	240 U
BENZO(G,H,I)PERYLENE	240 U
BENZO(K)FLUORANTHENE	240 U
BENZYL BUTYL PHTHALATE	240 U
CHRYSENE	240 U
DIBENZ(A,H)ANTHRACENE	240 U
FLUORANTHENE	240 U
INDENO(1,2,3-C,D)PYRENE	240 U
PHENANTHRENE	240 U
PYRENE	240 U

TBSD0004	
Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ANTHRACENE	190 U
BENZO(A)ANTHRACENE	190 U
BENZO(A)PYRENE	190 U
BENZO(G,H,I)PERYLENE	190 U
BENZO(K)FLUORANTHENE	190 U
BENZYL BUTYL PHTHALATE	190 U
CHRYSENE	190 U
DIBENZ(A,H)ANTHRACENE	190 U
FLUORANTHENE	190 U
INDENO(1,2,3-C,D)PYRENE	190 U
PHENANTHRENE	190 U
PYRENE	190 U

TBSD0002	
Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ANTHRACENE	200 U
BENZO(A)ANTHRACENE	200 U
BENZO(A)PYRENE	200 U
BENZO(G,H,I)PERYLENE	200 U
BENZO(K)FLUORANTHENE	200 U
BENZYL BUTYL PHTHALATE	200 U
CHRYSENE	200 U
DIBENZ(A,H)ANTHRACENE	200 U
FLUORANTHENE	200 U
INDENO(1,2,3-C,D)PYRENE	200 U
PHENANTHRENE	200 U
PYRENE	200 U

TBSD0001	
Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ANTHRACENE	200 U
BENZO(A)ANTHRACENE	200 U
BENZO(A)PYRENE	200 U
BENZO(G,H,I)PERYLENE	200 U
BENZO(K)FLUORANTHENE	200 U
BENZYL BUTYL PHTHALATE	200 U
CHRYSENE	200 U
DIBENZ(A,H)ANTHRACENE	200 U
FLUORANTHENE	200 U
INDENO(1,2,3-C,D)PYRENE	200 U
PHENANTHRENE	200 U
PYRENE	200 U

ETSD0001	
Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ANTHRACENE	220 U
BENZO(A)ANTHRACENE	220 U
BENZO(A)PYRENE	220 U
BENZO(G,H,I)PERYLENE	220 U
BENZO(K)FLUORANTHENE	220 U
BENZYL BUTYL PHTHALATE	220 U
CHRYSENE	220 U
DIBENZ(A,H)ANTHRACENE	220 U
FLUORANTHENE	110 J
INDENO(1,2,3-C,D)PYRENE	220 U
PHENANTHRENE	220 U
PYRENE	87 J

ETSD0002	
Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ANTHRACENE	210 U
BENZO(A)ANTHRACENE	92 J
BENZO(A)PYRENE	100 J
BENZO(G,H,I)PERYLENE	210 U
BENZO(K)FLUORANTHENE	110 J
BENZYL BUTYL PHTHALATE	210 U
CHRYSENE	120 J
DIBENZ(A,H)ANTHRACENE	210 U
FLUORANTHENE	330
INDENO(1,2,3-C,D)PYRENE	210 U
PHENANTHRENE	130 J
PYRENE	170 J

ETSD0004	
Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ANTHRACENE	270 U
BENZO(A)ANTHRACENE	270 U
BENZO(A)PYRENE	270 U
BENZO(G,H,I)PERYLENE	270 U
BENZO(K)FLUORANTHENE	270 U
BENZYL BUTYL PHTHALATE	270 U
CHRYSENE	270 U
DIBENZ(A,H)ANTHRACENE	270 U
FLUORANTHENE	270 U
INDENO(1,2,3-C,D)PYRENE	270 U
PHENANTHRENE	270 U
PYRENE	270 U

ETSD0003	
Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ANTHRACENE	210 U
BENZO(A)ANTHRACENE	210 U
BENZO(A)PYRENE	210 U
BENZO(G,H,I)PERYLENE	210 U
BENZO(K)FLUORANTHENE	210 U
BENZYL BUTYL PHTHALATE	210 U
CHRYSENE	210 U
DIBENZ(A,H)ANTHRACENE	210 U
FLUORANTHENE	210 U
INDENO(1,2,3-C,D)PYRENE	210 U
PHENANTHRENE	210 U
PYRENE	210 U

HDR

Combe Fill South Landfill
Superfund Site RI/FS

Aerial Background Credits: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IGN, and the GIS User Community.

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

Legend

- Sediment Sample Location
- OU2 Investigation Area
- OU1 - Landfill Property Boundary
- Surface Water

CONSTITUENT	CRITERION (1)
Anthracene	57.2
Benzo(a)anthracene	108
Benzo(a)pyrene	150
Benzo(g,h,i)perylene	170
Benzo(k)fluoranthene	240
Benzyl Butyl Phthalate	1970
Chrysene	166
Dibzneo(a,h)anthracene	33
Fluoranthene	423
Indeno(1,2,3-cd)pyrene	200
Phenanthrene	204
Pyrene	195

Notes

- Results and criteria shown in ug/kg.
- Exceedances shown with yellow highlighting.
- Only constituents with one or more exceedances are shown.
- UNT = Unnamed Tributary
- Inorganics analyzed from 0 to 0.5 foot interval only. Organics collected from both 0 to 0.5 and 0.5 to 1.0 foot intervals.
- Sample intervals marked with "D" indicate field duplicate.

1. New Jersey Department of Environmental Protection Ecological Screening Criteria - Freshwater Criteria for Sediment, Lowest Effects Level (LEL). (March 2009)

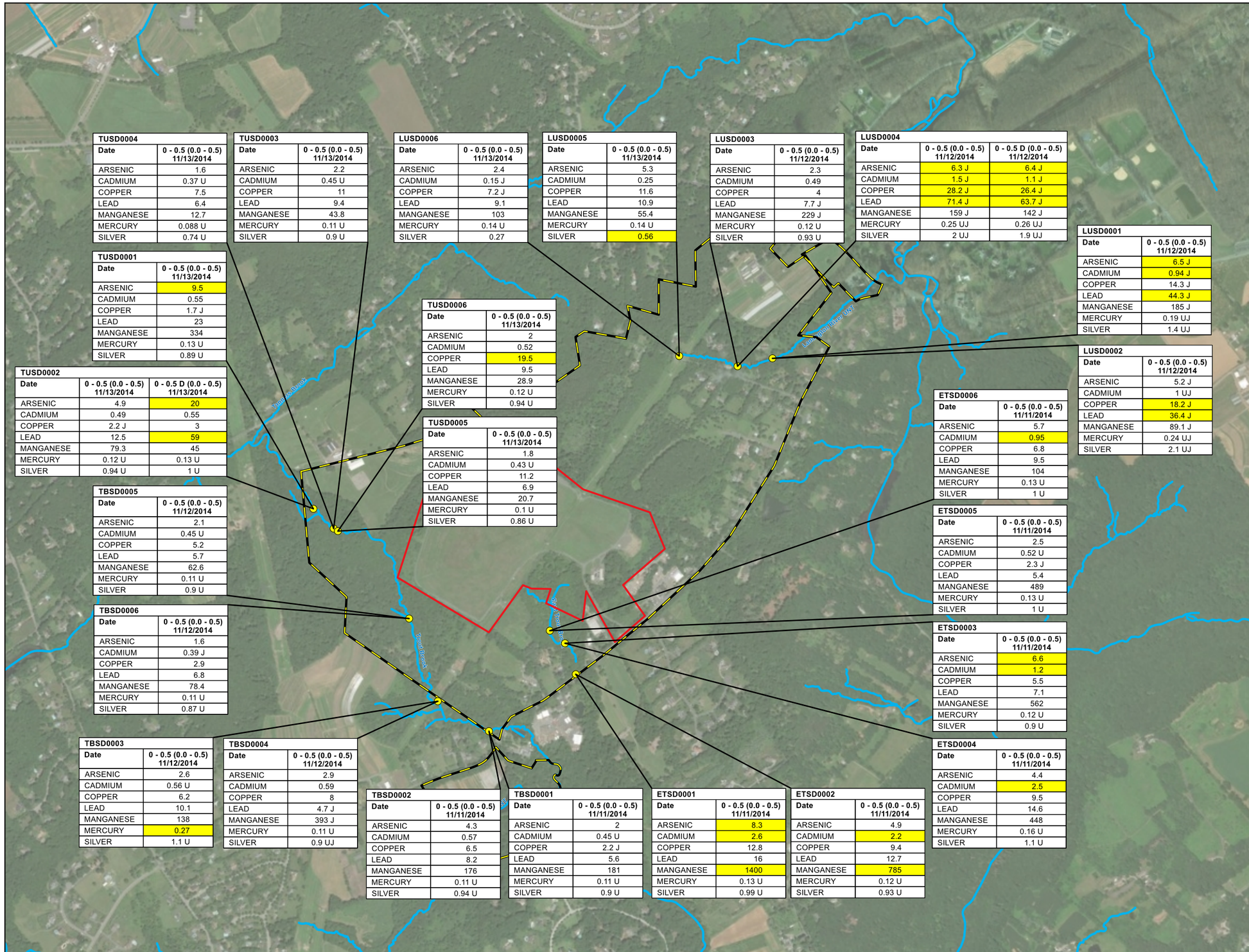
Note: Odd numbered samples (i.e. TUSD0001) were collected at approximately mid-channel. Even numbered samples were collected from a depositional area on the bank adjacent to the mid-channel sample. LUSD0005 and LUSD0006 were both collected on the bank of a pooled section of the stream.

0 1500 3000 feet
Not To Scale

2014 Organic Sample Results Exceeding Criteria in Sediment

Figure 4-4
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\100425771\7.0_GIS_Models\7.2_Work_In_Progress\EnviroInsite\vizx\Figure 4-4 Organics in Sediment.vizx



TUSD0004

Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ARSENIC	1.6
CADMIUM	0.37 U
COPPER	7.5
LEAD	6.4
MANGANESE	12.7
MERCURY	0.088 U
SILVER	0.74 U

TUSD0003

Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ARSENIC	2.2
CADMIUM	0.45 U
COPPER	11
LEAD	9.4
MANGANESE	43.8
MERCURY	0.11 U
SILVER	0.9 U

LUSD0006

Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ARSENIC	2.4
CADMIUM	0.15 J
COPPER	7.2 J
LEAD	9.1
MANGANESE	103
MERCURY	0.14 U
SILVER	0.27

LUSD0005

Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ARSENIC	5.3
CADMIUM	0.25
COPPER	11.6
LEAD	10.9
MANGANESE	55.4
MERCURY	0.14 U
SILVER	0.56

LUSD0003

Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ARSENIC	2.3
CADMIUM	0.49
COPPER	4
LEAD	7.7 J
MANGANESE	229 J
MERCURY	0.12 U
SILVER	0.93 U

LUSD0004

Date	0 - 0.5 (0.0 - 0.5) 11/12/2014	0 - 0.5 D (0.0 - 0.5) 11/12/2014
ARSENIC	6.3 J	6.4 J
CADMIUM	1.5 J	1.1 J
COPPER	28.2 J	26.4 J
LEAD	71.4 J	63.7 J
MANGANESE	159 J	142 J
MERCURY	0.25 UJ	0.26 UJ
SILVER	2 UJ	1.9 UJ

LUSD0001

Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ARSENIC	6.5 J
CADMIUM	0.94 J
COPPER	14.3 J
LEAD	44.3 J
MANGANESE	185 J
MERCURY	0.19 UJ
SILVER	1.4 UJ

LUSD0002

Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ARSENIC	5.2 J
CADMIUM	1 UJ
COPPER	18.2 J
LEAD	36.4 J
MANGANESE	89.1 J
MERCURY	0.24 UJ
SILVER	2.1 UJ

TUSD0001

Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ARSENIC	9.5
CADMIUM	0.55
COPPER	1.7 J
LEAD	23
MANGANESE	334
MERCURY	0.13 U
SILVER	0.89 U

TUSD0006

Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ARSENIC	2
CADMIUM	0.52
COPPER	19.5
LEAD	9.5
MANGANESE	28.9
MERCURY	0.12 U
SILVER	0.94 U

TUSD0002

Date	0 - 0.5 (0.0 - 0.5) 11/13/2014	0 - 0.5 D (0.0 - 0.5) 11/13/2014
ARSENIC	4.9	20
CADMIUM	0.49	0.55
COPPER	2.2 J	3
LEAD	12.5	59
MANGANESE	79.3	45
MERCURY	0.12 U	0.13 U
SILVER	0.94 U	1 U

TUSD0005

Date	0 - 0.5 (0.0 - 0.5) 11/13/2014
ARSENIC	1.8
CADMIUM	0.43 U
COPPER	11.2
LEAD	6.9
MANGANESE	20.7
MERCURY	0.1 U
SILVER	0.86 U

ETSD0006

Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ARSENIC	5.7
CADMIUM	0.95
COPPER	6.8
LEAD	9.5
MANGANESE	104
MERCURY	0.13 U
SILVER	1 U

TBSD0005

Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ARSENIC	2.1
CADMIUM	0.45 U
COPPER	5.2
LEAD	5.7
MANGANESE	62.6
MERCURY	0.11 U
SILVER	0.9 U

ETSD0005

Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ARSENIC	2.5
CADMIUM	0.52 U
COPPER	2.3 J
LEAD	5.4
MANGANESE	489
MERCURY	0.13 U
SILVER	1 U

TBSD0006

Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ARSENIC	1.6
CADMIUM	0.39 J
COPPER	2.9
LEAD	6.8
MANGANESE	78.4
MERCURY	0.11 U
SILVER	0.87 U

ETSD0003

Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ARSENIC	6.6
CADMIUM	1.2
COPPER	5.5
LEAD	7.1
MANGANESE	562
MERCURY	0.12 U
SILVER	0.9 U

TBSD0003

Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ARSENIC	2.6
CADMIUM	0.56 U
COPPER	6.2
LEAD	10.1
MANGANESE	138
MERCURY	0.27
SILVER	1.1 U

TBSD0004

Date	0 - 0.5 (0.0 - 0.5) 11/12/2014
ARSENIC	2.9
CADMIUM	0.59
COPPER	8
LEAD	4.7 J
MANGANESE	393 J
MERCURY	0.11 U
SILVER	0.9 UJ

TBSD0002

Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ARSENIC	4.3
CADMIUM	0.57
COPPER	6.5
LEAD	8.2
MANGANESE	176
MERCURY	0.11 U
SILVER	0.94 U

TBSD0001

Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ARSENIC	2
CADMIUM	0.45 U
COPPER	2.2 J
LEAD	5.6
MANGANESE	181
MERCURY	0.11 U
SILVER	0.9 U

ETSD0001

Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ARSENIC	8.3
CADMIUM	2.6
COPPER	12.8
LEAD	16
MANGANESE	1400
MERCURY	0.13 U
SILVER	0.99 U

ETSD0002

Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ARSENIC	4.9
CADMIUM	2.2
COPPER	9.4
LEAD	12.7
MANGANESE	785
MERCURY	0.12 U
SILVER	0.93 U

ETSD0004

Date	0 - 0.5 (0.0 - 0.5) 11/11/2014
ARSENIC	4.4
CADMIUM	2.5
COPPER	9.5
LEAD	14.6
MANGANESE	448
MERCURY	0.16 U
SILVER	1.1 U

Combe Fill South Landfill Superfund Site RI/FS

Aerial Background Credits: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IGN, and the GIS User Community.

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

Legend

- Sediment Sample Location
- OU2 Investigation Area
- OU1 - Landfill Property Boundary
- Surface Water

CONSTITUENT	CRITERION (1)
Arsenic	6
Cadmium	0.6
Copper	16
Lead	31
Manganese	630
Mercury	0.174
Silver	0.5

Notes

- Results and criteria shown in mg/kg.
- Exceedances shown with yellow highlighting.
- Only constituents with one or more exceedances are shown.
- UNT = Unnamed Tributary
- Inorganics analyzed from 0 to 0.5 foot interval only. Organics collected from both 0 to 0.5 and 0.5 to 1.0 foot intervals.
- Sample intervals marked with "D" indicate field duplicate.

1. New Jersey Department of Environmental Protection Ecological Screening Criteria - Freshwater Criteria for Sediment, Lowest Effects Level (LEL). (March 2009)

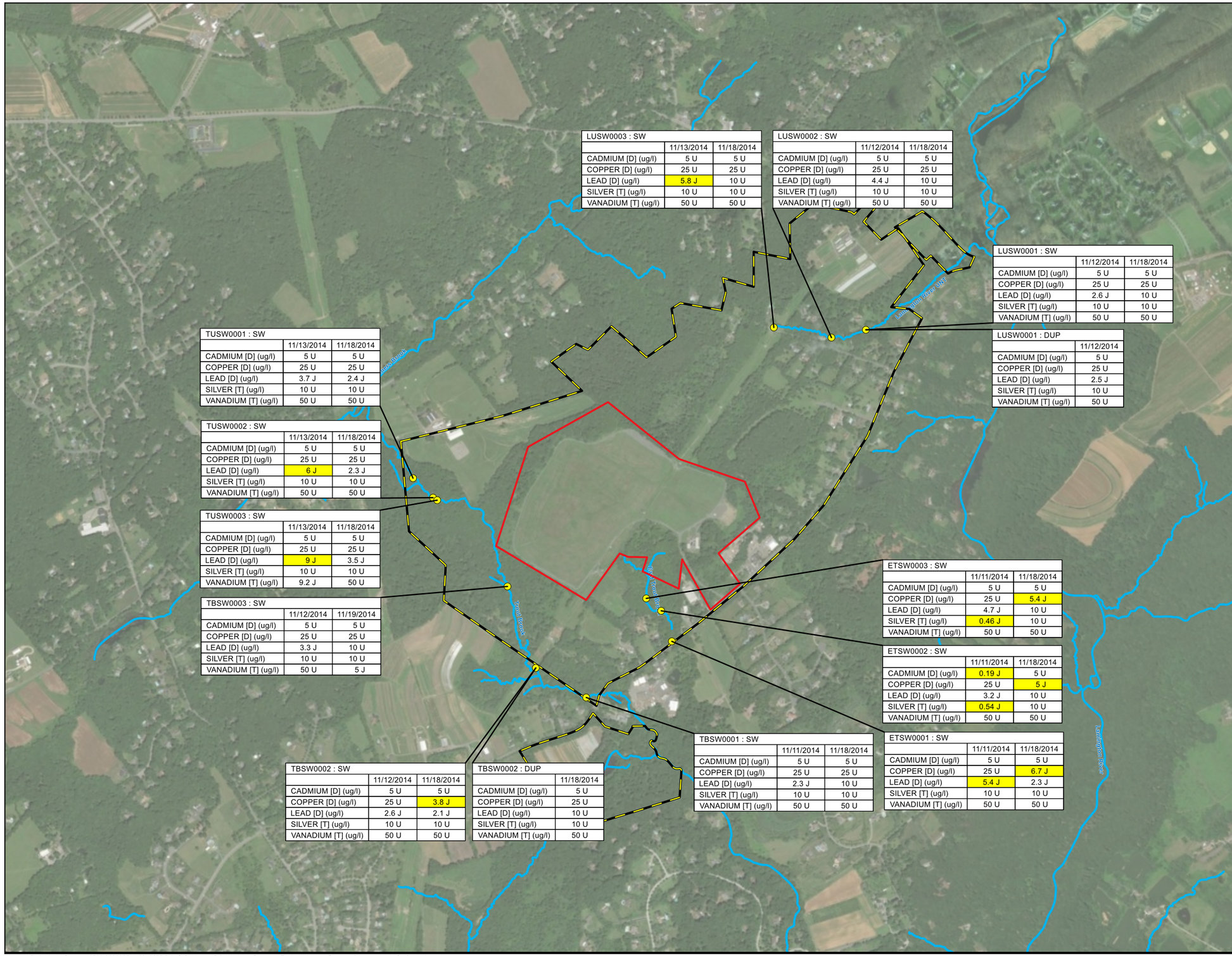
Note: Odd numbered samples (i.e. TUSD0001) were collected at approximately mid-channel. Even numbered samples were collected from a depositional area on the bank adjacent to the mid-channel sample. LUSD0005 and LUSD0006 were both collected on the bank of a pooled section of the stream.

0 1500 3000 feet
Not To Scale

2014 Inorganic Sample Results Exceeding Criteria in Sediment

Figure 4-5
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\1004257\7.0_GIS_Models\7.2_Work_In_Progress\EnviroInsite\vizx\Figure 4-5 Inorganics in Sediment.vizx



LUSW0003 : SW	11/13/2014	11/18/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	25 U
LEAD [D] (ug/l)	5.8 J	10 U
SILVER [T] (ug/l)	10 U	10 U
VANADIUM [T] (ug/l)	50 U	50 U

LUSW0002 : SW	11/12/2014	11/18/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	25 U
LEAD [D] (ug/l)	4.4 J	10 U
SILVER [T] (ug/l)	10 U	10 U
VANADIUM [T] (ug/l)	50 U	50 U

LUSW0001 : SW	11/12/2014	11/18/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	25 U
LEAD [D] (ug/l)	2.6 J	10 U
SILVER [T] (ug/l)	10 U	10 U
VANADIUM [T] (ug/l)	50 U	50 U

LUSW0001 : DUP	11/12/2014
CADMIUM [D] (ug/l)	5 U
COPPER [D] (ug/l)	25 U
LEAD [D] (ug/l)	2.5 J
SILVER [T] (ug/l)	10 U
VANADIUM [T] (ug/l)	50 U

TUSW0001 : SW	11/13/2014	11/18/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	25 U
LEAD [D] (ug/l)	3.7 J	2.4 J
SILVER [T] (ug/l)	10 U	10 U
VANADIUM [T] (ug/l)	50 U	50 U

TUSW0002 : SW	11/13/2014	11/18/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	25 U
LEAD [D] (ug/l)	6 J	2.3 J
SILVER [T] (ug/l)	10 U	10 U
VANADIUM [T] (ug/l)	50 U	50 U

TUSW0003 : SW	11/13/2014	11/18/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	25 U
LEAD [D] (ug/l)	9 J	3.5 J
SILVER [T] (ug/l)	10 U	10 U
VANADIUM [T] (ug/l)	9.2 J	50 U

TBSW0003 : SW	11/12/2014	11/19/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	25 U
LEAD [D] (ug/l)	3.3 J	10 U
SILVER [T] (ug/l)	10 U	10 U
VANADIUM [T] (ug/l)	50 U	5 J

ETSW0003 : SW	11/11/2014	11/18/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	5.4 J
LEAD [D] (ug/l)	4.7 J	10 U
SILVER [T] (ug/l)	0.46 J	10 U
VANADIUM [T] (ug/l)	50 U	50 U

ETSW0002 : SW	11/11/2014	11/18/2014
CADMIUM [D] (ug/l)	0.19 J	5 U
COPPER [D] (ug/l)	25 U	5 J
LEAD [D] (ug/l)	3.2 J	10 U
SILVER [T] (ug/l)	0.54 J	10 U
VANADIUM [T] (ug/l)	50 U	50 U

TBSW0002 : SW	11/12/2014	11/18/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	3.8 J
LEAD [D] (ug/l)	2.6 J	2.1 J
SILVER [T] (ug/l)	10 U	10 U
VANADIUM [T] (ug/l)	50 U	50 U

TBSW0002 : DUP	11/18/2014
CADMIUM [D] (ug/l)	5 U
COPPER [D] (ug/l)	25 U
LEAD [D] (ug/l)	10 U
SILVER [T] (ug/l)	10 U
VANADIUM [T] (ug/l)	50 U

TBSW0001 : SW	11/11/2014	11/18/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	25 U
LEAD [D] (ug/l)	2.3 J	10 U
SILVER [T] (ug/l)	10 U	10 U
VANADIUM [T] (ug/l)	50 U	50 U

ETSW0001 : SW	11/11/2014	11/18/2014
CADMIUM [D] (ug/l)	5 U	5 U
COPPER [D] (ug/l)	25 U	6.7 J
LEAD [D] (ug/l)	5.4 J	2.3 J
SILVER [T] (ug/l)	10 U	10 U
VANADIUM [T] (ug/l)	50 U	50 U

Combe Fill South Landfill
Superfund Site RI/FS

Aerial Background Credits: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IGN, and the GIS User Community.

