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110453

FINAL FEASIBILITY STUDY
LIGHTMAN DRUM SUPERFUND SITE
WINSLOW TOWNSHIP
CAMDEN COUNTY, NEW JERSEY

Prepared for:

Lightman Yard PRP Group

Prepared by:

Golder Associates Inc.
200 Century Parkway, Suite C
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February 2009 Project No.: 013-6054

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February 16, 2009 Project No.: 013-6054

United States Environmental Protection Agency
290 Broadway, 19th Floor
New York, New York 10007-1866

Attn.: Ms. Renee Gelblat

RE: LIGHTMAN DRUM FINAL FEASIBILITY STUDY

Dear Ms. Gelblat:

On behalf of the Lightman Yard PRP Group (Group), Golder Associates Inc. (Golder) is pleased to submit the Final Feasibility Study (FS) for the Lightman Drum Company Site (Site). Three copies have also been sent under separate cover to the New Jersey Department of Environmental Protection and one copy to CDM Federal.

The Final FS corresponds to the red-line revised version discussed at the meeting with USEPA on December 18, 2008 that was accepted by USEPA in its letter dated January 13, 2009. In addition, the Final FS addresses the recommendations made in USEPA's January 13, 2009 letter in the following way:

Recommendation 1. *Section 5.1.2: Plume evaluation using dispersion - The text should be revised to qualify the application of the C_{max} solution. The solution provides an estimate of plume migration and does not incorporate parameter variability like other methods (e.g., three dimensional numerical modeling). Also, the site uncertainties should be identified so that the solution limitations are recognized. An example list of uncertainties is preferential pathways, increased well pumping and initial concentration mass. The parameter variability that is not incorporated into the model and the site uncertainties needs to be identified in the text so that the application of the solution is properly qualified.*

Response. Section 5.1.2 has been expanded to qualify the use of the maximum concentration solution to provide a conservative estimate of plume migration in the absence of biodegradation. Uncertainties are recognized, and the calculation assumes pumping of the municipal well to account for the possibility that the well may be returned to service in the future. The calculation is based upon the current chemical mass in the plume (based on 2006-2007 data) and evaluates its fate and transport conservatively assuming that the mass is conserved.

Recommendation 2. *Section 5.1.2, Page 47 in the redline version, first paragraph: cis-1,2-DCE reduction in MW-12 is used as an example for declining trends in "parent" chlorinated volatile organic compounds and the presence of the "daughter" product cis-1,2-DCE. Since only reduction in cis-1,2-DCE is used, the statement is not supported. Other possibilities are besides the biodegradation process are that cis-1,2-DCE could be transported to this location from upgradient, or seasonal changes could also cause reduction of cis-1,2-DCE concentrations. EPA* *suggests it would be better to use total VOC concentrations and the PCE/cis-1,2-DCE ratio at MW-12 to compared to PCE/cis-1,2-DCE ratio at the source area to support the statement.*

Response. Text has been added that presents an analysis of the total molar concentration of chlorinated ethene compounds, the evolution of parent/daughter ratios ([PCE+TCE]/[cis-1,2-DCE+VC]) as a function of distance downgradient and evaluation of the ratio of cis-1,2-DCE to trans-1,2-DCE. These additional analyses support the concept that on-going intrinsic bioremediation of chlorinated ethenes is occurring in the source area and downgradient to approximately MW-12.

Recommendation 3. *Please provide a figure in Appendix E to show the well locations and the sampling dates for the concentrations used in the modeling calculations. Please also explain the extent each area in the modeling spreadsheet covered and show how the maximum concentrations were calculated.*

Response. Figure E-1 illustrates the isoconcentration contours used as the basis for the calculations presented in Appendix E. The text of Appendix E describes the calculation of maximum concentrations.

Recommendation 4. *This report does not provide supporting evidence that biodegradation is occurring in the downgradient areas. Cis-1,2-DCE could biodegrade under aerobic conditions but it has not been proved that it is in fact occurring. As a result, it maybe conservatively assumed that dispersion and dilution are the only mechanisms currently in effect to reduce the contamination at the downgradient locations. Please note this in the report.*

Response. This has been noted in Section 5.1.2 of the report.

Recommendation 5. *Please add time estimates to each of the remedial alternatives.*

Response. Estimated remedial time-frames used for cost estimating purposes have been added for each remedial alternative.

If any questions arise during your review of this report, please contact us at (856) 793-2005.

Very truly yours,

GOLDER ASSOCIATES INC.

P. Stephen Finn, C.Eng.
Principal

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cc: Michael vanItallie, Esq. USEPA
James DeNoble, NJDEP
Lightman Yard PRP Group

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List of Acronyms

AOC	Administrative Order on Consent
AS	Air Sparge
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CEA	Classification Exception Area
COPEC	Chemicals Of Potential Ecological Concern
CT	Central Tendency
DO	Dissolved Oxygen
FS	Feasibility Study
GAC	Groundwater Activated Carbon
GWQS	Groundwater Quality Standards
HI	Hazard Index
HRS	Hazard Ranking System
IC	Institutional Control
ISCO	In-Situ Chemical Oxidation
LDC	Lightman Drum Company
LEL	Lowest Effects Level
LOAEL	Lowest Observed Adverse Effect Level
MCL	Maximum Contaminant Levels
MNA	Monitored Natural Attenuation
NCP	National Contingency Plan
NJDEP	New Jersey Department of Environmental Protection
NOAEL	No Observed Adverse Effect Level
NOD	Natural Oxidization Demand
NPL	National Priorities List
NZVI	Nano-Scale Zero-Valent Iron
ORP	Oxidation Reduction Potential
PCE	Tetrachloroethene
PDI	Pre-Design Investigation
POTW	Publically Operated Treatment Works
PPB	Parts Per Billion
RAO	Remedial Action Objectives
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROI	Radius of Influence
SC	Source Control
SCC	Soil Cleanup Criteria
SLERA	Screening Level Ecological Risk Assessment
SSC	Sediment Screening Criteria
SVE	Soil Vapor Extraction
SVOC	Semi-Volatile Organic Compound
SWQC	Surface Water Quality Criteria
TCE	Trichloroethene
UCL	Upper Confidence Level
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WRA	Well Restriction Area
ZOI	Zone of Influence

1.0 INTRODUCTION

1.1 Purpose and Format of Report

This Final Feasibility Study Report (Report) has been prepared by Golder Associates Inc. (Golder) on behalf of the Lightman Yard PRP Group (Group), pursuant to the Administrative Order on Consent (AOC) executed by the United States Environmental Protection Agency (USEPA) in November 2000 (USEPA Index No. CERCLA-02-2000-2034); and the approved Remedial Investigation/Feasibility Study (RI/FS) Work Plan (Work Plan, Golder, July 2002), and associated Addenda (Golder, January 2004, September 2004, May 2006, May 2007, March 2008). This Final Feasibility Study addresses USEPA comments dated June 26, 2008 on the Feasibility Study Report dated December 21, 2007, USEPA comments dated November 26, 2008, and February 5, 2009 on the Revised Feasibility Study dated September 28, 2008, and USEPA comments dated January 13, 2009 on a redline version of the Feasibility Study dated December 18, 2008.

The Report presents the Feasibility Study (FS) conducted for the Lightman Drum Company Superfund Site (Site) based upon the results of the Remedial Investigation (RI) for the Site.[1] The main portion of the Remedial Investigation field work for the Site was completed in May, 2006 in accordance with the approved RI/FS Work Plan, and the results were presented in the Remedial Investigation Report (Golder, 2006). In response to the request of the USEPA, in a letter dated March 6, 2007, additional hydrogeologic investigations were subsequently conducted and the results were presented in an Addendum to Remedial Investigation Report (Golder, September 2007). Additional investigations of un-naturally colored soils were conducted in accordance with a Work Plan dated March 7, 2008 and the results were presented in an Addendum dated June 2008. A Revised Remedial Investigation Report[2] was submitted on October 31, 2008 which incorporated the results of the two Addenda and Agency comments dated August 25, 2008 on the Remedial Investigation Report submitted in August 2006.

[1] For the purposes of this report, and consistent with the AOC, the "Site" includes any area in the vicinity of the Lightman Drum Company Property to which "hazardous substances have migrated or threatened to migrate and all areas in close proximity to the contamination necessary for the implementation of the response actions required by the AOC."
[2] The Revised Remedial Investigation Report (Golder Associates, 2008) will be revised in response to USEPA comments dated January 13, 2009 and resubmitted in February 2009.

The objective of this FS, is to provide the technical basis for selection of a remedy for the Site that will be protective of human health and the environment and consistent with the National Contingency Plan (NCP). Specific objectives of this FS are to:

- Develop remedial action objectives (RAOs) and identify, screen, and select remedial technologies and process options that address the RAOs;
- Assemble the retained technologies into a list of potential remedial action alternatives; and,
- Screen and conduct a detailed analysis of the retained remedial action alternatives, and provide a comparative analysis of these alternatives.

The remainder of this Report is organized as follows:

- Section 2 provides the Site background, including: a description of the Lightman Drum Company (LDC) Property as defined in Section 2.1.1, historical operations, and previous investigations; a characterization of the Site-specific geology and hydrogeology; a summary of remedial investigations conducted; and a summary of the Baseline Human Health Risk Assessment and Screening Level Ecological Risk Assessment;
- Section 3 presents the RAOs for the Site and potential ARARs;
- Section 4 presents the identification and screening of remedial technologies that address the Site RAOs;
- Section 5 presents the identification and description of remedial alternatives;
- Section 6 provides a detailed evaluation of each of the remedial alternatives in accordance with the NCP evaluation criteria;
- Section 7 provides a comparative analysis of the remedial alternatives;
- Section 8 provides a summary of this FS; and,
- Section 9 provides a list of references used during the preparation of this FS.

1.2 Regulatory Background

As stated in the AOC, the LDC operated an industrial waste hauling and drum reclamation business at the LDC Property beginning in the spring of 1974. Various inspections of the property were conducted by the New Jersey Department of Environmental Protection (NJDEP) in 1974 and thereafter. In 1978, the NJDEP issued a one-year Temporary Operating Authorization that allowed the storage of various wastes on the property including chemical powders, pesticides, waste oil, oil sludges, paint, pigment, thinner, ink residues, ketones, alcohols, and mixed solvents. The permit was not renewed.

In 1987, NJDEP collected soil samples from the property that revealed the presence of various organic and inorganic compounds. In 1988, NJDEP issued an Administrative Order (the New Jersey Order) requiring LDC to conduct an RI/FS at the Site. International Exploration, Inc. (INTEX) performed investigation work in two phases in 1989 and 1990.

At the request of NJDEP, USEPA performed a Hazard Ranking System (HRS) Evaluation of the Site in May 1999. The purpose of the HRS Evaluation was to determine if the releases at the Site warranted placement of the Site on the National Priorities List (NPL) set forth in 40 CFR Part 300, Appendix B. The HRS Evaluation Site Score was 42.03, based solely on the Groundwater Pathway, and exceeded the 28.50 cut-off for potential listing on the NPL. USEPA placed the Site on the NPL by publication in the Federal Register on October 22, 1999.

An AOC was executed between the USEPA and the Group in November 2000, which set forth the requirements for conducting a Remedial Investigation and Feasibility Study. On February 2, 2001, Golder Associates submitted a workplan for the RI/FS on behalf of the Group and as required by the AOC. The Work Plan was conditionally approved on July 2, 2002 and the Final Remedial Investigation/Feasibility Study Work Plan was submitted on July 23, 2002. Following review of the initial investigation results, installation of additional wells and piezometers was approved by the USEPA on September 15, 2003. On January 19, 2004, the Remedial Investigation Update was submitted and, in response to Agency comments, an Addendum was submitted on September 1, 2004 and subsequently approved. At the request of USEPA, additional soil investigation work was conducted in accordance with a Revised Addendum Remedial Investigation/Feasibility Study Work Plan, submitted in May 2006 and additional hydrogeologic investigations were conducted in accordance with the Revised RI/FS Work Plan Addendum #2 approved by USEPA on May 15, 2007.

An Administrative Settlement Agreement and Order on Consent for Removal Action (Removal AOC), was entered between USEPA and some members of the Group (the Lightman Yard Source Removal Group, or Source Removal Group), and it became effective on September 17, 2007.

The Removal AOC required excavation of source area soils in the vicinity of the former underground waste storage tanks. This work was subsequently completed pursuant to the Soil Source Removal Work Plan, submitted to USEPA on October 16, 2007 and approved October 29, 2007. During the source area soils removal, discrete areas of un-naturally colored near-surface soils were observed. Investigations of these soils were conducted and summarized in an Addendum to the Remedial Investigation Report dated June 6, 2008. The Group initiated the removal of these un-naturally colored soils in October 2008 as an additional action required under the Removal AOC. It is anticipated that the removal of un-naturally colored soil will be completed in Spring 2009.

1.3 Previous Submittals

This Report follows several previous submittals required by the AOC and approved by USEPA. A Candidate Technologies Memorandum (Golder, June 2005) initially identified potential remedial technologies, and preliminary alternatives, based on the Candidate Technologies Memorandum, were presented to USEPA at a meeting on August 16, 2006. As requested by USEPA at that meeting, a subsequent Remedial Action Objectives and Remedial Alternatives Screening Memorandum (Golder, October 2006) was developed to provide an expanded description of the alternatives presented at the meeting. Following USEPA comments contained in a letter dated December 5, 2006, a Revised Remedial Alternatives Memorandum was presented to USEPA at a meeting on January 17, 2007. A Feasibility Study Progress Report was submitted in September 2007 (Golder, 2007c) to present remedial alternatives consistent with USEPA's letter dated March 6, 2007. USEPA comments on the Progress Report conveyed at a meeting on September 19, 2007, including consideration of additional remedial alternatives for downgradient groundwater were evaluated using the criteria established in the NCP in the Feasibility Study Report submitted December 21, 2007. A Revised Feasibility study that incorporated USEPA comments dated June 26, 2008 on the Feasibility Study Report, as clarified at a meeting on August 7, 2008 and in subsequent correspondence dated August 8 and August 28, 2008 from USEPA, and August 25 from the Group was submitted on September 29, 2008. This Report addresses Agency comments on the Revised Feasibility Study Report dated November 26, 2008 and February 5, 2009, as well as USEPA comments dated January 13, 2009 on a redline version of the Feasibility Study dated December 18, 2008.

Other key reports submitted to date pursuant to the AOC and approved Work Plan include:

- Remedial Investigation Data Validation Report, submitted on April 12, 2005 and approved on February 15, 2006;
- Site Characterization Summary Report, submitted on May 26, 2005;
- Remedial Investigation Report, submitted in August, 2006;
- Addendum to Remedial Investigation Report, submitted in September 2007;
- Draft Memorandum on Exposure Scenarios and Assumptions, submitted in September 2002;
- Interim Report Baseline Human Health Risk Assessment, submitted in July 2005;
- Baseline Human Health Risk Assessment and Screening Level Ecological Risk Assessment (BRA and SLERA), submitted in January, 2007;
- Addendum to Remedial Investigation Report, submitted June 2008;
- Revised Baseline Human Health Risk Assessment and Screening Level Ecological Risk Assessment (BRA and SLERA) submitted in October 2008; and,
- Revised Remedial Investigation Report submitted in October 2008.

In addition, a Soil Source Removal Work Plan was submitted and approved in October 2007 pursuant to the Removal AOC. Addendum No. 1 to the Soil Source Removal Work Plan was subsequently submitted in October 2008 to address un-naturally colored soils.

2.0 BACKGROUND

2.1 General Site Description

2.1.1 Description of Property

The Lightman Drum Company property (Property) covers approximately 15 acres and is located in Winslow Township, Camden County, New Jersey (Figure 2-1). The Property is narrow (approximately 300 feet wide) with access from Route 73. The majority of Property is wooded as shown on Figure 2-2. There is very little topographic relief across the Property with a maximum elevation range of 15 feet. As part of the RI, a topographic base map was completed encompassing the Lightman Property and a minimum 200-foot perimeter beyond the Property. Downgradient (to the south), mapping extended approximately 800 feet.

A portion of the Property is currently used as a drum brokerage business, operating under the name United Cooperage, with operations located in the eastern portion of the Property. Drums are stored in truck trailers and in open areas, and a small office is located near the Property entrance. A large concrete slab is located adjacent to the office, which served as the foundation for a former storage warehouse. According to a report by International Exploration, Inc. (INTEX), the warehouse was destroyed by fire in 1985 (INTEX, 1989). A water supply well is located near the office and is used for non-potable purposes. A small septic system, which was installed in 1975 to serve the office bathroom, is located adjacent to and west of the concrete slab.

An abandoned house is located adjacent to Route 73. A water well is reportedly located at the house, however entrance to the house is not safely available, and no exterior spigot was found.

2.1.2 Surrounding Land Use (and Demography)

The Property is bordered to the east by Route 73, to the west by the Pennsylvania Reading Railroad Line, to the north by farmland and wooded areas, and to the south by wooded areas and recent commercial development (Figure 2-3). The area in the vicinity of the Property is semi-rural and has historically been open land or used for agricultural purposes, with a few residences and small businesses located along Route 73.

The property and adjacent lands are currently zoned for industrial use only. A portion of the corridor along Route 73 southeast of the Site is zoned as minor commercial (PC-1). Certain areas to the south of the Property are in the process of being developed for industrial/commercial use, consistent with the current zoning, and all such properties are required by municipal ordinance to connect to the municipal water supply system. The area immediately south of the Property is currently used for recreational vehicle storage.

According to the AOC, approximately 8,000 people lived within a 3-mile radius of the Property in 2000. The Delaware Valley Regional Planning Commission indicates that the population in Winslow Township has grown from 20,034 people in 1980 to 30,087 in 1990 and 34,611 in 2000.

2.2 Historical Operations

Historical aerial photographs of the Property have been obtained and reviewed from the following dates:

1940	1979
1954	1984
1970	1986
1974	1987
1975	1989

In summary, these photographs confirm the following aspects of the Property history:

1. Prior to 1974, the currently active portion of the Property was used for agricultural purposes;

2. With the exception of the Unlined Waste Disposal Pit and associated access tracks, the wooded portion of the Property to the west and along the northern boundary has remained unchanged since at least 1940; and,

3. The current operational area has been remained essentially the same since 1974.

2.3 Previous Investigations

Pursuant to the New Jersey Order, an investigation was conducted in two phases (Phase I and Phase II) by INTEX on behalf of LDC (INTEX, 1989; INTEX, 1990). These investigations focused on delineating the extent of contamination in soil and groundwater. Approximately 80 soil samples were collected and twelve monitoring wells installed including shallow and deep well clusters at locations MW-2 and MW-8. The investigations were concentrated in known storage areas as shown on Figure 2-2 and briefly described below. Constituents detected in groundwater on the Property included chlorinated and aromatic Volatile Organic Compounds (VOCs), and Semi-Volatile Organic Compounds (SVOCs) in excess of federal drinking water standards (maximum contaminant levels; MCLs). Constituents detected in soils on the Property included VOCs (primarily chlorinated and aromatic solvents), SVOCs, pesticides, and inorganic compounds.

Following the Phase I investigation, a geophysical investigation was conducted to assist in locating additional monitoring wells downgradient of MW-2 and MW-3 during the Phase II investigation. The results of an electromagnetic terrain conductivity survey were inconclusive in the operational area of the site as a result of surficial interferences (i.e., metal drums and trailers). A small anomaly was identified in the area of a Former Unlined Waste Disposal Pit and monitoring well MW-7 was subsequently installed at that location. A summary of investigations conducted prior to the RI is provided below in relation to key historical operational areas.

Underground Diesel Fuel Tanks

Two fiberglass underground storage tanks of 750 and 1,500 gallon capacity were installed in 1976 along the southern property boundary (INTEX, 1989). The tanks were reportedly used for storing diesel fuel until the early 1980s and were removed in 1990. Soil samples were taken from the excavation as part of the Phase II investigation (INTEX, 1990) which indicated low levels of petroleum hydrocarbons and a single detection of trichloroethene.

Unlined Waste Disposal Pit

A Former Unlined Waste Disposal Pit is located in a wooded area in the west-central area of the Property. Historic aerial photographs indicate that the small pit was accessed by a track from the main operations area, and was located within a shallow depression. In 1974 a citizen reported the existence of this pit and that drum residues were deposited in it (USEPA, 2000). It was also reported (INTEX, 1989) that the pit was used for the disposal of a single tank trailer containing paint waste and possibly oil in 1976; LDC reportedly removed waste from the area shortly thereafter (INTEX, 1989) and the pit was subsequently filled. There are no known records or manifests describing the nature and volume of materials deposited in the pit (INTEX, 1989).

Underground Waste Storage Tanks

Two 5,000 gallon underground storage tanks were formerly located in the north-central area of the Property. The tanks were reportedly used to store waste paint pigments, ink sludges, and thinners, and were reportedly in use under a Temporary Operating Authority between November 2, 1978 and April 30, 1979 (INTEX, 1989). According to the findings of the AOC, NJDEP observed in 1984 that the tanks had been removed.

Warehouse

Drums were stored in a warehouse located in the eastern part of the Property prior to 1985. In September 1985, a fire destroyed the warehouse. The concrete foundation slab from the warehouse is still present.

Drum Storage Areas

Drum storage areas throughout the active portion of the Property were also investigated. The areas investigated included the main storage areas located along the southern property boundary, west of the former diesel tanks, and along the northern tree line east of the Former Waste Storage Tank Area.

Groundwater Sampling

In July of 2000, the USEPA conducted sampling of wells on the Lightman Property and tap water sampling of surrounding residential properties both north and south of the Lightman Property. The results from this sampling indicated that monitoring wells on the Lightman Property were contaminated with compounds exceeding the Federal Maximum Contaminant Levels (MCLs) and/or the New Jersey Groundwater Quality Standards (GWQS). Contaminants consisted primarily of VOCs, especially chlorinated solvents and BTEX compounds (benzene, toluene, ethylbenzene, and xylenes). The results of the residential tap water sampling indicated the presence of some metals (Lead, Iron, Manganese, and Aluminum) exceeding Federal and/or New Jersey State MCLs.

2.4 Site Geology

The Site is located in the Atlantic Coastal Plain Province of the eastern United States, which consists of a series of unconsolidated Cretaceous through Quaternary aged sands and clay sediments overlying Precambrian crystalline rocks. The sediments form a southeasterly-dipping wedge that gradually thickens from the outcrop areas near the Delaware River east toward the Atlantic Ocean (Hardt and Hilton, 1969).

The Site hydrogeologic model is characterized by the presence of a relatively uniform unconfined aquifer, known as the Cohansey Sand (Zapecza, 1989), consisting of yellowish brown coarse to fine grained sand, underlain at depth by the Kirkwood Formation. The base of the Cohansey-Kirkwood aquifer is defined by the top of a clay bed lying at the base of the Kirkwood Formation. Two test borings were drilled during the RI to locate the top of the Kirkwood Formation. It was encountered between 100 feet and 105 feet below ground surface at locations TB-01 and TB-02 (see Figure 2-3), indicating that the aquifer in the vicinity of the Site extends to a depth on the order of 100 feet.

Most of the soils in the Site area are mapped as Downer loamy sand, Klej loamy sand, and Leon soil. All three are well-drained soils which have poor filtering capacity (Markely, 1966). Much of the active area of the Property has been covered by a veneer of fill material. The fill is fairly impermeable in some areas, as evidenced by the presence of large puddles after storms which remain for as long as several days after the rain.

2.5 Site Hydrogeology

The Cohansey-Kirkwood aquifer system, is a water table aquifer that dips eastward toward the Atlantic Ocean. This aquifer is almost always unconfined, although local clay units in the Cohansey Sand occasionally create locally confined conditions. In the Site area, there are no such mapped continuous confining layers, nor were any identified during the field investigation. As discussed in Section 2.4, the first clay unit identified was within the Kirkwood Formation at 100 feet below ground surface. The Cohansey-Kirkwood aquifer is used extensively as a water resource, primarily for domestic and farm-irrigation uses. Recharge to the unit is high, due to its high permeability, and therefore, the quantity of water available for use is substantial (Rooney, 1971).

Groundwater contour maps based on the synoptic rounds of water levels collected on November 6, 2003; May 3, 2005; and March 13, 2006 were presented in the Revised Remedial Investigation Report, and are reproduced here as Figures 2-4 through 2-6. Groundwater flow is consistently in a south-southeasterly direction, at and downgradient of the Property, although at the southern extent, the groundwater contours appear to turn towards the south-southwest in the November 2003 measurements.

Groundwater appears to be sporadically connected to surface water far downgradient (4,000 feet south of the Property). During wet seasons where the Pump Branch Creek is more developed in this area, the stream elevation (based on a staff gauge SG-1) is similar to nearby groundwater elevations (e.g., during the May 3, 2005 event). Previous measurements indicated that the streambed was dry, and groundwater levels were well below the base of the stream.

The groundwater flow direction far downgradient of the Property may be affected by two Winslow Township municipal wells (#4 and #8) located roughly 7,500 feet southwest of the Site as shown on Figure 2-1. Based on information provided by Winslow Township to USEPA, well #4 is 97 feet deep and has a rated capacity of 250 gpm but is used for emergency purposes only. Well #8 is 140 feet deep, is pumped regularly, and has a rated capacity of 1,000 gpm. Groundwater level monitoring transducers were installed in select monitoring wells downgradient of the Site, including MW-18 (March 16, 2006 to April 26, 2006), and MW-16 and MW-17 (March 31, 2006 to April 26, 2006) to compare the response of water levels in these wells to municipal pumping records for wells #4 and #8 provided by Winslow Township (Appendix A). Municipal well pumping data is provided as total gallons pumped per day (in 100's of gallons) and is plotted with the transducer data from MW-18 in Figure 2-7. The effect of municipal pumping can be seen in MW-18 with higher pumping rates being reflected in decreases in water levels (on the order of 0.10 feet) measured in MW-18. A similar correlation was also evident in the records for MW-16 and MW-17, although the drawdown effects are smaller. These results confirm that the Municipal well can influence a broad area including the vicinity of the most downgradient site monitoring wells. Long-term pumping records available from NJDEP indicate that pumping rates from the municipal well vary significantly and most recently have been much lower than during the period of transducer monitoring. Based on recent discussions with Winslow Township, Well #8 has not been in operation since August 2007.

The Township has indicated to USEPA that the wells are sampled regularly for VOCs and no concerns have been reported. It is further understood that a carbon treatment system is installed at well #8 as a precautionary measure. Potential fate and transport of Site-related contaminants in relation to the Municipal well is further evaluated in Section 2.6.4.

2.5.1 Hydraulic Gradients

Based on the groundwater elevation data collected during the Remedial Investigation, horizontal hydraulic gradients are relatively low, at approximately $2x10^{-3}$ feet per foot (ft/ft). Nested well pairs on the Property include wells MW-2A and MW-2B, and MW-8A and MW-8B. Vertical gradients measured at these locations indicate modest downward gradients in the MW-2A/B cluster and slight upward gradients in the MW-8A/B cluster. At well cluster MW-2A/B, the vertical gradients ranged from about $5.17x10^{-2}$ under lower hydraulic head conditions (i.e., August 2002) to $5.74x10^{-2}$ ft/ft under higher hydraulic head conditions (i.e., May 2005). At well cluster MW-8A/B, located approximately 150 feet downgradient of MW-2A/B, the vertical gradients are slightly upward, ranging from $4.01x10^{-3}$ under low hydraulic head conditions to $3.01x10^{-3}$ ft/ft under higher hydraulic head conditions.

2.5.2 Hydraulic Conductivity

Hydraulic testing (i.e., slug tests) was conducted within monitoring wells during the Remedial Investigation. Analysis of slug tests exhibiting overdamped response indicate hydraulic conductivities ranging from $2.5x10^{-3}$ cm/sec to $3.4x10^{-2}$ cm/sec, with a geometric mean value of $1.0x10^{-2}$ cm/sec using the Bouwer and Rice method, and $4.4x10^{-4}$ cm/sec to $2.1x10^{-2}$ cm/sec, with a geometric mean value of $5.4x10^{-3}$ cm/sec using the Hvorslev analyses. The difference between the results of the two analysis methods is likely the result of the Bouwer and Rice method's more robust treatment of partially penetrating observation wells. Underdamped response was observed in slug tests of two wells, MW-16 and MW-20, and the results were analyzed by the van der Kamp method. The results indicate hydraulic conductivities ranging from $6.0x10^{-3}$ cm/sec to $1.0x10^{-2}$ cm/sec, which is within the range of values computed for other wells across the Site.

2.6 Nature and Extent of Contamination

The main field work for the RI began in August 2002 and was concluded in July, 2007. During this period, the work outlined in the original RI/FS Work Plan was expanded in off-Property areas downgradient, and an expanded monitoring well system was completed in accordance with the Remedial Investigation Update (Golder, 2004). Additional on-Property soil sampling was also conducted in the saturated zone (Figure 2-8), at the request of USEPA, to define the source area, and an additional round of groundwater samples was collected in accordance with the Revised

Addendum Remedial Investigation/Feasibility Study Work Plan (Golder, May 2006). Additional samples were collected from select wells in August 2006 and November 2006 subsequent to issuance of the Remedial Investigation Report, and USEPA requested further monitoring well sampling and completion of additional aquifer profile borings in specific areas in March 6, 2007. This work was carried out in accordance with RI/FS Work Plan Addendum #2 and reported in an Addendum to Remedial Investigation Report on September 7, 2007. In summary, the RI field work included the following activities:

- Installation of 57 direct-push groundwater profiles;
- Installation of 10 piezometers (including two replacements);
- Installation of 11 groundwater monitoring wells;
- Installation of a staff gauge in Pump Branch Creek;
- Soil sampling in both the saturated and unsaturated zones;
- Sediment/surface water sampling;
- Collection of two complete rounds of groundwater samples from 12 existing and 11 new monitoring wells and the on-Property office supply well;
- Collection of two additional rounds of groundwater samples from eight selected wells downgradient of the property;
- Topographic, property boundary, and soil boring/well surveying;
- Slug testing of monitoring wells;
- Continuous water level recording in select downgradient wells;
- Wetlands delineation;
- Phase IA Cultural Resources Survey; and,
- Survey for Swamp Pink, a federal endangered plant species.

All sampling was conducted in accordance with the approved workplans listed above and the associated Sampling and Analysis Plans.

2.6.1 Soil

Unsaturated soil samples taken to assess potential vadose zone contamination did not detect any exceedances of even the most stringent NJDEP Soil Cleanup Criteria (SCC). Saturated soil sampling identified a residual source area, in the Former Waste Storage Tank Area (Figure 2-8). Three VOCs (tetrachloroethene, ethylbenzene, and total xylenes) exceeded the most stringent of the NJDEP SCC (Impact to Groundwater) in two saturated zone borings in this area. There were no saturated zone exceedances in borings taken at the Former Unlined Waste Disposal Pit Area or the Former Southwest Drum Storage Area.

In summary, saturated soils in a localized zone close to the water table in the Former Waste Storage Tank Area were contaminated with VOCs and would have continued to provide a source for contaminated groundwater leaving the Site. Removal of these saturated soils was identified by the Group in the Remedial Action Objectives and Remedial Alternatives Screening Memorandum (RAO Memorandum) submitted to USEPA on October 31, 2006 as a potential alternative for Source Control (Alternative SC-2: Shallow Saturated Soil Excavation at the Former Waste Storage Tank Area). USEPA concurred with this alternative to address saturated soil contamination in letters dated December 5, 2006, and March 6, 2007 and an Administrative Order on Consent (Removal AOC) for removal of these soils was entered with certain members of the Group and became effective on September 17, 2007.

Soil source removal has been completed in accordance with the Soil Source Area Removal Work Plan (Golder, 2007d), that was approved by USEPA on October 24, 2007. The area of excavation was approximately 33-feet by 16-feet in plan dimensions and encompassed those RI borings where there was a positive field test result for residual product and borings that contained samples that exceeded the most stringent NJDEP SCC (see Figures 2-2 and 2-8). The excavation extended to a depth of 25 feet, including the entire zone where exceedances of criteria occurred, and the excavation was backfilled with clean fill. Basal samples were collected and analyzed for TCL VOCs, confirming that the remaining saturated soil was below the NJDEP SCC. Soil removed from the excavation was characterized and disposed off-site in accordance with the approved Work Plan.

During these Source Removal activities, discrete areas of un-naturally colored soils were observed. Investigations of the un-naturally colored soils were conducted and are summarized in an Addendum to the Remedial Investigation Report (Golder 2008). Lead was determined to be the primary contaminant of concern, with arsenic and pesticides also exceeding screening criteria in isolated areas. The horizontal extent of the impacted areas is shown on Figure 2-9. With the exception of an area of purple-colored soil adjacent to the previous soil source area excavation, impacts are limited to the top 6-inches of soil and generally do not extend below 4-inches. These shallow soils, as well as the area of purple-colored soil, are being excavated pursuant to the Removal AOC and work is scheduled to be completed in the Spring of 2009.

2.6.2 Sediment / Surface Water

Sediment samples taken in the wetland and Pump Branch Creek downgradient of the Site did not exceed the most stringent lowest effects level (LEL) of the NJDEP Sediment Screening Criteria (NJSSC) for VOCs or SVOCs. One pesticide (4,4'-DDT) exceeded the NJSSC LELs in 1 of 8 collected samples. The surrounding area has historically been farmed so that the detection of pesticides in the sediment may be anthropogenic. Four metals exceeded LELs (lead, copper, arsenic, and mercury), but the maximum detected concentrations of arsenic occurred in the upstream (background) samples. The highest concentrations of lead, copper, and mercury were in the furthest downgradient samples, suggesting that the inorganic exceedances are also not Site-related.

Surface water detections in excess of NJDEP Surface Water Quality Criteria (SWQC) for FW2 classified surface waters were limited to arsenic and lead. Both arsenic and lead were detected in the background surface water sample collected upstream of the Property as well as in background sediment samples.

2.6.3 Groundwater

The most significant transport mechanism for site contaminants is via groundwater flow. Groundwater has been impacted with chlorinated VOCs, namely tetrachloroethene (PCE) and trichloroethene (TCE), as well as BTEX compounds. PCE and TCE are found in the furthest downgradient portion of the groundwater plumes.

In addition to VOCs, samples taken from the 23 monitoring wells in 2005 and 2006 were analyzed for TCL SVOCs, pesticides, PCBs, TAL metals, and geochemical parameters. There were no PCBs detected. Nearly all SVOCs and pesticide detections were on-Property in wells proximate to the Former Waste Storage Tanks and within the larger chlorinated VOC plumes. There were a few low level detections of SVOCs and pesticides in downgradient wells, but no detections were repeated between the 2005 and 2006 sampling events.

Twenty-three different metals were detected over the two sampling periods, ten of which exceeded either the NJDEP GWQS or Federal MCLs. The inorganics that exceeded were, in decreasing order of number of exceedances: iron, aluminum, manganese, cadmium, thallium, arsenic, antimony, and lead. Of these, manganese, iron, and aluminum were ubiquitous and were detected in wells that showed VOC impacts and no VOC impacts; and were also detected in the background monitoring well (MW-1), indicating that these concentrations are naturally occurring. There were only isolated detections of cadmium, thallium, arsenic, antimony, and lead.

Based on VOC results from the aquifer profile borings and monitoring well samples, two main plumes were identified: one originating from the Former Waste Storage Tanks (eastern plume), and one originating from the Unlined Waste Disposal Pit Area in the western part of the Property (western plume). These are illustrated in plan view in Figures 2-10 (PCE) and Figure 2-11 (BTEX). The PCE plume is very similar in shape, extent, and overall concentrations to the TCE plume. Both plumes are relatively narrow in width horizontally and in thickness, and both gradually increase in depth with distance from the source areas such that non-impacted groundwater overlies the plumes starting a short distance downgradient of the Property (Figure 2-12). The eastern PCE/TCE plume extends a distance of approximately 4,500 feet downgradient of the Property, at which point it is approximately 85 feet bgs. The western PCE/TCE plume extends approximately 1,500 feet downgradient, at which point it is about 55 feet bgs.

BTEX compounds (mainly benzene and xylene) are co-located with the PCE/TCE; in the source areas however, the eastern and western BTEX plumes extend only a relatively short distance downgradient from the Lightman Drum Property. In the eastern plume, BTEX compounds have been detected a distance of approximately 1,500 feet downgradient, and in the western plume, BTEX compounds are detected approximately 300 feet downgradient. Given the elevated concentrations of BTEX in the Former Waste Storage Tank Area, and because BTEX compounds, in general, have higher solubilities than PCE and TCE, the lack of BTEX mobility suggests that active biodegradation of BTEX compounds is occurring in close proximity to the Former Waste Storage Tanks; this, in turn, limits off-property transport of these contaminants.

In both plan view and cross-section, the eastern and western plumes exhibit evidence of historical variations in the release rate (areas of higher concentration bounded by areas of lower concentration occurring throughout the overall plume), which is consistent with the operational history at the Property. Monitoring wells MW-15 and MW-16 were installed based on areas of higher concentration identified by aquifer profile borings GW2E-3 and GW2F-1. However, groundwater concentrations measured from these permanent monitoring wells in 2005 were significantly lower than those observed in the proximate aquifer profile borings completed in 2002 and 2003. Subsequent sampling of the permanent monitoring wells showed declines in the concentrations of PCE and TCE in all of the off-Property monitoring wells in most cases to trace levels (Figure 2-10, Appendix B).

Additional aquifer profile borings were conducted in July 2007 at the request of USEPA. The objective of the additional borings was to determine whether “hot spots” identified during the remedial investigation at previous profile borings GW2E-3 and GW2F-1 (upgradient of MW-15 and MW-16), were still present by focusing on areas of the plume that would likely have VOCs of approximately 100 ppb. The location of these borings are illustrated in Figure 2-10 and 2-11 and the maximum PCE and TCE detections from each boring are illustrated in Figure 2-13. These profile borings confirmed the monitoring well observations that the previous “hot spots” were no longer present. However, elevated concentrations of PCE and TCE were identified in borings taken at side-gradient locations west of monitoring wells MW-15 and MW-16. In these borings, elevated concentrations of PCE and TCE were encountered in a thin zone at 65-67 feet bgs. Concentrations drop more than an order of magnitude in the 10 feet intervals above and below this zone, demonstrating a very narrow vertical thickness of contamination. Based on this information, it appears that localized zones with higher levels of contamination can exist within the boundaries of the plume. These zones of higher concentration will be fully delineated during the remedial design.

2.6.4 Fate and Transport

The fate and transport of groundwater contaminants from the Site depends on groundwater velocity, contaminant velocity, and degradation. The Monte Carlo simulation method was used to compute advective groundwater flow velocities taking into account uncertainties in the measured values of hydraulic conductivity, hydraulic gradient, and literature-based ranges for porosity.

$$V_{gw} = KI / n$$

Where:

V_{gw} = advective groundwater flow velocity [feet/day]

K = hydraulic conductivity [feet/day]

I = horizontal hydraulic gradient [feet/foot]

n = effective porosity [-]

In each case, triangular distributions (minimum, maximum, and most likely) of the parameters were developed and the distribution of the groundwater velocity was calculated using 10,000 sampling iterations of the input parameter distributions (see table below). The computed most likely groundwater flow velocity was 102.2 ft/year (0.28 ft/day).

Contaminant velocity, as opposed to advective groundwater velocity, depends on retardation and degradation[3], which are chemical specific. The following analysis is based on tetrachloroethene (PCE) which is the contaminant observed to have migrated furthest from the Site. Retardation is related to both chemical and soil properties in the following manner:

$$R = 1 + \frac{(1-n)\,\rho\, Kd}{n}$$

Where: R = Retardation coefficient [-]

n = Effective porosity [-]

ρ = soil density [g/cm^3]

And: ***Kd*** **=** soil partitioning coefficient [mL/g] = f_{oc} K_{oc}

Where: f_{oc} = fraction of organic carbon in soil [g/cm^3]

K_{oc} = chemical-specific organic carbon-water partitioning coefficient [mL/g]

Contaminant velocity is then calculated as follows:

$$V_c = V_{gw}/R$$

[3] Degradation is not considered in the following calculations, which are therefore expected to be conservative. Some evidence of degradation exits, for example, the detection of daughter product cis-1,2-DCE, as further described in Section 5.1.3.