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

Legend

- Surface Water Sample Location
- OU2 Investigation Area
- OU1 - Landfill Property Boundary
- Surface Water

CONSTITUENT	CRITERION (1)
Cadmium [D] (2)	0.056
Copper [D] (2)	2.2
Lead [D] (3)	5.4
Silver [T]	0.12
Vanadium [T]	12

Notes

- Results shown in ug/L.
- Exceedances shown with yellow highlighting.
- Only constituents with one or more exceedances are shown.
- [T] indicates total fraction.
- [D] indicates dissolved fraction.
- UNT = Unnamed Tributary
- Samples collected between 11/11/14 and 11/13/14 are dry weather samples (baseflow).
- Samples collected between 11/18/14 and 11/19/14 are wet weather samples collected after >1 inch of rain fell in the area on 11/17/14.

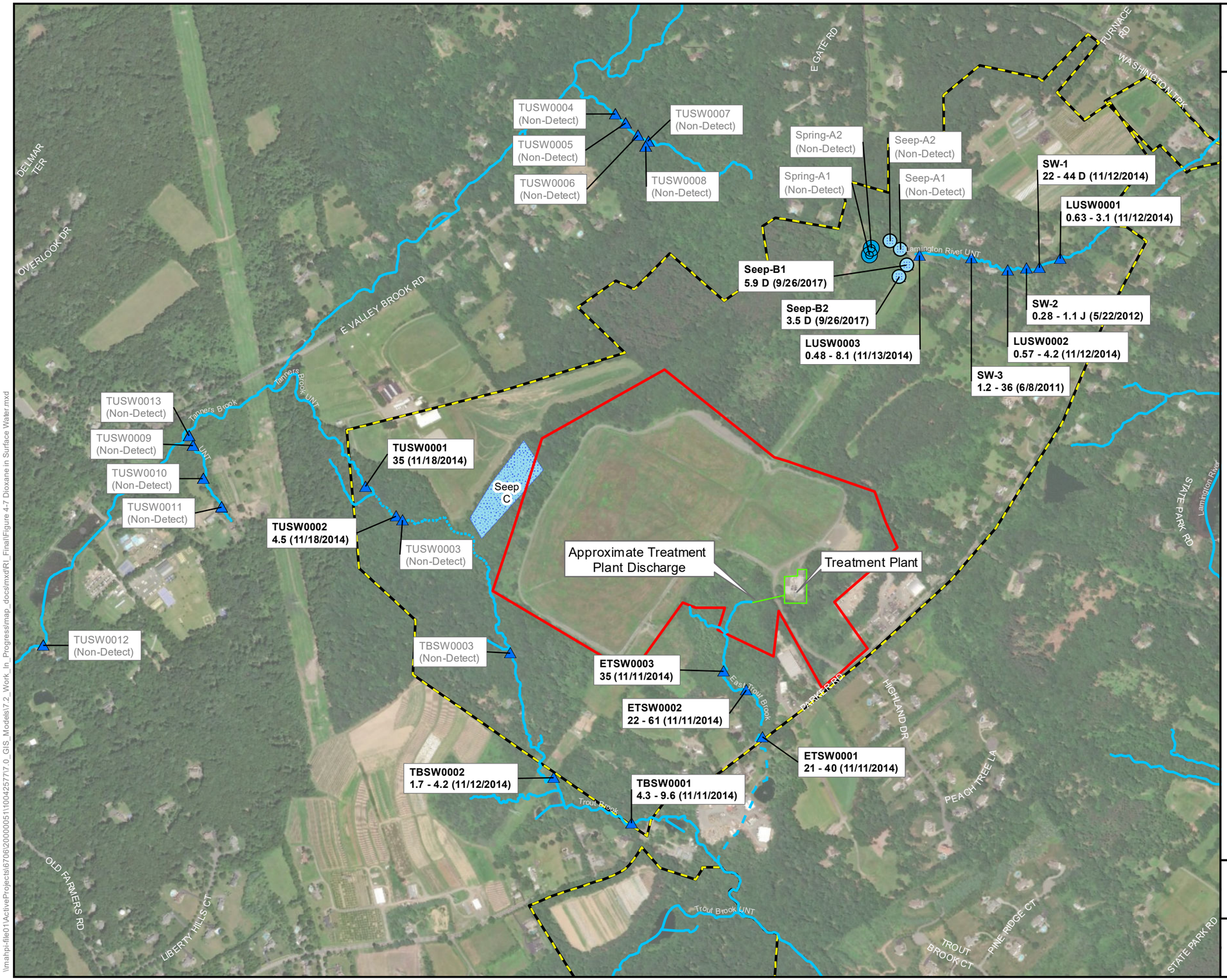
1. New Jersey Department of Environmental Protection (NJDEP) NJAC 7:9B Surface Water Quality Standards (re-adopted October 2016; amended January 2011). Fresh Water Class 2 (FW2) Surface Water Criteria Chronic.
2. Cadmium and Copper criteria are hardness dependent calculated criteria for the dissolved fraction. Criteria calculated using formluas provided in NJAC 7:9B.
3. Lead criteria is promulgated standard for dissolved fraction.

0 1500 3000 feet
Not To Scale

2014 Inorganic Sample Results Exceeding Criteria in Surface Water

Figure 4-6
June, 2018

\\mahpi-file01\ActiveProjects\6706\20000051\10042577\7.0_GIS_Models\7.2_Work_In_Progress\EnviroInsite\vizx\Figure 4-6 Inorganics in Surface Water.vizx



Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- OU2 Investigation Area
- Surface Water Samples
- Seeps
- Springs
- Surface Water
- Undefined Surface Water
- East Trout Brook culvert

UNT = Unnamed Tributary

Notes

Callout boxes portray the range of detected concentrations over the timeframe of the study. Samples from SW-1, SW-2, and SW-3 were collected by NJDEP between 2nd Quarter, 2011 and 2nd Quarter, 2015. All other samples were collected by HDR in 2014 and 2017. The date of the maximum detected concentration is shown.

Callout boxes with **bolded** font indicate detections of 1,4-Dioxane. Callout boxes with gray font indicate non-detects.

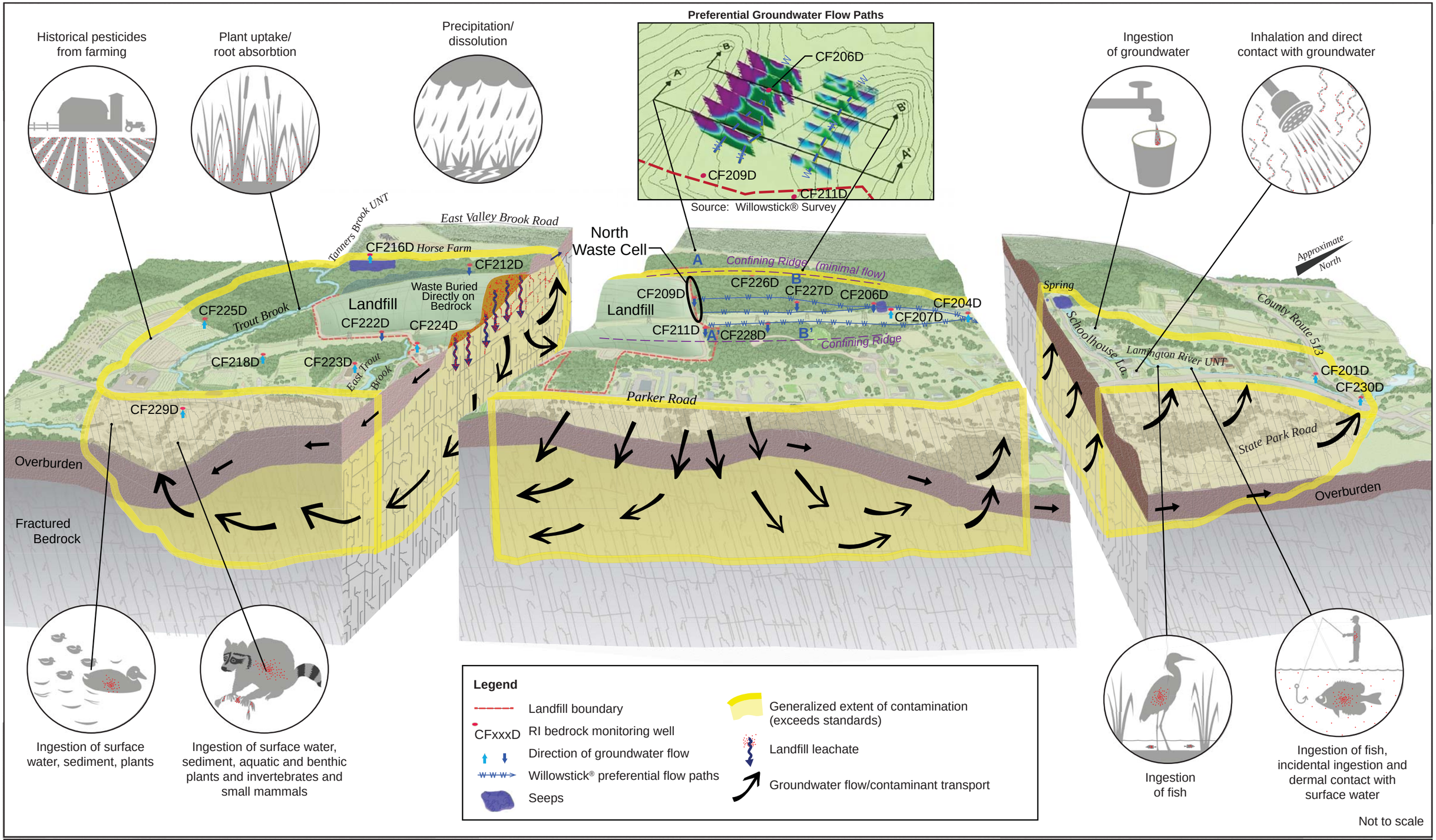
New Jersey does not have a surface water quality criteria for 1,4-dioxane. The USEPA Region 5 Ecological Screening Level for surface water (22,000 ug/L) was used to evaluate impacts to surface water. None of the detected concentrations exceeded this value.

0 400 800 Feet

1,4-Dioxane in Surface Water

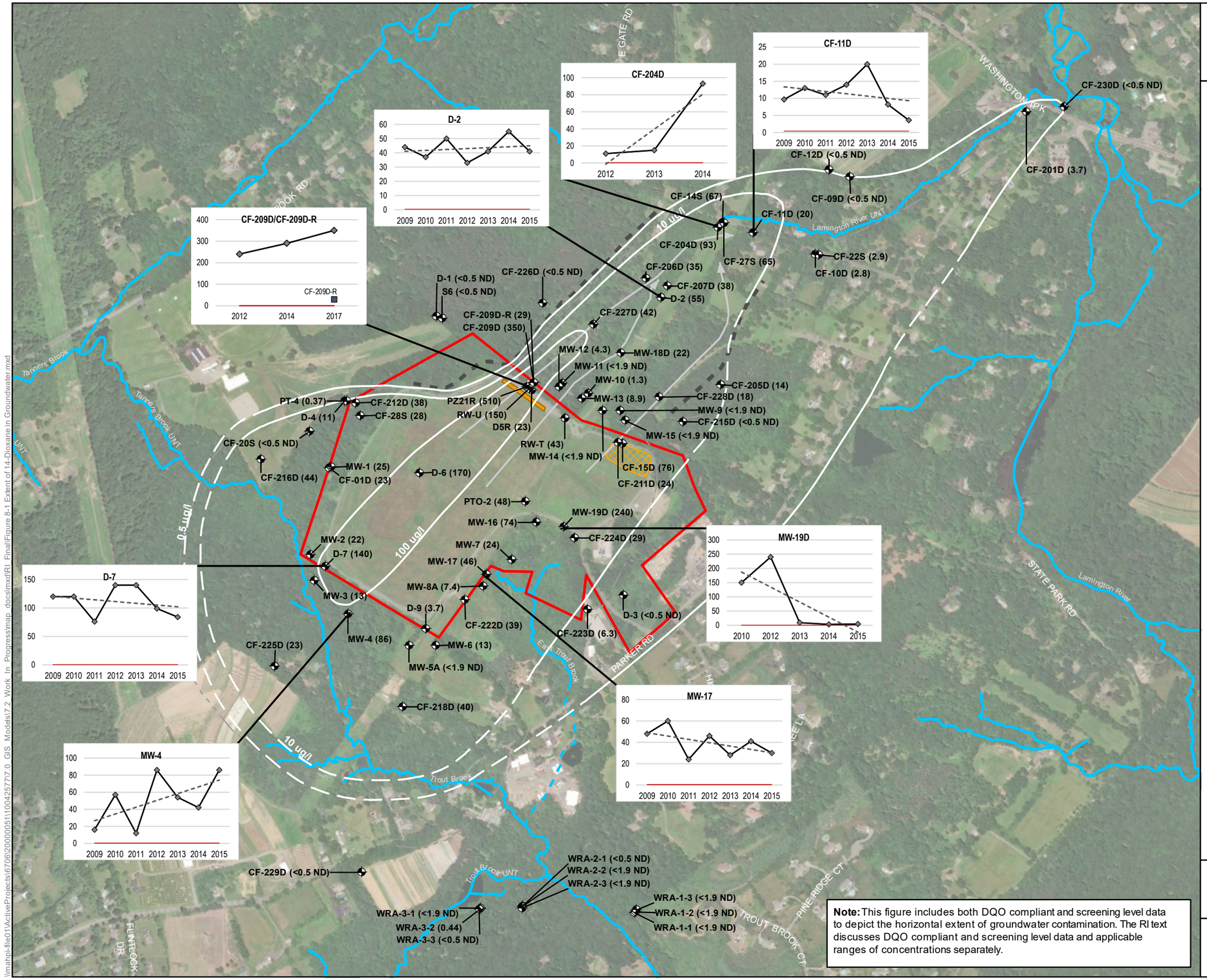
Figure 4-7
June, 2018

\\mahpi-file01\ActiveProjects\6706\2000000511\00425777\7.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 4-7 Dioxane in Surface Water.mxd



U.S. Environmental Protection Agency
Combe Fill South Landfill RI/FS
Chester & Washington Townships, New Jersey

Figure 5.1
Conceptual Site Model Illustration
June 2018



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Monitoring Well
- Isoconcentration Line (white)
- Interpreted Where Dashed
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes
Concentrations in ug/L.
ND = Constituent not detected above the analytical reporting limit.

For contouring, the maximum detected concentration of the constituent being mapped was used regardless of depth or sampling date in order to conceptualize the approximate extent of detections of the mapped constituent.

For 1,4-Dioxane, the lowest reporting limit (SVOC-SIM analysis) of 0.5 ug/l was contoured.

Wells MW-9 through MW-15 are overburden and shallow bedrock wells. Contaminant migration is thought to occur in the deeper bedrock in the area of these wells.

Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)
- Results from potable well sampling conducted by EPA in 2011 included in approximation of extent of contaminants (VOCs only). Individual results not shown due to sensitive nature of residential sampling.

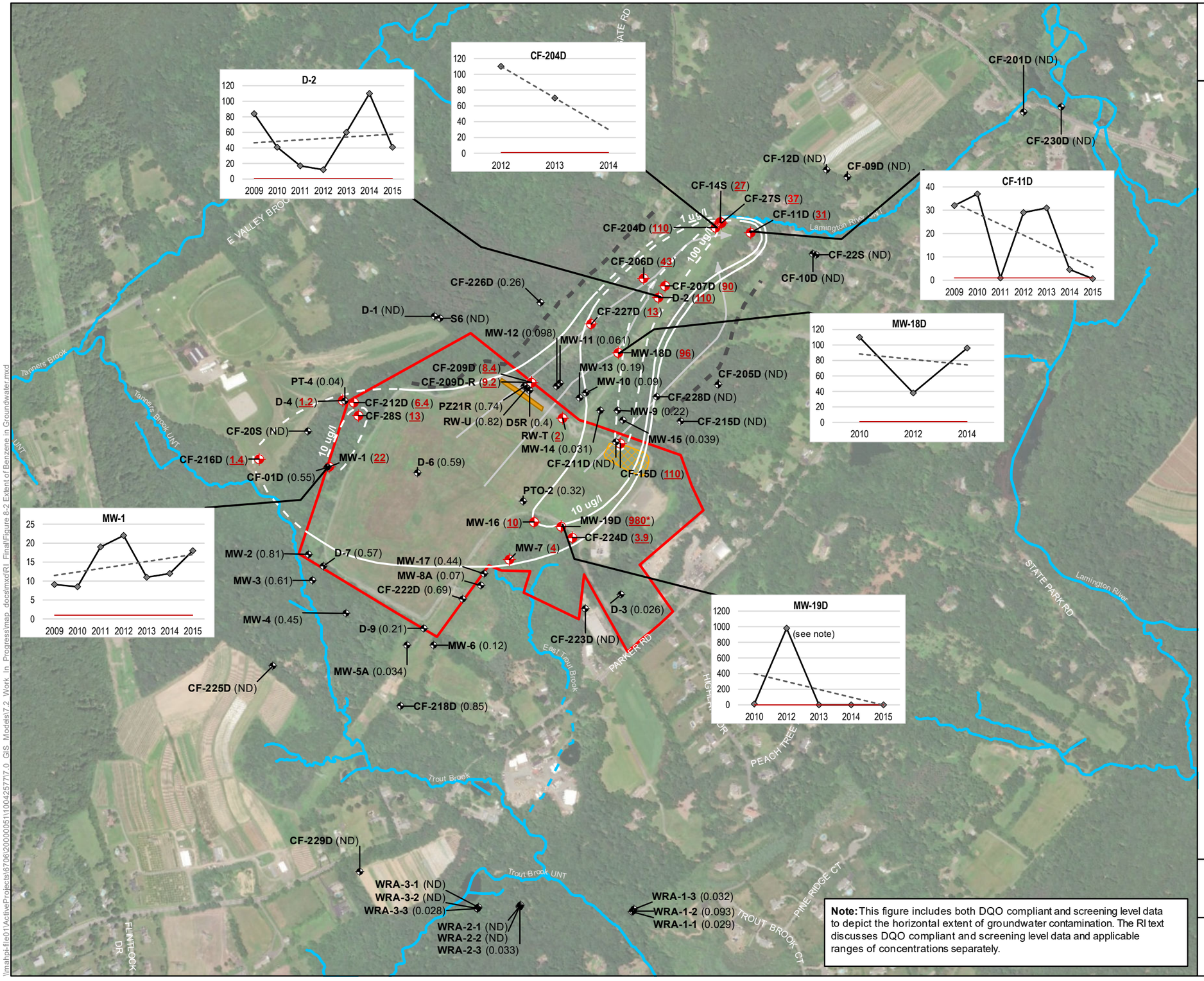
Chart Notes
- Horizontal red line represents GWQS.
- Trend charts for representative wells shown may include data collected prior to the RI period. Some of the pre-RI concentrations were higher than those observed during the RI.

0 400 800 Feet

Estimated Extent of 1,4-Dioxane in Groundwater

Figure 8-1
August, 2018

\\mahpi-file01\ActiveProjects\67062000005\1100425777.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 8-1 Extent of 14-Dioxane in Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Monitor well with maximum detected result exceeding GWQS
- Monitor well with maximum detected result below GWQS
- Isoconcentration Line
- Dashed where inferred
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes
Concentrations in ug/L.
ND = Constituent not detected above the reporting limit at this location.

For contouring, the maximum detected concentration of the constituent being mapped was used regardless of depth or sampling date in order to conceptualize the approximate extent of detections of the mapped constituent.

*MW-19D Note: 980 ug/l detected in spring 2012 is anomalous. The second highest concentration was 14 ug/l detected in fall of 2012.

Exceedance of NJDEP GWQS for benzene (1 ug/L) indicated by **bold, red, underlined** text.

Wells MW-9 through MW-15 are overburden and shallow bedrock wells. Contaminant migration is thought to occur in the deeper bedrock in the area of these wells.

Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)
- Results from potable well sampling conducted by EPA in 2011 included in approximation of extent of contaminants (VOCs only). Individual results not shown due to sensitive nature of residential sampling.

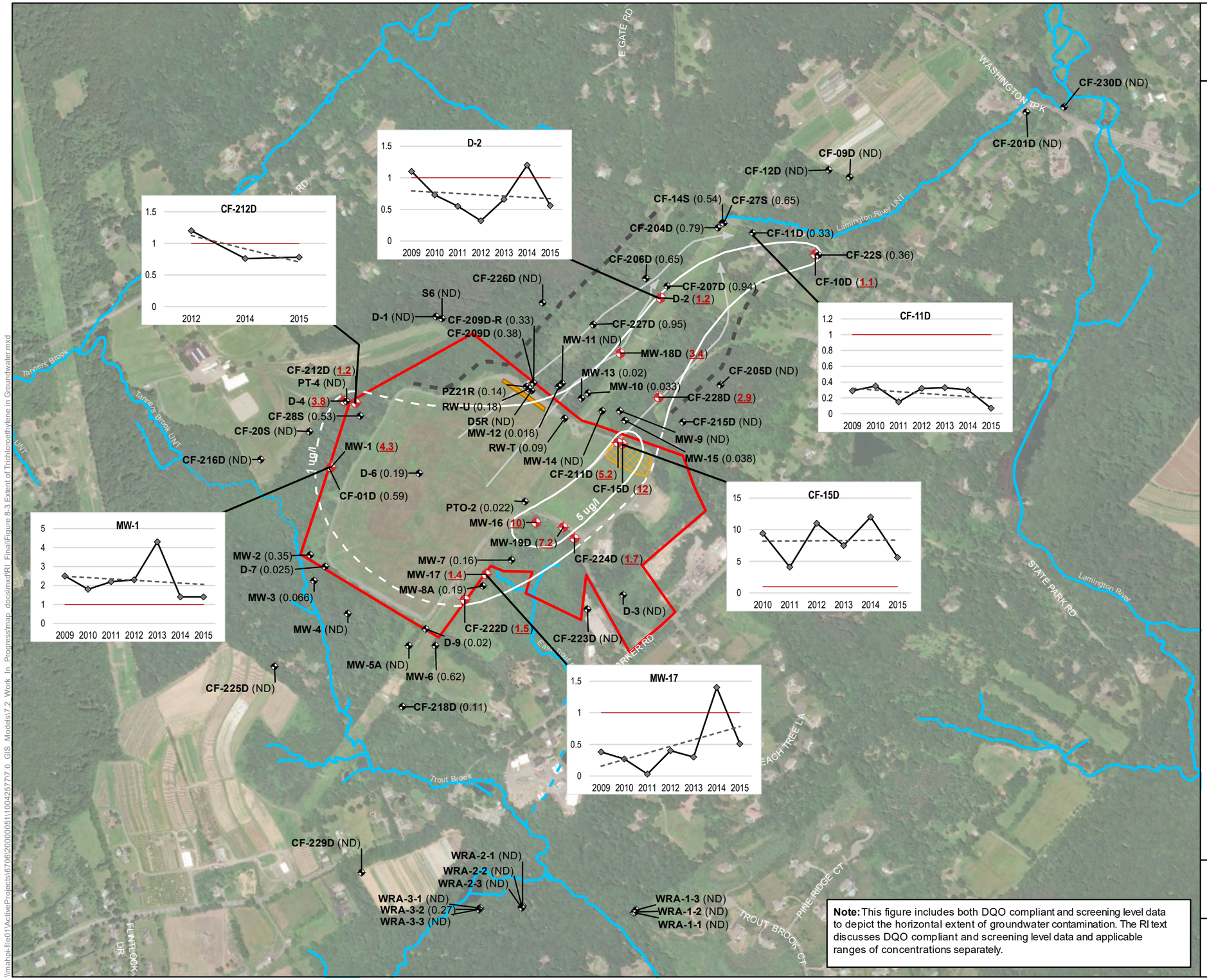
Chart Notes
- Horizontal red line represents GWQS.
- Trend charts for representative wells shown may include data collected prior to the RI period. Some of the pre-RI concentrations were higher than those observed during the RI.
- For wells sampled more than once in a year the maximum detected concentration is plotted. Non-detects are not shown.

0 400 800 Feet

Estimated Extent of Benzene in Groundwater

Figure 8-2
August, 2018

\\mahpi-file01\ActiveProjects\67061\00000511\004257\7.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 8-2 Extent of Benzene in Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Monitor well with maximum detected result exceeding GWQS
- Monitor well with maximum detected result below GWQS
- Isoconcentration line (white)
- Dashed where inferred
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes
Concentrations in ug/L.
ND = Constituent not detected above the reporting limit at this location.

For contouring, the maximum detected concentration of the constituent being mapped was used regardless of depth or sampling date in order to conceptualize the approximate extent of detections of the mapped constituent.

Exceedance of NJDEP GWQS for trichloroethylene (1 ug/L) indicated by **bold, red, underlined** text.

Wells MW-9 through MW-15 are overburden and shallow bedrock wells. Contaminant migration is thought to occur in the deeper bedrock in the area of these wells.

Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)
- Results from potable well sampling conducted by EPA in 2011 included in approximation of extent of contaminants (VOCs only). Individual results not shown due to sensitive nature of residential sampling.

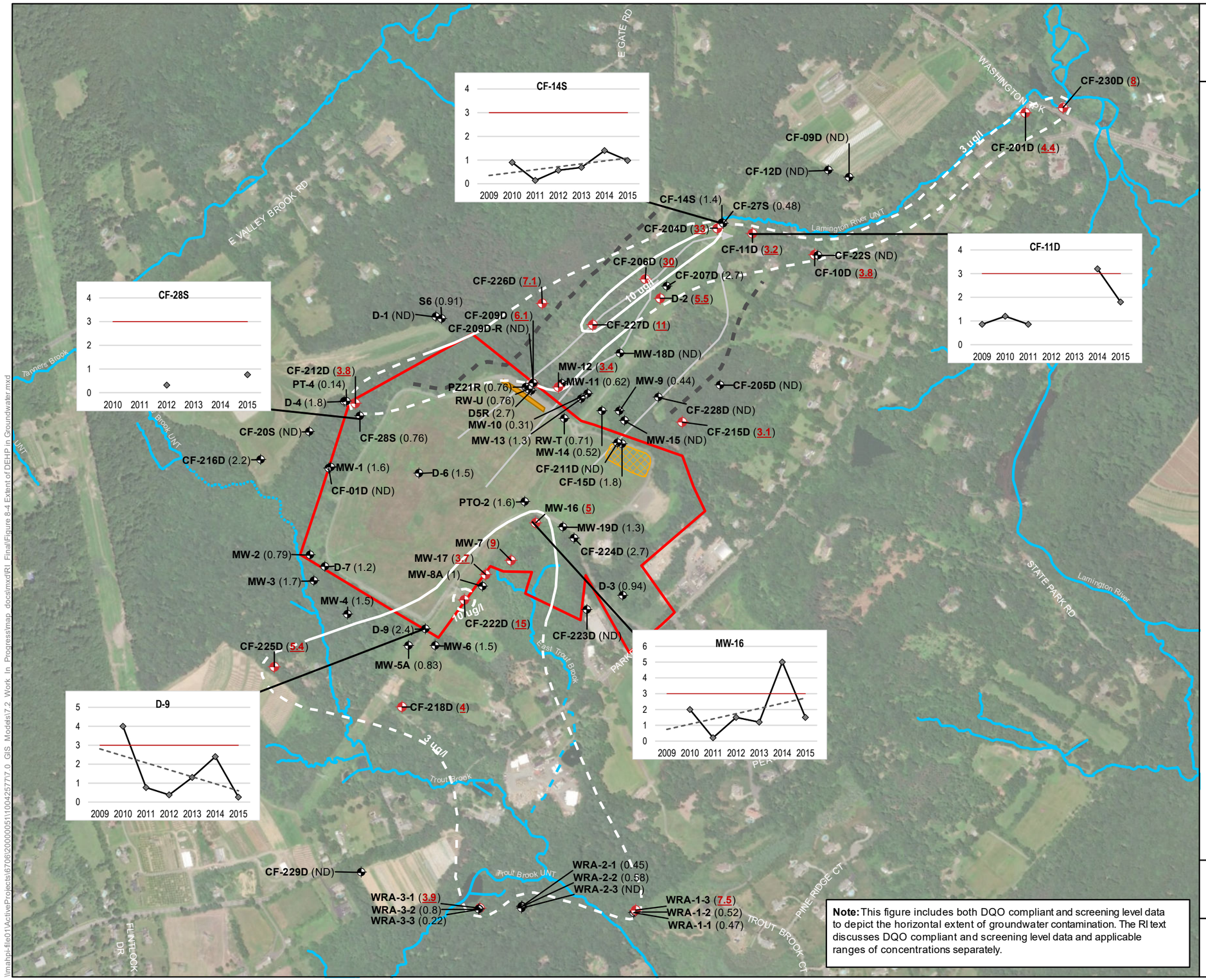
Chart Notes
- Horizontal red line represents GWQS.
- Trend charts for representative wells shown may include data collected prior to the RI period. Some of the pre-RI concentrations were higher than those observed during the RI.
- For wells sampled more than once in a year the maximum detected concentration is plotted. Non-detects are not shown.

0 400 800 Feet

Estimated Extent of Trichloroethylene in Groundwater

Figure 8-3
August, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1100425777.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 8-3 Extent of Trichloroethylene in Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Monitor well with maximum detected result exceeding GWQS
- Monitor well with maximum detected result below GWQS
- Isoconcentration line (white)
- Dashed where inferred
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes
DEHP: di(2-ethylhexyl) phthalate; synonym: bis(2-ethylhexyl)phthalate
Concentrations in ug/L.
ND = Constituent not detected above the reporting limit at this location.

For contouring, the maximum detected concentration of the constituent being mapped was used regardless of depth or sampling date in order to conceptualize the approximate extent of detections of the mapped constituent.

Exceedance of NJDEP GWQS for DEHP (3 ug/L) indicated by **bold, red, underlined** text.

Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

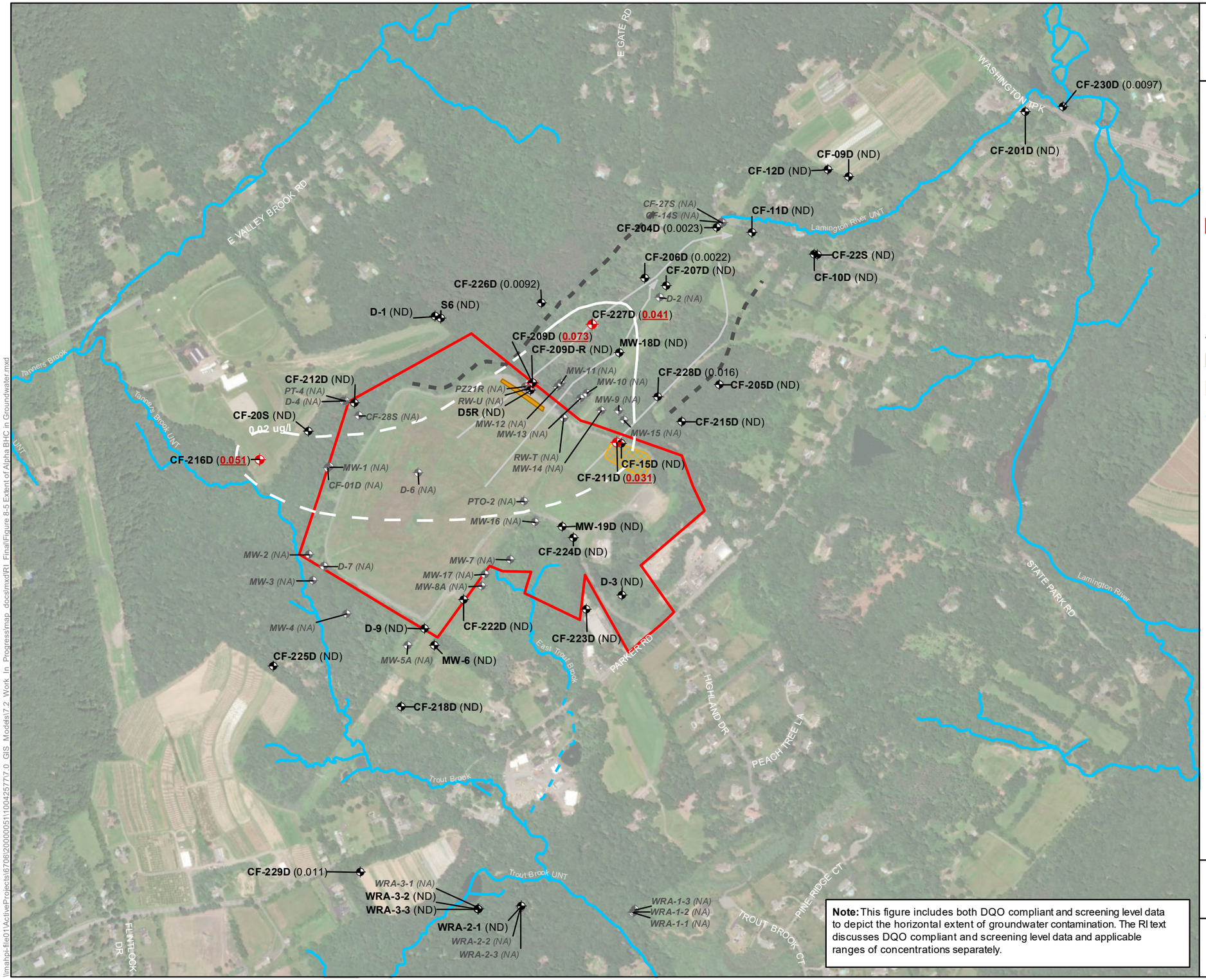
Chart Notes
- Horizontal red line represents GWQS.
- Trend charts for representative wells shown may include data collected prior to the RI period. Some of the pre-RI concentrations were higher than those observed during the RI.
- For wells sampled more than once in a year the maximum detected concentration is plotted. Non-detects are not shown.

0 400 800 Feet

Estimated Extent of DEHP in Groundwater

Figure 8-4
August, 2018

\\mahpi-file01\ActiveProjects\670\2000005\1\004257717.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 8-4 Extent of DEHP in Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Monitor well with maximum detected result exceeding GWQS
- Monitor well with maximum detected result below GWQS
- Isoconcentration line (white)
- Dashed where inferred
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water (LEGEND)
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes

Alpha BHC: *alpha*-benzenehexachloride
Concentrations in ug/L.
ND = Constituent not detected above the reporting limit at this location.
NA = Not Analyzed. NJDEP PCEM sampling program does not include pesticides.

For contouring, the maximum detected concentration of the constituent being mapped was used regardless of depth or sampling date in order to conceptualize the approximate extent of detections of the mapped constituent.

Exceedance of NJDEP GWQS for alpha-BHC (0.02 ug/L) indicated by **bold, red, underlined** text.

Analytical Data Sources

- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

Chart Note

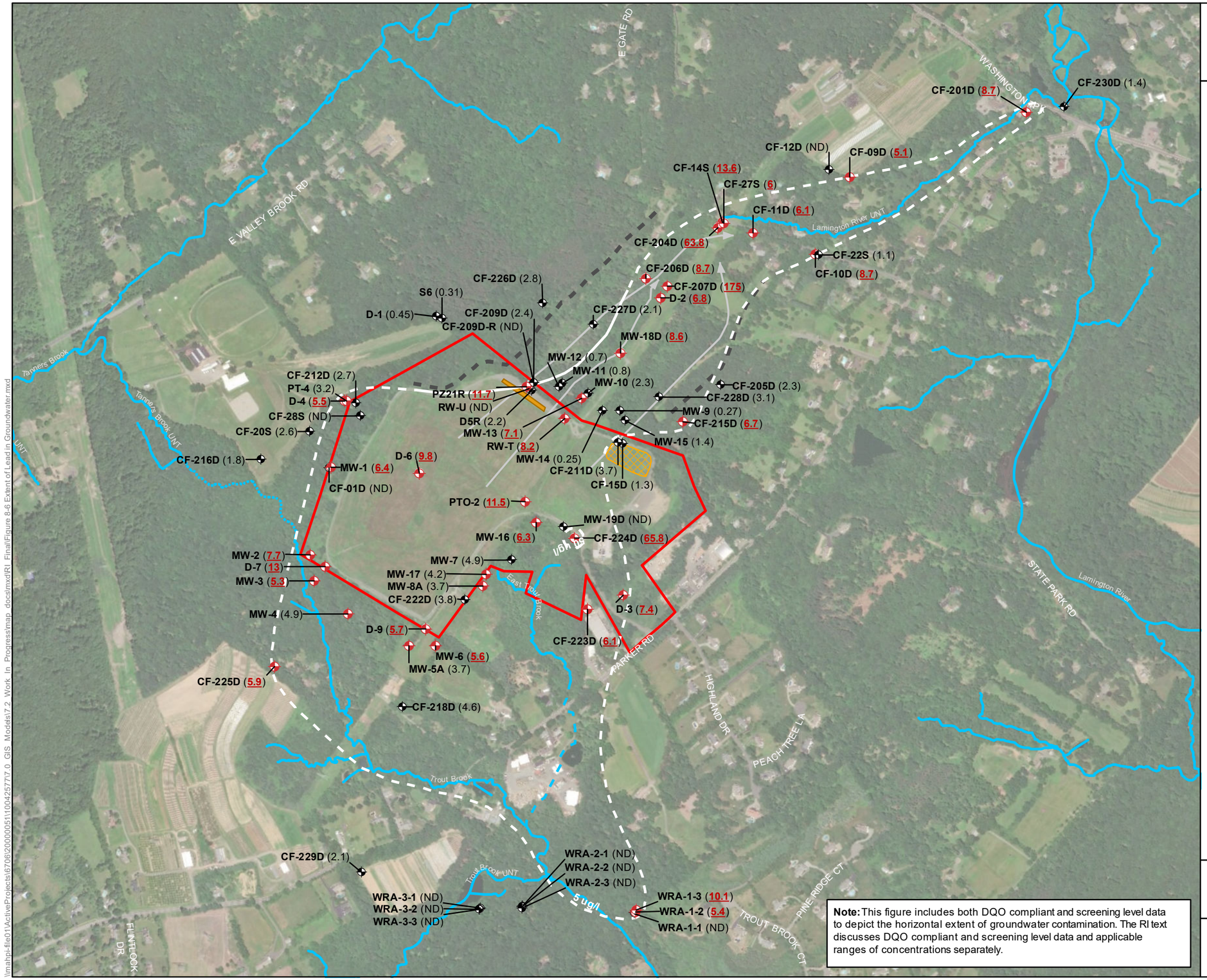
Trend charts not shown due to insufficient frequency of detections.

0 400 800 Feet

Estimated Extent of Alpha BHC in Groundwater

Figure 8-5
August, 2018

\\mahpi-file01\ActiveProjects\67060200005\1100425717.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 8-5 Extent of Alpha BHC in Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Monitor well with maximum detected result exceeding GWQS
- Monitor well with maximum detected result below GWQS
- Isoconcentration line (white)
- Dashed where inferred
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes
Concentrations in ug/L (total fraction).
ND = Constituent not detected above the reporting limit at this location.

For contouring, the maximum detected concentration of the constituent being mapped was used regardless of depth or sampling date in order to conceptualize the approximate extent of detections of the mapped constituent. Results from RI surface water samples included in approximation of excent of lead contamination. See Figure 4-6 for additional information.

Exceedance of NJDEP GWQS for lead (5 ug/L) indicated by **bold, red, underlined** text.

Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

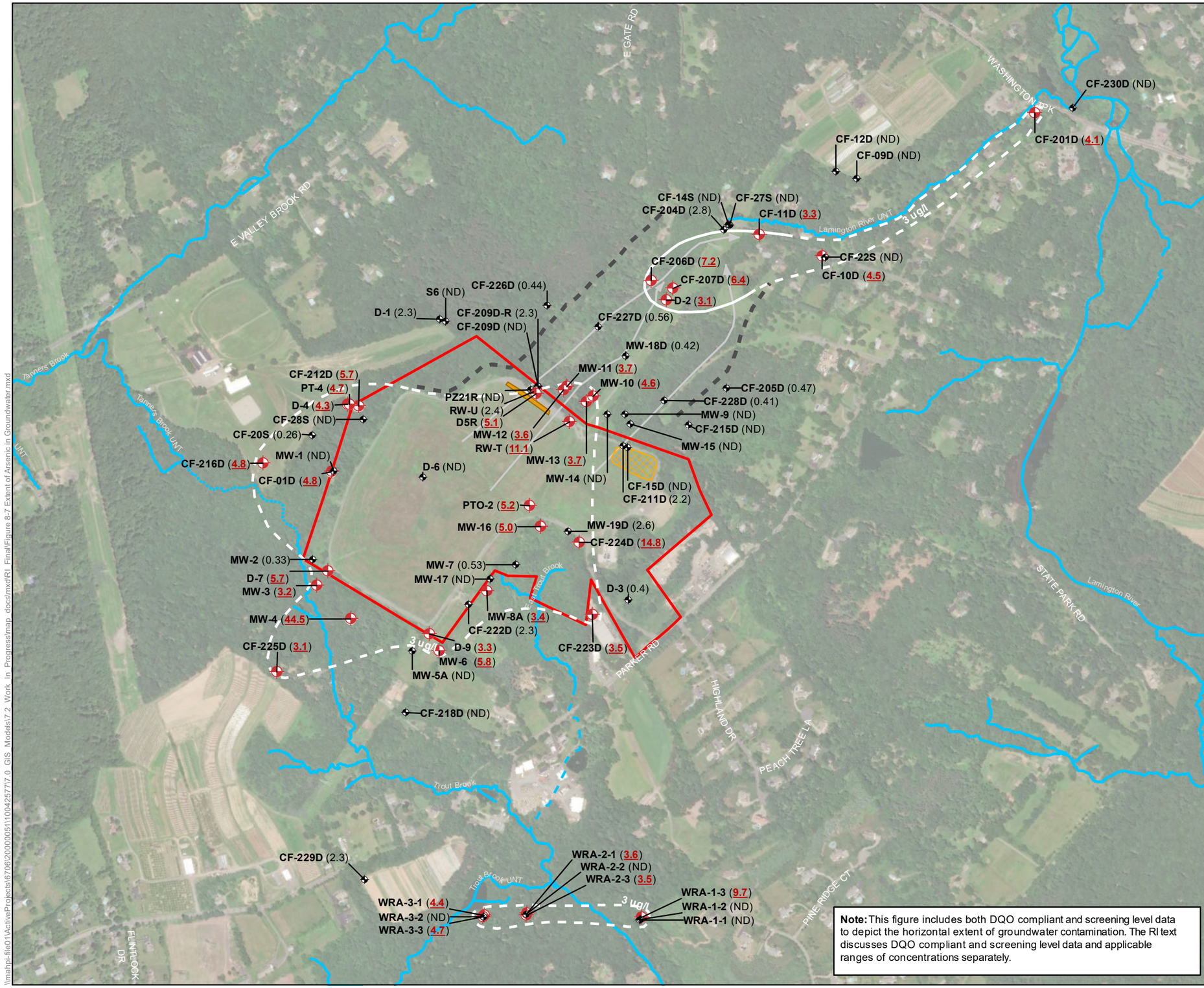
Chart Note
Trend charts not shown due to insufficient frequency of detections.

0 400 800 Feet

Estimated Extent of Lead in Groundwater

Figure 8-6
August, 2018

\\mahpi-file01\ActiveProjects\6706\2000005\1100425717.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 8-6 Extent of Lead in Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Monitor well with maximum detected result exceeding GWQS
- Monitor well with maximum detected result below GWQS
- Isoconcentration line (white)
- Dashed where inferred
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes
Concentrations in ug/L (total fraction).

ND = Constituent not detected above the reporting limit at this location.

The maximum detected concentration of the constituent being mapped was used regardless of depth or sampling date in order to conceptualize the approximate extent of detections of the mapped constituent.

Exceedance of NJDEP GWQS for arsenic (3 ug/L) indicated by **bold, red, underlined** text.

Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

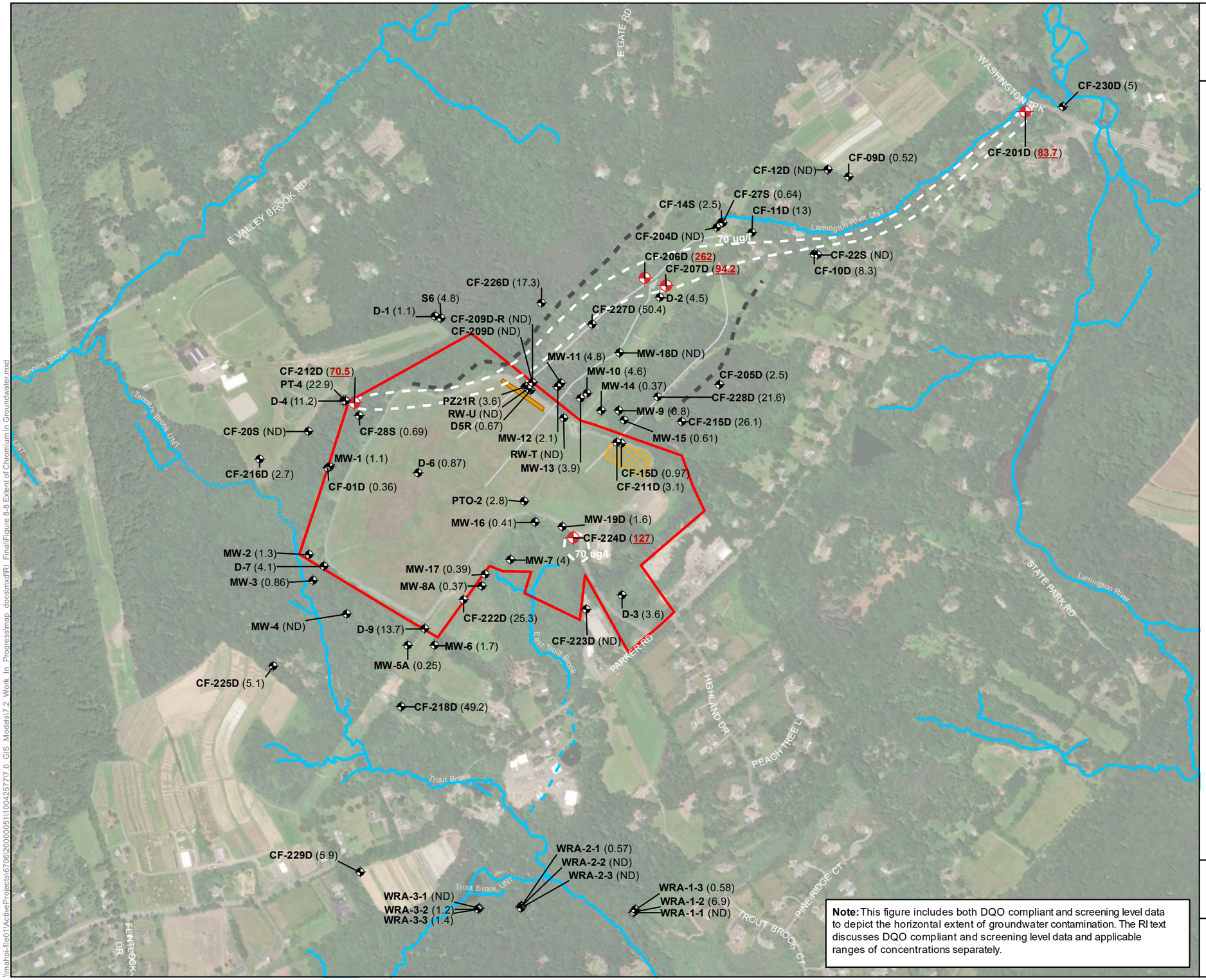
Chart Note
Trend charts not shown due to insufficient frequency of detections.

0 400 800 Feet

Estimated Extent of Arsenic in Groundwater

Figure 8-7
August, 2018

\\mahpi-file01\ActiveProjects\670\2000005\1100\04257717.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 8-7 Extent of Arsenic in Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Monitor well with maximum detected result exceeding GWQS
- Monitor well with maximum detected result below GWQS
- Isoconcentration line (white)
- Dashed where inferred
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes
Concentrations in ug/L (total fraction).

ND = Constituent not detected above the reporting limit at this location.