Where:

V_c = contaminant velocity [feet/day]

V_{gw} = advective groundwater flow velocity [feet/day]

R = Retardation factor [-]

Monte Carlo simulation was again used with triangular distributions (minimum, maximum, and most likely) of the input parameters (see table below). Calculations of Kd and R were made using 10,000 sampling iterations of the input parameter distributaries. The results indicate for PCE a most likely Kd of 0.08 mL/g and a most likely retardation factor of 1.34. The most likely Monte Carlo simulated PCE contaminant velocity was 0.22 feet/day or 80 feet/year.

Input and simulated parameters are summarized in the table below. Simulated parameters are shown with italic font, with the most likely values are shown in bold font.

	K[4]	**I[5]**	**n[6]**	**Vgw = KI/n**	**foc[7]**	**Koc[8]**	**Kd = foc Koc**	**ρ[9]**	$R = 1 + \frac{(1-n)\,\rho\,Kd}{n}$ **R = 1-**	**Vc = Vgw/R**
	[ft/day]	[ft/ft]	[-]	[ft/day]	[g/cm^3]	[mL/g]	[mL/g]	[g/cm^3]	[-]	ft/day
Minimum	10.4	0.001	0.2	*0.05*	0.00005	36.0	*0.0018*	1.3	*1.01*	*0.05*
Most likely	60.4	0.002	0.3	***0.28***	0.0001	150.0	***0.08***	1.5	***1.34***	***0.22***
Maximum	71.7	0.003	0.4	*0.54*	0.0010	303.0	*0.303*	1.9	*1.86*	*0.29*

The Site history indicates that the release of contaminants on-Property commenced approximately 30 years ago. Using 30 years as the PCE travel time and the most likely PCE velocity (0.22 feet/day), the PCE center of mass should currently be located at about 2,400 feet from the source. This corresponds to the location of the downgradient groundwater "hot spot" identified in the area of MW-16, GW2E-4, GW2F-1, GW2F-2 and provides confidence in the fate and transport parameters developed herein. Using the same contaminant velocity, the estimated travel time

[4] Hydraulic conductivity (range defined by field-based slug testing)
[5] Hydraulic gradient (range defined by field-based observation from synoptic groundwater levels during RI)
[6] Effective porosity (range assessed from literature values and general characteristics of Cohansey Formation)
[7] Fraction of organic carbon (range assessed from literature values and general characteristics of the Cohansey Formation)
[8] Organic carbon-water partitioning coefficient (literature-based range of values for PCE)
[9] Soil density (range assessed from literature values for sandy soils)

from this location to the Municipal Supply Well #8 located 4,500 feet to the southeast is about 55 years.

An uncertainty in this calculation is the effect of regional pumping which varies according to water resource needs in the region. The table below provides average pumping rates over the past 5 years, which have varied between a high of 888 gpm to a recent low of 130 gpm. The Municipality has also indicated that Well #8 has not been pumped since August 2007. During periods of high pumping, the gradient towards the municipal well would be increased, reducing travel time, and under low pumping groundwater is expected to follow the natural southerly/southeasterly flow direction of the Mullica River hydrographic basin, bypassing the municipal well. This flow direction is illustrated by the synoptic water levels shown in Figures 2-4 through 2-6.

Year	Gallons Pumped per			
	Year [gal/year]	Month [gal/month]	Day [gal/day]	Minute [gpm]
2003	4.08E+08	3.40E+07	1,117,137	776
2004	3.49E+08	2.90E+07	955,005	663
2005	4.37E+08	3.64E+07	1,197,151	831
2006	4.67E+08	3.89E+07	1,278,901	888
2007	6.85E+07	5.71E+06	187,658	130
2008	0	0	0	0

Source: NJDEP Preliminary Data and communication with Winslow Township

In summary, depending upon the future usage of Municipal Well #8, site contaminants may or may not continue to migrate towards the well. If the well is pumped at a high rate, gradients in the vicinity of the well may increase to the upper end of the simulation range and the travel time from the most downgradient monitoring well would be reduced to about 40 years. In any event, the travel time will be lengthy, providing ample time to monitor the plume concentration changes and potential plume advancement. It is also anticipated that additional data on the downgradient plume “hot spots” will be collected during a pre-design investigation, allowing for the completion of a more sophisticated groundwater fate and transport model at that time to refine estimates of the travel time and potential for impact at the Municipal Supply Well #8.

2.7 Risk Assessment Summary

The Baseline Human Health Risk Assessment and Screening Level Ecological Risk Assessment was submitted in January, 2007 and a revised version, addressing EPA comments, was submitted in October 2008. A Final Report will be submitted in February 2009 addressing USEPA comments. The results of the revised assessment are summarized in the following sections and on Tables 2-1A and 2-1B.

2.7.1 Human Health Risks

Quantitative risks were estimated for industrial/commercial workers, trespassers (both pre-adolescent and adolescent), residents (adult and child), and construction workers. Both cancer risks and hazard indices were estimated for both reasonable maximum exposure (RME) and central tendency (CT) scenarios using site-specific exposure pathways (both current and potential future exposure) for the five media: groundwater, surface soil, subsurface soil, surface water, and sediment. In order to conservatively estimate potential risks, USEPA recommends conducting the risk assessment using reasonable maximum (95^{th} percentile) variables for most parameters. This approach is used to intentionally provide health-protective estimates of the risks that may be associated with the Site. Calculations based on central tendency (CT) variables are included in the risk assessment to provide context and assist USEPA in making risk management decisions for pathways that exceed acceptable risk ranges, based on the more conservative RME analyses. The USEPA's acceptable risk range for cancer induction from exposure to contaminants is 10^{-4} to 10^{-6}. Non-carcinogenic risks are evaluated on the basis of a hazard index (HI), which is a comparison of the estimated exposure dose to a reference dose or estimated exposure concentration to a reference concentration, which is an estimate of an exposure level that is not expected to result in adverse health effects. Therefore HI values of less than one (1) indicate no potential for adverse effects.

The assessment identified risks that exceed USEPA guidelines for exposure to volatile organic compounds in groundwater by potential future industrial/commercial workers and potential future on-Property residents. Potential risks to on-Property receptors have subsequently been mitigated by the Source Removal Action. During Source Removal activities in November 2007, discrete areas of un-naturally colored soils were observed. Analysis of the near surface colored soils indicated lead was the primary contaminant of concern, and exceeded New Jersey screening criteria in seven of nine samples. These soils are to be removed, pursuant to the Removal AOC, which will effectively eliminate any potential risks from exposure to these soils.

The potential future exposure of construction workers to on-site subsurface soil also had a total hazard index greater than one based mainly on the potential inhalation of hexavalent chromium. For purposes of this calculation, it was conservatively assumed that all detected chromium was in the more toxic hexavalent form. It should likewise be noted that the 95% upper confidence level (UCL) exposure concentration used for calculating these estimated risks (213.65 mg/kg) was dominated by a single elevated chromium detection of 912 mg/kg (SB25-06), which has been removed as part of the colored-soils removal action.

It should be noted that there is no current exposure pathway to contaminated groundwater, and that new developments in the vicinity of the Site are required by municipal ordinance to connect to the municipal water supply system. MW-18, which is the most downgradient well, shows very low-level detections of chlorinated ethenes (PCE of 0.82 J µg/L, TCE of 1.8 J µg/L, and cis-DCE of 3.4 µg/L in February 2007) and is located approximately 2,800 feet east of the nearest Municipal Pumping Well, #8. The groundwater plumes associated with the Site[10], therefore do not represent a current risk to the quality of the municipal water supply.

2.7.2 Ecological Risk

The objective of the Screening Level Ecological Risk Assessment (SLERA) was to identify, qualitatively and quantitatively (where appropriate), the potential current and future environmental risks associated with the Site that would exist if no action is taken. Pursuant to USEPA guidance, conservative assumptions were used in the SLERA to assess which contaminants and exposure pathways present at the Site might potentially present ecological risks and therefore warrant additional evaluation. The SLERA evaluated chemicals of potential ecological concern (COPECs), receptor species, and exposures, including assessment of food chain risks.

Potential risks to the aquatic and terrestrial invertebrate communities were evaluated by comparing maximum surface water/sediment and surface soil contaminant concentrations to relevant protective

[10] As noted in Section 2.5, the municipal well is also equipped with precautionary carbon treatment at the wellhead.

guidance values. Potential risks to mammals and birds were evaluated by comparison of estimated daily dietary doses of contaminants of concern to dose-based ecotoxicity values that are associated with no observed adverse effect levels (NOAELs) and lowest observed adverse effect levels (LOAELs), resulting in a Hazard Quotient (HQ).

NOAEL-based HQ values greater than 1 were calculated for herbivorous small mammals for aluminum and endrin, for omnivorous birds for aluminum, chromium, lead, 4,4'DDD, 4,4'-DDT, and endrin. NOAEL-based HQ values greater than 1 were calculated for carnivorous mammals for aluminum, chromium, mercury, endrin, and dieldrin, and for carnivorous birds for aluminum, chromium, 4,4'-DDT, and endrin. LOAEL-based HQ values exceeded 1 only for mammals for aluminum and omnivorous birds for chromium and endrin.

Results of the SLERA indicate some potential risk in the event of sustained exposure to the maximum level of chemicals detected. However, the pathways/receptors of concern are driven primarily by the following data:

- A single high measurement of chromium that does not represent overall site conditions, and which has been removed as part of the colored-soils removal action;
- By 4,4'-DDT, 4,4'-DDD, and dieldrin detected primarily along the fence line adjacent to a formerly farmed area (and therefore likely not Site-related). Average concentration on-Site would not exceed a NOAEL-based HQ of 1;
- By mercury, where the average concentration on-Site would not exceed a NOAEL-based HQ of 1; and,
- By aluminum, where on-Property concentrations are consistent with natural background levels.

3.0 REMEDIAL ACTION OBJECTIVES AND ARARS

3.1 Remedial Action Objectives

As discussed above, the primary contaminants of concern are chlorinated solvents and aromatic hydrocarbons in the groundwater beneath localized areas of the Property and in defined groundwater plumes downgradient. The primary potential exposure routes to these contaminants are through ingestion, inhalation, and dermal adsorption by potential future users of the portion of the aquifer impacted by the Site contaminants, or through exposure to vapors resulting from the volatilization of contaminants in shallow groundwater, where applicable. As noted previously, the plumes of groundwater contamination sink in depth with distance from the Property, so that large portions of the plumes downgradient are overlain by a thick layer of clean groundwater; as a result, potential vapor exposure concerns are limited to areas in close proximity to the Lightman Property. As defined in previous deliverables, the RAOs for the Site are therefore to:

1. Prevent unacceptable exposures to contaminated groundwater and associated vapors;
2. Control future migration of the contaminants of concern in groundwater; and,
3. Restore groundwater quality to regulatory levels[11].

3.2 ARARs

Section 121(d) of CERCLA requires that remedial actions at CERCLA sites comply with legally applicable or relevant and appropriate cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations promulgated under Federal or State law, which are collectively referred to as “Applicable or Relevant and Appropriate Requirements” (ARARs), unless such ARARs are waived under CERCLA § 121(d)(4). “Applicable” requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. “Relevant and appropriate” requirements are those requirements that, while not legally “applicable”, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site. Only those State standards that are promulgated, are identified by the State in a

[11] The Site falls within the New Jersey Pinelands protected area and so the groundwater is classified as Class I-PL by the NJDEP and the groundwater quality standards correspond to background values or the practical quantitation limit (PQL), whichever is higher.

timely manner, and are more stringent than Federal requirements may be applicable or relevant and appropriate. ARARs may relate to the substances addressed by the remedial action (chemical-specific), to the location of the site (location-specific), or the manner in which the remedial action is implemented (action-specific).

The following discussion focuses on potential chemical-specific ARARs for the Site (Table 3-1). Location-specific and action-specific ARARs are specific to each alternative and are therefore discussed in greater detail in Section 6.

3.2.1 Chemical-Specific ARARs

Chemical-specific ARARs represent health or risk-based concentration limits in various environmental media for relevant chemicals. Because the Site falls within the New Jersey Pinelands protected area, the groundwater is classified as Class I-PL by the NJDEP and the groundwater quality standards correspond to background values or the practical quantitation limit (PQL), whichever is higher. Groundwater contaminants and their applicable clean up criteria are shown in Table 2-1A. For all groundwater COPCs, the Class I-PL standards are more stringent than the Federal Maximum Contaminant Levels (MCLs), with the exception of thallium, where the MCLs and Class I-PL standards are equivalent.

3.2.2 Location-Specific ARARs

Location-specific ARARs set restrictions on the conduct of remedial activities in particular locations (e.g. floodplains). Potential State and Federal location-specific ARARs include Executive Orders on Floodplain Management and Wetlands Protection, the Federal Fish and Wildlife Conservation Act, and the New Jersey Soil Erosion and Sediment Control Act.

3.2.3 Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions or conditions taken with respect to specific hazardous substances. Action-specific ARARs do not determine the remedial alternative; rather, they indicate how a selected alternative must be implemented. Potential Federal and State action-specific ARARs are contained in the Resource Conservation and Recovery Act (RCRA); the Clean Water Act; the Clean Air Act; and

New Jersey statutes for pollutant Discharge, Surface Water Quality, and Toxic Pollutant Effluent Standards.

4.0 DEVELOPMENT AND SCREENING OF TECHNOLOGIES

This section identifies and describes technologies that could be utilized in formulating a remedy to meet the preliminary remedial action objectives described above. A wide range of technologies were considered in the previous Candidate Technologies Memorandum (Golder, 2005). Technologies were screened for applicability to the Site using the following qualitative criteria:

- Potential contribution to meeting the RAOs; and,
- Technical feasibility/implementability considering site-specific conditions.

The technologies retained following the screening process are described in more detail below. One or more of the retained technologies may be used to effectively address contamination associated with the Site, and different approaches may be utilized for different parts of the Site. The technologies described below are grouped according to whether they are applicable for the entire Site, applicable to source areas, or may be most useful for addressing the localized areas of elevated concentrations in the deeper portion of the eastern plume downgradient.

4.1 Site-Wide Technologies

Institutional Controls (IC)

Restrictive covenants can be placed on the Property to control future land and/or water use. Restrictions may be legally attached to the Property deed so that if title to the Property is transferred to a new owner, the restrictions remain in place. Deed restrictions are often used in conjunction with other technologies for the purpose of protecting human health while cleanup is in progress and to protect the integrity of the remedial measures. Restrictions on real property in the form of a Deed Notice require landowner consent and can be used to limit excavations, groundwater use, and certain types of future land use, such as building over areas that may be susceptible to vapor intrusion. For groundwater, a Classification Exception Area / Well Restriction Area (CEA/WRA) may be established by the State to prevent use of contaminated groundwater while cleanup is in progress. A CEA/WRA is established by the NJDEP and serves as notice that the constituent standards for a given aquifer classification are not met in a localized area, and that designated aquifer uses, including the installation of wells, are suspended in the affected area for the term of the CEA to ensure that the uses of the aquifer are restricted until standards are achieved.

Monitored Natural Attenuation (MNA)

MNA, as defined in the USEPA Directive 9200.4-17 (1999), refers to the reliance on natural attenuation processes to achieve Site-specific remediation objectives within a time-frame that is reasonable compared to that offered by other more active methods. MNA utilizes natural in-situ processes including physical, biological or chemical methods to reduce the mass, toxicity, mobility, volume, or concentration of chemicals in groundwater (USEPA, 1999). In-situ processes include biodegradation, dispersion, dilution, sorption, volatilization, stabilization, transformation, and destruction. These natural processes are monitored via regular sampling and analysis of wells, including downgradient “sentinel wells” positioned to assure that the area of contamination is not expanding in size. In the present case, establishing an appropriate monitoring program that will adequately monitor the plumes and be protective of potential receptors may require installation and monitoring of additional wells in strategic locations.

4.2 Source Area Technologies

4.2.1 Air Sparging/Soil Vapor Extraction (AS/SVE)

Air Sparging is an in-situ remedial technology for the removal of volatile and some semi-volatile organic compounds from groundwater. Application of air sparging transfers dissolved phase contamination in groundwater into air that is injected below the water table and percolates up into the vadose zone. Sparging is therefore implemented with soil vapor extraction which removes contaminated vapors from the vadose zone. Capture of these vapors in the vadose zone prevents fugitive emissions into the atmosphere and mitigates possible vapor intrusion issues into adjacent structures.

For air sparging/SVE to be successful, the physical properties of the contaminants of concern must fall within certain specific ranges as detailed below (Montgomery, 1995)

Contaminant Properties

	Henry's Law Constant (atm)	Boiling Point (Celsius)	Vapor Pressure (Torr)
Contaminant/Screening Criteria	> 100 atm	< 300 °C	> 0.5
Tetrachloroethene (PCE)	579	121	18.2
Trichloroethene (TCE)	346	87	75
Cis-1,2-Dichoroethene (cis-DCE)	143	60	200
Chlorobenzene	191	80	85
Benzene	115	131	6
Total Xylene	156	138	5
Ethyl Benzene	240	136	10

The groundwater plumes are located in Cohansey Sand, which provides an effective intrinsic permeability that will support the required air flow. The treatment area is relatively homogeneous with no evidence of interbedded lenses. The downgradient plumes plunge to deeper depths within the groundwater as they travel away from the source area. This provides a unique situation where a layer of non-impacted groundwater exists over the plumes downgradient of the source area. The depth to groundwater is shallow, which limits the depth of SVE well screen intervals. In addition, the ground surface is permeable, which may limit the effective zone of influence (ZOI) of SVE wells.

A pilot test as part of a Pre-Design Investigation (PDI) will be required to provide detailed design criteria for the implementation of AS/SVE. In particular, pilot testing will enable site-specific evaluation of the following:

- Zone of Influence (ZOI) of sparge wells and vapor extraction wells
- Injection air flow rates
- Sparging injection pressure
- Injection depth
- Extraction vapor flow rates
- Vacuum pressure
- Contaminant removal rates
- Condensate production rates

Design considerations would include the evaluation of vertical wells, horizontal trenches, and the placement of an impervious cover to reduce air infiltration.

SVE is an accepted, proven technology that is applicable to the Site contaminants and is readily implementable. Air sparging is a developing technology that with appropriate PDI-derived data, could be applied to the Site contaminants.

4.2.2 In-Situ Chemical Oxidation (ISCO)

ISCO is a remedial technology that utilizes strong oxidants to oxidize organic compounds to water, carbon dioxide (CO_2) and inorganic salts. ISCO is a non-specific technology and will treat all compounds that are capable of oxidation, not simply contaminants of concern. The natural oxidization demand (NOD) is therefore an important design consideration. Accordingly, ISCO treatment is commonly focused on source areas (typically >10 ppm concentrations) or areas with high oxidation efficiency (Huling and Pivetz, 2005). The oxidation efficiency is defined as the mass of contaminants transformed divided by the mass of oxidant reacted. At the Lightman Drum Site, the oxidization efficiency is anticipated to be low, on the order of <1%, although the NOD of the soil is uncertain. ISCO treatment is not usually applied to low concentration groundwater plumes because of the low oxidant efficiency, large volumes and the associated high costs.

The three (3) most commonly applied oxidants are permanganate (MnO_4^-), hydrogen peroxide (H_2O_2) plus iron (Fe), known as Fenton's Reagent, and persulfate ($S_2O_8^{2-}$). Several factors contribute to the applicability of each oxidant to Site-specific conditions. In particular, reactivity with contaminants of concern, oxidant persistence (reaction rate), and NOD are critical to selecting an appropriate oxidant. The NOD includes all of the oxidizable compounds in the system (inorganic and organic) apart from the target compounds. The most important oxidant characteristic is its ability to treat the particular contaminants of concern at the Site. The table below summarizes the three (3) most common oxidants and their applicability to Site-specific compounds, expressed as reactivity from literature reported values (Sperry and Cookson, 2002; ITRC, 2005; Brown, 2003; Siegrist et al., 2001).

Reactivity of Oxidants Toward Specific Compounds

Contaminant	Permanganate	Fenton's Reagent	Persulfate
Toluene, xylenes, ethylbenzene	High	High	Medium
Benzene	Low	High	Medium
Chlorinated ethenes (e.g., PCE)	High	High	Medium

Based on its more limited reactivity, persulfate has not been retained in this Feasibility Study. In addition, persulfate requires activation in-place and therefore is more applicable to limited areas of impact (~50 ft). Fenton's Reagent has been retained due to its high reactivity toward all of the Site-specific compounds. Permanganate has been retained for potential use as a polishing oxidant after benzene is degraded or for down-gradient use in areas that have not been impacted with benzene. The persistence of each of the two retained oxidants is an important consideration and is summarized in the table below.

Chemical Specifics and Persistence of Retained Oxidants Table

Oxidant	Reactive Species	Form	Persistence
Permanganate	MnO_4^-	Powder/Liquid	> 3 months
Fenton's Reagent	$OH\bullet$, $O_2^-\bullet$, $HO_2\bullet$, HO_2^-	Liquid	minutes to hours

NOD is Site-specific and must be determined thorough bench-scale treatability testing. NOD may represent as much as 99% of the total oxidant demand resulting in most of the mass of oxidant actually treating NOD rather than target compounds. In general, Fenton's Reagent is more susceptible to NOD than permanganate and costs can rapidly rise as a function of increasing NOD.

Two common forms of permanganate are available, potassium permanganate ($KMnO_4$) and sodium permanganate ($NaMnO_4$) and may be evaluated for usage during bench-scale testing. Sodium permanganate is more soluble and can produce more highly concentrated solutions for injection. However, sodium permanganate is more reactive and may have a smaller zone of influence due to reactive transport issues. Permanganate is effective over the entire pH range, but the mechanisms involved vary as a function of pH. The oxidation mechanism for permanganate is direct electron transfer to organic compounds. Included below are a number of advantages and limitations specific to permanganate.

Advantages of permanganate:

- High concentrations can be safely and effectively injected;
- Long-term persistence (weeks to months) may permit a larger ROI;
- Higher density of permanganate facilitates density-driven vertical transport;
- Limited reactivity with non-target compounds; and,
- Ease of visual conformation at monitoring wells (purple color).

Limitations of permanganate:

- Some important compounds are not amenable to oxidation by permanganate (benzene);
- MnO_2 (a reaction by-product) can accumulate and clog the aquifer;
- High NOD can result in excessive oxidant usage and associated high cost;
- High oxidant usage can cause density-driven vertical transport out of the target zone, resulting in inefficient utilization of oxidant; and,
- Significant health and safety concerns are associated with reagent handling and implementation.

Fenton's reagent is the combination of hydrogen peroxide (H_2O_2) with ferrous iron (Fe^{2+}). In aquifers with limited native iron concentrations, ferrous sulfate is typically injected prior to injection of hydrogen peroxide to produce Fenton-type chemistry. The inclusion of iron allows for the decomposition of H_2O_2 to radical intermediates that non-selectively oxidize available compounds, including organic contaminants. Fenton's Reagent is effective over a relatively small pH range (pH 3-4). Therefore, pH amendment is typically needed to condition the aquifer for effective treatment using Fenton's Reagent. Depending on aquifer soil buffering capacity, cost can increase rapidly based on acid consumption during pH amendment. The oxidation mechanism for Fenton's Reagent is radical attack of organic compounds along with reductive decomposition via some of the peroxide intermediate compounds. Included below are a number of advantages and limitations specific to Fenton's Reagent.

Advantages of Fenton's Reagent:

- Powerful, non-specific, oxidant capable of degrading many organic compounds;
- Rapid reaction (reaction rate of minutes to hours);
- Intermediate reaction by-products can reductively degrade contaminants, useful for plume mixtures (BTEX and chlorinated ethenes);
- Release of heat and O_2 can enhance biodegradation; and,
- Low cost of oxidant.

Limitations of Fenton's Reagent:

- Excessive reactions with non-target compounds (NOD);
- pH modification is necessary (acidification);
- pH adjustment may enhance metal or contaminant migration;
- Significant cost can be incurred for pH adjustment;
- Iron amendment may be necessary;
- Reactive transport issues (delivery);
- Potential migration of contaminants;
- Potential mobilization of metals (oxidation and pH);
- Heat release during injection and reaction;
- Health and safety issues; and,
- Security issues associated with storage of large amounts of H_2O_2.

Careful engineering design of the system and proper construction of the delivery equipment is critical to successful *in situ* remediation via chemical oxidant injection. Bench- and pilot-scale testing as part of a PDI would be required to establish the NOD, confirm the suitability of oxidants to treat the Site-specific COCs, and to verify the zone of influence of injection wells. Also, gas and heat generation must be managed to avoid Health and Safety issues. Oxidants could be injected into the subsurface using Direct-Push Technology (e.g., Geoprobe®) and either temporary injection borings or permanent injection wells.

ISCO as an overall technology is potentially applicable to the Site, although, as with all technologies, it has advantages and limitations. The most critical limitation of ISCO at the Site is that it is not an established technology for large, low concentration plumes, and may not be a cost-effective remedy for such situations. Higher oxidant demand would also require multiple oxidant injections to be performed. Because large volumes of oxidant would need to be injected, a significant concern is the potential mobilization of contaminants downgradient through groundwater mounding and increased flow. Finally, the use of strong oxidants raises health and safety concerns with flammability and potential for explosive off-gas production.

4.2.3 Reductive Dechlorination

Reductive dechlorination is the removal of chlorine from a substance by chemically replacing it with hydrogen. Zero-valent iron is an effective reductant that can treat many contaminants, and is particularly effective for chlorinated solvents, which can be completely reduced to non-toxic compounds such as ethene and ethane. Granular zero-valent iron has been successfully utilized at multiple sites. Nano-scale zero-valent iron (NZVI) particles have been shown to be more reactive and extremely effective because of their increased surface area to mass ratio compared to granular iron.

Nano-scale zero-valent iron was retained in the Candidate Technologies Memorandum because the technology has been demonstrated to be effective for chlorinated solvents. A pilot test was subsequently conducted at the Lightman Drum Site according to the approved Nano-Scale Zero-Valent Iron Pilot Test Work Plan (Golder 2005). NZVI was injected into well MW-2A, in the Former Waste Storage Tank Area and performance monitoring was conducted in wells MW-2B, MW-8A, MW-8B, and MW-21. The NZVI pilot test demonstrated that while NZVI was effective at degrading groundwater contaminants, the NZVI could not be effectively distributed in the subsurface, making the technology difficult to implement and not cost-effective. As a result, this technology is not retained in the FS.

4.3 Downgradient Technologies

As discussed in Section 2.6, elevated concentrations in downgradient areas appear to be localized both laterally and vertically. Based on the substantial decline of concentrations in monitoring wells, located downgradient of the underground waste storage tanks, contaminants could be naturally attenuating rapidly or could have shifted since the initial investigations were conducted, or both.

Accordingly, implementation of any active downgradient groundwater remedy would need to confirm the presence and current location of target areas as part of a Pre-Design Investigation. Descriptions of each potentially applicable technology are presented below.

4.3.1 Groundwater Extraction and Treatment (P&T)

This technology consists of the physical extraction of impacted groundwater, treatment, and disposal of the treated groundwater.

Extraction

Extraction wells are used to capture and withdraw degraded groundwater with well locations dependent on geologic and hydrogeologic conditions of the aquifer, and the nature and extent of contamination. Because the localized areas of downgradient contamination ("hot spots") are not well defined, the effective application of this technology will require additional delineation during the remedial design phase. Extraction wells are generally a long term remedial technology that can also control the mobility of contaminants in groundwater. Operation and maintenance of the wells is critical to maintain effectiveness because of susceptibility to biologic growth and precipitation of metals. Installation of off-Property extraction wells and related header systems will require access agreements with, and the cooperation of, appropriate landowners.

On-Site Treatment

On-Site treatment of extracted groundwater would require construction of a water treatment system, which may include the following technologies:

Air Stripping: Air stripping is a mass transfer process in which volatile organic contaminants in groundwater are transferred to the gaseous (vapor) phase. This technology is widely used to treat volatile organic compounds in groundwater. The vapor phase stream may require subsequent treatment to comply with ARARs.

Carbon Adsorption: Carbon adsorption is widely used in the removal of organic compounds from water. Carbon adsorption is a physical treatment process involving adsorption of chemical contaminants onto granular activated carbon contained in large vessels. The activated carbon adsorbs constituents and once the micro-pore carbon surfaces are saturated, the carbon is "spent" and must either be replaced or removed and regenerated.

Discharge

On-Site Re-injection: Effluent from an on-site treatment system may be disposed by discharging to shallow infiltration galleries or injection wells. Discharge permit equivalencies would be required and possible hydraulic effects on the downgradient plumes must be considered. Such discharge may be part of a horizontal or vertical recirculation system that may provide hydraulic containment as well as aquifer flushing. Additional treatment of extracted ground water may be required to prevent fouling of injection points by iron precipitation or bio-mass growth.

Discharge to Surface Water/Wetlands: Effluent from an on-site treatment system may be disposed by discharging to wetlands associated with Pump Branch Creek or possibly to the stream itself. Permit equivalencies are required for surface water discharge and the effluent must meet regulatory discharge standards. Pump Branch Creek adjacent to the site is ephemeral and access to the wetland/creek will necessitate horizontal drilling under railroad tracks.

Discharge to Publically Operated Treatment Works (POTW): Effluent from an on-site treatment system may be disposed by discharging into the sanitary sewer along Route 73 that conveys flow to the Camden County Municipal Utility Authority (CCMUA) treatment facilities. Permit equivalencies are required for such a discharge and the effluent quality must meet standards set by the POTW and be otherwise acceptable to the CCMUA. This would require construction of discharge pipeline over private property to the nearest available discharge point.

Each of the discharge options described above has distinct advantages and limitations as discussed below:

On-site re-injection wells provide the ability to locally affect groundwater flow so as to direct contaminated groundwater inwards toward the extraction wells, but these systems typically require more maintenance than other discharge options. Discharge directly to surface water at this Site is limited by access difficulties related to the need for the discharge line to cross an active rail line, wetlands, and private property. Discharge to the POTW has the advantage of treatment by the POTW, and the possibility that pre-treatment may not be necessary, however, a lengthy pipeline beneath private property would be required to convey flow to the discharge point.

Extraction and Treatment as an overall technology is potentially applicable to the downgradient eastern plume. There are, however, limitations to use of this technology in this case, including discharge challenges and the need for extensive long-term access to private property. The relatively high volumes of water that would be extracted with low concentrations also make this technology inefficient.

ART System

An innovative alternative to conventional extraction and treatment involves the use of in-well treatment offered by Advanced Remediation Technology (ART). This method, which has been favorably evaluated by USEPA elsewhere (Field, et. al., 2007), uses patented technology to achieve extraction, in-well treatment and reinjection in an integrated manner. Remediation activities are conducted essentially within the limits of the well and involve lifting of the groundwater from the bottom of the well; in-well treatment and discharge back to the aquifer. This arrangement creates an in-situ circulation of groundwater within the effective radius of influence.

The in-well treatment technology combines *in situ* air stripping, air sparging, soil vapor extraction and enhanced bioremediation/oxidation. Groundwater is re-circulated through a dual casing well to enhance air stripping efficacy by allowing multiple passes of a water slug through the treatment system. Air sparging provides elevated oxygen concentrations to groundwater that is recharged into the aquifer, allowing the development of a radius of aerobic conditions proximal to the treatment well. The system requires treatment of collected vapors and has been reported to effectively treat CAHs and BTEX compounds. If groundwater extraction and treatment is ultimately selected, this process option may be further evaluated as part of a PDI. The approach appears to be potentially suitable to address downgradient “hot spots” by creating an effective capture/treatment zone corresponding to the area of elevated concentrations. An advantage of the ART process option is that extracted groundwater is re-injected into the formation after treatment, avoiding impact to the water resource.

4.3.2 In-Situ Treatment

Anaerobic Engineered Bioremediation

Anaerobic engineered bioremediation involves the injection of organic carbon (e.g., lactate, methanol or emulsified oil substrate) to stimulate indigenous microorganisms to produce hydrogen (H_2), which results in the further stimulation of organisms capable of degrading chlorinated aliphatic hydrocarbons. In many cases, the groundwater system is limited by the presence of suitable electron donors (e.g. organic carbon) to support anaerobic microbial respiration processes. In turn, dechlorinating organisms are limited by the lack of hydrogen available for respiration. Dechlorinating organisms are highly specific and only use molecular hydrogen as an electron acceptor coupled to the reduction of chlorinated ethenes. Therefore, both organic substrate and a sufficiently high concentration of chloroethenes (> 100 ppb) are necessary to support dechlorinating organisms. Thus, even with the presence of an available organic carbon source, the biodegradation of low concentrations of chloroethenes may still be limited. The biostimulation process is based on the ability of microbes to obtain energy from the oxidation of the injected organic carbon substrate coupled to the reduction of a terminal electron acceptor (nitrate, iron, sulfate, etc.). This process also changes the redox conditions in the zone of influence as organisms degrade organic carbon and produce reducing conditions through the production of hydrogen. However, without the presence of appropriate organisms, these changes may still not effectively treat chlorinated compounds. Therefore, in addition to biostimulation, it is anticipated that bioaugmentation (addition of microbial species capable of degrading target compounds) would also be necessary. The overall geochemistry at the Site is not conducive to the support of indigenous dechlorinating microorganisms, however, in any natural system micro-environments may exist that support continuing intrinsic anaerobic bioremediation. These organisms are strict anaerobes and are intolerant to dissolved oxygen levels greater that ~0.5 mg/L. Generally, conditions in the plumes exceed this oxygen tolerance. For a successful community of microorganisms to inhabit the subsurface, geochemical conditions must be altered to produce anaerobic conditions that are significantly reducing. Several commercial cultures are then available that can be injected into the subsurface to propagate the appropriate dechlorinating species. To further develop biostimulation/bioaugmentation as process options bench- and pilot-scale studies would be necessary.

Anaerobic engineered bioremediation is a proven technology for the downgradient plume contaminants, if the geochemical and microbial conditions are appropriate. However, conditions in the downgradient plumes limit the applicability of the technology in this case. Aquifer geochemical conditions are aerobic and will need to be conditioned to support anaerobic biodegradation and even then, the chlorinated ethene concentrations may be too low (<100 ppb) to support dechlorinating organisms. For these reasons, anaerobic engineered bioremediation is not retained for consideration as part of the alternatives evaluated in this FS.

Permanganate ISCO

As described in Section 4.2, ISCO is a remedial technology that utilizes the reactivity of strong oxidants to break down organic compounds to water, carbon dioxide (CO_2) and inorganic salts. Because permanganate is more persistent than Fenton's Reagent, and is effective on chlorinated ethenes, it would be the oxidant of choice for downgradient contaminants. Unlike in the source area, however, the zone(s) to be treated are not well defined, and effective application of this technology would require additional delineation.

ISCO as an overall technology can be potentially applicable to the downgradient area. Advantages of using ISCO to address localized downgradient contaminants include: organic compounds are destroyed in-situ over relatively short time-scales and implementation typically produces limited volumes of waste material; following reaction there is no residual reagent left in the system. A significant limitation for using ISCO to address the downgradient "hot spots" is that, as mentioned in Section 4.2, ISCO treatment is commonly focused on source areas or areas with high oxidation efficiency (Huling and Pivetz, 2005). ISCO treatment is therefore not usually sufficiently efficient to warrant use in lower concentration downgradient groundwater plumes. Because of the low efficiency, downgradient treatment may require impractical volumes of oxidant and may require multiple injections at excessively high cost. Since the treatment is non-specific, it would be critical to clearly delineate localized areas for treatment.

5.0 REMEDIAL ALTERNATIVES

The retained technologies presented in Section 4.0 were assembled into the following seven remedial action alternatives for further evaluation:

- Alternative 1 No Further Action
- Alternative 2 Air Sparging/ Soil Vapor Extraction + Institutional Controls + Monitored Natural Attenuation
- Alternative 3 *In situ* Chemical Oxidation + Institutional Controls + Monitored Natural Attenuation
- Alternative 4A Air Sparging/ Soil Vapor Extraction + Downgradient Pump and Treat + Institutional Controls + Monitored Natural Attenuation
- Alternative 4B *In situ* Chemical Oxidation + Downgradient Pump and Treat + Institutional Controls + Monitored Natural Attenuation
- Alternative 5A Air Sparging/ Soil Vapor Extraction + Downgradient *in situ* Chemical Oxidation + Institutional Controls + Monitored Natural Attenuation
- Alternative 5B ISCO + Downgradient *in situ* Chemical Oxidation + Institutional Controls + Monitored Natural Attenuation

The No Further Action alternative (Alternative No. 1) is included for consistency with the NCP and includes Soil Source Removal which has been completed. The remaining alternatives were assembled as follows:

- Alternatives 2 and 3 include active remediation of groundwater using AS/SVE or ISCO. Far downgradient groundwater contamination would be treated by ongoing natural attenuation processes. Institutional controls and monitoring are included to ensure protection of human health while the active elements of the remedy become effective.
- Alternatives 4A, 4B, 5A and 5B include active treatment of far downgradient groundwater "hot spots" in combination with the elements of Alternatives 2 and 3, respectively. Both extraction and treatment and in-situ treatment are evaluated. Institutional controls and monitoring are included to ensure protection of human health while the active elements of the remedy become effective.

Each of the alternatives, other than the No Further Action Alternative, include certain common elements that are discussed below, followed by a description of the elements of each alternative.

5.1 Common Elements

5.1.1 Institutional Controls (IC)

As described in Section 4.1, restrictive covenants would be put in place to limit or control future land and/or water use. In the case of the Lightman Property, deed restrictions would preclude groundwater use in the contaminated areas and construction of structures over areas that may be susceptible to vapor intrusion, in addition to prohibiting actions that would interfere with any remedial activities for so long as they are active (e.g.; AS/SVE systems). In order to provide protection from exposure to impacted groundwater, a Classification Exception Area/Well Restriction Area (CEA/WRA) would be established to prevent groundwater use within the plume areas at and downgradient of the Site.

5.1.2 Monitored Natural Attenuation (MNA)

As described previously, MNA utilizes natural in-situ processes to reduce the mass, toxicity, mobility, volume, and/or concentration of chemicals through biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants (EPA OSWER Directive 9200.4-17, 1999). The primary in-situ processes believed to be contributing to ongoing natural attenuation at the Lightman Drum Site include, dispersion, dilution, sorption and degradation.

The influence of dispersion, dilution, and sorption can be estimated using relatively simple analytical solutions to the advection-dispersion equation as discussed by Freeze and Cherry (1979). The following calculation defines the maximum concentration and the specific location and time at which it occurs based on Site-specific parameters. For a solute release into a steady-state uniform flow field in a homogeneous isotropic aquifer, the maximum concentration is given by:

$$C_{max} = \frac{Mo}{8\,(\pi t)^{3}/_{2}\sqrt{D_x D_y D_z}}$$

Where:

M_o = Initial contaminant mass

t = Time

D_n = Dynamic dispersivity in coordinate direction n

In the present case, the total mass of contaminant present has been estimated for the plume based on the interpreted groundwater concentration contours as shown in Table E-3, and dispersivities may be calculated using the method recommended in USEPA (2002). Table 5-1 presents the maximum concentration versus time, and the distance from the source to the location of the maximum concentration. For the case without any downgradient mass removal, the maximum concentration at the location of the Municipal Well (4,500 feet downgradient) is expected not to exceed 9.5 µg/L and the peak would occur in about 57 years. In the event that an active downgradient "hot spot" remedy is implemented, reducing the total mass of contaminants, the maximum concentration at the location of the Municipal Well would not exceed 3.5 µg/L (Table 5-2). It is important to note that these analyses do not include any concentration reduction as a result of biodegradation, and furthermore since the plume would affect only a very small portion of the capture zone of the Municipal well, the concentration in the well water would not be detectable. This simple calculation assumes that the flow-field is uniform and that the aquifer is homogenous and isotropic, and uses hydraulic parameters as discussed in Section 2.6.4.

An analysis of the degradation component of natural attenuation is presented in the following paragraphs based on natural attenuation indicator parameters (NAP) including: chloride, ethene, ethane, methane. nitrate, phosphate, sulfate, sulfide, TOC, alkalinity, DO, pH and ORP, using data collected during sampling events in 2006 and 2007 as well as concentration trend data. This evaluation shows the presence of two (2) geochemically distinct areas of the Site corresponding to the source area and the downgradient plume.