The maximum detected concentration of the constituent being mapped was used regardless of depth or sampling date in order to conceptualize the approximate extent of detections of the mapped constituent.

Exceedance of NJDEP GWQS for chromium (70 ug/L) indicated by **bold, red, underlined** text.

Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

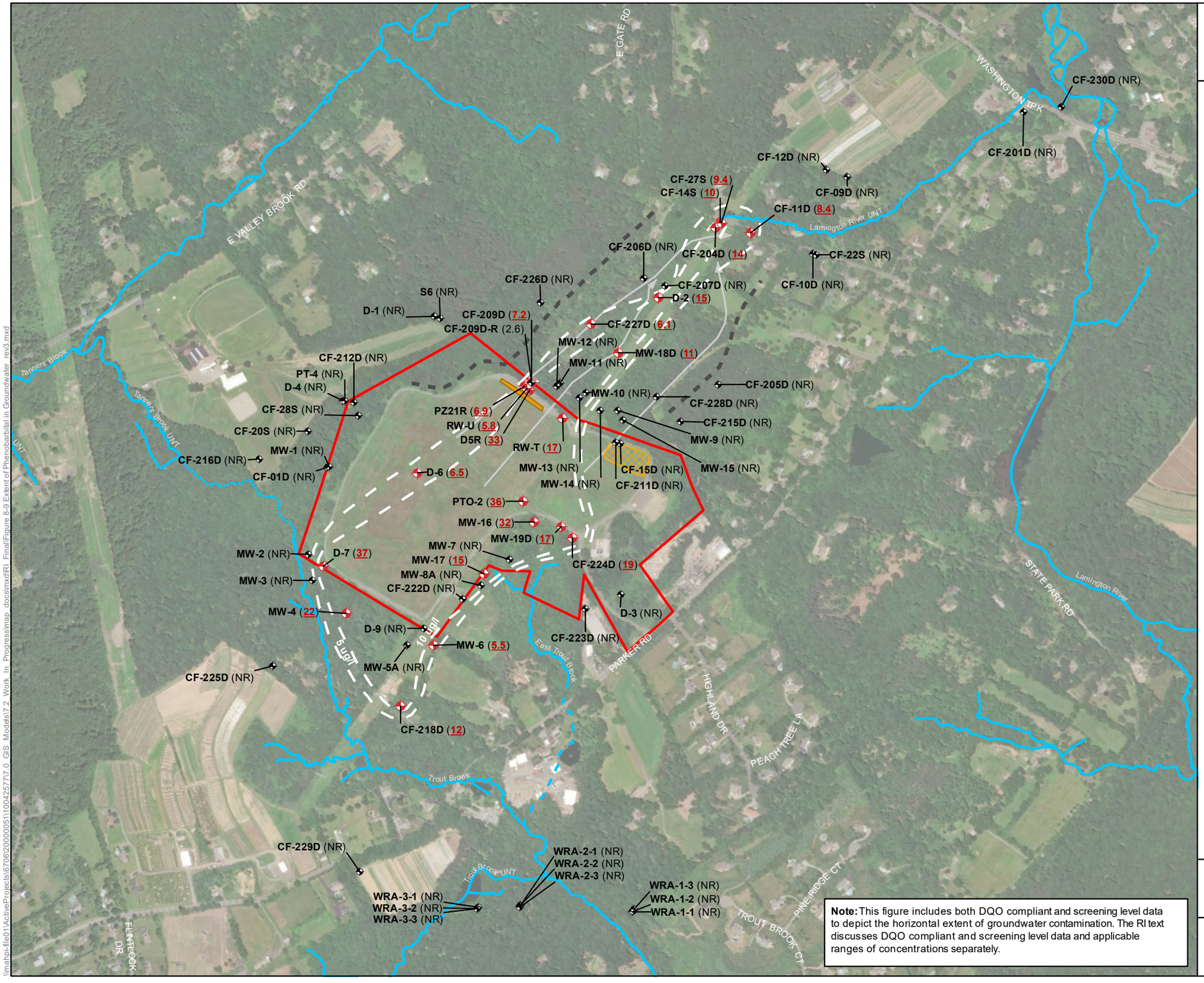
Chart Note
Trend charts not shown due to insufficient frequency of detections.

0 400 800 Feet

Estimated Extent of Chromium in Groundwater

Figure 8-8
August, 2018

\\mahps-file01\ActiveProjects\6706\2000005\1100425717.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 8-8 Extent of Chromium in Groundwater.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Monitor well with maximum detected result exceeding GWQS.
- Monitor well with maximum detected result below
- Isoconcentration line (white)
- Dashed where inferred
- North Waste Cell Excavation
- Approximate Location of NJDEP Drum Removals (1993-1995)
- Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes

Concentrations in ug/L.
NR = analyte not reported.

For contouring, the maximum detected concentration of the constituent being mapped was used regardless of depth or sampling date in order to conceptualize the approximate extent of detections of the mapped constituent.

MW-9 through MW-15 are overburden and shallow bedrock wells. Contaminant migration is thought to occur in the deeper bedrock in the area of these wells.

NJDEP individual Interim Generic Groundwater Quality Criteria of 5 ug/L for carcinogenic synthetic organic chemicals (SOCs) is used for evaluation. Exceedances indicated by **bold, red, underlined** text.
Phenobarbital is listed as a possible human carcinogen (Group 2B) by the IARC.

The extent of contamination is considered to be inferred because this constituent is reported as a tentatively identified compound (TIC) in the analytical datasets. It is therefore only reported when the laboratory determined there was sufficient presumptive evidence of its presence. Concentrations are estimated.

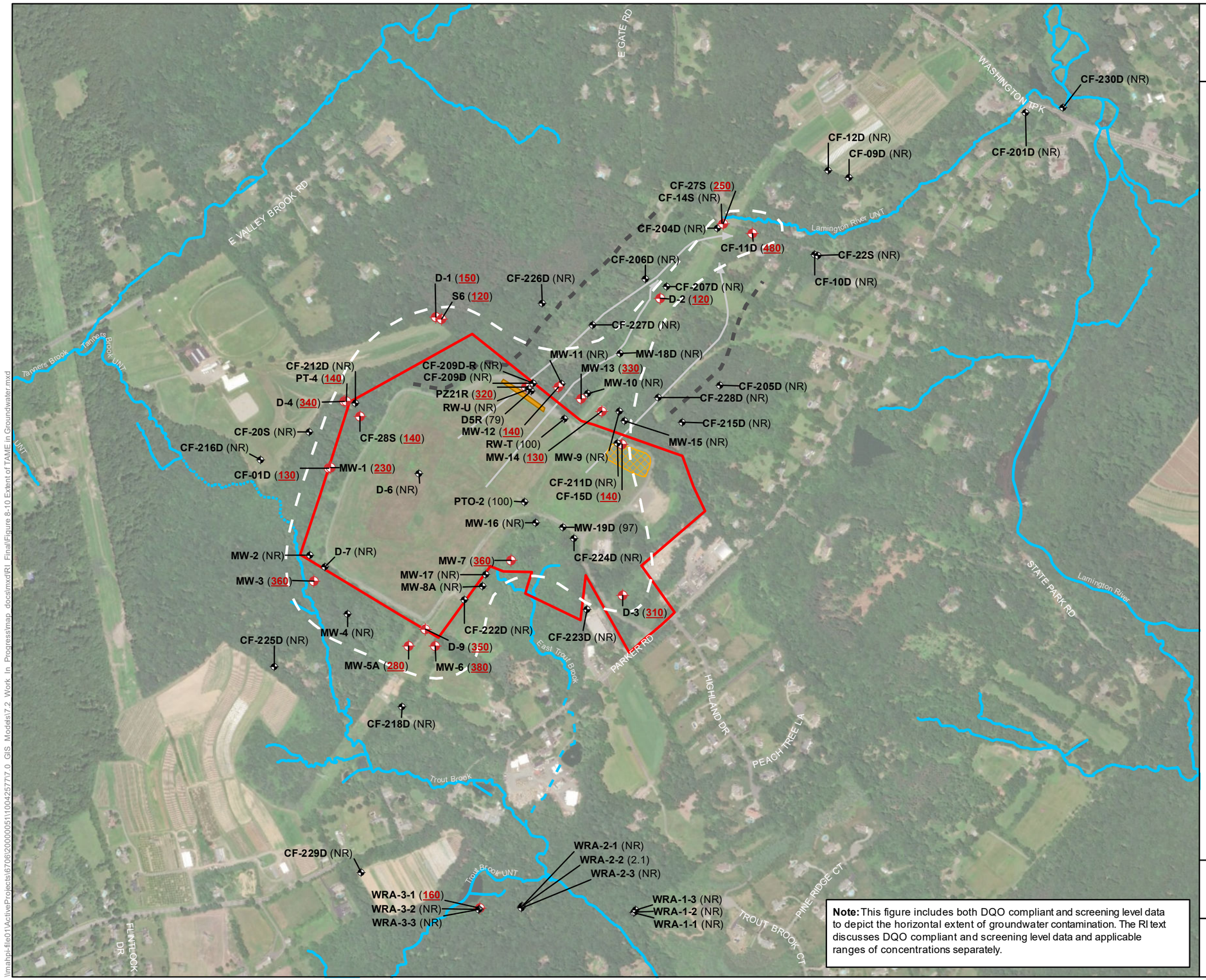
Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

0 400 800 Feet

Estimated Extent of Phenobarbital in Groundwater

Figure 8-9
August, 2018

\\mahpi-file01\ActiveProjects\67062000005\1100425777.0 GIS Models\7.2 Work In Progress\map docs\mxd\RI Final\Figure 8-9 Extent of Phenobarbital in Groundwater rev3.mxd



Note: This figure includes both DQO compliant and screening level data to depict the horizontal extent of groundwater contamination. The RI text discusses DQO compliant and screening level data and applicable ranges of concentrations separately.

Combe Fill South Landfill Superfund Site RI/FS

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US

Legend

- OU1 - Landfill Property Boundary
- Monitor well with maximum detected result exceeding GWQS.
- Monitor well with maximum detected result below GWQS.
- Isoconcentration line (white)
- Dashed where inferred
- North Waste Cell Excavation
- Approximate Area of NJDEP Drum Removals (1993-1995)
- Surface Water
- Undefined Surface Water
- Aquitard (Source: Willowstick report)
- Preferential Flow Path (Source: Willowstick report)

Notes
- Concentrations in ug/L.
- NR = analyte not reported.
- TAME (tert amyl methyl ether) is a synonym of butane, 2-methoxy-2-methyl (CAS 994-05-8)

For contouring, the maximum detected concentration of the constituent being mapped was used regardless of depth or sampling date in order to conceptualize the approximate extent of detections of the mapped constituent.

Wells MW-9 through MW-15 are overburden and shallow bedrock wells. Contaminant migration is thought to occur in the deeper bedrock in the area of these wells.

NJDEP individual Interim Generic Groundwater Quality Criteria of 100 ug/L for non-carcinogenic synthetic organic chemicals (SOCs) is used for evaluation. Exceedances indicated by **bold, red, underlined** text. IARC does not provide a determination on the carcinogenicity of TAME. The non-carcinogenic SOC criterion is applied for evaluation purposes only.

The extent of contamination is considered to be inferred because this constituent is reported as a tentatively identified compound (TIC) in the analytical datasets. It is therefore only reported when the laboratory determined there was sufficient presumptive evidence of its presence. Concentrations are estimated.

Analytical Data Sources
- OU2 Remedial Investigation Sampling (HDR, 2011-2015)
- OU2 Monitoring Well Packer Results (HDR, 2011)
- OU2 FS Pump Test (HDR, 2017)
- Post-Construction Environmental Monitoring (PCEM) Program Samples (NJDEP, Q4 2011 to Q4 2015)

0 400 800 Feet

Estimated Extent of TAME in Groundwater

Figure 8-10
August, 2018

\\mahpi-file01\ActiveProjects\67061200000511\00425717.0_GIS_Models\7.2_Work_In_Progress\map_docs\mxd\RI_Final\Figure 8-10 Extent of TAME in Groundwater.mxd

TABLES

Table 2-1
Field Activity Summary
Combe Fill South Landfill OU2

Field Activity	Work Conducted By	Dates
Phase I		
Mobilization	HDR	April 11, 2011
Site Surveys	BSM	April 1 - May 31, 2012
Well Condition Survey - Existing monitoring well network	HDR	April 18 - 29, 2011
Resistivity Survey	Delta	May 23 - June 1, 2011
Residential Well Sampling - Collect sample for tritium analysis as part of EPA sampling for environmental contaminants	Weston Solutions, Inc.	June 20 - 24, 2011
Utility mark-out - Piezometers & Soil Borings	Delta	June 30, 2011
Utility mark-out - Monitoring Wells	Delta	July 22, 2011
Piezometer/Stream Gauge Installation	HDR, BB	July 14 - 29, 2011
Surface water/Groundwater Interaction Study	HDR	August 1 - November 8, 2011
Bedrock Borehole/Well Drilling	HDR, BB	July 25 - November 23, 2011
IDW Sampling	TTI	August 8, 2011
Downhole Geophysical Logging	Delta	August 9 - 12, 2011
		September 2 & 26, 2011
		November 28 - December 6, 2011
FLUTe Hydraulic Profiling	FLUTe	August 22 - 26, 2011
		September 27-28, 2011
		December 5-9 & 20, 2011
Packer Testing	HDR, BB	December 1, 2011 - February 24, 2012
Synoptic groundwater elevations measurements	HDR	May 30, 2012
Water FLUTe completion (wells drilled during Phase I)	FLUTe, BB	June 4, 21, 26, 2012
Traditional monitoring well completion	BB	June 12-13, 2012
Groundwater sampling	HDR	December 1, 2011 - October 18, 2012
IDW Disposal	TTI	February 17, 2012
Phase II		
Mobilization	HDR	May 15, 2013
Willowstick Electromagnetic Survey	HDR, WS, BB	May 20 - June 28, 2013
Borehole Drilling	HDR, BB	September 12 - 24, 2013
		September 30 - October 16, 2013

Table 2-1
Field Activity Summary
Combe Fill South Landfill OU2

Field Activity	Work Conducted By	Dates
Well Completion; CF230D	HDR, BB	December 2 - 9, 2013
Downhole Geophysical Logging	Delta	October 28 - 30, 2013
FLUTe Hydraulic Profiling	FLUTe	December 2 - 5, 2013
Traditional monitoring well completion	BB	May 24 & December 6, 2013
Water FLUTe completion	FLUTe, BB	August 1, 2013 & June 4 - 6, 2014
Well Condition Survey - Schoolhouse Lane Potable Wells	HDR, BB	August 19-22, 2013
Packer Testing	HDR, BB	January 30 - February 20, 2014
Groundwater sampling	HDR	August 5, 2013 -June 13, 2014
IDW Sampling	BB	August 27, 2014
IDW Disposal	BB	December 24, 2014
Phase III		
Soil Boring/Sampling	HDR, SDC	November 17 - 24, 2014
Surface Water Sampling - Dry weather event	HDR	November 11 - 13, 2014
Surface Water Sampling - Wet weather event	HDR	November 18, 2014
Groundwater sampling	HDR	September 8, 2014 - July 7, 2015
IDW Sampling	AEAC	December 24, 2014
IDW Disposal	AEAC	April 6, 2015
Demobilization	HDR	December 23, 2014
Phase IV		
Groundwater sampling	HDR	January 12 - March 24, 2017
Well Modification and Development(CF209D/CF209D-R)	HDR, BB	January 23 - March 10, 2017
Hydraulic Testing	HDR, BB	February 1 - 27, 2017
1,4-Dioxane Removal Pilot Test	HDR, ECT_2	February 2 - 27, 2017
Surface Water and Sediment Sampling	HDR	September 20 - 26, 2017
IDW Disposal	BB, HDR, ECT_2	January - July 2017

Subcontractors

BSM - Borbas Surveying & Mapping, LLC
Delta - Delta Geophysics, Inc.
BB - B&B Drilling, Inc.
TTI - TTI Environmental, Inc.
FLUTe - Flexible Liner Underground Technologies, LLC
WS - Willowstick Technologies LLC
SDC - Summit Drilling Co.,
AEAC - American Environmental Assessment Corporation
ECT_2 - Emerging Compounds Treatment Technologies

Table 2-2
Resistivity Survey Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Profile Number	Profile Location*		Start Station	End Station	Start Station		End Station		Profile Orientation, Station 0 to End
					Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	
1	~400 ft N	across Utility Corridor	0	1040	426,231.6	707,021.4	427,145.0	706521.9	W to E
2	~1200 ft N	across Utility Corridor	0	1240	426,635.5	707,733.9	427,727.0	707123.4	W to E
3	~2000 ft N	across Utility Corridor	0	1240	427,171.8	708,264.2	428,349.8	707877.7	W to E
4	~100 ft S	across Utility Corridor	0	1040	424,737.1	704,945.4	425,609.5	704379.1	W to E
5	~450 ft S	across Utility Corridor	0	1040	424,536.5	704,629.0	425,458.0	704145.5	W to E
6	~2100 ft N	across Lamington UNT	0	410	428,033.0	707,983.5	428,077.7	708403.6	S to N

* Profile Location Distances: North of the north landfill perimeter fence (Profiles 1-3 and 6) or south of the south landfill perimeter fence (Profiles 4 & 5).

Abbreviations

ft	feet
N	North
S	South
E	East
W	West

Table 2-3
Willowstick Electromagnetic Survey Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Survey No.	Electrode 1 Location	Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	Ground Surface Elevation, ft amsl	Electrode 1 Depth, ft bgs	Electrode 1 Elevation, ft AMSL	Electrode 2 Location	Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	Ground Surface Elevation, ft amsl	Electrode 2 Depth, ft bgs	Electrode 2 Elevation, ft AMSL
1	CF216D	423810.9	706162.9	797.1	280	517.1	CF204D	427561.2	708068.5	777.1	81	696.1
3	CF205D	427586.3	706775.2	856.4	155	701.4	22.16	427580.6	706757.4	858	690	168
4	CF209D	426047.4	706795.7	834.6	500	334.6	Pond	427232.1	708163.4	790	0	790
5	CF209D	426047.4	706795.7	834.6	500	334.6	PZ-21R	425991.4	706761.5	837	90	747
6	CF211D	426744.4	706303.2	823.1	245	578.1	22.07	427768.3	707220.6	808	290	518
7	Pond	427232.1	708163.4	790	0	790	CF12D	428484.2	708547.97	792.1	85	707.1

*Survey No. 2 was begun, but not completed due to poor electrical connection between the well pair.

Abbreviations

ft feet
bgs below ground surface

Table 2-4
Potable Well Construction Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Tax Parcel (Block, Lot)		Survey Date	Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	Ground Surface Elevation [ft amsl]	Well Diameter [in]	Open Hole Interval [ft bgs]	Total Depth [ft bgs]	Pump Depth [ft bgs]	Depth-to-water [ft bgs]	Pump Type	Completion Detail	Date Well was Abandoned*
17	22.01	8/21/2013	428014.1	707677	778.585	6	unk	72.7	61	19.46	Submersible	Stick-up	7/6/2015
17	22.03	8/19/2013	428474.8	707640	773.037	6	48-139	139	91	23.16	Submersible	Stick-up	6/26/2015
17	22.04	8/19/2013	428717.3	707670	771.09	6	46.5-195.5	195.5	152	25	Submersible	Buried (1.5 ft bgs)	6/11/2015
17	42	8/21/2013	428862	707821	765.626	6	31.1-82.1	82.1	70.9	25.3	Submersible	Stick-up	6/8/2015
17	43	8/20/2013	NS	NS	NS	6	20-44.4	44.4	34	4.45	Jet Pump	Buried (3.9 ft bgs)	7/6/2015
17	44	8/22/2013	427992.024	708336	781.353	6	unk	80	70	2.63	Jet Pump	Buried (4 ft bgs)	7/1/2015
17	44.01	8/22/2013	428118.302	708272	768.419	6	21-78.5	78.5	62	6.65	Submersible	Stick-up	7/1/2015
17	44.02	8/19/2013	428182.172	708017	764.986	6	18-88	88	62	8.71	Submersible	Stick-up	7/2/2015
17	45	8/20/2013	427580.041	708347	783.182	6	unk	162.7	102	3	Submersible	Stick-up	7/2/2015

Notes

* The surveyed wells were abandoned/sealed by EPA in 2015 as part of the Parker Road Water Main Extension Remedial Action.

NS	Not surveyed. Well could not be located by surveyor.
unk	Measurement attempted, but could not be determined.

Abbreviations

ft	feet
amsl	above mean sea level
in	inch
bgs	below ground surface

Table 2-5
Groundwater Level Measurements May 2012
Combe Fill South Landfill OU2
Morris County, New Jersey

Well	Screen Formation	TOC Elevation, ft AMSL	Ground Surface Elevation, ft AMSL	Depth to Bottom, ft bgs	Bottom Elevation, ft AMSL	Screen Interval, ft bgs*		Screen/Open	DTW 5/30/12, ft bTOC	Water Table Elevation 5/30/12, ft AMSL
NJDEP - CF-Series										
CF-01D	BR	795.62	793.36	86	707.36	62	86	Open	7.21	788.41
CF-02S	OB/BR	814.04	814.3	45	769.3	20	45	Screen	24.2	789.84
CF-03S	OB/BR	812.07	812.37	45	767.37	20	45	Screen	24.47	787.6
CF-09D	BR	781.83	782.3	170	612.3	145	170	Screen	40.54	741.29
CF-09S	OB	763.17	763.37	20	743.37	10	20	Screen	12.14	751.03
CF-10D	BR	762.77	763.09	170	593.09	145	170	Screen	10.18	752.59
CF-11D	BR	772.23	772.61	170	602.61	145	170	Screen	3.24	768.99
CF-12D	BR	791.78	792.08	90	702.08	65	90	Screen	28.74	763.04
CF-13S	OB	772.28	772.4	14	758.4	4	14	Screen	2.64	769.64
CF-14S	OB	774.06	774.31	20	754.31	10	20	Screen	NM	NM
CF-15D	BR	823.08	823.4	190	633.4	165	190	Screen	26.91	796.17
CF-20S	OB	795.65	793.57	16	777.57	6	16	Screen	5.63	790.02
CF-21S	OB	793.29	791.16	22	769.16	12	22	Screen	4.9	788.39
CF-22S	BR	763.13	763.45	50	713.45	40	50	Screen	11.95	751.18
CF-23S	OB	771.52	766.56	30	736.56	15	30	Screen	9.7	761.82
CF-24S	OB	771.52	772.02	20	752.02	10	20	Screen	9.31	762.21
CF-25S	OB	766.19	772.59	20	752.59	10	20	Screen	NM	NM
CF-26S	OB	772.37	773.03	40	733.03	30	40	Screen	2.93	769.44
CF-27S	OB	773.83	774.14	40	734.14	30	40	Screen	NM	NM
CF-28S	OB	803.13	800.74	37	763.74	12	37	Screen	9.96	793.17
Millstone										
22.07	BR	**	809	398	411	200	398	Open	22.71	786.29
22.08	BR	**	806	381	425	200	381	Open	21.74	784.26
22.10	BR	**	812.2	423	389	200	423	Open	33.49	778.71
22.11	BR	**	822	598	224	200	598	Open	31.72	790.28
22.12	BR	**	828	698	130	200	698	Open	43.34	784.66
22.13	BR	**	838	345	493	200	345	Open	NM	NM
22.14	BR	**	860	345	515	200	345	Open	76.98	783.02
22.15	BR	**	842.6	511	332	200	511	Open	88.35	754.25
22.16	BR	**	857	748	109	200	748	Open	74.06	782.94
22.19	BR	**	828	635	193	200	635	Open	44.27	783.73
NJDEP - WRA Series										
WRA-3-1	BR	763.13	763.45	254	509.45	229	254	Open	2.25	760.88
WRA-3-2	BR	763.13	763.45	220	543.45	195	220	Open	2.3	760.83
WRA-3-3	BR	763.13	763.45	103	660.45	80	103	Open	4.49	758.64

Table 2-5
Groundwater Level Measurements May 2012
Combe Fill South Landfill OU2
Morris County, New Jersey

Well	Screen Formation	TOC Elevation, ft AMSL	Ground Surface Elevation, ft AMSL	Depth to Bottom, ft bgs	Bottom Elevation, ft AMSL	Screen Interval, ft bgs*		Screen/Open	DTW 5/30/12, ft bTOC	Water Table Elevation 5/30/12, ft AMSL
HDR - Bedrock										
CF-201D	BR	690.92	690.7	571	119.7	59	571	Open	2.34	688.58
CF-204D	BR	777.47	777.1	700	77.1	66	700	Open	-0.75	778.22
CF-205D	BR	856.95	856.4	200	656.4	19	200	Open	67.43	789.52
CF-206D	BR	798.71	798.4	560	238.4	80.5	560	Open	8.55	790.16
CF-207D	BR	791.96	791.4	610	181.4	78	610	Open	1.48	790.48
CF-209D	BR	834.78	834.6	700	134.6	95	700	Open	NM	NM
CF-211D	BR	823.74	823.1	500	323.1	99	500	Open	28.36	795.38
CF-212D	BR	804.46	803.8	500	303.8	58	500	Open	NM	NM
CF-215D	BR	860.23	859.8	200	659.8	19	200	Open	51.71	808.52
CF-216D	BR	797.48	797.1	700	97.1	14	700	Open	NM	NM
CF-218D	BR	775.5	775.2	700	75.2	72	700	Open	9.2	766.3
CF-222D	BR	806.34	805.6	200	605.6	70	200	Open	19.89	786.45
CF-223D	BR	813.11	812.6	200	612.6	48	200	Open	30.99	782.12
CF-224D	BR	819.51	818.9	200	618.9	48	200	Open	28.16	791.35
CF-225D	BR	794.47	794.5	500	294.5	65	500	Open	13.65	780.82

* The May 2012 water level measurments were collected before the new boreholes that had been installed at that point (CF-201D through CF-225D) were completed as monitoring wells (i.e., conventional, screened wells or multi-port wells). Construction details for the completed wells are included in Table 2-11.