Monitoring wells within the source area (e.g., MW-21) show NAPs consistent with on-going biodegradation of contaminants, including BTEX compounds and chlorinated compounds. The redox condition in this area is mildly reducing with ORP values between ±0 mV and +100 mV, and is coupled with suboxic to anoxic conditions with DO levels <1.0 mg/L to non-detect. In addition there is evidence of iron reduction as the predominant terminal electron acceptor based on detectable concentrations of ferrous iron (0.5 mg/L to 3 mg/L). TOC levels are the highest observed (~30 mg/L) and are adequate to provide electron donor to dechlorinating microorganisms. This zone, where moderately efficient natural degradation would be expected, extends from the source area to approximately MW-12, a distance of approximately 700 feet. Within this zone, concentrations of BTEX compounds show sharp declines with distance from the source area (see Section 2.6), indicating that natural degradation of these compounds is occurring.

It is likely that in these areas, where BTEX and chlorinated compounds were co-located, BTEX was utilized as an electron donor by microorganisms capable of anaerobically dechlorinating chlorinated compounds. Degradation of chlorinated ethenes is evidenced by detections of the daughter product cis-1,2-DCE. Ten (10) out of 23 monitoring wells detected concentrations of cis-1,2-DCE and monitoring wells MW-2A, MW-3, MW-12, MW-19, and MW-21 have cis-1,2-DCE concentrations >100 ppb. Several wells have a high proportion of their total VOC concentration as cis-1,2-DCE. However, none of the monitoring wells with observed concentrations of cis-1,2-DCE have detectable concentrations of the dechlorination products of cis-1,2-DCE, namely vinyl chloride or ethene. While observed NAP levels do not indicate a geochemical environment supportive of *complete* biodegradation of chlorinated ethenes the conditions are consistent with reductive dechlorination to cis-1, 2-DCE. In general, microorganisms capable of complete reductive dechlorination of PCE and TCE (e.g., *Dehalococcoides*) are obligate anaerobes (requiring anoxic conditions; DO < 0.5 mg/L) and require strongly reducing conditions (ORP <-50 mV).

Beyond this zone of moderately effective biodegradation, in the downgradient plume, conditions are observed to be less reducing (ORP > +100mV), more oxic (DO > 2.0 mg/L) and typically carbon limited (TOC < 3.0 mg/L). These conditions are not compatible with active biodegradation of chlorinated compounds by anaerobic mechanisms. Alternative aerobic degradation pathways exist for PCE, TCE, and cis-1,2-DCE degradation as co-metabolites (Bradley & Chapelle, 1998, Gerritse et al., 1995, Sorenson et al., 2000, Deckard et al., 1994, Ryoo et al., 2000, Shim et al., 2001). The daughter product of these oxygenase enzyme co-metabolic pathways is carbon dioxide, rather than lesser chlorinated ethenes. In addition, abiotic degradation through hydrolysis is known to occur (McConnell et al, 1975; Dilling et al, 1975). Published half-lives by these various mechanisms range from less than 1 week to more than 10 years. Even at relatively long half-lives (e.g., 13 years for TCE aerobic degradation), degradation will result in mass removal (~25 % percent in 5 years and ~45 percent in 10 years). Site-specific biodegradation half-lives for PCE, TCE and cis-1,2-DCE will be investigated further if MNA is used as a remedial component at this Site.

As described in the Remedial Investigation Report Addendum, concentration trends in monitoring wells (i.e. MW-12, MW-15 and MW-16) within the eastern plume have showed consistent reductions in concentrations since initial sampling in 2005 (Appendix B). The monitoring well results from the February 2007 event indicate that the concentrations of tetrachloroethene (PCE) and trichloroethene (TCE) in all of the off-Property monitoring wells have declined to low levels. The concentration of PCE was below 1 µg/L in all off-Property sampled wells, except MW-16 (1.2 J µg/L) and MW-20 (3.1 J µg/L), and the maximum off-Property concentration of TCE was 6.1 µg/L in MW-12 (down from 250 µg/L in 2005). This data suggests that two processes may be at work. First, the generally declining trends in "parent" chlorinated volatile organic compounds (cVOCs) in many wells, and the presence of the "daughter" product cis-1,2-DCE suggests that intrinsic anaerobic bioremediation is occurring, or has occurred in the past in some areas. For example, in MW-12, cis 1,2-DCE was observed at 500 ppb in 2006, declining to 200 ppb in 2007, when it represented greater than 80% of the mass of cVOCs in the well. An evaluation of the ratio of the molar concentration of parent compounds (PCE + TCE) to the molar concentration daughter compounds (cis 1,2-DCE + vinyl chloride) suggests that daughter products are increasing as a function of distance, at least as far as monitoring well MW-12 and potentially as far as monitoring well MW-15. This shift in ratio suggests that anaerobic biodegradation has occurred and daughter product concentrations are increasing downgradient with respect to parent compounds (as opposed to downgradient transport of daughter products from upgradient areas). In addition, the ratio of cis-1,2-DCE to trans-1,2-DCE (~2000:1 at MW-12) indicates a biological role in the production of cis-1,2-DCE. (A ratio >5:1 is generally accepted as showing a biological component as the cis-1,2-DCE isomer is preferentially generated by microbial action.) Alternatively, co-metabolic aerobic biodegradation pathways or abiotic mechanisms may be transforming TCE, cis-1,2-DCE and vinyl chloride to CO_2.

Further insight into the natural attenuation of chlorethenes is provided by considering the total combined molar concentration of PCE, TCE, cis-1,2-DCE, vinyl chloride and ethene along a downgradient transect including MW-21, MW-8A, MW- 12, MW-15, MW-16 and MW-18. The results suggest that a significant amount of chlorinated ethenes are being eliminated by mechanisms other than typical reductive dechlorination.

The second potential process that could result in decreasing temporal trends in downgradient wells such as MW-15 and MW-16 may be that the "hot spots" previously detected at these locations have shifted to the west of the monitoring wells based on the detections of PCE and TCE in profile borings conducted in 2007.

A critical component of MNA is a well-designed regular monitoring program. This monitoring program would include a network of wells for monitoring the existing plumes and satisfying NJDEP requirements for a CEA. The details of the monitoring program would be developed during design, but would likely include the installation of additional sentinel wells and additional plume wells to delineate the plume in the westerly direction where some uncertainty remains based on the data included in the Remedial Investigation Report Addendum. Parameters to be monitored would include VOCs, and relevant natural attenuation indicator parameters including, specific conductivity, DO, ORP, pH, temperature, alkalinity, ethane, ethene, methane, nitrate/nitrite as N, sulfate, sulfide, total organic carbon (TOC), total manganese, ferrous iron, and total iron. Water levels would also be measured during each sampling event and equipotential maps would be constructed to monitor groundwater flow particularly in the area of the plume closest to the Municipal wells. Monitoring of the plumes downgradient of the Site would require continued access for sampling of downgradient monitoring wells.

5.2 Alternative 1: No Further Action

This option is required by the National Contingency Plan as an alternative that must be retained through the Feasibility Study. In this alternative, other than the source area soil removal that has already been completed, no additional measures would be taken to protect human health and the environment. This alternative relies solely on natural processes to reduce the mobility, toxicity, and volume of contaminants. The alternative may be selected if natural processes would result in the degradation and reduction in the mobility of contaminants within a reasonable time frame. The No Further Action Alternative will require an extremely long time period to meet the remedial action objectives.

5.3 Alternative 2: AS/SVE + IC + MNA

The conceptual design of Alternative 2 consists of separate AS/SVE systems for both the west and east plumes and builds on soil source removal conducted in the eastern plume source zone (Former Waste Storage Tanks) to further address source area groundwater in the vicinity of the Former Waste Storage Tanks and unlined pit and the plumes immediately downgradient. The conceptual design evaluated for feasibility study purposes is based upon performance parameters determined from known site conditions and previous experience of similar systems.

The proposed treatment area for both the eastern and western plumes is shown on Figure 5-2. The treatment area includes zones defined by a total volatile organic compounds (VOC) concentration of 100 parts per billion (ppb), both within the Lightman Drum Property and downgradient beneath the adjacent property, Block 4004, Lot 7.01.

The design approach involves continuous air sparging of the groundwater in the treatment area to address concentrations of dissolved total volatile organic compounds and any absorbed contaminants on saturated soils.

The dissolved phase plumes sink as they migrate downgradient south of the Lightman Property. In this area “clean” water is present over the plumes. In order to limit the potential for impacting this layer of clean water with impacted groundwater underlying it, the anticipated operation of the downgradient portions of air sparge system would be on a daily intermittent basis. The design of the air sparge wells in this area, would utilize a lower range of air injection volume and pressures to reduce the potential of creating vertical circulation of groundwater above the air sparge injection points as a result of the lower density of the air sparged water. In turn, this would reduce the potential affect on the normal gradient of the groundwater flow. The relatively low rate of groundwater flow permits this intermittent air sparge operation to still achieve the desired remedial effect.

The zone of influence (ZOI) for air sparge wells was estimated to extend 20 feet from the sparge location (Appendix C), based upon the soil gradation and depth of injection points, and each sparge point was estimated to be effective for 15 feet vertically through the plume. Based upon experience of similar systems, effective air sparge rates would range from 15 to 30 SCFM with a design average of 20 SCFM at 50 psi. A total of approximately 68 air sparge wells, ranging from 35 to 50 feet in depth, have been anticipated for feasibility study purposes[12].

In conjunction with the air sparge system, a soil vapor extraction (SVE) system would be required to capture and treat the resulting volatized contaminants that would enter the vadose zone. The effective zone of influence for the SVE wells is expected to be limited to 40 feet, due to the shallow groundwater depth at the site, despite the highly permeable soil. The design capacity of

[12] All design parameters utilized herein are for the purposes of evaluating the cost of alternatives in this Feasibility Study and do not necessarily constitute design criteria.

the SVE system has been estimated based on 1.5 times the total air sparging capacity. The conceptual system would include approximately 42 shallow SVE wells. Actual design would be based upon performance parameters obtained from a series of pilot tests for both air sparge and SVE. Design evaluation would consider potential utilization of horizontal SVE wells. Part of the pilot test would entail review of the benefits of installing an impervious membrane over the treatment area to reduce any “short-circuiting” directly to the atmosphere and thus increasing the influence of the SVE wells. Performance monitoring would include monitoring wells to assess the progress of air sparging and vapor probes to monitor the SVE system.

Collected vapors would be treated with granular activated carbon (GAC) and carbon usage rates are expected to be moderate (Figure 5-3).

In addition to the implementation of the AS/SVE, Alternative 2 includes the common elements of institutional controls and monitored natural attenuation as discussed in Section 5.1.

Typically, AS/SVE remedies require approximately three (3) to five (5) years to achieve remedial goals. Five (5) years of operation and maintenance was assumed for cost estimating purposes. For cost estimating purposes 30 years of monitoring was assumed for the MNA portion of the remedy.

5.4 Alternative 3: ISCO + IC + MNA

Alternative 3 utilizes ISCO to build on the soil source removal conducted in the eastern plume source zone (Former Waste Storage Tanks) to further address source area groundwater and the plumes immediately downgradient as shown on Figure 5-4. Alternative 3 includes two (2) different process options for ISCO technology: permanganate and hydrogen peroxide plus iron (Fenton’s Reagent). The advantages and limitations of each process option are described in Section 4.2. In this alternative, Fenton’s Reagent has been selected for use during the initial injection in the eastern plume due to benzene impacts in that area. After removal of benzene, subsequent injection would be performed using permanganate. Because of the less reactive nature of permanganate this would allow for a larger ROI and longer-term treatment for future injections in the eastern plume. Injection of permanganate after Fenton’s Reagent would require less oxidant to overcome NOD. Permanganate would be used exclusively in the western plume as there are no benzene impacts in this area. Reagent selection would be finalized following results of a pre-design investigation (PDI) study.

As ISCO is typically only effective for localized high concentration areas of contamination, ISCO would be focused in the source areas (Former Waste Storage Tanks and unlined pit) on the Lightman property and in the eastern plume defined by the area within the 1,000 ppb total VOC isoconcentration contour (Figure 5-4). It is anticipated that a ROI of approximately 10 to 20 feet would be obtained during ISCO injection based on the generally sandy aquifer material (Appendix D). A ROI of 10 to 20 feet is similar to the range of anticipated ROIs (15 to 25 feet) for sandy aquifers as indicated in the ITRC ISCO guidance document (ITRC, 2005). Based on this assumption a preliminary conceptual design has been developed that includes approximately 110 total injection points to treat both the eastern and western plumes. This estimate includes approximately 60 injection points in the eastern plume and approximately 20 injection points in the western plume. These estimates would need to be refined based on pre-design studies that would include bench tests and evaluation of the ORP, DO, iron concentration, temperature and conductivity in areas where Fenton's Reagent would be used and manganese concentrations where permanganate would be used. It is also recommended that a biological analysis be performed to determine the intrinsic bioremediation potential before and after treatment with ISCO so as to evaluate the potential adverse impact to MNA. A pilot-scale injection test would be conducted to further evaluate the ROI and NOD in the field prior to completing the final design of the injection system.

An ISCO process and performance monitoring program would be necessary. This program would include verification of the injection ROI, as well as the oxidation and potential migration of groundwater contaminants.

In addition to the implementation of ISCO, Alternative 3 includes the common elements of institutional controls and monitored natural attenuation as discussed in Section 5.1.

Typically, ISCO remedies require on the order of one (1) year to address source area contamination. For cost estimating purposes, 30 years of monitoring was assumed for the MNA portion of the remedy.

5.5 Alternatives 4A and 4B: Alternative 2 or 3 + Downgradient P&T

Alternatives 4A and 4B consist of Alternatives 2 and 3, respectively, but instead of relying on MNA alone for the far downgradient areas, localized “hot spot” areas would be addressed by the installation of a groundwater extraction and treatment system.

Design and implementation of a downgradient extraction and treatment system would require a PDI which would include delineation of the downgradient “hot spots” and a pumping test to provide design parameters. An initial evaluation of potential capture zones has been conducted using the approach proposed by Todd, 1980. Calculations based on a hydraulic conductivity of $2.1x10^{-2}$ cm/s (see Section 2.5.2), a 35 foot aquifer thickness (based on the maximum plume thickness), a horizontal hydraulic gradient of $2.1x10^{-3}$ feet/foot (see Section 2.5.1) are presented in Appendix E. The calculation results indicate that for a pumping rate of 10 gpm the capture zone width is in excess of 400 feet, while the capture zone width corresponding to 5 gpm is in excess of 200 feet. For Feasibility Study purposes and given the uncertainty on the location and size of groundwater “hot spots”, Alternatives 4A & 4B assume the installation of one (1) extraction well to address a PDI-delineated “hot spot”. The estimated pumping rate necessary to capture a “hot spot” is assumed to be 5 gpm for Feasibility Study costing purposes, but will be determined based on the PDI delineation. Treatment would consist of filtration and granular activated carbon adsorption followed by reinjection utilizing two injection wells. Figure 5-5 depicts a conceptual process flow diagram of such a system. Given the low contaminant concentration, mass removal rates would be extremely low.

For Alternative 4A, typically AS/SVE remedies require approximately three (3) to five (5) years to achieve remedial goals and five (5) years of O&M was assumed for cost estimating purposes. For Alternative 4B, typically ISCO remedies require on the order of one (1) year to address source area contamination. For both alternatives, the remedial time-frame for Pump and Treat is highly dependent on the mass of contaminants that are to be addressed and the system efficiency. Due to the uncertainty in the extent of impact in the downgradient plume, it is difficult to estimate the remedial time-frame for Pump and Treat at this time. Typically, Pump and Treat remedial actions require long time-frames to achieve remedial goals. Thirty (30) years of O&M was assumed for cost estimating purposes.

5.6 Alternative 5A and 5B: Alternative 2 or 3 + Downgradient ISCO

Alternatives 5A and 5B consist of Alternatives 2 and 3, respectively, but instead of relying on MNA along the far downgradient areas, localized "hot spot" areas would may be addressed by in-situ treatment using permanganate based ISCO.

Alternatives 5A and 5B include the use of potassium permanganate as the oxidant for treatment since benzene is not present in these areas. It is anticipated that a ROI of approximately 10 feet to 20 feet would be obtained during ISCO injection based on the generally sandy aquifer material. Design of a downgradient ISCO treatment system would require additional delineation of the downgradient "hot spots".

For Alternative 5A, typically AS/SVE remedies require approximately three (3) to five (5) years to achieve remedial goals. Five (5) years of O&M was assumed for cost estimating purposes. For Alternative 5B, typically ISCO remedies require on the order of one (1) year to address source area contamination. Since the conceptual ISCO design included in both Alternatives 5A and 5B requires treatment of the downgradient plume, multiple injection events may be necessary and could require longer time-frames to achieve remedial goals.

6.0 NCP CRITERIA EVALUATION

The selection of a remedial alternative is based on an evaluation of nine criteria established in the NCP pursuant to CERCLA statutory requirements. Two of these criteria (state acceptance and community acceptance) will be addressed during the public comment period following USEPA's publication of a Proposed Remedial Action Plan. The remaining criteria are summarized below and evaluated in subsequent sections of this Feasibility Study.

- Overall Protection of Human Health and the Environment: Under this criterion, an alternative is assessed to determine whether it can adequately protect human health and the environment, in both the short-term and long-term, from unacceptable risks posed by hazardous substances, pollutants or contaminants present at the Site, by eliminating, reducing or controlling exposures to levels established during development of remediation goals.

- Compliance with ARARs: This criterion evaluates whether and how the alternative attains applicable or relevant and appropriate requirements under federal environmental laws and state environmental or facility siting laws, or provides grounds for invoking the legal waiver of such requirements.

- Short-Term Effectiveness: This criterion evaluates the impacts of the alternative during implementation with respect to human health and the environment.

- Reduction of Toxicity, Mobility, and Volume Through Treatment: Under this criterion, the degree to which an alternative employs recycling or treatment that reduces toxicity, mobility, or volume is assessed, including how treatment is used to address the principal threats posed at the Site.

- Long-Term Effectiveness and Permanence: Under this criterion, an alternative is assessed for the long-term effectiveness and permanence it affords, along with the degree of uncertainty that the alternative will prove successful.

- Implementability: This criterion addresses the technical and administrative feasibility of implementing the alternative as well as the availability of various services and materials required.

- Cost: This criterion addresses the estimated costs of implementing the alternative to the level necessary for comparison between alternatives with a typical accuracy of plus 50% and minus 30%. Costs considered include capital and operation and maintenance costs with net present worth costs calculated over a 30 year period using a discount factor of 7%.

A summary of the alternatives analysis presented in the following sections is provided in Table 6-1.

6.1 Alternative 1: No Further Action

Overall Protection of Human Health and the Environment

There are no current receptors for contaminated groundwater and new properties are required by municipal ordinance to connect to the municipal water supply system. In addition, there are currently no structures over the shallow portions of groundwater contamination that could result in a risk from vapor intrusion. Although substantial source mass has been removed pursuant to the Removal AOC, contamination remains in groundwater in source areas related to the Former Waste Storage Tanks and unlined pit that is not addressed by this alternative and would remain for the foreseeable future.

Compliance with ARARs

This alternative is not expected to achieve the NJDEP Groundwater Quality Standards for Class I-PL groundwater under N.J.A.C 7:9C in a reasonable time frame. Location-specific and action-specific ARARs do not apply to this alternative as no further actions will be completed.

Short-Term Effectiveness

The “No Further Action” Alternative includes no further remedial actions so that there would be no short-term impact to the local community or the environment.

Reduction of Toxicity, Mobility, and Volume through Treatment

The soil source removal has significantly addressed the toxicity, mobility, and volume of contaminant mass in the saturated soils associated with the Former Waste Storage Tank Area. This alternative relies on current natural processes to reduce the toxicity, mobility, or volume of remaining groundwater contamination.

Long-Term Effectiveness and Permanence

Substantial source mass in the Former Waste Storage Tank Area has been effectively removed and will no longer contribute as a source to groundwater contamination in the eastern plume. Contamination remains in groundwater in source areas related to the Former Waste Storage Tanks and Unlined Pit that are not addressed by this alternative and would remain for the foreseeable future.

Implementability

This alternative is readily implementable.

Cost

There is no cost for this alternative.