** Millstone borehole measurements collected from ground surface.
HDR - Bedrock series elevations measured from survey point prior to well completion.
The May 30, 2012 water level measurements comprise the most comprenhensive set of measurements during the RI.
Additional water level measurements are included in Appendix G of the RI report.

Table 2-5a
Selected Water Level Measurements for Stream Gauge/Piezometer Pairs
Combe Fill South Landfill OU2
Morris County, New Jersey

Well	TOC Elevation [ft amsl]	8/1/2011		11/8/2011		5/30/2012		7/7/2015	
		DTW [ft bTOC]	Elevation [ft amsl]	DTW [ft bTOC]	Elevation [ft amsl]	DTW [ft bTOC]	Elevation [ft amsl]	DTW [ft bTOC]	Elevation [ft amsl]
PZ-101	745.64	2.78	742.86	1.86	743.78	2.14	743.5	NM	NM
SG-101	745.61	3.23	742.41	2.91	742.73	3.17	742.44	NM	NM
PZ-102	773.14	4.72	740.92	3.91	741.73	4.56	768.58	4.72	740.92
SG-102	770.54	2.72	742.92	2.63	743.01	2.57	767.97	2.82	742.82
PZ-103	690.41	10.53	735.11	9.05	736.59	9.51	680.9	9.43	736.21
SG-103	687.16	4.37	741.27	4.43	741.21	4.58	682.58	4.59	741.05
PZ-104	773.36	7.73	737.91	6.41	739.23	6.87	766.49	6.65	738.99
SG-104	769.01	1.87	743.77	1.82	743.82	1.94	767.07	1.61	744.03
PZ-105	754.41	4.19	741.45	2.61	743.03	3.02	751.39	3.79	741.85
SG-105	450.66	3.61	742.03	3.25	742.39	3.71	746.95	3.91	741.73
PZ-106	781.87	6.17	739.47	4.26	741.38	4.97	776.9	NM	NM
SG-106	778.89	3.15	742.49	3.04	742.6	3.09	775.8	3.41	742.23
PZ-107	770.37	0.5	745.14	0	745.64	0.14	770.23	0	745.64
SG-107	771.49	3.94	741.7	3.59	742.05	3.74	767.75	3.71	741.93
PZ-108	794.47	6.81	738.83	4.37	741.27	5.4	789.07	NM	NM
SG-108	789.04	2.76	742.88	1.9	743.74	2.09	786.95	2.32	743.32
PZ-109	804.14	15.92	729.72	11.49	734.15	13.77	790.37	14.61	731.03
SG-109	791.51	3.25	742.39	1.81	743.83	5	786.51	5	740.64

Table 2-6
Piezometer/Stream Gauge
Construction Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Piezometer/ Stream Gauge ID	Installation Date	Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	Ground Surface Elevation, ft AMSL	TOC Elevation, ft amsl	Well Diameter, in	Total Depth, ft bgs	Screen Interval, ft	Completion Details
PZ-101	7/21/2011	428602.3	708060.1	745.9	745.64	2	9	4-9	Flush-mount
SG-101	7/21/2011	NS	NS	NS	745.61	2	*	5	Stick-up
PZ-102	7/14/2011	427783.3	708135.7	771.1	773.14	2	7.5	2.5-7.5	Stick-up
SG-102	7/19/2011	NS	NS	NS	770.54	2	*	5	Stick-up
PZ-103	7/19/2011	430069.0	709057.6	690.9	690.41	2	16	6-16	Flush-mount
SG-103	7/19/2011	NS	NS	NS	687.16	2	*	5	Stick-up
PZ-104	7/21/2011	426432.4	704235.8	771.5	773.36	2	14	4-14	Stick-up
SG-104	7/21/2011	NS	NS	NS	769.01	2	*	5	Stick-up
PZ-105	7/20/2011	425399.3	703458.7	752.7	754.41	2	15	5-15	Stick-up
SG-105	7/20/2011	NS	NS	NS	750.66	2	*	5	Stick-up
PZ-106	7/22/2011	424273.4	704952.5	779.7	781.87	2	11	6-11	Stick-up
SG-106	7/28/2011	NS	NS	NS	778.89	2	*	5	Stick-up
PZ-107	7/15/2011	424370.2	704344.8	770.7	770.37	2	10	1-10	Flush-mount
SG-107	7/20/2011	NS	NS	NS	771.49	2	*	5	Stick-up
PZ-108	7/22/2011	423985.5	706074.4	792.8	794.47	2	16	6-16	Stick-up
SG-108	7/26/2011	NS	NS	NS	789.04	2	*	5	Stick-up
PZ-109	7/15/2011	426198.2	705285.9	802.2	804.14	2	20	10-20	Stick-up
SG-109	7/28/2011	NS	NS	NS	791.51	2	*	5	Stick-up

Notes

*	Stream gauges constructed with 5 ft PVC well screen installed about 1-3 ft into sediment.
NS	Not Surveyed - Only TOC elevation surveyed at Stream Gauge locations.

Abbreviations

ft	feet
in	inch
amsl	above mean sea level
bgs	below ground surface

Table 2-7
Groundwater/Surface Water Interaction Monitoring Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Piezometer/ Stream Gauge ID	TOC Elevation, ft amsl	Transducer ID	Depth-to-transducer, ft bTOC	Installation			Removal		
				Date Started	DTW, ft bTOC	DTB, ft bTOC	Date Ended	DTW, ft bTOC	DTB, ft bTOC
PZ101	745.64	15162	8.12	8/1/2011	2.78	9.34	11/2/2011	1.86	9.32
SG101	745.61	14271	4.4	8/1/2011	3.23	5.82	11/2/2011	2.91	5.52
PZ102	773.14	14699	8.32	8/1/2011	4.72	9.67	11/2/2011	3.91	9.69
SG102	770.54	15157	4.33	8/1/2011	2.72	5.61	11/2/2011	2.63	5.25
PZ103	690.41	12297	14.21	8/1/2011	10.53	15.67	11/2/2011	9.05	15.58
SG103	687.16	14625	5.13	8/1/2011	4.37	5.74	11/2/2011	4.43	5.68
PZ104	773.36	14578	15.67	8/1/2011	7.73	16.67	11/2/2011	6.41	16.67
SG104	769.01	15158	3.8	8/1/2011	1.87	5.27	11/2/2011	1.82	4.77
PZ105	754.41	16212	15.88	8/1/2011	4.19	17.57	11/2/2011	2.61	17.49
SG105	750.66	14717	4.79	8/1/2011	3.61	5.52	11/2/2011	3.25	5.42
PZ106	781.87	14537	12.32	8/1/2011	6.17	13.08	11/2/2011	4.26	13.08
SG106	778.89	15164	4.72	8/1/2011	3.15	5.47	11/2/2011	3.04	5.37
PZ107	770.37	15825	8.97	8/1/2011	0.5	10.02	11/2/2011	Flowing	10.01
SG107	771.49	16143	4.9	8/1/2011	3.94	5.61	11/2/2011	3.59	5.62
PZ108	794.47	14495	15.03	8/2/2011	6.81	17.52	11/2/2011	4.37	17.27
SG108	789.04	14276	4.94	8/2/2011	2.76	5.7	11/2/2011	1.9	5.57
PZ109	804.14	14054	21.21	8/1/2011	15.92	22.57	11/2/2011	11.49	22.57
SG109	791.51	13894	4.5	8/1/2011	3.25	5.62	11/2/2011	1.81	5.57
Barometer	N/A	A01309	N/A	8/1/2011	N/A	N/A	11/2/2011	N/A	N/A

Notes

N/A Barometer placed at representative location near the Site to measure atmospheric pressure.

Abbreviations

ft feet
amsl above mean sea level
bTOC below top of casing

Table 2-8a
Long-Term Water Level Monitoring - Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Well ID	TOC Elevation, ft amsl	Transducer ID	Depth-to-transducer, ft bTOC	Installation		Removal	
				Date Started	DTW, ft bTOC	Date Ended	DTW, ft bTOC
CF201D-P2	689.71	312023	FLUTe	7/31/2012	NM	11/1/2012	2.91
CF201D-P3		312049	FLUTe	7/31/2012	NM	11/1/2012	2.63
CF09D	781.83	164032	50	7/31/2012	39.69	11/1/2012	37.1
CF223D	811.63	117822	42	7/31/2012	31.85	11/1/2012	31.65
CF11D	772.23	310659	15	7/31/2012	4.48	11/1/2012	3.9
CF15D	823.08	156135	40	7/31/2012	29.36	11/1/2012	32.68
PZ8	846.55	16141	65	7/31/2012	55.45	11/1/2012	57.38
D1	837.72	175135	40	7/31/2012	29.39	11/1/2012	33.74
PZ21R	837.19	164026	50	7/31/2012	43.28	11/1/2012	43.93
D5R	835.02	17467	50	7/31/2012	41.04	11/1/2012	43.62
D2	794.47	164036	20	7/31/2012	9.83	11/1/2012	11.13
CF206D-P2	797.72	307725	FLUTe	7/31/2012	NM	11/1/2012	NM
CF206D-P4		308707	FLUTe	7/31/2012	NM	11/1/2012	NM
CF206D-P5		312219	FLUTe	7/31/2012	NM	11/1/2012	NM
CF205D	858.84	13503	90	7/31/2012	78.57	11/1/2012	79.44
CF218D-P1	774.16	308882	FLUTe	7/31/2012	NM	11/1/2012	NM
CF218D-P2		308746	FLUTe	7/31/2012	NM	11/1/2012	NM
CF218D-P3		308719	FLUTe	7/31/2012	NM	11/1/2012	NM

Notes

The following Water FLUTe ports were included at the outset of the monitoring, but were unable to connect at the end of the survey; CF201D Ports 1 and 4, CF206D Ports 1 and 3.

Abbreviations

ft	feet	TOC	top of casing
amsl	above mean sea level	bTOC	below top of casing
bgs	below ground surface	NM	Not measured

Table 2-8b
Long-Term Water Level Monitoring - Hydrograph Summaries
Combe Fill South Landfill OU2
Morris County, New Jersey

Monitoring Well	Monitored Interval [ft. bgs]	Nearest Known Pumping Well(s)	Pumping Interval [ft. bgs]	Distance to Pumping Well [ft., approx.]	Pumping Influence ? [Y/N]	Precipitation Influence ? [Y/N]	Description
CF201D-P2	240 - 245	Church/Residential Wells	Unknown	Unknown (<150)	Y	Y	The two ports (P2 & P3) at this well appear to be influenced by pumping (pump cycling) between approximately September 26 and October 3. The abrupt change in water levels (apparent rise in port 2 and apparent drop in port 3) on September 11 was caused when the transducers were checked. Minor influences from some precipitation events.
CF201D-P3	311 - 316				Y	Y	
CF09D	145 - 170	Two irrigation wells	103 to 655 70 to 311	Unknown (estimated as 350 and 700)	Y	N	Well CF09D is strongly influenced by pump cycling and transient pumping throughout most of the monitoring period (i.e., pumping at 2 locations and frequencies). There appear to be pumping influences (cycling or transient) after October 29 (due to a power outage caused by Hurricane Sandy).
CF223D	145 - 160	RW-A	8 - 38	815	N	Y	Well CF223D does not appear to be influenced by pumping. The abrupt change in water level on October 16 was caused by sampling of the well. The nearest pumping recovery well (RW-A) is upgradient of CF223D.
CF11D	145 - 170	RW-S	17 - 57	2025	N	Y	Well CF11D does not appear to be influenced by pumping. The water level at the well rebounds quickly after major rain events, including significant recharge after Hurricane Sandy (October 29 -30). The abrupt change in water level on October 18 was caused by sampling of the well.
CF15D	145 - 190	RW-S	17 - 57	20	N	Y	This location does not appear to be influenced by transient pumping. Influence from some precipitation events is observed at this location. The abrupt change in water level on October 19 was caused by sampling.
PZ8	17 - 77	RW-R	11 - 51	220	N	Y	PZ-8 does not appear to be influenced by transient pumping. Minor influences from precipitation can be seen over several days after significant precipitation events.
D1	89 - 147	RW-N	15 - 55	815	N	Y	This location does not appear to be influenced by transient pumping. The change in water level on October 16 was caused by sampling of the well. The water level increase observed on October 29 and 30 resulted from the major precipitation event during Hurricane Sandy.
PZ21R	45 - 95	RW-U	39 - 89	25	Y	Y	PZ-21R appears to be influenced by pump cycling at nearby landfill recovery wells, transient pumping, and long term pumping throughout the monitoring period (i.e., influenced by pumping at 3 locations and frequencies). Influences from precipitation can be seen after significant rain events. There appear to be no pumping influences (cycling, transient, or long term) after October 29 (power outage caused by Hurricane Sandy). The abrupt change in water level on October 18 was caused by sampling of the well. The period from August 31 to September 14 is characterized by continuous pumping that lowered the water level by 2.5 feet, interrupted by a short stoppage on September 9 during which the water level rebounded by five feet (coincident with a minor precipitation event). During this time, nearby bedrock recovery well RW-T, which extracts about three times as much as RW-U, on average, was not pumping, which accounts for the absence of the cyclical pumping influence that is present when RW-T is running. The review of facility daily pumping records did not indicate which recovery well or wells caused the large drawdown at PZ21R between 8/31 and 9/14. Maintenance records, which may have shed light on this, were not available.
D5R	50 - 125	RW-U	39 - 89	25	N	Y	Well D5R did not seem to be influenced by pumping. The abrupt change in water level (apparent drop) on September 11 was caused when the transducers were checked. The well was influenced by precipitation events.
D2	80 - 124.5	RW-R; RW-S	RW-R: 11 - 51 RW-S: 17 - 57	Both: 1225	N	Y	D2 does not appear to be influenced by transient pumping. The abrupt change in water level on October 18 was caused by sampling of the well. The water level increase observed on October 29 and 30 was attributed to a major precipitation event (Hurricane Sandy).
CF206D-P1	147 - 152	RW-U	39 - 89	1320	N	Y	The ports at FLUTe well CF206D (ports 1, 4 & 5) do not appear to be influenced by transient pumping. Influence from some precipitation events was also observed. The abrupt change in water level (apparent rise in port 1) September 11th resulted from technicians checking the transducers. The overall downward trend in the curves for Ports 4 and 5 reflects the seasonal water level decline through summer and fall.
CF206D-P4	278 - 283	RW-U	39 - 89	1320	N	Y	
CF206D-P5	553 - 558	RW-U	39 - 89	1320	N	Y	
CF205D	150 - 160	RW-S	17 - 57	940	N	Y	CF205D does not appear to be influenced by transient pumping. It showed some minor influence after some precipitation events. The abrupt change in water level on October 18 was caused by sampling of the well.
CF218D-P1	171 - 176	RW-D	12 - 42	1030	N	Y	Well CF218D with three ports (ports 1, 2 & 3) does not appear to be influenced by pumping. It showed influence after some precipitation events. The abrupt change in water level on September 11 (apparent drop in port 3) was caused by checking of the transducers. The nearest pumping recovery well (RW-D) is upgradient of CF218D.
CF218D-P2	292 - 297	RW-D	12 - 42	1030	N	Y	
CF218D-P3	688 - 693	RW-D	12 - 42	1030	N	Y	

Notes

Transducers were also installed in the following Water FLUTe ports but were unable to connect at the end of the survey: CF201D Ports 1 & 4, CF206D Ports 1 & 3.
Influences from diurnal earth tides and barometric weather events were noted but are not described above.
The overall downward trend of the curves, except at CF09D, which is strongly influenced by pumping, reflects the seasonal water level decline throughout the summer and fall.

Abbreviations

ft	feet
bgs	below ground surface

Table 2-9
Monitoring Well Location Rationale
Combe Fill South Landfill OU2
Morris County, New Jersey

Well ID	Rationale
Phase I	
CF201D	Determine the nature and/or extent of the contamination to the north.
CF204D	Determine nature and extent of contamination in bedrock aquifer on Schoolhouse Lane.
CF205D	Determine the nature and/or extent of the contamination to the northeast.
CF206D	Investigate possible fracture.
CF207D	Investigate possible fracture.
CF209D/CF209D-R*	Investigate former waste cell area as a potential existing source of groundwater contamination.
CF211D	Investigate suspected buried drum area as a potential existing source of groundwater contamination.
CF212D	Determine the nature and/or extent of the contamination to the west.
CF215D	Determine the nature and/or extent ot the VOC plume to the northeast. Abandoned due to poor water production (nearby well CF205D provides delineation to the northeast).
CF216D	Determine the nature and/or extent of the contamination to the southwest.
CF218D	Determine the nature and/or extent of the contamination to the south.
CF222D	Investigate groundwater in the vicinty of East Trout Brook.
CF223D	Determine the nature of groundwater contamination to the east.
CF224D	Investigate suspected buried drum area as a potential existing source of groundwater contamination.
CF225D	Determine the nature and/or extent of the contamination to the south.
Phase II	
CF226D	Determine extent of contamination to the north by placing well outside landfill influence as determined by Willowstick.
CF227D	Target fracture identified in Willowstick® survey.
CF228D	Target fracture identified in Willowstick® survey.
CF229D	Determine extent of contamination to the south.
CF230D	Determine extent of contamination to the north.

Table 2-10
Downhole Geophysical Logging Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Well ID	Land Surface Elevation, ft amsl	Well Depth, ft bgs	Casing Depth, ft bgs	Well Diameter, in	Date of Log	Geophysical Suite
CF201D	690.7	571	59	6	9/26/2011	Full
CF204D	777.1	700	66	6	12/1/2011	Full
CF205D	856.4	200	19	6	8/12/2011	Full
CF206D	798.4	560	80.5	6	11/29/2011	Full
CF207D	791.4	610	78	6	12/2/2011	Full
CF209D	834.6	700	95	6	12/4/2011	Full
CF211D	823.1	500	99	6	8/9/2011	Full
CF212D	803.8	500	58	6	12/3/2011	Full
CF215D	859.8	200	19	6	8/12/2011	Full
CF216D	797.1	700	14*	6	11/28/2011	Full
CF218D	775.2	700	72	6	12/5/2011	Full
CF222D	805.6	200	70	6	9/2/2011	Full
CF223D	812.6	200	48	6	8/10/2011	Full
CF224D	818.9	200	48	6	8/10/2011	Full
CF225D	794.5	500	65	6	12/6/2011	Full
CF226D	869.01	200	41	6	10/28/2013	Full
CF227D	819.03	478	90.6	6	10/29/2013	Full
CF228D	825.97	500	60.5	6	10/30/2013	Full
CF229D	785.13	197	52.4	6	12/6/2013	Full

Geophysical Suite - Full

Caliper diameter	16” normal resistivity
Fluid temperature	32” normal resistivity
Fluid resistivity	64” normal resistivity
Gamma ray	Spontaneous potential
Single point resistance	Heat pulse flow meter
8” normal resistivity	Acoustic televiewer

* Downhole log erroneously lists casing depth. Correct value listed in table.

Table 2-11
Monitoring Well Installation Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Well ID	Completion Date	Borehole Depth, ft bgs	Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	Longitude West, NAD83	Latitude North, NAD83	Surface Elevation, ft amsl	Elevation Top of Inner Casing, ft amsl	Casing Depth, ft bgs	Port No.	Zone/Screen Interval, ft bgs	Zone/Screen Length, ft	Zone/Screen Interval Elevation, ft amsl
Multiport Wells - Water FLUTe Systems in 6 inch borehole													
CF201D	6/26/2012	569	430,094.7	709,018.6	74°43'26.39"	40°46'46.92"	690.7	689.71	59	P1	114 - 119	5	576.7 - 571.7
										P2	240 - 245	5	450.7 - 445.7
	(Heavy Mud,									P3	311 - 316	5	379.7 - 374.7
	1.10 density)									P4	518 - 523	5	172.7 - 167.7
CF204D	8/1/2013	700	427,561.2	708,068.5	74°43'59.30"	40°46'37.46"	777.1	775.90	66	P1	155 - 160	5	622.1 - 617.1
	(Grout)									P2	195 - 200	5	582.1 - 577.1
										P3	433 - 438	5	344.1 - 339.1
CF206D	7/10/2012	561	426,974.2	707,650.2	74°44'06.91"	40°46'33.31"	798.4	797.72	80.5	P1	86 - 91	5	712.4 - 707.4
										P2	147 - 152	5	651.4 - 646.4
	(Heavy Mud,									P3	271 - 276	5	527.4 - 522.4
	1.05 density)									P4	278 - 283	5	520.4 - 515.4
										P5	553 - 558	5	245.4 - 240.4
CF207D	7/13/2012	610	427,145.8	707,588.4	74°44'04.68"	40°46'32.71"	791.4	790.78	78	P1	106 - 111	5	685.4 - 680.4
										P2	182 - 192	10	609.4 - 599.4
	(Heavy Mud,									P3	412 - 417	5	379.4 - 374.4
	1.05 density)									P4	604 - 609	5	187.4 - 182.4
CF209D*	6/6/2014	700	426,047.4	706,795.7	74°44'18.93"	40°46'24.84"	834.6	834.78	95	P1	150 - 160	10	684.6 - 674.6
										P2	227 - 237	10	607.6 - 597.6
										P3	295 - 305	10	539.6 - 529.6
										P4	335 - 345	10	499.6 - 489.6
CF211D	6/5/2014	500	426,744.4	706,303.2	74°44'09.85"	40°46'20.00"	823.1	822.00	99	P1	124 - 131	7	699.1 - 692.1
										P2	215 - 220	5	608.1 - 603.1
										P3	360 - 365	5	463.1 - 458.1
CF212D	6/21/2012	500	424,590.2	706,626.9	74°44'37.87"	40°46'23.14"	803.8	804.46	58	P1	98 - 103	5	705.8 - 700.8
	(Heavy Mud, 1.10 density)									P2	153 - 158	5	650.8 - 645.8
CF216D	8/1/2013	700	423,810.9	706,162.9	74°44'47.98"	40°46'18.53"	797.1	797.48	14	P1	51 - 71	20	746.1 - 726.1
	(Grout)									P2	205 - 210	5	592.1 - 587.1
										P3	268 - 273	5	529.1 - 524.1
										P4	495 - 500	5	302.1 - 297.1
CF218D	7/31/2012	700	424,969.2	704,131.0	74°44'32.85"	40°45'58.48"	775.2	774.16	72	P1	171 - 176	5	604.2 - 599.2
										P2	292 - 297	5	483.2 - 478.2
										P3	688 - 693	5	87.2 - 82.2
CF222D	6/4/2012	200	425,485.1	705,014.5	74°44'26.18"	40°46'07.23"	805.6	808.53	70	P1	92 - 96	4	713.6 - 709.6
										P2	134 - 139	5	671.6 - 666.6
										P3	165 - 170	5	640.6 - 635.6

Table 2-11
Monitoring Well Installation Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Well ID	Completion Date	Borehole Depth, ft bgs	Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	Longitude West, NAD83	Latitude North, NAD83	Surface Elevation, ft amsl	Elevation Top of Inner Casing, ft amsl	Casing Depth, ft bgs	Port No.	Zone/Screen Interval, ft bgs	Zone/Screen Length, ft	Zone/Screen Interval Elevation, ft amsl
CF225D	7/13/2012	500	423,923.2	704,463.8	74°44'46.45"	40°46'01.74"	794.5	797.46	65	P1	76 - 81	5	718.5 - 713.5
										P2	106 - 111	5	688.5 - 683.5
	(Heavy Mud, 1.10 density)									P3	357 - 362	5	437.5 - 432.5
CF227D	6/4/2014	482	426,538	707,276	74°44'12.568"	40°46'29.605"	819.03	819.28	90	P1	110 - 120	10	709.0 - 699.0
										P2	150 - 160	10	669.0 - 659.0
										P3	408 - 413	5	411.0 - 406.0
										P4	475 - 482	7	344.0 - 337.0
CF228D	6/6/2014	500	427,081	706,680	74°44'04.496"	40°46'23.725"	825.97	825.99	58	P1	58 - 63	5	768.0 - 763.0
										P2	220 - 230	10	606.0 - 596.0
										P3	409 - 419	10	417.0 - 407.0
Traditional Monitoring Wells - 2 inch PVC in 6 inch borehole													
CF205D	6/12/2012	160	427,586.3	706,775.2	74°43'58.93"	40°46'24.68"	856.4	858.84	19		150 - 160	10	706.4 - 696.4
CF209D-R*	3/10/2017	163	426,047.4	706,795.7	74°44'18.93"	40°46'24.84"	834.6	834.78	150		150 - 160	10	684.6 - 674.6
CF223D	6/13/2012	160	426,493.8	704,932.9	74°44'13.06"	40°46'16.45"	812.6	811.63	48		145 - 160	15	667.6 - 652.6
CF224D	6/12/2012	160	426,384.2	705,520.8	74°44'14.51"	40°46'12.25"	818.9	821.55	37		145 - 160	15	673.9 - 658.9
CF226D	5/24/2014	200	426,122	707,449	74°44'17.978"	40°46'31.302"	869.01	869.32	20		105 - 200	95	764.0 - 669.0
CF229D	5/24/2014	197	424,634	702,777	74°44'37.155"	40°45'45.088"	785.13	785.16	52		182 - 197	15	603.1 - 588.1
CF230D	12/6/2013	135	430,405	709,062	74°43'22.359"	40°46'47.348"	696.48	698.06	--		120 - 135	15	576.5 - 561.5

Abbreviations

ft	feet
bgs	below ground surface
amsl	above mean sea level
P#	Port #

Notes:

* Well CF209D was converted from a multi-port well to a screened well (CF209D-R) in March 2017.