6.2 Alternative 2: AS/SVE + IC + MNA

Overall Protection of Human Health and the Environment

This alternative would achieve overall protection of human health and the environment. Substantial source mass has been removed in the Former Waste Storage Tank Area pursuant to the Removal AOC and will no longer contribute to groundwater contamination in the eastern plume. AS/SVE would address remaining groundwater contamination in the Former Waste Storage Tank Area and Former Unlined Pit Areas and immediate downgradient areas. SVE is a proven technology for the remediation of volatile organic compounds and air sparging is a developing technology for the removal of VOCs from groundwater. The implementation of the SVE system would provide for the capture of vapor phase contaminants released by air-sparging, mitigating the potential for vapor intrusion into structures and utilities. The captured VOCs would be absorbed on granular activated carbon, and subsequently destroyed at a carbon regeneration facility.

This alternative relies on MNA to address areas of far downgradient groundwater contamination as discussed in Section 5.1.3. Installation of additional sentinel and in-plume wells and establishment of a rigorous monitoring program would demonstrate the continued improvement of groundwater quality, provide adequate warning should conditions change, thereby assuring continued protection of the Municipal wells from Site-related impacts. Institutional controls in the form of a CEA and use restrictions on the Lightman Property would provide protective measures until such time as the groundwater cleanup has been completed.

Compliance with ARARs

This alternative would be expected to achieve ARARs as described below.

Chemical-Specific ARARs

This alternative is expected to, over time, comply with the chemical specific groundwater quality ARARs (NJDEP Groundwater Quality Standard for Class I-PL Groundwater, N.J.A.C. 7:9C) through remediation of the source area and downgradient groundwater in combination with natural attenuation processes in accordance with N.J.A.C. 7:26E-6.3.

Location-Specific ARARs

Because the Former Unlined Pit is located within the 100 year floodplain, implementation of this alternative in the area may be subject to ARARs regulating the protection of floodplains. These include the Federal National Environmental Policy Act (40 CFR 6, Appendix A) and the New Jersey Flood Hazard Control Act (N.J.A.C. 7:13). Disturbance of this area is expected to be minimal, and would consist of localized clearing to install AS/SVE wells and associated piping with no net filling anticipated. Engineering controls would need to be established to minimize the disturbance and the area would be restored in accordance with ARARs. Implementation of this alternative in the area of the Former Unlined Pit, which is not a currently active portion of the facility, may be subject to the Federal Fish and Wildlife Conservation Act (16 USC 2901 et seq.) which aims to protect non-game wildlife and their habitats.

Potential ARARs also include the State Endangered and Non-Game Species Act (N.J.S.A. 23:2A-1), Federal Endangered Species Act (16 USC 1531 et seq. and 40 CFR 400), the Endangered Plant Species List Act (N.J.S.A. 13:1B et seq.), and the Federal National Historic Preservation Act (16 USC 469 et seq., 40 CFR 6301(c)). While Swamp Pink was identified as a federally-listed threatened plant species that could be located on or adjacent to the Site, a survey conducted during the RI found no evidence of the plant and indicated that the hydrologic conditions have changed and no longer provides the constant moisture required by Swamp Pink. Also, a Stage IA Cultural Resources Survey conducted during the RI indicated low to moderate potential for pre-historic archaeological remains and a low potential for historic archeological remains.

Action-Specific ARARs

Because this alternative includes volatilization of groundwater contaminants, emission controls may be regulated under N.J.A.C. 7:27 (Subchapters 8 and 16). Spent carbon would be transported under DOT regulations and regenerated at licensed facilities. System condensate would be characterized and transported to a licensed treatment works. Potential ARARs would include the Clean Air Act (42 USC 7401); National Ambient Air Quality Standards (40 CFR 50); National Emission Standards for Hazardous Air Pollutants (40 CFR 63); the Resource Conservation and Recovery Act (RCRA, 42 USC 6901 et seq.) including 40 CFR Part 261, Part 263, part 268 and Part 270, and DOT rules including 49 CFR Parts 107, 171 and 173.

All construction, maintenance and monitoring activities would be subject to the Occupational Safety and Health Act (OSHA, 29 USC 651-678) and may be subject to the New Jersey Soil Erosion and Sediment Control Act (N.J.S.A. 4:24-39 et seq.). Institutional controls would be implemented in accordance with N.J.A.C. 7.26E (Subchapter 8).

Short-Term Effectiveness

The construction activities involved with the AS/SVE Alternative could pose restrictions to current businesses operating in the treatment area including the Lightman Property and adjacent property as a result of the installation of well-points and vacuum system piping. With proper health and safety procedures, the short term risks to construction workers and site workers are low for the installation of the AS/SVE system.

Reduction of Toxicity, Mobility, and Volume through Treatment

The soil source removal has significantly addressed the toxicity, mobility, and volume of contaminant mass in the saturated soils associated with the Former Waste Storage Tank Area. The dissolved phase volatile compounds would be effectively removed from the groundwater, collected by the SVE wells and absorbed on activated carbon for future off-site destruction at a licensed facility. The AS/SVE system would reduce the total mass (volume) of contaminants in the groundwater, thus reducing mobility and toxicity through treatment. Natural attenuation processes that have reduced the concentration of contaminants in the downgradient groundwater would continue and the time of remediation would be reduced as a result of the source area excavation and treatment with AS/SVE reducing significant plume mass.

Long-Term Effectiveness and Permanence

Substantial source mass in the Former Waste Storage Tank Area has been effectively removed and will no longer contribute as a source to groundwater contamination in the eastern plume. The effectiveness and permanence of AS/SVE to address remaining VOC contamination in the source areas and downgradient over the duration of the remediation is high. The equipment would require a high level of preventative maintenance but generally has a major repair frequency greater than the estimated duration of the system operation.

Over the long-term, natural attenuation of groundwater impacts in the plumes is expected to continue resulting in the destruction and transformation of contaminant mass. Long-term monitoring would be conducted to verify performance including five-year reviews to assess the continued effectiveness.

Implementability

This alternative would be readily implementable. AS/SVE has been successfully used in similar circumstances and the site conditions are conducive to the application of air sparging and SVE technologies. Less desirable for the implementation of air sparging, is the depth of the plumes within the aquifer downgradient and the presence of non-impacted groundwater above the plumes of dissolved contaminants as the plumes plunge away from the property. These conditions could be addressed in the design of the system to address the Lightman Property and a reasonable distance downgradient. The shallow depth of the ground water poses several design issues, including possible short-circuiting of vapor from the ground surface, reduced zone of influence, and the recovery of high volumes of condensate. These issues could be addressed in design and would not significantly affect the implementability. Access agreements would be required with at least one adjacent property owner. MNA would be readily implementable assuming continued access to downgradient wells.

Cost

The preliminary net present worth cost estimate for Alternative 2 is $7,330,000 USD; this cost includes $5,450,000 for AS/SVE and $1,880,000 for MNA. The AS/SVE cost is primarily driven by the initial engineering and construction costs, but also includes estimated costs for securing access and operation and maintenance. Costs for MNA include establishment of a CEA, regular sampling of wells, laboratory analyses, data evaluation, and reporting costs.

6.3 Alternative 3: ISCO + IC + MNA

Overall Protection of Human Health and the Environment

This alternative would achieve overall protection of human health and the environment. Substantial source mass has been removed in the Former Waste Storage Tank Area pursuant to the Removal AOC and will no longer contribute to groundwater contamination in the eastern plume. ISCO would address the most significant remaining groundwater contamination in the Former Waste Storage Tank Area and the Former Unlined Pit Areas and immediate downgradient areas by converting toxic compounds to non-toxic by-products (CO_2). Once treatment is complete, rebound of contamination would be expected to be limited. When using Fenton's Reagent, any residual hydrogen peroxide decomposes to water and oxygen and remaining iron particles ultimately settle out in the subsurface. Permanganate would react fully to produce insoluble MnO_2 solids.

This alternative relies on MNA to address areas of far downgradient groundwater contamination as discussed in Section 5.1.3. Installation of additional sentinel and in-plume wells and establishment of a rigorous monitoring program would demonstrate the continued improvement of water quality, provide adequate warning should conditions change, thereby assuring continued protection of the Municipal wells from Site-related impacts. Institutional controls in the form of a CEA and use restrictions on the Lightman Property would provide protective measures until such time as the groundwater cleanup has been completed.

Compliance with ARARs

This alternative would be expected to achieve ARARs as described below.

<u>Chemical-Specific ARARs</u>

This alternative is expected to, over time, comply with chemical specific groundwater quality ARARs (NJDEP Groundwater Quality Standard for Class I-PL Groundwater, N.J.A.C. 7:9C) through remediation of the source area and downgradient groundwater in combination with natural attenuation processes in accordance with N.J.A.C. 7:26E-6.3.

<u>Location-Specific ARARs</u>

Because the Former Unlined Pit is located within the 100 year floodplain, implementation of this alternative in the area may be subject to ARARs regulating the protection of floodplains. These include the Federal National Environmental Policy Act (40 CFR 6, Appendix A) and the New Jersey Flood Hazard Control Act (N.J.A.C. 7:13). Disturbance of this area is expected to be minimal, and would consist of localized clearing to provide access for injection points. No net filling is anticipated. Engineering controls would need to be established to minimize the disturbance and the area would be restored in accordance with ARARs requirements. Implementation of this alternative in the area of the Former Unlined Pit, which is not a currently active portion of the facility, may be subject to the Federal Fish and Wildlife Conservation Act (16 USC 2901 et seq.) which aims to protect non-game wildlife and their habitats.

Potential ARARs also include the State Endangered and Non-Game Species Act (N.J.S.A. 23:2A-1), Federal Endangered Species Act (16 USC 1531 et seq. and 40 CFR 400), the Endangered Plant Species List Act (N.J.S.A. 13:1B et seq.), and the Federal National Historic Preservation Act (16 USC 469 et seq., 40 CFR 6301(c)). While Swamp Pink was identified as a federally-listed threatened plant species that could be located on or adjacent to the Site, a survey conducted during the RI found no evidence of the plant and indicated that the hydrologic conditions have changed and no longer provides the constant moisture required by Swamp Pink. Also, a Stage IA Cultural Resources Survey conducted during the RI indicated low to moderate potential for pre-historic archaeological remains and a low potential for historic archeological remains.

<u>Action-Specific ARARs</u>

Because this alternative includes the injection of oxidizing materials to treat the contaminants, regulations protecting groundwater quality would be relevant and appropriate. Specifically, injections of oxidants may trigger the New Jersey Pollutant Discharge Elimination System rules (N.J.A.C.7:14A).

All construction, maintenance and monitoring activities for this and other alternatives would be subject to the Occupational Safety and Health Act (OSHA, 29 USC 651-678) and may be subject to the New Jersey Soil Erosion and Sediment Control Act (N.J.S.A. 4:24-39 et seq.). Institutional controls would be implemented in accordance with N.J.A.C. 7.26E (Subchapter 8).

Short-Term Effectiveness

The construction activities associated with ISCO injections could pose significant restrictions to current businesses operating in the treatment area, including the Lightman and adjacent property, as a result of the installation and operation of a large number of injection points.

Addition of strong oxidants may increase the mobile fraction of some redox sensitive metals (e.g., Chromium) and may increase groundwater concentrations of these constituents in the short-term representing a potential risk to the environment during implementation. Injection of large volumes of oxidant could enable movement of contaminants and may require additional injections at downgradient locations to eliminate this threat. There is also the potential for migration of contaminants into the vapor phase, which would represent a potential risk to Site workers during implementation. The oxidants used would require special handling and storage and pose a short-term hazard. The oxidation of organic compounds is an exothermic process and can be highly energetic when using strong oxidants and precautions must be taken to mitigate this threat to Site workers. The by-product of permanganate treatment, MnO_2, could accumulate and inhibit flow through the aquifer representing a threat to the environment during implementation.

Reduction of Toxicity, Mobility, and Volume through Treatment

The soil source removal has significantly addressed the toxicity, mobility, and volume of contaminant mass in the saturated soils associated with the Former Waste Storage Tank Area. Fenton's Reagent would be selected as the most appropriate oxidant for use in the eastern source area plume associated with the Former Waste Storage Tank Area where BTEX compounds are located. Permanganate would be selected for the western source area plume associated with the Former Unlined Pit where there is no impact from BTEX compounds. Additionally, permanganate could be used in future injections in the eastern plume after BTEX has been successfully removed. Chlorinated VOCs and BTEX compounds could be effectively treated using ISCO; however, success is dependent on the ability to distribute oxidant into the contaminated zone. Contaminants are destroyed by the ISCO process treatment, which is considered irreversible. ISCO is typically considered a source area treatment and is anticipated to remove significant contaminant mass; however, it is unlikely that treatment would achieve groundwater standards. Additional processes, namely natural attenuation, are anticipated to reduce the remaining mass through time to achieve ARARs. Additionally, natural attenuation processes that have reduced the concentration of contaminants in the downgradient groundwater would continue and would require less time to achieve clean-up goals as a result of the source area excavation and treatment of groundwater contaminant with ISCO.

Long-Term Effectiveness and Permanence

Substantial source mass in the Former Waste Storage Tank Area has been effectively removed and would no longer contribute as a source to groundwater contamination in the eastern plume. ISCO is potentially effective in addressing contaminants in the source area from a contaminant mass perspective, however, ISCO is not anticipated to achieve groundwater clean-up goals in the source area. Once significant mass destruction is achieved, which may require multiple treatments, the magnitude of residual risk from the implementation of ISCO is relatively low as the target compounds are oxidized completely to CO_2. Any residual hydrogen peroxide decomposes to water and oxygen and remaining iron or MnO_2 particles ultimately settle out in the subsurface. Remaining contaminant mass would be further degraded by natural attenuation processes.

Over the long-term, natural attenuation of groundwater impacts in the plumes is expected to continue resulting in the destruction and transformation of contaminant mass. Long-term monitoring would be conducted to verify performance including five-year reviews to assess the continued effectiveness.

Implementability

In general, the equipment, services, and materials for chemical oxidation would be readily available. However, the uniform delivery of the oxidants may potentially be difficult to implement. Because of the extent of contamination, the volume of oxidant necessary to treat the natural oxidant demand (NOD) along with the total VOC mass would be very high. As such, ISCO would be focused on the source areas within the Lightman Property and higher concentrations (>1,000 ug/l) of groundwater on the adjacent property. The injection of large volumes of oxidant solution during each injection round would also be difficult and could result in significant groundwater mounding and potential migration of contaminants. Access agreements would be required with at least one adjacent property owner. MNA would be readily implementable, assuming continued access to downgradient wells.

Cost

The preliminary net present worth cost estimate for Alternative 3 is approximately $10,030,000 USD; this cost includes $8,150,000 for ISCO and $1,880,000 for MNA. The ISCO cost is primarily driven by the potentially large volume of oxidant that may be required to satisfy the NOD, but also includes estimated costs for securing access and operation and maintenance. Costs for MNA include establishment of a CEA, regular sampling of wells, laboratory analyses, data evaluation, and reporting costs.

6.4 Alternative 4A: Alternative 2 + Downgradient P&T

Overall Protection of Human Health and the Environment

This alternative would achieve overall protection of human health and the environment. Substantial source mass has been removed in the Former Waste Storage Tank Area pursuant to the Removal AOC and will no longer contribute to groundwater contamination in the eastern plume. AS/SVE would address remaining groundwater contamination in the Former Waste Storage Tank Area and Former Unlined Pit Areas and immediate downgradient areas. SVE is a proven technology for the remediation of volatile organic compounds and air sparging is a developing technology for the removal of VOCs from groundwater. The implementation of the SVE system would provide for the capture of vapor phase contaminants released by air-sparging, mitigating the potential for vapor intrusion into structures and utilities. The captured VOCs would be absorbed on granular activated carbon, and subsequently destroyed at a carbon regeneration facility.

The groundwater extraction and treatment system would provide additional protection of human health and the environment by removal and treatment of contaminants in localized downgradient areas. While the Site falls within the New Jersey Pinelands protected area and therefore the aquifer is classified as Class I-PL by the NJDEP, there is no current or anticipated future exposure to the contamination. Depending upon the future usage of Municipal Well #8, which has not been operational since August 2007, and is located approximately 2,800 feet to the southwest of the most downgradient monitoring well, Site contaminants may or may not migrate towards the Municipal Well. However, a pump and treat system in the downgradient plume may enhance the future protection of human health and the environment by preventing contaminant migration. MNA would continue to address the far downgradient groundwater contamination. Installation of additional sentinel and in-plume wells and establishment of a rigorous monitoring program would demonstrate the continued improvement of groundwater quality, provide adequate warning should conditions change, thereby assuring continued protection of the Municipal wells from Site-related impacts. Institutional controls in the form of a CEA and use restrictions on the Lightman Property would provide protective measures until such time as the groundwater cleanup has been completed.

Compliance with ARARs

This alternative would be expected to achieve ARARs as described below.

Chemical-Specific ARARs

This alternative is expected to, over time, comply with the chemical specific groundwater quality ARARs (NJDEP Groundwater Quality Standard for Class I-PL Groundwater, N.J.A.C. 7:9C) through remediation of the source area and downgradient groundwater in combination with natural attenuation processes in accordance with N.J.A.C. 7:26E-6.3.

Location-Specific ARARs

Because the Former Unlined Pit is located within the 100 year floodplain, implementation of this alternative in the area may be subject to ARARs regulating the protection of floodplains. These include the Federal National Environmental Policy Act (40 CFR 6, Appendix A) and the New Jersey Flood Hazard Control Act (N.J.A.C. 7:13). Because the downgradient extraction and treatment system may be located in the 100 year floodplain, and may impact the hydrology of Pump Branch Creek and associated wetlands, implementation of this alternative may be subject to the ARARs regulating the protection of floodplains noted above, as well as those regulating the protection of wetlands, including New Jersey Freshwater Wetlands Protection Act (N.J.A.C. 7:7A, N.J.S.A. 13:9B-1), and the Federal National Environmental Policy Act (40 CFR 6, Appendix A). Implementation of this alternative in the area of the Former Unlined Pit, which is not a currently active portion of the facility, may be subject to the Federal Fish and Wildlife Conservation Act (16 USC 2901 et seq.) which aims to protect non-game wildlife and their habitats. Disturbance of this area is expected to be minimal, consisting of localized clearing to install AS/SVE wells and associated piping with no net filling anticipated. Engineering controls would need to be established to minimize the disturbance and the area would be restored in accordance with ARARs.

Potential ARARs also include the State Federal Endangered and Non-Game Species Act (N.J.S.A. 23:2A-1), Federal Endangered Species Act (16 USC 1531 et seq. and 40 CFR 400), the Endangered Plant Species List Act (N.J.S.A. 13:1B et seq.), and the Federal National Historic Preservation Act (16 USC 469 et seq., 40 CFR 6301(c)). While Swamp Pink was identified as a federally-listed threatened plant species that could be located on or adjacent to the Site, a survey conducted during the RI found no evidence of the plant and indicated that the hydrologic conditions have changed and no longer provides the constant moisture required by Swamp Pink. Also, a Stage IA Cultural Resources Survey conducted during the RI indicated low to moderate potential for pre-historic archaeological remains and a low potential for historic archeological remains.

Action-Specific ARARs

Because this alternative would include volatilization of groundwater contaminants as a result of AS/SVE, emission controls may be regulated under N.J.A.C. 7:27 (Subchapters 8 and 16). Spent carbon would be transported under DOT regulations and regenerated at licensed facilities. System condensate would be characterized and transported to a licensed treatment works. Materials received at the end of each treatment stream would be subject to regulating guidelines the transport and disposal of waste. Appropriate and relevant regulations include the Clean Air Act (42 USC 7401); National Ambient Air Quality Standards (40 CFR 50); National Emission Standards for Hazardous Air Pollutants (40 CFR 63); the Resource Conservation and Recovery Act (RCRA, 42 USC 6901 et seq.) including 40 CFR Part 261, Part 263, part 268 and Part 270, and DOT rules including 49 CFR Parts 107, 171 and 173.

Achievement of ARARs for the various discharge options related to extraction and treatment would be significant design consideration. Potential ARARs for each of the discharge options are described below:

On-Site Re-injection: Because this discharge option includes the injection of treated groundwater, regulations protecting groundwater quality would be appropriate and this option would be subject to The Safe Drinking Water Act (40 CFR 144-147) and the New Jersey Pollutant Discharge Elimination System rules (N.J.A.C.7:14A).