Boring CF215D was not completed as a monitoring well. The borehole was packer tested and abandoned after review of the packer test analytical results because of poor water production and because nearby well CF205D provided delineation to the northeast.

Table 2-12
Packer Testing Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Boring/Well ID	Surface Elevation, ft amsl	Sample Intervals, ft bgs	Interval Length, ft	Sample Interval Elevations, ft amsl	Sample ID	Date Sampled	Comments
CF201D	690.7	235 - 255	20	455.7 - 435.7	CF201D-GW-PT-CDF-CFF-0	12/5/2011	
		310 - 330	20	380.7 - 360.7	CF201D-GW-PT-DBA-DDA-0	12/5/2011	
		515 - 525	10	175.7 - 165.7	CF201D-GW-PT-FBF-FCF-0	12/1/2011	
CF204D	777.1	155 - 165	10	622.1 - 612.1	CF204D-GW-PT-BFF-BGF-0	1/24/2012	Dry. Low water production.
		191 - 201	10	586.1 - 576.1	CF204D-GW-PT-BJB-CAB-0	1/23/2012	
		432 - 442	10	345.1 - 335.1	CF204D-GW-PT-EDC-EEC-0	1/20/2012	Dry. Low water production.
CF205D	856.4	150 - 160	10	706.4 - 696.4	CF205D-GW-PT-BFA-BGA-0	1/5/2012	
CF206D	798.4	82 - 92	10	716.4 - 706.4	CF206D-GW-PT-AIC-AJC-0	1/13/2012	Dry. Low water production.
		159 - 169	10	639.4 - 629.4	CF206D-GW-PT-BFJ-BGJ-0	1/12/2012	Dry. Low water production.
		255 - 285	30	543.4 - 513.4	CF206D-GW-PT-CFF-CIF-0	1/11/2012	
		550 - 561	11	248.4 - 237.4	CF206D-GW-PT-FFA-FGB-0	1/10/2012	
CF207D	791.4	105 - 115	10	686.4 - 676.4	CF207D-GW-PT-BAF-BBF-0	1/18/2012	
		182 - 192	10	609.4 - 599.4	CF207D-GW-PT-BIC-BJC-0	1/18/2012	Dry. Low water production.
		410 - 420	10	381.4 - 371.4	CF207D-GW-PT-EBA-ECA-0	1/17/2012	
CF209D	834.6	150 - 160	10	684.6 - 674.6	CF209D-GW-PT-BFA-BGA-0	1/31/2012	
		227 - 237	10	607.6 - 597.6	CF209D-GW-PT-CCH-CDH-0	1/30/2012	
		295 - 325	30	539.6 - 509.6	CF209D-GW-PT-CJF-DCF-0	1/30/2012	
		335 - 345	10	499.6 - 489.6	CF209D-GW-PT-DDF-DEF-0	1/27/2012	
CF211D	823.1	125 - 140	15	698.1 - 683.1	CF211D-GW-PT-BCF-BEA-0	12/22/2011	
		215 - 225	10	608.1 - 598.1	CF211D-GW-PT-CBF-CCF-0	12/8/2011	
CF212D	803.8	60 - 70	10	743.8 - 733.8	CF212D-GW-PT-AGA-AHA-0	2/15/2012	
		90 - 110	20	713.8 - 693.8	CF212D-GW-PT-AJA-BBA-0	2/15/2012	
		148 - 158	10	655.8 - 645.8	CF212D-GW-PT-BEI-BFI-0	2/14/2012	
		370 - 380	10	433.8 - 423.8	--	2/13/2012	Attempted, but not sampled due to low production.
CF215D	859.8	110 - 130	20	749.8 - 729.8	CF215D-GW-PT-BBA-BDA-0	1/4/2012	Both intervals dry and low water production. Not completed as a monitoring well (abandoned after packer testing).
		144 - 154	10	715.8 - 705.8	CF215D-GW-PT-BEE-BFE-0	1/3/2012	
CF216D	797.1	50 - 70	20	747.1 - 727.1	CF216D-GW-PT-AFA-AHA-0	2/22/2012	
		115 - 130	15	682.1 - 667.1	CF216D-GW-PT-BBF-BDA-0	2/21/2012	
		205 - 215	10	592.1 - 582.1	CF216D-GW-PT-CAF-CBF-0	2/17/2012	
		270 - 300	30	527.1 - 497.1	CF216D-GW-PT-CHA-DAA-0	2/16/2012	
CF218D	775.2	170 180	10	605.2 - 595.2	CF218D-GW-PT-BHA-BIA-0	2/8/2012	
		205 215	10	570.2 - 560.2	CF218D-GW-PT-CAF-CBF-0	2/7/2012	
		290 300	10	485.2 - 475.2	CF218D-GW-PT-CJA-DAA-0	2/7/2012	
		310 320	10	465.2 - 455.2	CF218D-GW-PT-DBA-DCA-0	2/6/2012	
CF222D	805.6	90 - 100	10	715.6 - 705.6	CF222D-GW-PT-AJA-BAA-0	12/16/2011	Dry. Low water production.
		140 - 150	10	665.6 - 655.6	CF222D-GW-PT-BEA-BGA-0	12/19/2011	Sample name indicates 140-160, but actual test interval was 140-150. Extremely low water production.
CF223D	812.6	80 - 90	10	732.6 - 722.6	CF223D-GW-PT-AIF-AJA-0	12/20/2011	
		145 - 160	15	667.6 - 652.6	CF223D-GW-PT-BEF-BGA-0	12/21/2011	
CF224D	818.9	80 - 90	10	738.9 - 728.9	CF224D-GW-PT-AIA-AJA-0	12/12/2011	Dry. Low water production.
		145 - 160	15	673.9 - 658.9	CF224D-GW-PT-BEF-BGA-0	12/9/2011	Dry. Low water production.
CF225D	794.5	75 - 85	10	719.5 - 709.5	CF225D-GW-PT-AHF-AIF-0	2/3/2012	
		105 - 115	10	689.5 - 679.5	CF225D-GW-PT-BAF-BBF-0	2/3/2012	
CF226D	869.01	49 - 54	5	820.01 - 815.01	CF226D-GW-PT-AEJ-AFE-0	2/24/2014	
		105 - 200	95	764.01 - 669.01	CF226D-GW-PT-BAF-CAA-0	2/24/2014	
CF227D	819.03	110 - 120	10	709.03 - 699.03	CF227D-GW-PT-BBA-BCA-0	2/6/2014	
		150 - 160	10	669.03 - 659.03	CF227D-GW-PT-BFA-BGA-0	2/6/2014	
		408 - 413	5	411.03 - 406.03	CF227D-GW-PT-EAI-EBD-0	1/30/2014	
		475 - 482	7	344.03 - 337.03	CF227D-GW-PT-EHF-EIC-0	2/4/2014	
CF228D	825.97	68 - 73	5	757.97 - 752.97	CF228D-GW-PT-AFI-AGD-0	2/12/2014	Sample name indicates 58-73, but actual test interval was 68-73.
		205 - 220	15	620.97 - 605.97	CF228D-GW-PT-CAF-CCA-0	2/11/2014	
		409 - 419	10	416.97 - 406.97	CF228D-GW-PT-EAJ-EBJ-0	2/10/2014	
CF229D	785.13	52 - 62	10	733.13 - 723.13	CF229D-GW-PT-AFC-AGC-0	2/20/2014	
		138 - 158	20	647.13 - 627.13	CF229D-GW-PT-BDI-BFI-0	2/20/2014	
		185 - 196	11	600.13 - 589.13	CF229D-GW-PT-BIF-BJG-0	2/19/2014	

Abbreviations

ft	feet
bgs	below ground surface
amsl	above mean sea level

The packer GW samples were analyzed for the following analytical groups:

Target Compound List (TCL) Volatile Organic Compounds	Cyanide
TCL Semivolatile Organic Compounds	Total Organic Carbon (TOC)
TCL Pesticides	Total Dissolved Solids (TDS)
TCL Polychlorinated Biphenyls	Total Suspended Solids (TSS)
Target Analyte List (TAL) Metals	Chloride

Table 2-13
Monitoring Well Sampling Summary - Included Wells
Combe Fill South Landfill OU2
Morris County, New Jersey

Well	Port	Sample 1 ID	Sample 1 CLP ID	Sample 1 Date	Sample 1 QC	Sample 2 ID	Sample 2 CLP ID	Sample 2 Sample Date	Sample 2 QC
Multiport Wells - Water FLUTe Systems									
CF201D	P1	CF201D-GW-R2-P1-0	BAFG9	10/18/2012		CF201D-GW-RS-P1-0	BBFK3	12/3/2014	
	P2	CF201D-GW-R2-P2-0	BA968	10/11/2012		CF201D-GW-RS-P2-0	BBFK4	12/3/2014	
	P3	CF201D-GW-R2-P3-0	BA969	10/11/2012		CF201D-GW-RS-P3-0	BBFK5	12/3/2014	
	P4	CF201D-GW-R2-P4-0	BA970	10/11/2012		CF201D-GW-RS-P4-0	BBFK6	12/3/2014	
CF204D	P1	CF204D-GW-R1-P1-0	BAFJ9	8/8/2013		CF204D-GW-R2-P1-0	BAFN7	9/11/2014	
	P2	CF204D-GW-R1-P2-0	BAFK0	8/8/2013		CF204D-GW-R2-P2-0	BAFN8	9/11/2014	
	P3	CF204D-GW-R1-P3-0	BAFK1	8/8/2013		CF204D-GW-R2-P3-0	BAFN9	9/11/2014	
CF206D	P1	CF206D-GW-R2-P1-0	BA957	10/10/2012		CF206D-GW-RS-P1-0	BBFJ7	12/4/2014	
	P2	CF206D-GW-R2-P2-0	BA958	10/10/2012		CF206D-GW-RS-P2-0	BBFJ8	12/4/2014	
	P3	CF206D-GW-R2-P3-0	BA959	10/10/2012		CF206D-GW-RS-P3-0	BBFJ9	12/4/2014	
	P4	CF206D-GW-R2-P4-0	BA960	10/10/2012		CF206D-GW-RS-P4-0	BBFK0	12/4/2014	
						CF206D-GW-RS-P4-1	BBFK2	12/4/2014	FD of: CF206D-GW-RS-P4-0
	P5	CF206D-GW-R2-P5-0	BA961	10/10/2012		CF206D-GW-RS-P5-0	BBFK1	12/4/2014	
CF207D	P1	CF207D-GW-R2-P1-0	BA963	10/10/2012		CF207D-GW-RS-P1-0	BBFJ3	12/3/2014	
	P2	CF207D-GW-R2-P2-0	BAFJ0	8/5/2013		CF207D-GW-RS-P2-0	BBFJ4	12/3/2014	
	P3	CF207D-GW-R2-P3-0	BA965	10/10/2012		CF207D-GW-RS-P3-0	BBFJ5	12/3/2014	
	P4	CF207D-GW-R2-P4-0	BA966	10/10/2012		CF207D-GW-RS-P4-0	BBFJ6	12/3/2014	
CF209D*	P1	CF209D-GW-R1-P1-0	BAFP3	6/9/2014		CF209D-GW-R2-P1-0	BBEZ4	9/12/2014	
	P2	CF209D-GW-R1-P2-0	BAFP4	6/9/2014		CF209D-GW-R2-P2-0	BBEZ5	9/12/2014	
	P3	CF209D-GW-R1-P3-0	BAFP5	6/9/2014		CF209D-GW-R2-P3-0	BBEZ6	9/12/2014	
	P4	CF209D-GW-R1-P4-0	BAFP6	6/9/2014		CF209D-GW-R2-P4-0	BBEZ7	9/12/2014	
CF209D*	P1	CF209D-GW-R3-P1-0	-	1/12/2017					
	P2	CF209D-GW-R3-P2-0	-	1/12/2017					
	P2	CF209D-GW-R3-P2-1	-	1/12/2017	FD of: CF209D-GW-R3-P2-0				
	P3	CF209D-GW-R3-P3-0	-	1/12/2017					
	P4	CF209D-GW-R3-P4-0	-	1/12/2017					
CF211D	P1	CF211D-GW-R1-P1-0	BAFP0	6/9/2014		CF211D-GW-R2-P1-0	BBEZ8	9/12/2014	
	P2	CF211D-GW-R1-P2-0	BAFP1	6/9/2014		CF211D-GW-R2-P2-0	BBEZ9	9/12/2014	
	P3	CF211D-GW-R1-P3-0	BAFP2	6/9/2014		CF211D-GW-R2-P3-0	BBF00	9/12/2014	
CF212D	P1	CF212D-GW-R2-P1-0	BA971	10/11/2012		CF212D-GW-RS-P1-0	BBFF5	12/2/2014	
	P2	CF212D-GW-R2-P2-0	BA972	10/11/2012		CF212D-GW-RS-P2-0	BBFF6	12/2/2014	
CF216D	P1	CF216D-GW-R1-P1-0	BAFJ2	8/7/2013		CF216D-GW-R2-P1-0	BBEW2	6/11/2014	
	P2	CF216D-GW-R1-P2-0	BAFJ3	8/7/2013		CF216D-GW-R2-P2-0	BBEW3	6/11/2014	
		CF216D-GW-R1-P2-1	BAFJ4	8/7/2013	FD of: CF216D-GW-R1-P2-0				
	P3	CF216D-GW-R1-P3-0	BAFJ5	8/7/2013		CF216D-GW-R2-P3-0	BBEW4	6/11/2014	
	P4	CF216D-GW-R1-P4-0	BAFJ6	8/7/2013		CF216D-GW-R2-P4-0	BBEX9	9/8/2014	
CF218D	P1	CF218D-GW-R2-P1-0	BA977	10/12/2012		CF218D-GW-RS-P1-0	BBEE7	11/19/2014	
	P2	CF218D-GW-R2-P2-0	BA978	10/12/2012		CF218D-GW-RS-P2-0	BBEE8	11/19/2014	
	P3	CF218D-GW-R2-P3-0	BA979	10/12/2012		CF218D-GW-RS-P3-0	BBEE9	11/19/2014	
		CF218D-GW-R2-P3-1	BA980	10/12/2012	FD of: CF218D-GW-R2-P3-0				
CF222D	P1	CF222D-GW-R2-P1-0	BBEW6	6/11/2014		CF222D-GW-RS-P1-0	BBED1	11/17/2014	
	P2	CF222D-GW-R2-P2-0	BA955	10/9/2012		CF222D-GW-RS-P2-0	BBED2	11/17/2014	
		CF222D-GW-R2-P2-1	BA954	10/9/2012	FD of: CF222D-GW-R2-P2-0				
	P3	CF222D-GW-R2-P3-0	BA956	10/9/2012		CF222D-GW-RS-P3-0	BBED3	12/4/2014	
CF225D	P1	CF225D-GW-R2-P1-0	BA973	10/11/2012		CF225D-GW-RS-P1-0	BBEE3	11/18/2014	
						CF225D-GW-RS-P1-1	BBEE6	11/18/2014	FD of: CF225D-GW-RS-P1-0
	P2	CF225D-GW-R2-P2-0	BA974	10/11/2012		CF225D-GW-RS-P2-0	BBEE4	11/18/2014	
	P3	CF225D-GW-R2-P3-0	BA975	10/11/2012		CF225D-GW-RS-P3-0	BBEE5	11/18/2014	
CF227D	P1	CF227D-GW-R1-P1-0	BAFP8	6/10/2014		CF227D-GW-R2-P1-0	BBEY4	9/10/2014	
	P2	CF227D-GW-R1-P2-0	BAFP9	6/10/2014		CF227D-GW-R2-P2-0	BBEY5	9/10/2014	
		CF227D-GW-R1-P2-1	BAFQ2	6/10/2014	FD of: CF227D-GW-R1-P2-0				
	P3	CF227D-GW-R1-P3-0	BAFQ0	6/10/2014		CF227D-GW-R2-P3-0	BBEY6	9/10/2014	
	P4	CF227D-GW-R1-P4-0	BAFQ1	6/10/2014		CF227D-GW-R2-P4-0	BBEY7	9/10/2014	
CF228D	P1	CF228D-GW-R1-P1-0	BAFQ3	6/10/2014		CF228D-GW-R2-P1-0	BBEY8	9/11/2014	
	P2	CF228D-GW-R1-P2-0	BAFQ4	6/10/2014		CF228D-GW-R2-P2-0	BBEY9	9/11/2014	
	P3	CF228D-GW-R1-P3-0	BAFQ5	6/10/2014		CF228D-GW-R2-P3-0	BBEZ0	9/11/2014	
						CF228D-GW-R2-P3-1	BBEZ1	9/11/2014	FD of: CF228D-GW-R2-P3-0
Traditional Monitoring Wells - OU2 Installed									
CF205D		CF205D-GW-R2-BFF-0	BAFG1	10/17/2012		CF205D-GW-RS-BFF-0	BBFF4	11/19/2014	
		CF205D-GW-R2-BFF-1	BAFG2	10/17/2012	FD of: CF205D-GW-R2-BFF-0				
CF209D-R*		CF-209D-20170324-BD710-N	BD710	3/24/2017					
CF223D		CF223D-GW-R2-BFD-0	BAFF8	10/16/2012		CF223D-GW-RS-BFD-0	BBFF3	11/19/2014	
CF224D		CF224D-GW-R2-BFD-0	BAFG3	10/17/2012		CF224D-GW-RS-BFD-0	BBFG5	11/20/2014	
CF226D		CF226D-GW-R1-BFF-0	BBEX1	6/13/2014		CF226D-GW-R2-BFF-0	BBEY2	9/9/2014	
CF229D		CF229D-GW-R1-BJA-0	BBEW8	6/13/2014		CF229D-GW-R2-BJA-0	BBEY0	9/9/2014	
CF230D		CF230D-GW-R1-BCI-0	BAFK3	12/23/2013		CF230D-GW-R2-BCI-0	BBEW9	6/12/2014	
						CF230D-GW-R2-BCI-1	BBEX0	6/12/2014	FD of: CF230D-GW-R2-BCI-0
Traditional Monitoring Wells - Pre-existing Network									
CF10D		CF10D-GW-R2-BFI-0	BA981	10/15/2012		CF10D-GW-RS-BFI-0	BBED8	11/17/2014	
CF22S		CF22S-GW-R2-AEF-0	BA982	10/15/2012		CF22S-GW-RS-AEF-0	BBED0	11/17/2014	
CF11D		CF11D-GW-RS-BFI-0	BBEE2	11/18/2014					
WRA3-2		WRA3-2-GW-R2-CAF-0	BAFH1	10/18/2012					
WRA2-1		WRA2-1-GW-R2-CAJ-0	BAFH0	10/18/2012					
WRA3-3		WRA3-3-GW-R2-AIA-0	BAFH2	10/18/2012					

Abbreviations

P# Port #
FD Field duplicate

Notes

Wells with gray-shading in the Round 2 columns were sampled only on one occasion.

* Monitoring well CF209D was modified in 2017. It was converted from a multi-port well to a conventional screened well (CF209D-R). Samples were colelcted both before and after the modification.

All GW samples analyzed for the analytical groups shown below (3/24/2017 sample from well CF209D-R also analyzed for ammonia and sulfate).

Target Compound List (TCL) Volatile Organic Compounds
TCL Semivolatile Organic Compounds
TCL Pesticides
TCL Polychlorinated Biphenyls
Target Analyte List (TAL) Metals
Cyanide
Total Organic Carbon (TOC)
Total Dissolved Solids (TDS)
Total Suspended Solids (TSS)
Chloride

Table 2-13a
Monitoring Well Resample Summary - Included Wells
Combe Fill South Landfill OU2
Morris County, New Jersey

Well	Port	Resample ID	Resample CLP ID	Resample Date	Resample QC	Analyses
CF201D	P1	CF201D-GW-R2SV-P1-0	BD0B4	7/7/2015		TCL VOC
	P2	CF201D-GW-R2SV-P2-0	BD0B5	7/7/2015		
	P3	CF201D-GW-R2SV-P3-0	BD0B6	7/7/2015		
	P4	CF201D-GW-R2SV-P4-0	BD0B7	7/7/2015		
CF206D	P1	CF206D-GW-R2SV-P1-0	BD0A4	7/6/2015		
	P2	CF206D-GW-R2SV-P2-0	BD0A5	7/6/2015		
	P3	CF206D-GW-R2SV-P3-0	BD0A6	7/6/2015		
	P4	CF206D-GW-R2SV-P4-0	BD0A7	7/6/2015		
	P5	CF206D-GW-R2SV-P5-0	BD0A8	7/6/2015		
CF207D	P1	CF207D-GW-R2SV-P1-0	BD0A9	7/6/2015		
	P2	CF207D-GW-R2SV-P2-0	BD0B0	7/6/2015		
	P3	CF207D-GW-R2SV-P3-0	BD0B1	7/6/2015		
	P4	CF207D-GW-R2SV-P4-0	BD0B2	7/6/2015		
CF212D	P1	CF212D-GW-R2SV-P1-0	BD0C2	7/7/2015		
	P2	CF212D-GW-R2SV-P2-0	BD0C3	7/7/2015		
CF218D	P1	CF218D-GW-RS2V-P1-0	BD0A0	7/6/2015		
	P2	CF218D-GW-R2SV-P2-0	BD0A1	7/6/2015		
	P3	CF218D-GW-R2SV-P3-0	BD0A2	7/6/2015		
		CF218D-GW-RS2V-P3-1	BD0A3	7/6/2015	FD of: CF218D-GW-R2SV-P3-0	
CF222D	P1	CF222D-GW-R2SV-P1-0	BD0B8	7/7/2015		
		CF222D-GW-R2SV-P1-1	BD0C1	7/7/2015	FD of: CF222D-GW-R2SV-P1-0	
	P2	CF222D-GW-R2SV-P2-0	BD0B9	7/7/2015		
	P3	CF222D-GW-R2SV-P3-0	BD0C0	7/7/2015		

Abbreviations

P#	Port #
FD	Field duplicate
TCL VOC	Target Compound List Volatile Organic Compounds

Table 2-13b
Monitoring Well Sampling Summary - Excluded Wells
Combe Fill South Landfill OU2
Morris County, New Jersey

Well	Sample 1 ID	Sample 1 CLP ID	Sample 1 Date	Sample 1 QC	Sample 2 ID	Sample 2 CLP ID	Sample 2 Date	Sample 2 QC
CF09D	CF09D-GW-R2-BFI-0	BAFF1	10/16/2012		CF09D-GW-RS-BFI-0	BBEA1	11/13/2014	
					CF09D-GW-RS-BFI-1	BBEA2	11/13/2014	FD of: CF09D-GW-RS-BFI-0
CF12D	CF12D-GW-R2-AHI-0	BAFF2	10/15/2012		CF12D-GW-RS-AHI-0	BBEA3	11/14/2014	
CF20S	CF20S-GW-R2-ABB-0	BAFG4	10/17/2012		CF20S-GW-RS-ABB-0	BBFF2	11/19/2014	
MW18D	MW18D-GW-R2-BBE-0	BAFG7	10/17/2012		MW18D-GW-RS-BBE-0	BBFG4	11/20/2014	
CF15D	CF15D-GW-R2-BHI-0	BAFH6	10/19/2012					
D1	D1-GW-R2-AFJ-0	BAFF6	10/16/2012					
D3	D3-GW-RS-BBI-0	BBFG9	11/20/2014					
D5R	D5R-GW-R2-AII-0	BAFH7	10/19/2012					
D9	D9-GW-RS-BAD-0	BBFF1	11/19/2014					
MW6	MW6-GW-RS-ACI-0	BBEC8	11/17/2014					
MW19D	MW19D-GW-R2-AJE-0	BAFH5	10/19/2012					
S6	S6-GW-R2-AFJ-0	BAFF7	10/16/2012					

Abbreviations

FD Field Duplicate

Notes

Wells with gray-shading in the Round 2 columns were sampled only on one occasion.

All GW samples were analyzed for the following analytical groups:

Target Compound List (TCL) Volatile Organic Compounds
TCL Semivolatile Organic Compounds
TCL Pesticides
TCL Polychlorinated Biphenyls
Target Analyte List (TAL) Metals
Cyanide
Total Organic Carbon (TOC)
Total Dissolved Solids (TDS)
Total Suspended Solids (TSS)
Chloride

Table 2-13c
Monitoring Well Inclusion/Exclusion List
Combe Fill South Landfill OU2
Morris County, New Jersey

Well		Well Owner	Completion Date	Total Depth, ft bgs	Screen Interval, ft bgs	Screen Length, ft	Screen Formation	Construction Summary	NJDEP 7:9D Compliant (Y/N)	Other Reason(s) for Exclusion	No. Samples Collected	Included/Excluded (I/E)
CF201D	P1	EPA/HDR	6/26/2012	569	114 - 119	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			240 - 245	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			311 - 316	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P4	EPA/HDR			518 - 523	5	Competent Bedrock	Water FLUTe	N (d)		2	I
CF204D	P1	EPA/HDR	8/1/2013	700	155 - 160	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			195 - 200	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			433 - 438	5	Competent Bedrock	Water FLUTe	N (d)		2	I
CF206D	P1	EPA/HDR	7/10/2012	561	86 - 91	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			147 - 152	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			271 - 276	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P4	EPA/HDR			278 - 283	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P5	EPA/HDR			553 - 558	5	Competent Bedrock	Water FLUTe	N (d)		2	I
CF207D	P1	EPA/HDR	7/13/2012	610	106 - 111	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			182 - 192	10	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			412 - 417	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P4	EPA/HDR			604 - 609	5	Competent Bedrock	Water FLUTe	N (d)		2	I
CF209D*	P1	EPA/HDR	6/6/2014*	700	150 - 160	10	Competent Bedrock	Water FLUTe	N (d)		3	I
	P2	EPA/HDR	Modified in 2017		227 - 237	10	Competent Bedrock	Water FLUTe	N (d)		3	I
	P3	EPA/HDR	(separate entry and		295 - 305	10	Competent Bedrock	Water FLUTe	N (d)		3	I
	P4	EPA/HDR	footnote, below)		335 - 345	10	Competent Bedrock	Water FLUTe	N (d)		3	I
CF211D	P1	EPA/HDR	6/5/2014	500	124 - 131	7	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			215 - 220	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			360 - 365	5	Competent Bedrock	Water FLUTe	N (d)		2	I
CF212D	P1	EPA/HDR	6/21/2012	500	98 - 103	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			153 - 158	5	Competent Bedrock	Water FLUTe	N (d)		2	I
CF216D	P1	EPA/HDR	8/1/2013	700	51 - 71	20	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			205 - 210	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			268 - 273	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P4	EPA/HDR			495 - 500	5	Competent Bedrock	Water FLUTe	N (d)		2	I
CF218D	P1	EPA/HDR	7/31/2012	700	171 - 176	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			292 - 297	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			688 - 693	5	Competent Bedrock	Water FLUTe	N (d)		2	I
CF222D	P1	EPA/HDR	6/4/2012	200	92 - 96	4	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			134 - 139	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			165 - 170	5	Competent Bedrock	Water FLUTe	N (d)		2	I
CF225D	P1	EPA/HDR	7/13/2012	500	76 - 81	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			106 - 111	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			357 - 362	5	Competent Bedrock	Water FLUTe	N (d)		2	I
CF205D		EPA/HDR	6/12/2012	160	150 - 160	10	Competent Bedrock	2" PVC in 6" borehole. Traditional MW construction.	Y		2	I
CF209D-R*		EPA/HDR	6/10/2017	163	150 - 160	10	Competent Bedrock	2" PVC in 6" borehole. Traditional MW construction.	Y		1	I
CF215D		EPA/HDR	N/A	N/A	N/A	N/A	Competent Bedrock	Abandoned (see Notes)	N/A	1	0	E
CF223D		EPA/HDR	6/13/2012	160	145 - 160	15	Competent Bedrock	2" PVC in 6" borehole. Traditional MW construction.	Y		2	I
CF224D		EPA/HDR	6/12/2012	160	145 - 160	15	Competent Bedrock	2" PVC in 6" borehole. Traditional MW construction.	Y		2	I
CF226D		EPA/HDR	5/24/2014	200	105 - 200	95	Competent Bedrock	2" PVC in 6" borehole. Traditional MW construction.	N (e)		2	I
CF227D	P1	EPA/HDR	6/4/2014	482	110 - 120	10	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			150 - 160	10	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			408 - 413	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P4	EPA/HDR			475 - 482	7	Competent Bedrock	Water FLUTe	N (d)		2	I
CF228D	P1	EPA/HDR	6/6/2014	500	58 - 63	5	Competent Bedrock	Water FLUTe	N (d)		2	I
	P2	EPA/HDR			220 - 230	10	Competent Bedrock	Water FLUTe	N (d)		2	I
	P3	EPA/HDR			409 - 419	10	Competent Bedrock	Water FLUTe	N (d)		2	I
CF229D		EPA/HDR	5/24/2014	197	182 - 197	15	Competent Bedrock	2" PVC in 6" borehole. Traditional MW construction.	Y		2	I
CF230D		EPA/HDR	12/6/2013	135	118 - 135	17	Competent Bedrock	2" PVC in 6" borehole. Traditional MW construction.	Y		2	I
CF22S		NJDEP	10/18/2005	50	40 - 50	10	Competent Bedrock	4" PVC in 8" borehole. Traditional MW construction.	Y		2	I
CF11D		NJDEP	8/29/2002	170	145 - 170	25	Competent Bedrock	4" PVC in 8" borehole. Traditional MW construction.	Y		1	I
CF10D		NJDEP	8/26/2002	170	145 - 170	25	Competent Bedrock	4" PVC in 8" borehole. Traditional MW construction.	Y		2	I
WRA3-2		NJDEP	11/8/1993	220	196 - 220	24	Competent Bedrock	6" open borehole. Steel casing set to 196', more than 10' into competent bedrock.	Y		1	I
WRA2-1		NJDEP	10/25/1993	221	196 - 221	25	Competent Bedrock	6" open borehole. Steel casing set to 196', more than 10' into competent bedrock.	Y		1	I
WRA3-3		NJDEP	11/1/1993	103	80 - 103	23	Competent Bedrock	6" open borehole. Steel casing set to 80', more than 10' into competent bedrock.	Y		1	I
MW6		NJDEP	6/30/1993	41	15 - 40	25	Saprolite	4" PVC in 12" borehole. Traditional MW construction.	Y	2	1	E
MW18D		NJDEP	8/5/2010	143	76 - 143	67	Competent Bedrock	6" open borehole. Steel casing only 3' into competent bedrock.	N (b,c)		2	E
D9		NJDEP	12/26/1984	125	81 - 125	44	Competent Bedrock	6" open borehole. Steel casing only 6' into competent bedrock.	N (b,c)		1	E
D3		NJDEP	1/10/1985	70	49 - 85	36	Competent Bedrock	6" open borehole. Steel casing only 7' into competent bedrock. MW later modified.	N (b,c)		1	E
CF20S		NJDEP	10/15/2005	16	6 - 16	10	Unconsolidated.	4" PVC in 8" borehole. Traditional MW construction.	Y	2	2	E
CF12D		NJDEP	8/19/2005	90	65 - 90	25	Competent Bedrock	4" PVC in 6" borehole. Traditional MW construction, but inadequate annular space.	N (a)		2	E
CF09D		NJDEP	8/19/2005	170	145 - 170	25	Competent Bedrock	4" PVC in 6" borehole. Traditional MW construction, but inadequate annular space.	N (a)		2	E
CF15D		NJDEP	8/17/2005	190	165 - 190	25	Competent Bedrock	4" PVC in 6" borehole. Traditional MW construction, but inadequate annular space.	N (a)		1	E
D1		NJDEP	11/19/1984	147	91 - 147	56	Competent Bedrock	6" open borehole. Steel casing only 9' into competent bedrock.	N (b,c)		1	E
D5R		NJDEP	12/5/2008	125	50 - 125	75	Saprolite/Competent Bedrock	6" open borehole. Steel casing not into competent bedrock.	N (b,c)	2	1	E
MW19D		NJDEP	8/20/2010	107	80 - 107	27	Competent Bedrock	6" open borehole. Steel casing only 9' into competent bedrock.	N (b,c)		1	E
S6		NJDEP	1/8/1985	69	54 - 69	15	Saprolite	4" stainless steel. Borehole diameter unspecified.	Y	2	1	E

Table 2-13c
Monitoring Well Inclusion/Exclusion List
Combe Fill South Landfill OU2
Morris County, New Jersey

Well	Well Owner	Completion Date	Total Depth, ft bgs	Screen Interval, ft bgs	Screen Length, ft	Screen Formation	Construction Summary	NJDEP 7:9D Compliant (Y/N)	Other Reason(s) for Exclusion	No. Samples Collected	Included/Excluded (I/E)
Packer Testing											
CF201D	EPA/HDR	12/5/2011	569	235 - 255	20	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		12/5/2011		310 - 330	20	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		12/1/2011		515 - 525	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF211D	EPA/HDR	12/22/2011	500	125 - 140	15	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		12/8/2011		215 - 225	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF222D	EPA/HDR	12/16/2011	200	90 - 100	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		12/19/2011		140 - 150	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF223D	EPA/HDR	12/20/2011	200	85 - 90	5	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		12/21/2011		145 - 160	15	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF224D	EPA/HDR	12/12/2011	200	80 - 90	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		12/9/2011		145 - 160	15	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF215D	EPA/HDR	1/4/2012	200	110 - 130	20	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/3/2012		144 - 154	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF205D	EPA/HDR	1/5/2012	200	150 - 160	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF206D	EPA/HDR	1/13/2012	561	82 - 92	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/12/2012		159 - 169	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/11/2012		255 - 285	30	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/10/2012		550 - 561	11	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF207D	EPA/HDR	1/18/2012	610	105 - 115	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/18/2012		182 - 192	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/17/2012		410 - 420	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF204D	EPA/HDR	1/24/2012	700	155 - 165	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/23/2012		191 - 201	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/20/2012		432 - 442	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF209D	EPA/HDR	1/27/2012	700	335 - 345	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/30/2012		295 - 320	25	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/30/2012		227 - 237	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/31/2012		150 - 160	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF225D	EPA/HDR	2/3/2012	500	105 - 115	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/3/2012		75 - 85	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF218D	EPA/HDR	2/6/2012	700	310 - 320	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/7/2012		290 - 300	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/7/2012		205 - 215	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/8/2012		170 - 180	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF212D	EPA/HDR	2/13/2012	500	370 - 380	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/14/2012		148 - 158	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/15/2012		90 - 110	20	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/15/2012		60 - 70	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF216D	EPA/HDR	2/16/2012	700	270 - 300	30	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/17/2012		205 - 215	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/21/2012		115 - 130	15	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/22/2012		50 - 70	20	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF226D	EPA/HDR	2/24/2014	200	49 - 54	5	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/24/2014		105 - 200	95	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF227D	EPA/HDR	2/6/2014	482	110 - 120	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/6/2014		150 - 160	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		1/30/2014		408 - 413	5	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/4/2014		475 - 482*	7	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF228D	EPA/HDR	2/12/2014	500	58 - 63	5	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/11/2014		205 - 235	30	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/10/2014		409 - 419	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
CF229D	EPA/HDR	2/20/2014	197	52 - 62	10	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/20/2014		138 - 158	20	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E
		2/19/2014		185 - 196*	11	Competent Bedrock	Packers on steel riser in open borehole.	N/A (f)	3	1	E

Footnotes/Abbreviations

a	Inadequate annular space (7:9D-2.2(a)9).
b	Steel casing not adequately set in bedrock (7:9D-2.4(b)1).
c	Open hole length exceeds maximum allowable (7:9D-2.4(a)4).
d	Variance obtained from NJDEP for Water FLUTe systems.
e	Variance obtained from NJDEP for long screen interval. Competent unfractured rock below water producing zone.
f	Not Applicable. Borehole had not yet been completed as a monitoring well.
1	Abandoned
2	Screened outside or across competent bedrock and therefore not part of OU2.
3	Packer testing for screening to inform final well construction. Submersible pump used, not low-flow protocol.
N/A	Not applicable
P#	Water FLUTe port

Notes:

*: Well CF209D was converted from a multi-port well to a screened well (CF209D-R) in March 2017.

Boring CF215D was not completed as a monitoring well. The borehole was packer tested and abandoned after review of the packer test analytical results because of poor water production and because nearby well CF205D provided delineation to the northeast.

Table 2-14a
November 2014 Surface Water Sampling Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Stream	Transect	Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	Wet/Dry	Surface Water Sample Name	Sample Date	Sample Depth, ft bws	Stream Depth, ft	Analyses	QA/QC
ET	1	426352.0	704181.4	Dry	ETSW0001-SW-AA-RS1-0	11/11/2014	0.25	0.5	TCL VOCs, TCL SVOCs, TCL Pesticides, TCL PCBs, TAL Metals (total & dissolved), cyanide, TOC, TDS/TSS, Chloride, Alkalinity	
				Wet	ETSW0001-SW-AA-RS2-0	11/18/2014	0.25	0.5		
ET	2	426217.4	704567.0	Dry	ETSW0002-SW-AA-RS1-0	11/11/2014	0.25	0.5		
				Wet	ETSW0002-SW-AA-RS2-0	11/18/2014	0.25	0.5		
ET	3	426029.0	704723.6	Dry	ETSW0003-SW-AB-RS1-0	11/11/2014	0.5	1		
				Wet	ETSW0003-SW-AB-RS2-0	11/18/2014	0.5	1		
LU	1	428800.3	708114.7	Dry	LUSW0001-SW-AF-RS1-0	11/12/2014	2.5	5		
				Dry	*LUSW0001-SW-AF-RS1-1*	*11/12/2014*	*2.5*	*5*		*Duplicate of LUSW0001-SW-AF-RS1-0*
				Wet	LUSW0001-SW-AF-RS2-0	11/18/2014	2.5	5.76		
LU	2	428366.3	708016.4	Dry	LUSW0002-SW-AA-RS1-0	11/12/2014	0.25	0.5		
				Wet	LUSW0002-SW-AA-RS2-0	11/18/2014	0.25	0.5		
LU	3	427639.3	708143.8	Dry	LUSW0003-SW-AD-RS1-0	11/13/2014	1.5	3		
				Wet	LUSW0003-SW-AD-RS2-0	11/18/2014	1.5	3		
TB	1	425271.3	703472.7	Dry	TBSW0001-SW-AB-RS1-0	11/11/2014	0.5	1		
				Wet	TBSW0001-SW-AB-RS2-0	11/18/2014	0.5	1		
TB	2	424635.2	703845.7	Dry	TBSW0002-SW-AA-RS1-0	11/12/2014	0.25	0.5		
				Wet	TBSW0002-SW-AB-RS2-0	11/18/2014	0.5	1		
				Wet	*TBSW0002-SW-AB-RS2-1*	*11/18/2014*	*0.5*	*1*		*Duplicate of TBSW0002-SW-AB-RS2-0*
TB	3	424278.1	704874.5	Dry	TBSW0003-SW-AA-RS1-0	11/12/2014	0.25	0.5		
				Wet	TBSW0003-SW-AA-RS2-0	11/18/2014	0.25	0.5		
TU	1	423086.0	706241.6	Dry	TUSW0001-SW-AA-RS1-0	11/13/2014	0.25	0.5		
				Wet	TUSW0001-SW-AA-RS2-0	11/18/2014	0.25	0.5		
TU	2	423338.6	705995.6	Dry	TUSW0002-SW-AA-RS1-0	11/13/2014	0.25	0.5		
				Wet	TUSW0002-SW-AA-RS2-0	11/18/2014	0.25	0.5		
TU	3	423391.0	705963.7	Dry	TUSW0003-SW-AA-RS1-0	11/13/2014	0.25	0.5		
				Wet	TUSW0003-SW-AA-RS2-0	11/18/2014	0.25	0.5		

Stream Names

ET	Trout Brook Uncoded Tributary (aka, East Trout Brook)
TB	Trout Brook
LU	Lamington River Unnamed Tributary
TU	Tanners Brook Uncoded Tributary

Abbreviations

ft	feet
bgs	below ground surface
TCL	Target Compound List
VOC	Volatile Organic Compounds
SVOC	Semivolatile Organic Compounds
PCBs	Polychlorinated Biphenyls
TAL	Target Analyte List
TOC	Total Organic Carbon
TDS/TSS	Total Dissolved Solids/Total Suspended Solids

Notes

All SW samples were analyzed for the same analytical groups.

Table 2-14b
September 2017 Springs, Seeps and Surface Water Background Sampling Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Spring, Seep or Stream	Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	Sample Identifier	Sample Date	Sample Depth, ft bws	Stream Depth, inches	Analyses	QA/QC
Springs								
Spring-A1	708146.6112	427232.4233	SPRING_A1-SW-AA-0	9/22/2017	0.25	0.5-60	TCL VOCs, SVOCs, SVOCs - SIM, Pesticides, PCBs; TAL Metals (total & dissolved), cyanide, TOC, TDS/TSS, Chloride, Alkalinity	
Spring-A2	708201.8615	427245.3614	SPRING_A2-SW-AC-0	9/25/2017	1.0	0.5-60		
Seeps								
Seep-A1	708187.7107	427486.2988	SEEP_A1-SW-AA-0	9/22/2017	0.25	1-2	TCL VOCs, SVOCs, SVOCs - SIM, Pesticides, PCBs; TAL Metals (total & dissolved), cyanide, TOC, TDS/TSS, Chloride, Alkalinity	
Seep-A1	708187.7107	427486.2988	SEEP_A1-SW-AA-1	9/22/2017	0.25	1-2		*Duplicate of SEEP_A1-SW-AA-0*
Seep-A2	708259.4406	427400.6064	SEEP_A2-SW-AA-0	9/22/2017	0.25	2-3		
Seep-B1	708059.7125	427537.0992	SEEP_B1-SW-AA-0	9/26/2017	0.25	2-3		
Seep-B2	707967.1989	427476.7512	SEEP_B2-SW-AA-0	9/26/2017	0.25	2-3		
Streams								
TU	709304.6439	425140.603	TUSW0004-SW-AA-0	9/20/2017	0.25	1-4	TCL VOCs, SVOCs, SVOCs - SIM, Pesticides, PCBs; TAL Metals (total & dissolved), cyanide, TOC, TDS/TSS, Chloride, Alkalinity	
TU	709228.5996	425226.8048	TUSW0005-SW-AA-0	9/20/2017	0.25	2		
TU	709126.2977	425328.3498	TUSW0006-SW-AA-0	9/20/2017	0.25	1-2		
TU	709077.4553	425409.4988	TUSW0007-SW-AA-0	9/20/2017	0.25	1-2		
TU	709035.1096	425391.5219	TUSW0008-SW-AA-0	9/21/2017	0.25	1-2		
TU	706579.701	421666.0019	TUSW0009-SW-AA-0	9/25/2017	0.25	1-12		
TU	706306.527	421750.4427	TUSW0010-SW-AA-0	9/21/2017	0.25	1-2		
TU	706070.8639	421902.5326	TUSW0011-SW-AA-0	9/21/2017	0.25	2-4		
TU	704936.078	420437.896	TUSW0012-SW-AA-0	9/25/2017	0.25	6-12		
TU	706659.1012	421635.7656	TUSW0013-SW-AA-0	9/25/2017	0.25	2-3		

Stream Names

TU	Tanners Brook/Tanners Brook Uncoded Tributary

All SW samples were analyzed for the same analytical groups.
All samples collected during dry-weather conditions.