Discharge to Surface Water/Wetlands: Surface waters and wetlands are protected by the Clean Water Act (33 USC 151 et. seq.), EPA Water Quality Standards (40 CFR 131), the New Jersey Pollutant Discharge Elimination System (N.J.A.C. 7:14A), New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B), New Jersey Freshwater Protection Act (N.J.A.C. 7:7A, N.J.S.A. 13:9B-1), and the Federal National Environmental Policy Act (40 CFR 6, Appendix A).

Discharge to Publically Operated Treatment Works (POTW): Discharges to POTW are subject to the Federal Clean Water Act (40 CFR 403). Effluent quality must meet standards set by the POTW.

All construction, maintenance and monitoring activities would be subject to the Occupational Safety and Health Act (OSHA, 29 USC 651-678) and, in some cases, may be subject to the New Jersey Soil Erosion and Sediment Control Act (N.J.S.A. 4:24-39 et seq.). Institutional controls would be implemented in accordance with N.J.A.C. 7.26E (Subchapter 8).

Short-Term Effectiveness

The construction activities could pose significant restrictions to current businesses operating in the treatment area including the Lightman Property and multiple downgradient properties through installation of groundwater extraction and AS/SVE piping and treatment systems. With proper health and safety procedures, the short term risks to construction workers and site workers are low.

Reduction of Toxicity, Mobility, and Volume through Treatment

The soil source removal has significantly addressed the toxicity, mobility, and volume of contaminant mass in the saturated soils associated with the Former Waste Storage Tank Area. The dissolved phase volatile compounds would be effectively removed from the groundwater, collected by the SVE wells and absorbed on activated carbon for future off-site destruction at a licensed facility. The AS/SVE system would reduce the total mass (volume) of contaminants in the groundwater, thus reducing mobility and toxicity through treatment.

The mobility and volume of a small additional mass of the dissolved phase contaminants within the groundwater would be reduced by groundwater extraction and treatment. The activated carbon would require off-site destruction or regeneration at a licensed facility. The maximum mass removal rate of pump and treat is estimated to be on the order of 1 kg/yr to 2 kg/year (Appendix E). The actual mass removal rate of the extraction system is expected to be more variable for the following reasons:

- Plume concentrations are expected to decrease with time as a result of addressing the source area. As a result, the extraction system initial mass removal rates of 1 kg to 2 kg per year is expected to decrease with time to lower levels; and,

- Although reductive dechlorination is not a dominant process downgradient of the source, other biotic and abiotic processes may degrade chlorinated solvents. Contaminant mass within the aquifer is expected to be reduced at a low rate[13] (see Section 2.6.4 for additional details) which in turn will result in a continuous decrease in concentration of extracted groundwater.

Based on the above, it is expected that the concentration of extracted groundwater will decrease with time and an asymptotic level may be reached.

[13]Contaminant degradation with a half-life of 13 years is an estimated slow degradation rate for aerobic TCE degradation referenced in the literature (see Section 5.1.3). At this rate, degradation will reduce the downgradient plume mass by ~25 percent in 5 years, ~45 percent in 10 years, and ~65 percent in 20 years.

Natural attenuation processes in the downgradient groundwater would continue and the time of remediation would be reduced as a result of the combined effects of source area excavation, treatment with AS/SVE and groundwater extraction and treatment.

Long-Term Effectiveness and Permanence

Substantial source mass in the Former Waste Storage Tank Area has been effectively removed and will no longer contribute as a source to groundwater contamination in the eastern plume. The effectiveness and permanence of AS/SVE to address remaining VOC contamination in the source areas and downgradient over the duration of remediation would be high. The equipment would require a high level of preventative maintenance but generally has a major repair frequency greater than the estimated duration of the system operation. The groundwater extraction and treatment system would be less efficient in treating contaminants due to the relatively low mass removal rate. The overall effectiveness of pump and treat would also be dependent on accurate delineation of the "hot spots" and the actual contaminant mass within the "hot spots".

Over the long-term, natural attenuation of groundwater impacts in the plumes is expected to continue, resulting in the removal of additional contaminant mass. Long-term monitoring would be conducted to verify performance, including five-year reviews to assess the continued effectiveness.

Implementability

AS/SVE has been successfully used in similar circumstances and the site conditions are conducive for the application of both technologies. Less desirable parameters for the implementation of air sparging, is the depth of the plumes within the aquifer downgradient and the presence of non-impacted groundwater above the plumes of dissolved contaminants as the plumes plunge away from the site. These conditions could be reasonably addressed in the design of the system to address the Lightman Property and a reasonable distance downgradient. The shallow depth of the ground water posses several design issues, including possible short-circuiting of vapor from the ground surface, reduced zone of influence, and the recovery of high volumes of condensate. These issues could be addressed in the design and would not significantly affect the implementability. Access agreements would be required with at least one adjacent property owner.

Design of the groundwater extraction and treatment system requires additional information on the current size and location of “hot spot” areas. There are also several implementation challenges, including:

1. Long-term access would be required to several private properties for the construction and operation of the system. Access to private properties would be required to install wells, pipelines, and treatment units. Operation and maintenance of the system would result in long-term disruption to the effected properties.

2. Discharge of treated groundwater would require extensive piping on private property: to connect to the sewer system along Route 73; to potential discharge galleries or injection wells; or to Pump Branch Creek. Discharge to Pump Branch Creek would also require piping below railroad tracks and disruption of wetlands.

3. Implementability of groundwater extraction to the west side of the railroad tracks is limited due to severe access restrictions posed by the railroad tracks, the wetlands associated with Pump Branch Creek and residential development beyond.

MNA is readily implementable assuming continued access to downgradient wells.

Cost

The preliminary net present worth cost estimate for Alternative 4A is $10,140,000 USD; this cost includes $5,450,000 for AS/SVE, $2,810,000 for downgradient groundwater extraction and treatment, and $1,880,000 for MNA. The AS/SVE and extraction and treatment costs are primarily driven by the initial engineering and construction costs, but also include estimated costs for securing access and operation and maintenance. Costs for MNA include establishment of a CEA, regular sampling of wells, laboratory analyses, data evaluation, and reporting costs.

6.5 Alternative 4B: Alternative 3 + Downgradient P&T

Overall Protection of Human Health and the Environment

This alternative would achieve overall protection of human health and the environment. Substantial source mass has been removed in the Former Waste Storage Tank Area pursuant to the Removal AOC and will no longer contribute to groundwater contamination in the eastern plume. ISCO would address the most significant remaining groundwater contamination in the Former Waste Storage Tank Area and the Former Unlined Pit Areas and immediate downgradient areas by converting toxic compounds to non-toxic by-products (CO_2). Once treatment is complete, rebound of contamination is expected to be limited. In using Fenton’s Reagent, any residual hydrogen peroxide decomposes to water and oxygen and remaining iron particles ultimately settle out in the subsurface. Permanganate would react fully to produce insoluble MnO_2 solids.

The groundwater extraction and treatment system would provide additional protection of human health and the environment by removal and treatment of contaminants in localized downgradient areas. As there is no current or anticipated future exposure to the contamination, implementing groundwater extraction and treatment would not significantly enhance the protection of human health and the environment, but may accelerate the restoration of groundwater quality through limited mass removal. The overall effectiveness of pump and treat would be dependent on accurate delineation of the "hot spots". MNA would continue to address the far downgradient groundwater contamination. Installation of additional sentinel and in-plume wells and establishment of a rigorous monitoring program would demonstrate the continued improvement of groundwater quality, provide adequate warning should conditions change, thereby assuring continued protection of the Municipal wells from Site-related impacts. Institutional controls in the form of a CEA and use restrictions on the Lightman Property would provide protective measures until such time as the groundwater cleanup has been completed.

Compliance with ARARs

This alternative would be expected to achieve ARARs as described below.

<u>Chemical-Specific ARARs</u>

This alternative is expected to, over time, comply with chemical specific groundwater quality ARARs (NJDEP Groundwater Quality Standard for Class I-PL Groundwater, N.J.A.C. 7:9C) through remediation of the source area and downgradient groundwater in combination with extraction and treatment downgradient and natural attenuation processes in accordance with N.J.A.C. 7:26E-6.3.

<u>Location-Specific ARARs</u>

Because the Former Unlined Pit is located within the 100 year floodplain, implementation of this alternative in the area may be subject to ARARs regulating the protection of floodplains. These include the Federal National Environmental Policy Act (40 CFR 6, Appendix A) and the New Jersey Flood Hazard Control Act (N.J.A.C. 7:13). Because the downgradient extraction and treatment system may be located in the 100 year floodplain, and may impact the hydrology of

Pump Branch Creek and associated wetlands, implementation of this alternative may be subject to the ARARs regulating the protection of floodplains noted above, as well as those regulating the protection of wetlands, including New Jersey Freshwater Wetlands Protection Act (N.J.A.C. 7:7A, N.J.S.A. 13:9B-1), and the Federal National Environmental Policy Act (40 CFR 6, Appendix A). Disturbance of this area would consist of localized clearing to provide access for injection points. Engineering controls would need to be established to minimize the disturbance and the area would be restored in accordance with ARARs. Implementation of this alternative in the area of the Former Unlined Pit, which is not a currently active portion of the facility, may be subject to the Federal Fish and Wildlife Conservation Act (16 USC 2901 et seq.), which aims to protect non-game wildlife and their habitats.

Potential ARARs also include the State Endangered and Non-Game Species Act (N.J.S.A. 23:2A-1), Federal Endangered Species Act (16 USC 1531 et seq. and 40 CFR 400), the Endangered Plant Species List Act (N.J.S.A. 13:1B et seq.), and the Federal National Historic Preservation Act (16 USC 469 et seq., 40 CFR 6301(c)). While Swamp Pink was identified as a federally-listed threatened plant species that could be located on or adjacent to the Site, a survey conducted during the RI found no evidence of the plant and indicated that the hydrologic conditions have changed and no longer provides the constant moisture required by Swamp Pink. Also, a Stage IA Cultural Resources Survey conducted during the RI indicated low to moderate potential for pre-historic archaeological remains and a low potential for historic archeological remains.

Action-Specific ARARs

Because this alternative includes the injection of oxidizing materials to treat the contaminants, regulations protective of groundwater quality would be relevant and appropriate. Injections of oxidants may trigger the New Jersey Pollutant Discharge Elimination System rules under N.J.A.C. 7:14A.

Material recovered at the end of each treatment stream would be subject to regulations governing the transport and disposal of waste. Appropriate and relevant regulations include the Clean Air Act (42 USC 7401); National Ambient Air Quality Standards (40 CFR 50); National Emission Standards for Hazardous Air Pollutants (40 CFR 63); the Resource Conservation and Recovery Act (RCRA, 42 USC 6901 et seq.) including 40 CFR Part 261, Part 263, part 268 and Part 270, and DOT rules including 49 CFR Parts 107, 171 and 173. Spent carbon would be transported under DOT regulations and regenerated at licensed facilities.

Achievement of ARARs for the various discharge options related to extraction and treatment would be a significant design consideration. Potential ARARs for each of the discharge options are described below:

> *On-Site Re-injection:* Because this discharge option includes the injection of treated groundwater, regulations protecting groundwater quality would be appropriate and this option would be subject to The Safe Drinking Water Act (40 CFR 144-147) and the New Jersey Pollutant Discharge Elimination System rules (N.J.A.C.7:14A).
>
> *Discharge to Surface Water/Wetlands*: Surface waters and wetlands are protected by the Clean Water Act (33 USC 151 et. seq.), EPA Water Quality Standards (40 CFR 131), the New Jersey Pollutant Discharge Elimination System (N.J.A.C. 7:14A), New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B), New Jersey Freshwater Protection Act (N.J.A.C. 7:7A, N.J.S.A. 13:9B-1), and the Federal National Environmental Policy Act (40 CFR 6, Appendix A).
>
> *Discharge to Publically Operated Treatment Works (POTW)*: Discharges to POTW are subject to the Federal Clean Water Act (40 CFR 403). Effluent quality must meet standards set by the POTW.

All construction, maintenance and monitoring activities would be subject to the Occupational Safety and Health Act (OSHA, 29 USC 651-678) and, in some cases, may be subject to the New Jersey Soil Erosion and Sediment Control Act (N.J.S.A. 4:24-39 et seq.). Institutional controls would be implemented in accordance with N.J.A.C. 7.26E (Subchapter 8).

Short-Term Effectiveness

The construction activities could pose significant restrictions to current businesses operating in the treatment area including the Lightman Property and multiple downgradient properties including the installation of ISCO injection points and groundwater extraction and treatment systems. With proper health and safety procedures, the short term risks to construction workers and site workers would be low.

Addition of strong oxidants may increase the mobile fraction of some redox sensitive metals (e.g., Chromium) and may increase groundwater concentrations of these constituents in the short-term and represent a potential risk to the environment during implementation. Injection of large volumes of oxidant could enable movement of contaminants and may require additional injections at downgradient locations to eliminate this threat. There is also the potential for migration of contaminants into the vapor phase, which would represent a potential risk to Site workers during implementation. The oxidants used would require special handling and storage and pose a short-term hazard. The oxidation of organic compounds is an exothermic process and can be highly energetic when using strong oxidants and precautions must be taken to mitigate this threat to Site workers. The by-product of permanganate treatment, MnO_2, can accumulate and inhibit flow through the aquifer representing a threat to the environment during implementation.

Reduction of Toxicity, Mobility, and Volume through Treatment

The soil source removal has significantly addressed the toxicity, mobility, and volume of contaminant mass in the saturated soils associated with the Former Waste Storage Tank Area. Fenton's Reagent was selected as the most appropriate oxidant for use in the eastern source area plume where BTEX compounds are located. Permanganate has been selected for the western source area plume where there is no impact from BTEX compounds. Additionally, permanganate could be used in future injections in the eastern plume after BTEX has been successfully removed. Chlorinated VOCs and BTEX compounds could be effectively treated using ISCO; however, success is dependent on the ability to distribute oxidant into the contaminated zone. Contaminants are destroyed by the ISCO process treatment, which is considered irreversible.

The mobility and volume of a small additional mass of the dissolved phase contaminants within the groundwater would be reduced by groundwater extraction and treatment. The activated carbon would require off-site destruction or regeneration at a licensed facility. The maximum mass removal rate of pump and treat is estimated to be on the order of 1 kg/yr to 2 kg/year (Appendix E). The actual mass removal rate of the extraction system is expected to be more variable for the following reasons:

- Plume concentrations are expected to decrease with time as a result of addressing the source area. As a result, the extraction system initial mass removal rates of 1 kg to 2 kg per year is expected to decrease with time to lower levels; and,

- Although reductive dechlorination is not a dominant process downgradient of the source, other biotic and abiotic processes may degrade chlorinated solvents. Contaminant mass within the aquifer is expected to be reduced at a low rate[14] (see Section 2.6.4 for

[14]Contaminant degradation with a half-life of 13 years is an estimated slow degradation rate for aerobic TCE degradation referenced in the literature (see Section 5.1.3). At this rate, degradation will reduce the downgradient plume mass by ~25 percent in 5 years, ~45 percent in 10 years, and ~65 percent in 20 years.

additional details) which in turn will result in a continuous decrease in concentration of extracted groundwater

Based on the above, it is expected that the extraction system effluent concentration will decrease with time and an asymptotic level will be reached.

Natural attenuation processes in the downgradient groundwater would continue and the time of remediation would be reduced as a result of the combined effects of source area excavation, treatment with ISCO and groundwater extraction and treatment.

Long-Term Effectiveness and Permanence

Substantial source mass in the Former Waste Storage Tank Area has been effectively removed and will no longer contribute as a source to groundwater contamination in the eastern plume. ISCO is potentially effective in addressing contaminants in the source area. Once treatment of the contaminant is achieved, which may require multiple treatments, the magnitude of residual risk from the implementation of ISCO would be relatively low as the target compounds are oxidized completely to CO_2, any residual hydrogen peroxide decomposes to water and oxygen, and remaining iron or MnO_2 particles ultimately settle out in the subsurface. The groundwater extraction and treatment system would be less efficient in treating contaminants due to the relatively low mass removal rate in downgradient areas. The overall effectiveness of pump and treat would also be dependent on accurate delineation of the "hot spots" and the actual contaminant mass within the "hot spots".

Over the long-term, natural attenuation of groundwater impacts in the plumes is expected to continue, resulting in the removal of additional contaminant mass. Long-term monitoring would be conducted to verify performance, including five-year reviews to assess the continued effectiveness.

Implementability

In general, the equipment, services, and materials for chemical oxidation are readily available. However, the uniform delivery of the oxidants would potentially be difficult to implement. Because of the extent of contamination, the volume of oxidant necessary to treat the natural oxidant demand (NOD) along with the total VOC mass would be very high. As such, ISCO would be focused on the source areas within the Lightman property and higher concentrations

(>1,000 ug/l) of groundwater on the adjacent property. The injection of large volumes of oxidant solution during each injection round would also be difficult and could result in significant groundwater mounding and potential migration of contaminants. Access agreements would be required with at least one adjacent property owner.

Design of the groundwater extraction and treatment system requires additional information on the current size and location of "hot spot" areas. There would also be several implementation challenges including:

1. Long term access would be required to several private properties for the construction and operation of the system. Access to private properties would be required to install wells, pipelines, and treatment units. Operation and maintenance of the system would result in long-term disruption to the affected properties.

2. Discharge of treated groundwater would require extensive piping on private property: to connect to the sewer system along Route 73; to potential discharge galleries or injection wells; or to Pump Branch Creek. Discharge to Pump Branch Creek would also require piping below railroad tracks and disruption of wetlands.

3. Implementability of groundwater extraction to the west side of the railroad tracks is limited due to severe access restrictions posed by the railroad tracks, the wetlands associated with Pump Branch Creek and residential development beyond.

MNA is readily implementable assuming continued access to downgradient wells.

Cost

The preliminary net present worth cost estimate for Alternative 4B is approximately $12,840,000 USD; this cost includes $8,150,000 for ISCO, $2,810,000 for the downgradient extraction and treatment system, and $1,880,000 for MNA. The ISCO cost is primarily driven by the potentially large volume of oxidant that may be required to satisfy the NOD, but also includes estimated costs for securing access, and operation and maintenance. The groundwater extraction and treatment cost is primarily driven by the initial engineering and construction costs but also includes estimated costs for access and operation and maintenance. Costs for MNA include establishment of a CEA, regular sampling of wells, laboratory analyses, data evaluation, and reporting costs.

6.6 Alternative 5A: Alternative 2 + Downgradient ISCO

Overall Protection of Human Health and the Environment

This alternative would achieve overall protection of human health and the environment. Substantial source mass has been removed in the Former Waste Storage Tank Area pursuant to the Removal AOC and will no longer contribute to groundwater contamination in the eastern plume. AS/SVE would address remaining groundwater contamination in the Former Waste Storage Tank Area and Former Unlined Pit Areas and immediate downgradient areas. SVE is a proven technology for the remediation of volatile organic compounds and air sparging is a developing technology for the removal of VOCs from groundwater. The implementation of the SVE system would provide for the capture of vapor phase contaminants released by air-sparging, mitigating the potential for vapor intrusion into structures and utilities. The captured VOCs would be absorbed on granular activated carbon and subsequently destroyed at a carbon regeneration facility.

As discussed in Section 6.3, ISCO would convert toxic compounds to non-toxic by-products (CO_2) reducing the total contaminant mass. Because ISCO treatment is not usually applied to low concentration groundwater plumes as a result of the low oxidant efficiency, large volumes, and the associated high costs, it is not a proven technology for this application. The overall effectiveness of ISCO in the downgradient area would be dependent not only on effective injection of sufficient oxidants, but also on accurate delineation of the “hot spots”. Implementing ISCO could accelerate the restoration of groundwater quality through mass removal and MNA would continue to address residual groundwater contamination. Installation of additional sentinel and in-plume wells and establishment of a rigorous monitoring program would demonstrate the continued improvement of groundwater quality, provide adequate warning should conditions change, thereby assuring continued protection of the Municipal wells from Site-related impacts. Institutional controls in the form of a CEA and use restrictions on the Lightman Property would provide protective measures until such time as the groundwater cleanup has been completed.

Compliance with ARARs

This alternative would be expected to achieve ARARs. This alternative would be subject to the same potential ARARs as described for Alternative 2 (Section 6.2) and Alternative 3 (Section 6.3).