Abbreviations

bws	below water surface	TAL	Target Analyte List
VOC	Volatile Organic Compounds	TOC	Total Organic Carbon
SVOCs	Semivolatile Organic Compounds	TDS/TSS	Total Dissolved Solids/Total Suspended Solids
SIM	Select Ion Monitoring	TCL	Target Compound List
PCBs	Polychlorinated Biphenyls		

Table 2-15a
November 2014 Sediment Sampling Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Stream	Transect	Sediment Sample Name	Sample Date	Sample Depth, ft bgs	Location on Transect	Analyses	QA/QC
ET	1	ETSD0001-SD-AA-AB-RS-0	11/11/2014	0-0.5	Mid-stream	Full Suite*	
ET	1	ETSD0001-SD-AB-AC-RS-0	11/11/2014	0.5-1.0		TCL VOCs	
ET	1	ETSD0002-SD-AA-AB-RS-0	11/11/2014	0-0.5	Stream bank	Full Suite*	
ET	1	ETSD0002-SD-AB-AC-RS-0	11/11/2014	0.5-1.0		TCL VOCs	
ET	2	ETSD0003-SD-AA-AB-RS-0	11/11/2014	0-0.5	Mid-stream	Full Suite*	
ET	2	ETSD0003-SD-AB-AC-RS-0	11/11/2014	0.5-1.0		TCL VOCs	
ET	2	ETSD0004-SD-AA-AB-RS-0	11/11/2014	0-0.5	Stream bank	Full Suite*	
ET	2	ETSD0004-SD-AB-AC-RS-0	11/11/2014	0.5-1.0		TCL VOCs	
ET	3	ETSD0005-SD-AA-AB-RS-0	11/11/2014	0-0.5	Mid-stream	Full Suite*	
ET	3	ETSD0005-SD-AB-AC-RS-0	11/11/2014	0.5-1.0		TCL VOCs	
ET	3	ETSD0006-SD-AA-AB-RS-0	11/11/2014	0-0.5	Stream bank	Full Suite*	
ET	3	ETSD0006-SD-AB-AC-RS-0	11/11/2014	0.5-1.0		TCL VOCs	
LU	1	LUSD0001-SD-AA-AB-RS-0	11/12/2014	0-0.5	Mid-pond	Full Suite*	
LU	1	LUSD0001-SD-AB-AC-RS-0	11/12/2014	0.5-1.0		TCL VOCs	
LU	1	LUSD0002-SD-AA-AB-RS-0	11/12/2014	0-0.5	Pond bank	Full Suite*	
LU	1	LUSD0002-SD-AB-AC-RS-0	11/12/2014	0.5-1.0		TCL VOCs	
LU	2	LUSD0003-SD-AA-AB-RS-0	11/12/2014	0-0.5	Mid-stream	Full Suite*	
LU	2	LUSD0003-SD-AB-AC-RS-0	11/12/2014	0.5-1.0		TCL VOCs	
LU	2	LUSD0004-SD-AA-AB-RS-0	11/12/2014	0-0.5	Stream bank	Full Suite*	
LU	*2*	*LUSD0004-SD-AA-AB-RS-1*	*11/12/2014*	*0-0.5*		Full Suite*	*Duplicate of LUSD0004-SD-AA-AB-RS-0*
LU	2	LUSD0004-SD-AB-AC-RS-0	11/12/2014	0.5-1.0		TCL VOCs	
LU	*2*	*LUSD0004-SD-AB-AC-RS-1*	*11/12/2014*	*0.5-1.0*		TCL VOCs	*Duplicate of LUSD0004-SD-AB-AC-RS-0*
LU	3	LUSD0005-SD-AA-AB-RS-0	11/13/2014	0-0.5	Pond bank	Full Suite*	
LU	3	LUSD0005-SD-AB-AC-RS-0	11/13/2014	0.5-1.0		TCL VOCs	
LU	3	LUSD0006-SD-AA-AB-RS-0	11/13/2014	0-0.5	Pond bank	Full Suite*	
LU	3	LUSD0006-SD-AB-AC-RS-0	11/13/2014	0.5-1.0		TCL VOCs	
TB	1	TBSD0001-SD-AA-AB-RS-0	11/11/2014	0-0.5	Mid-stream	Full Suite*	
TB	1	TBSD0001-SD-AB-AC-RS-0	11/11/2014	0.5-1.0		TCL VOCs	
TB	1	TBSD0002-SD-AA-AB-RS-0	11/11/2014	0-0.5	Stream bank	Full Suite*	
TB	1	TBSD0002-SD-AB-AC-RS-0	11/11/2014	0.5-1.0		TCL VOCs	
TB	2	TBSD0003-SD-AA-AB-RS-0	11/12/2014	0-0.5	Mid-stream	Full Suite*	
TB	2	TBSD0003-SD-AB-AC-RS-0	11/12/2014	0.5-1.0		TCL VOCs	
TB	2	TBSD0004-SD-AA-AB-RS-0	11/12/2014	0-0.5	Stream bank	Full Suite*	
TB	2	TBSD0004-SD-AB-AC-RS-0	11/12/2014	0.5-1.0		TCL VOCs	
TB	3	TBSD0005-SD-AA-AB-RS-0	11/12/2014	0-0.5	Mid-stream	Full Suite*	
TB	3	TBSD0005-SD-AB-AC-RS-0	11/12/2014	0.5-1.0		TCL VOCs	
TB	3	TBSD0006-SD-AA-AB-RS-0	11/12/2014	0-0.5	Stream bank	Full Suite*	
TB	3	TBSD0006-SD-AB-AC-RS-0	11/12/2014	0.5-1.0		TCL VOCs	
TU	1	TUSD0001-SD-AA-AB-RS-0	11/13/2014	0-0.5	Mid-stream	Full Suite*	
TU	1	TUSD0001-SD-AB-AC-RS-0	11/13/2014	0.5-1.0		TCL VOCs	
TU	1	TUSD0002-SD-AA-AB-RS-0	11/13/2014	0-0.5	Stream bank	Full Suite*	
TU	*1*	*TUSD0002-SD-AA-AB-RS-1*	*11/13/2014*	*0-0.5*		Full Suite*	*Duplicate of TUSD0002-SD-AA-AB-RS-0*
TU	1	TUSD0002-SD-AB-AC-RS-0	11/13/2014	0.5-1.0		TCL VOCs	
TU	*1*	*TUSD0002-SD-AB-AC-RS-1*	*11/13/2014*	*0.5-1.0*		TCL VOCs	*Duplicate of TUSD0002-SD-AB-AC-RS-0*
TU	2	TUSD0003-SD-AA-AB-RS-0	11/13/2014	0-0.5	Mid-stream	Full Suite*	
TU	2	TUSD0003-SD-AB-AC-RS-0	11/13/2014	0.5-1.0		TCL VOCs	
TU	2	TUSD0004-SD-AA-AB-RS-0	11/13/2014	0-0.5	Stream bank	Full Suite*	
TU	2	TUSD0004-SD-AB-AC-RS-0	11/13/2014	0.5-1.0		TCL VOCs	
TU	3	TUSD0005-SD-AA-AB-RS-0	11/13/2014	0-0.5	Mid-stream	Full Suite*	
TU	3	TUSD0005-SD-AB-AC-RS-0	11/13/2014	0.5-1.0		TCL VOCs	
TU	3	TUSD0006-SD-AA-AB-RS-0	11/13/2014	0-0.5	Stream bank	Full Suite*	
TU	3	TUSD0006-SD-AB-AC-RS-0	11/13/2014	0.5-1.0		TCL VOCs	

Stream Names

ET	Trout Brook Uncoded Tributary aka East Trout Brook
TB	Trout Brook
LU	Lamington River Unnamed Tributary
TU	Tanners Brook Uncoded Tributary

Notes

Full Suite* TCL SVOCs, TCL Pesticides, TCL PCBs, TAL Metals, cyanide, TOC, grain size

Abbreviations

ft	feet	PCBs	Polychlorinated Biphenyls
bgs	below ground surface	TAL	Target Analyte List
VOC	Volatile Organic Compounds	TOC	Total Organic Carbon
SVOCs	Semivolatile Organic Compounds	TCL	Target Compound List

Table 2-15b
September 2017 Background Sediment Sampling Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Stream	Sediment Sample Name	Sample Date	Sample Depth, ft bgs	Analyses	QA/QC
TU	TUSD0007-SD-AA-AB-0	9/20/2017	0-0.5	Full Suite*	
TU	TUSD0007-SD-AA-AB-1	9/20/2017	0-0.5	Full Suite*	*Duplicate of TUSD0007-SD-AA-AB-0*
TU	TUSD0007-SD-AB-AC-0	9/20/2017	0.5-1.0	TCL VOCs	
TU	TUSD0007-SD-AB-AC-1	9/20/2017	0.5-1.0	TCL VOCs	*Duplicate of TUSD0007-SD-AB-AC-0*
TU	TUSD0008-SD-AA-AB-0	9/20/2017	0-0.5	Full Suite*	
TU	TUSD0008-SD-AB-AC-0	9/20/2017	0.5-1.0	TCL VOCs	
TU	TUSD0009-SD-AA-AB-0	9/20/2017	0-0.5	Full Suite*	
TU	TUSD0009-SD-AB-AC-0	9/20/2017	0.5-1.0	TCL VOCs	
TU	TUSD0010-SD-AA-AB-0	9/20/2017	0-0.5	Full Suite*	
TU	TUSD0010-SD-AB-AC-0	9/20/2017	0.5-1.0	TCL VOCs	
TU	TUSD0011-SD-AA-AB-0	9/21/2017	0-0.5	Full Suite*	
TU	TUSD0011-SD-AB-AC-0	9/21/2017	0.5-1.0	TCL VOCs	
TU	TUSD0012-SD-AA-AB-0	9/25/2017	0-0.5	Full Suite*	
TU	TUSD0012-SD-AB-AC-0	9/25/2017	0.5-1.0	TCL VOCs	
TU	TUSD0013-SD-AA-AB-0	9/21/2017	0-0.5	Full Suite*	
TU	TUSD0013-SD-AB-AC-0	9/21/2017	0.5-1.0	TCL VOCs	
TU	TUSD0014-SD-AA-AB-0	9/21/2017	0-0.5	Full Suite*	
TU	TUSD0014-SD-AB-AC-0	9/21/2017	0.5-1.0	TCL VOCs	
TU	TUSD0015-SD-AA-AB-0	9/25/2017	0-0.5	Full Suite*	
TU	TUSD0015-SD-AB-AC-0	9/25/2017	0.5-1.0	TCL VOCs	
TU	TUSD0016-SD-AA-AB-0	9/25/2017	0-0.5	Full Suite*	
TU	TUSD0016-SD-AB-AC-0	9/25/2017	0.5-1.0	TCL VOCs	

Stream Names

TU	Tanners Brook/Tanners Brook Uncoded Tributary

Notes

Full Suite*:	TCL SVOCs, TCL Pesticides, TCL PCBs, TAL Metals, cyanide, TOC, grain size

Abbreviations

ft	feet	PCBs	Polychlorinated Biphenyls
bgs	below ground surface	TAL	Target Analyte List
VOC	Volatile Organic Compounds	TOC	Total Organic Carbon
SVOCs	Semivolatile Organic Compounds	TCL	Target Compound List

Table 2-16
Soil Boring Sampling Summary
Combe Fill South Landfill OU2
Morris County, New Jersey

Boring ID	Ground Surface Elevation, ft AMSL	Easting (NJ State Plane), US Survey Feet NAD83	Northing (NJ State Plane), US Survey Feet NAD83	Boring Depth, ft bgs	Bedrock Surface Elevation, ft AMSL	Sample Depth, ft bgs	Sample Name	Sample Date	Analyses	QA/QC
CFB001	831	426919.5	706248.2	18	813	3.5-5.5	CFB001-SS-RS-AH-AL-0	11/18/2014	Full Suite + GS	
						14-16	CFB001-SS-RS-BC-BG-0	11/18/2014	Full Suite	
CFB002	826	426836.3	706274.7	36	790	4-6	CFB002-SS-RS-AE-AI-0	11/18/2014	Full Suite	
						4-6	*CFB002-SS-RS-AE-AI-1*	*11/18/2014*	*Full Suite*	*Duplicate of CFB002-SS-RS-AE-AI-0*
						10-12	CFB002-SS-RS-AU-AY-0	11/18/2014	Full Suite	
						20-22	CFB002-SS-RS-BO-BS-0	11/18/2014	Full Suite	
						30-32	CFB002-SS-RS-CI-CM-0	11/19/2014	Full Suite + GS	
						35-36	CFB002-SS-RS-CS-CU-0	11/19/2014	Full Suite except inorganics (not enough volume)	
CFB003	818	426336.6	705593	28	790	1.5-3.5	CFB003-SS-RS-AD-AH-0	11/17/2014	Full Suite	
						10-12	CFB003-SS-RS-AU-AY-0	11/17/2014	Full Suite	
						20-22	CFB003-SS-RS-BO-BS-0	11/17/2014	Full Suite	
CFB004	836	426017.7	706735.7	46	790	10-12	CFB004-SS-RS-AU-AY-0	11/24/2014	Full Suite	
						20-22	CFB004-SS-RS-BO-BS-0	11/24/2014	Full Suite + GS	
						32-34	CFB004-SS-RS-CM-CQ-0	11/24/2014	Full Suite	
						32-34	*CFB004-SS-RS-CM-CQ-1*	*11/24/2014*	*Full Suite*	*Duplicate of CFB004-SS-RS-CM-CQ-0*
						40-42	CFB004-SS-RS-DC-DG-0	11/24/2014	Full Suite	
CFB005	823	426743.7	706306.2	72	751	3.5-5.5	CFB005-SS-RS-AH-AL-0	11/19/2014	Full Suite	
						10-12	CFB005-SS-RS-AU-AY-0	11/19/2014	Full Suite + GS	
						20-22	CFB005-SS-RS-BO-BS-0	11/19/2014	Full Suite	
						30-32	CFB005-SS-RS-CI-CM-0	11/20/2014	Full Suite	
						40-42	CFB005-SS-RS-DC-DG-0	11/20/2014	Full Suite	
						50-52	CFB005-SS-RS-DW-EA-0	11/20/2014	Full Suite	
						60-62	CFB005-SS-RS-EQ-EU-0	11/20/2014	Full Suite	
						70-72	CFB005-SS-RS-FK-F0-0	11/21/2014	Full Suite	

Notes

Full Suite - TCL VOCs, TCL SVOCs, TCL Pesticides, TCL PCBs, TAL Metals, cyanide, TOC

Full Suite + GS - Full suite, listed above, plus grain size

Abbreviations

ft	feet
bgs	below ground surface

Table 3-1
Borehole Testing Data Summary for Sample Port/Screen Intervals
Combe Fill South Landfill OU2
Morris County, New Jersey

Well ID	Borehole Depth, ft bgs	Surface Elevation, ft amsl	Elevation Top of Inner Casing, ft amsl	Casing Depth, ft bgs	Bedrock Surface, ft bgs	Bedrock Surface Elevation, ft amsl	Flute-Calculated Borehole Transmissivity, cm2/s	Port No.	Zone/Screen Interval, ft bgs	Monitored Fracture Depth, ft bgs	Monitored Fracture Elevation, ft amsl	FLUTe-Calculated Fracture Transmissivity, cm2/s	Comment
Multiport Wells - Water FLUTe Systems in 6 inch borehole													
CF201D	569	690.7	689.71	59	49	642	15	P1	114 - 119	117	574	0.50	
								P2	240 - 245	244	447	0.38	
								P3	311 - 316	315	376	0.37	Upward flow from fracture at 244 ft bgs.
								P4	518 - 523	520	171	4.08	Little flow below.
CF204D	700	777.1	775.90	66	60	717	0.85	P1	155 - 160	157	620	0.04	
								P2	195 - 200	199	578	0.03	
								P3	433 - 438	435	342	<0.02	No measurable flow in borehole.
CF206D	561	798.4	797.72	80.5	70.0	728	64.9	P1	86 - 91	89	709	NM	
								P2	147 - 152	149	649	7.50	
								P3	271 - 276	275	523	3.00	
								P4	278 - 283	280	518	3.00	Fractures at 225 and 280 ft receive water
								P5	553 - 558	556	242	16.10	from above and below.
CF207D	610	791.4	790.78	78	40	751	6	P1	106 - 111	109	682	0.06	
								P2	182 - 192	185	606	0.06	
								P3	412 - 417	415	376	0.50	
								P4	604 - 609	609	182	1.75	
CF209D	700	834.6	834.78	95	95	740	3	P1	150 - 160	155	680	0.10	
								P2	227 - 237	230	605	0.10	Profile indicates multiple fractures with low
								P3	295 - 305	300	535	0.11	Transmissivities. Moderate downward
								P4	335 - 345	336	499	0.08	flow.
CF211D	500	823.1	822.00	99	96	727	2	P1	124 - 131	127	696	0.05	Moderate downward flow to 218 fracture.
								P2	215 - 220	218	605	0.02	Lower downward flow below. Most
								P3	360 - 365	366	457	0.01	transmissivity near bedrock surface.
CF212D	500	803.8	804.46	58		804	1	P1	98 - 103	99	705	<0.01	Very low flow. Mostly downward. Most
								P2	153 - 158	154	650	<0.01	transmissivity near bedrock surface.
CF216D	700	797.1	797.48	14	4	793	100	P1	51 - 71	60	737	4.70	
								P2	205 - 210	206	591	1.50	Moderate upward flow from 295 ft
								P3	268 - 273	272	525	2.20	fracture (T=4.2). Very low downward flow
								P4	495 - 500	497	300	0.25	below.
CF218D	700	775.2	774.16	72	50	725	30	P1	171 - 176	174	601	1.30	
								P2	292 - 297	294	481	3.70	Moderate upward flow from 315 ft
								P3	688 - 693	691	84	<0.01	fracture. Very low flow below.
CF222D	200	805.6	808.53	70	60	746	1	P1	92 - 96	94	712	0.03	Low downward flow.
								P2	134 - 139	135	671	0.02	
								P3	165 - 170	168	638	0.02	

Table 3-1
Borehole Testing Data Summary for Sample Port/Screen Intervals
Combe Fill South Landfill OU2
Morris County, New Jersey

Well ID	Borehole Depth, ft bgs	Surface Elevation, ft amsl	Elevation Top of Inner Casing, ft amsl	Casing Depth, ft bgs	Bedrock Surface, ft bgs	Bedrock Surface Elevation, ft amsl	Flute-Calculated Borehole Transmissivity, cm2/s	Port No.	Zone/Screen Interval, ft bgs	Monitored Fracture Depth, ft bgs	Monitored Fracture Elevation, ft amsl	FLUTe-Calculated Fracture Transmissivity, cm2/s	Comment
CF225D	500	794.5	797.46	65	45	750	3	P1	76 - 81	77	718	0.4	
								P2	106 - 111	108	687	0.3	
								P3	357 - 362	358	437	<0.01	Low upward flow above 200 ft. Little flow underneath 200 ft.
CF227D	482	819.03	819.28	90	70	749	350	P1	110 - 120	115	704	*	Strong downward flow.
								P2	150 - 160	158	661	*	
								P3	408 - 413	410	409	*	
								P4	475 - 482	480	339	42	
CF228D	500	825.97	825.99	58	50	776	1.2	P1	58 - 63	62	764	0.01	Moderate downward flow.
								P2	220 - 230	226	600	0.03	
								P3	409 - 419	417	409	0.31	
Traditional Monitoring Wells - 2 inch PVC in 6 inch borehole													
CF205D	160	856.4	858.84	19	5	854	0.1		150 - 160	155	704	0.01	Low downward flow.
CF223D	160	812.6	811.63	48	40	772	3		145 - 160	150	662	0.1	Upward flow from 125 ft up and mainly low downward flow below.
CF224D	160	818.9	821.55	37	27	795	2		145 - 160	148	674	<0.01	Upward flow from 125 ft up and mainly low downward flow below. Most transmissivity near bedrock surface.
CF226D	200	869.01	869.32	20	5	864	7		105 - 200	105-200		<0.01	Most transmissivity between 40-60 ft bgs.
CF229D	197	785.13	785.16	52	35	750	2		182 - 197	195	590	0.25	Moderate downward flow.
CF230D	135	696.48	698.06	--	26	672	NT		120 - 135	130	568	NT	Not tested

Abbreviations

ft	foot
bgs	below ground surface
amsl	above mean sea level
P#	FLUTe Port Number

Table 4-1 Vertical Extent of Groundwater Contamination
Combe Fill South RI/FS
Chester and Washington Townships, New Jersey

Well/Total Depth (ft. bgs)	Surface Elevation (site benchmark datum)	Depth to Competent Bedrock (ft. bgs)	Maximum Depth of Liner Eversion (ft. bgs)	Elevation in Rock of Liner Eversion (site benchmark datum)	Maximum Depth of Liner Eversion (ft. below competent rock surface)	Remaining Transmissivity at Maximum Liner Eversion Depth (cm^2/ second)	Maximum Depth Range for Concentrations above Criteria[1] (ft. bgs)	Vertical Flow Direction
CF-201D/571	690.7	30	570	120.7	540.0	0.28	235-311	Upwards
CF-204D/700	777.1	56	205	*	149.0	0.15	433-438	Artesian
CF-205D/198	856.4	6	173	683.4	167.0	0.025	160-173	Down or none
CF-206D/561	798.4	70	561	237.4	491.0	1.75	558-561	Artesian
CF-207D/561	791.4	40	490	301.4	450.0	0.6	604-609	Down or none
CF-209D/700	834.6	65	480	354.6	415.0	0.076	335-345	Down or none
CF-211D/499	823.1	87	359	464.1	272.0	0.12	360-365	Down or none
CF-212D/500	803.8	50	220	583.8	170.0	0.16	158-220	Down or none
CF-215D/200	859.8	15	68	791.8	53.0	0.021	No COCs	Down or none
CF-216D/700	797.1	0	539	258.1	539.0	0.13	500-539	Upwards
CF-218D/700	775.2	67	698	77.2	631.0	0.2	693-698	Upwards
CF-222D/200	805.6	60	200	605.6	140.0	0	170-200	Down or none
CF-223D/201	812.6	38	195	617.6	157.0	0.025	160-195	Upwards
CF-224D/200	818.9	27	140	678.9	113.0	0.038	145-160	Upwards
CF-225D/500	794.5	45	177	617.5	132.0	0.095	357-362	Upwards
CF-226D/200	867.0	3	94	*	91.0	0.026	No COCs	Down or none
CF-227D/480	816.9	75	480	336.9	405.0	0.22	475-482	Down or none
CF-228D/499	823.6	35	428	395.6	393.0	0.035	419-428	Down or none
CF-229D/197	782.8	35	197	585.8	162.0	0.37	No COCs	Down or none
		Average:	330.2	453.6	287.9			

Acronyms:
ft. bgs - feet below grade surface

Notes:
[1]Not including aluminum, iron or manganese.
RI boreholes only; borehole CF-230D not profiled.
*: Boreholes excluded from averaging:
CF-204D was artesian; hydrostatic pressure rather than actual borehole trasmissivity prevented further liner eversion.
CF-226D is on a ridge and only 200 feet deep, so it did not reach the same elevations as nearby holes (Figure 3-4).

Table 5-1
Chemical Properties of Target Contaminants of Concern
Combe Fill South Landfill OU2
Morris County, New Jersey

Chemical	CAS Number	Molar Mass, g/mol		Density, g/cm^3		Vapor Pressure at 25 °C, mm Hg		Henry's Law Constant, $atm\text{-}m^3/mol$		Henry's Law Constant (dimensionless)		Water Solubility, mg/L		K_{oc}		f_{oc} (high)	Calculated K_d based on highest soil f_{oc}	Adsorption based on K_d	Volatilization based on Henry's Law Constant
1,4-dioxane	123-91-1	88.11	b	1.0329	b	38.1	b	4.80E-06	b			Miscible	b	17.00	b	0.0036	0.0612	Low	Moderate
Benzene	71-43-2	78.11	c	0.787	c	95.2	c	5.55E-03	a	2.28E-01	a	1.75E+03	a	58.90	a	0.0036	0.21204	Low	High
Trichloroethylene	79-01-6	131.39	j	1.4642	j	69*	j	1.03E-02	a	4.22E-01	a	1.10E+03	a	166.00	a	0.036	5.976	Low	High
Bis(2-ethylhexyl)phthalate	117-81-7	390.57	h	0.984	h	1.00E-07	h	1.70E-05	h	4.18E-06	a	3.40E-01	a	1.50E+07	a	0.0036	54000	Moderate	Low
α-BHC	319-84-6	290.83	k	1.87	k	4.50E-05	k	1.06E-05	a	4.35E-04	a	2.00E+00	a	7.34E-06	a	0.0036	1.23E+03	High	
Arsenic (elemental)	7440-38-2	74.92	d	5.778	d	7.5E-03**	d	ND		ND		Insoluble	d	ND		0.0036	ND	ND	None
Lead (elemental)	7439-92-1	207.2	e	11.34	e	1.77^	e	ND		ND		Insoluble	e	ND		0.0036	ND	ND	None
Chromium (elemental)	7440-47-3	51.996	i	7.14	i	1^^	i	ND		ND		Insoluble	g	ND		0.0036	ND	ND	None

* at 20°C
** at 280°C
^ at 1,000°C
^^ at 1,616°C

a	Chemical Properties for Calculation of Impact to Ground Water Soil Remediation Standards, NJDEP
b	ATSDR Toxicological Profile 1,4-Dioxane, 2012
c	ATSDR Toxicological Profile Benzene, 2007
d	ATSDR Toxicological Profile Arsenic, 2007
e	ATSDR Toxicological Profile Lead, 2007
f	Merck Index, 11th Edition, 1989
g	CDC NIOSH Pocket Guide to Chemical Hazards, 2015
h	ATSDR Toxicological Profile DEHP, 2002
i	ATSDR Toxicological Profile Chromium, 2012
j	ATSDR Toxicological Profile TCE, Draft, 2015
k	ATSDR Toxicological Profile HCH, 2005