Short-Term Effectiveness

The construction activities involved with this alternative could pose significant restrictions to current businesses operating in the treatment area including the Lightman Property and multiple downgradient properties through installation of AS/SVE wells, vacuum system piping, and ISCO injection points. With proper health and safety procedures, the short term risks to construction workers are low.

Addition of strong oxidants may increase the mobile fraction of some redox sensitive metals (e.g., Chromium) and may increase groundwater concentrations of these constituents in the short-term representing a potential risk to the environment during implementation. Injection of large volumes of oxidant could enable movement of contaminants and may require additional injections at downgradient locations to eliminate this threat. There is also the potential for migration of contaminants into the vapor phase which would represent a potential risk to Site workers during implementation. The oxidants used would require special handling and storage and pose a short-term hazard. The oxidation of organic compounds is an exothermic process and can be highly energetic when using strong oxidants and precautions must be taken to mitigate this threat to Site workers. The by-product of permanganate treatment, MnO_2, could accumulate and inhibit flow through the aquifer representing a threat to the environment during implementation.

Reduction of Toxicity, Mobility, and Volume through Treatment

The soil source removal has significantly addressed the toxicity, mobility, and volume of contaminant mass in the saturated soils associated with the Former Waste Storage Tank Area. VOCs would be effectively removed from the groundwater by air sparging and collected by the SVE wells and absorbed on activated carbon for future off-site destruction at a licensed facility. The AS/SVE system reduces the total mass (volume) of contaminants in the groundwater, thus reducing mobility and toxicity through treatment.

ISCO could further reduce the toxicity, mobility, and volume of an additional mass of dissolved phase contaminants downgradient. However, success is dependant on the ability to distribute oxidant into the contaminated zones, which occur at significant depths. A large volume of oxidants would be required to overcome the natural NOD to address a relatively small mass of contaminants. It is expected that with multiple injections the contaminant mass could be reduced.

Natural attenuation processes would continue and the time of remediation would be reduced as a result of the source area excavation, AS/SVE, and treatment with ISCO.

Long-Term Effectiveness and Permanence

Substantial source mass in the Former Waste Storage Tank Area has been effectively removed and will no longer contribute as a source to groundwater contamination in the eastern plume. The effectiveness and permanence of AS/SVE to address remaining VOC contamination in the source areas and downgradient over the duration of the remediation would be high. The equipment requires a high level of preventative maintenance but generally has a major repair frequency greater than the estimated duration of the system operation.

Once treatment of the contaminants is achieved, the magnitude of residual risk from the implementation of ISCO downgradient is relatively low as the target compounds are oxidized completely to CO_2, any residual hydrogen peroxide decomposes to water and oxygen and remaining iron or MnO_2 particles ultimately settle out in the subsurface.

Over the long-term, natural attenuation of groundwater impacts in the plumes is expected to continue resulting in the destruction and transformation of contaminant mass. Long-term monitoring would be conducted to verify performance including five-year reviews to assess the continued effectiveness.

Implementability

AS/SVE has been successfully used in similar circumstances and the Site conditions are conducive to the application of these technologies. Less desirable parameters for the implementation of air sparging are the depth of the plumes within the aquifer downgradient and the presence of non-impacted groundwater above the plumes of dissolved contaminants as the plumes plunge away from the site. These conditions could be reasonably addressed in the design of the system to address the Lightman Property and a reasonable distance downgradient. The shallow depth of the ground water posses several design issues, including possible short-circuiting of vapor from the ground surface, reduced zone of influence, and the recovery of high volumes of condensate. These issues could be addressed in the design of the system and would not significantly affect the implementability. Access agreements would be required with at least one adjacent property owner.

In general, the equipment, services, and materials for chemical oxidation are readily available. However, the uniform delivery of the oxidants is potentially difficult to implement. Because of the low concentration of total VOCs in the impacted zones, the amount of oxidant needed to treat NOD along with the total VOC mass is very high. Accurate delineation of the "hot spot" would be required. ISCO would be significantly limited to the west of the railroad tracks due to severe access restrictions placed by the railroad tracks, the wetland areas associated with Pump Branch Creek, and residential development beyond. Access agreements would be required with several property owners.

MNA would be readily implementable, assuming continued access to downgradient wells.

Cost

The preliminary net present worth cost estimate for Alternative 5A is $11,520,000 USD; this cost includes $5,450,000 for AS/SVE, $4,190,000 for downgradient ISCO and $1,880,000 for MNA. The AS/SVE cost is primarily driven by the initial engineering and construction costs but also includes estimated costs for securing access and operation and maintenance. The ISCO cost is primarily driven by the volume of oxidant that may be required to satisfy the NOD. Costs for MNA include establishment of a CEA, regular sampling of wells, laboratory analyses, data evaluation, and reporting costs.

6.7 Alternative 5B: Alternative 3 + Downgradient ISCO

Overall Protection of Human Health and the Environment

This alternative would achieve overall protection of human health and the environment. Substantial source mass has been removed in the Former Waste Storage Tank Area pursuant to the Removal AOC and will no longer contribute to groundwater contamination in the eastern plume. ISCO would address the most significant remaining groundwater contamination in the Former Waste Storage Tank Area and the Former Unlined Pit Area and immediate downgradient areas, as well as in "hot spots" further downgradient by converting toxic compounds to non-toxic by-products (CO_2). Once treatment is complete, rebound of contamination is expected to be limited. In using Fenton's Reagent, any residual hydrogen peroxide decomposes to water and oxygen and remaining iron particles ultimately settle out in the subsurface. Permanganate would react fully to produce insoluble MnO_2 solids.

Because ISCO treatment is not usually applied to low concentration groundwater plumes as a result of the low oxidant efficiency, large volumes, and the associated high costs, it is not a proven technology for the downgradient "hot spots". The overall effectiveness of ISCO in the downgradient "hot spots" would be dependent not only on effective injection of sufficient oxidants, but also on accurate delineation of the "hot spots".

Implementing ISCO could accelerate the restoration of groundwater quality through mass removal and MNA would continue to address the residual groundwater contamination. Installation of additional sentinel and in-plume wells and establishment of a rigorous monitoring program would demonstrate the continued improvement of groundwater quality, provide adequate warning should conditions change, thereby assuring continued protection of the Municipal wells from Site-related impacts. Institutional controls in the form of a CEA and use restrictions on the Lightman Property would provide protective measures until such time as the groundwater cleanup has been completed.

Compliance with ARARs

This alternative would be expected to achieve ARARs. This alternative would be subject to the same potential ARARs as described for Alternative 3 (Section 6.3).

Short-Term Effectiveness

Construction activities associated with ISCO injections could pose significant short-term restrictions to businesses operating in the treatment area including the Lightman Property and multiple downgradient properties as a result of the installation of closely spaced injection points. Addition of strong oxidants may increase the mobile fraction of some redox sensitive metals (e.g., Chromium) and may increase groundwater concentrations of these constituents in the short-term and represent a potential risk to the environment during implementation. Injection of large volumes of oxidant could enable movement of contaminants and may require additional injections at downgradient locations to eliminate this threat. There would also be the potential for migration of contaminants into the vapor phase which would represent a potential risk to Site workers during implementation. The oxidants used would require special handling and storage and would pose a short-term hazard. The oxidation of organic compounds is an exothermic process and can be highly energetic when using strong oxidants and precautions must be taken to mitigate this threat to Site workers. The by-product of permanganate treatment, MnO_2, could accumulate and inhibit flow through the aquifer representing a threat to the environment during implementation.

Reduction of Toxicity, Mobility, and Volume through Treatment

The soil source removal has significantly addressed the toxicity, mobility, and volume of contaminant mass in the saturated soils associated with the Former Waste Storage Tank Area. Fenton's Reagent would be selected as the most appropriate oxidant for use in the eastern source area plume where BTEX compounds are located. Permanganate would be selected for the western source area plume and in select localized “hot spot” zones downgradient where there is no impact from BTEX compounds. Additionally, permanganate could be used in future injections in the eastern plume after BTEX has been successfully removed. Chlorinated VOCs and BTEX compounds can be effectively treated using ISCO; however, success is dependant on the ability to distribute oxidant into the contaminated zone. Contaminants are destroyed by the ISCO process treatment, which is considered irreversible.

Natural attenuation processes would continue and the time of remediation would be reduced as a result of the source area excavation and treatment with ISCO reducing the plume mass.

Long-Term Effectiveness and Permanence

Substantial source mass in the Former Waste Storage Tank Area has been effectively removed and will no longer contribute as a source to groundwater contamination in the eastern plume. ISCO would be potentially effective in addressing contaminants in the source area. Once treatment of the contaminants is achieved, which may require multiple treatments, the magnitude of residual risk from the implementation of ISCO would be relatively low as the target compounds are oxidized completely to CO_2, any residual hydrogen peroxide decomposes to water and oxygen, and remaining iron or MnO_2 particles ultimately settle out in the subsurface.

Over the long-term, natural attenuation of groundwater impacts in the plumes is expected to continue resulting in the destruction and transformation of contaminant mass. Long-term monitoring would be conducted to verify performance, including five-year reviews to assess the continued effectiveness.

Implementability

In general, the equipment, services, and materials for chemical oxidation are readily available. However, the uniform delivery of the oxidants would potentially be difficult to implement. Because of the extent of contamination, the volume of oxidant necessary to treat the natural oxidant demand (NOD) along with the total VOC mass is very high. As such, ISCO would be focused on the source areas within the Lightman Property, and higher concentrations (>1,000 ug/l) of groundwater on the adjacent property and localized areas far downgradient where accurate delineation of the "hot spot" areas would be required. ISCO would be significantly limited to the west of the railroad tracks due to severe access restrictions placed by the railroad tracks, the wetland area associated with Pump Branch Creek and residential development beyond. Because of the generally low concentration of total VOCs in the impacted zone, the amount of oxidant needed to treat NOD versus total VOC mass is large, especially far downgradient. The injection of large volumes of oxidant solution during each injection round would also be difficult and could result in significant groundwater mounding and potential migration of contaminants. Access agreements would be required with multiple property owners.

MNA is readily implementable assuming continued access to downgradient wells.

Cost

The preliminary net present worth cost estimate for Alternative 5B is $14,220,000 USD; this cost includes $8,150,000 for Source Area ISCO, $4,190,000 for downgradient ISCO and $1,880,000 for MNA. The ISCO cost is primarily driven by the potentially large volume of oxidant that may be required to satisfy the NOD but also includes estimated costs for securing access and operation and maintenance. Costs for MNA include establishment of a CEA, regular sampling of wells, laboratory analyses, data evaluation, and reporting costs.

7.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

A comparative analysis of the alternatives presented in Section 6.0 is presented below and summarized in Table 7-1.

Overall Protection of Human Health and the Environment:

Under current use scenarios all alternatives, including No Further Action, provide protection of human health. However, with No Further Action, substantial VOC contamination remains in groundwater within the source area and this alternative does not take any additional measures for long-term protection of human health and the environment.

Alternatives 2, 3, 4A, 4B, 5A and 5B would be protective of human health and the environment. Each alternative builds on the saturated soil source removal action to address remaining source contaminants in the vicinity and downgradient of the Former Waste Storage Tanks and Unlined Pit. Each alternative includes MNA to address downgradient groundwater contamination while utilizing institutional controls to provide protective measures until such time groundwater cleanup has been achieved. Alternatives 4A, 4B, 5A and 5B provide additional measures to address downgradient groundwater "hot spots". Depending upon future pumping rates, these "hot spots" could migrate towards a municipal well, although travel times would be lengthy and migration would be detected by downgradient monitoring.

There is no current exposure to downgradient contamination and mass removal from the "hot spots" would be relatively low.

Compliance with ARARs

Alternative 1 would not be expected to achieve groundwater ARARs in a reasonable time frame as groundwater source contamination would remain. Alternatives 2, 3, 4A, 4B, 5A and 5B are expected to comply with groundwater ARARs in a reasonable time frame through remediation of the source areas and downgradient monitored natural attenuation.

Short-Term Effectiveness

The construction activities involved with the AS/SVE Alternatives could pose significant restrictions to current businesses operating in the treatment area. Installation of AS/SVE wells and vacuum system piping will disturb significant areas of the Site and could interfere with daily activities for local businesses. With proper health and safety procedures, the short term risks to construction workers are low. Alternatives which include ISCO involve the addition of strong oxidants that may represent a potential risk to the environment during implementation, potential for migration of contaminants into the vapor phase, which represents a potential risk to Site workers during implementation, and special handling and storage concerns that pose a short-term hazard to Site workers. Alternatives which include groundwater extraction and treatment would likely result in significant short-term negative impacts involving construction of pipelines, wells and treatment systems on private property. Provided adequate health and safety measures are employed, negative impacts to workers during construction would be minimal.

Reduction of Toxicity, Mobility, and Volume through Treatment

The saturated soil source removal action has significantly addressed the toxicity, mobility and volume of source contaminants in the area of the Former Waste Storage Tanks. Alternatives 2, 3, 4A, 4B, 5A, 5B would effectively reduce the toxicity, mobility and volume through treatment of contaminants in the source areas and immediately downgradient areas. Alternatives that utilize AS/SVE (2, 4A and 5A) physically remove contaminants and would directly address a larger area of the plumes downgradient of the source areas and thereby would be more effective in reducing the toxicity, mobility and volume of contaminants than those alternatives that rely on ISCO (3, 4B, and 5B). Alternatives 4A, 4B, 5A, 5B further treat groundwater contamination in localized downgradient "hot spots", however, the mass of additional contaminants treated by Alternatives 4 and 5 is not likely to be significantly higher than Alternatives 2 and 3.

Long-Term Effectiveness and Permanence

Substantial source mass in the vicinity of the Former Waste Storage Tanks has been removed and would no longer contribute as a source to groundwater contamination. Alternatives 2, 3, 4A, 4B, 5A, 5B can effectively treat remaining contaminants in the source areas and immediately downgradient areas. Alternatives that utilize AS/SVE (2, 4A and 5A) would address a larger area of the plumes downgradient of the source areas. In addition, the effectiveness of alternatives that utilize ISCO (3, 4B, 5A and 5B) is likely to be lower than those that utilize AS/SVE as ISCO is not as effective for larger areas with low concentrations of organics. Alternatives that utilize pump and treat (4A and 4B) are likely to approach an asymptotic, low rate of mass removal that is not efficient in the long term.

Implementability

In general, the equipment, services and materials to implement Alternatives 2, 3, 4A, 4B, 5A and 5B are readily available. SVE is a proven technology for the remediation of volatile organic compounds and air sparging is a developing technology for the removal of VOCs from groundwater. AS/SVE alternatives (2, 4A, 5A) are considered to be more readily implementable than those utilizing ISCO (3, 4B and 5B) due to the high volume of oxidants that would be necessary to treat the VOC mass.

Alternatives 2 and 3 are more readily implemented as they require access agreements from only the adjacent property, whereas Alternatives 4A, 4B, 5A and 5B would require access agreements for multiple private properties. Alternatives that utilize pump and treat (4A and 4B) are considered the least implementable as they would require extensive construction of pipelines, wells and treatment systems on multiple private properties with operation and maintenance resulting in significant long-term disruption to the affected properties.

Cost

Alternative 1 is the most cost effective followed by Alternatives 2 and 3. Alternatives 4A and 5A costs are generally comparable and are approximately $3.0 to $4.2 million higher than Alternative 2. Costs for Alternatives 4B and 5B are generally comparable and approximately $3.0 to $4.2 million higher than Alternative 3. In general, the costs for alternatives that utilize ISCO are least certain due to the potential variability in oxidant quantities.

8.0 SUMMARY

A comprehensive Remedial Investigation (RI) was conducted at the Site between 2002 and 2008. The RI and associated Baseline Risk Assessment indicate that the primary contaminants of concern are aromatic hydrocarbons and chlorinated solvents in the groundwater beneath and extending downgradient of the Property. The primary potential exposure routes to these contaminants are through ingestion, inhalation, and dermal adsorption by future users of the portion of the aquifer impacted by the Site contaminants, or through exposure to vapors resulting from the volatilization of contaminants in groundwater to the vadose zone in the vicinity of the Lightman Property. Importantly, the RI identified two Winslow Township Municipal wells located approximately 7,500 feet from the Site.

Two main groundwater plumes were identified during the RI, one originating from the Former Waste Storage Tank Area (eastern plume) and one from the Former Unlined Waste Disposal Pit area in the western part of the site (western plume). Low levels of PCE/TCE associated with the eastern plume extend a distance of approximately 4,500 feet from the Property at which point the plume is located at approximately 85 feet bgs. A municipal supply well, which has not been operational since August 2007, is located approximately 2,800 feet from the downgradient extent of the eastern plume. Low levels of PCE/TCE associated with the western plume extend approximately 1,500 feet downgradient at which point the plume is at about 55 feet bgs. BTEX compounds (mainly benzene and xylene) are co-located with the PCE and TCE at the Lightman Property but are of much more limited extent downgradient.

The RI also concluded that groundwater flow was the most significant mechanism for transport of site contaminants. BTEX compounds were measured at significant levels in the area of the Former Waste Storage Tanks (94,000 ppb), however, migration is limited to approximately 1,500 feet downgradient. The lack of mobility and geochemical parameters downgradient of the Property suggest that the BTEX compounds are being biodegraded. PCE and TCE have mobilized furthest downgradient. Some evidence of limited dechlorination of chlorinated ethenes is evidenced by the detection of the intermediate degradation product 1,2-DCE in 10 of the 23 monitoring wells. Concentrations in downgradient monitoring wells have showed consistent reductions in concentrations of VOC contaminants in samples collected between 2005 and 2007 to the extent that only trace levels of PCE and TCE are now found in downgradient wells. However, horizontally and vertically discrete “hot spots” remain in downgradient areas.

Contaminant fate calculations indicate that these "hot spots" may, or may not, migrate towards the municipal wells, depending upon future pumping rates. If migration occurs, travel times are estimated to be measured in decades.

The RI also revealed that significant source area contamination remained associated with saturated soils in the area of the Former Waste Storage Tanks. As this area represented a significant mass of contaminants that would continue to contribute to groundwater contamination, a saturated soil source removal action was undertaken by a certain members of the Lightman Group under a separate Removal AOC. This action has been completed and will be immediately effective in reducing source contamination. In addition, shallow areas of un-naturally colored soil are currently being removed pursuant to the Removal AOC.

Based on the results of the RI and Baseline Risk Assessment, the Remedial Action Objectives for the site include:

1. Prevent unacceptable exposures to contaminated groundwater and associated vapors;
2. Control future migration of the contaminants of concern in groundwater; and,
3. Restore groundwater quality to regulatory levels[15].

To meet the Remedial Action Objectives, the following seven remedial action alternatives were developed, in consultation with USEPA, for evaluation against the NCP criteria:

- Alternative 1 No Further Action
- Alternative 2 AS/SVE + IC + MNA
- Alternative 3 ISCO + IC + MNA
- Alternative 4A AS/SVE + Downgradient P&T + IC + MNA
- Alternative 4B ISCO + Downgradient P&T + IC + MNA
- Alternative 5A AS/SVE + Downgradient ISCO + IC + MNA
- Alternative 5B ISCO + Downgradient ISCO + IC + MNA

[15] The Site falls within the New Jersey Pinelands protected area and so the groundwater is classified as Class I-PL by the NJDEP and the groundwater quality standards correspond to background values or the practical quantitation limit (PQL), whichever is higher.

Under current use scenarios, each alternative provides protection of human health as there are no completed exposure pathways and potential future groundwater users are required by municipal ordinance to connect to municipal water supply. However, substantial VOC contamination would remain in the source zone under No Further Action and this alternative does not take any additional measures for long term protectiveness of human health and the environment. All other alternatives will be protective of human health and the environment and would be expected to achieve groundwater ARARs in a reasonable time frame.

Alternatives 2, 3, 4A, 4B, 5A, and 5B satisfy the statutory preference for treatment and the treatment processes employed are permanent. Each of these alternatives will effectively treat the remaining contaminants in the source areas and the groundwater contamination downgradient. Alternatives that utilize AS/SVE will address larger areas of the plumes and thereby be more effective in reducing toxicity, mobility and volume. The effectiveness of alternatives that utilize ISCO is likely to be lower as ISCO is not typically as effective for larger areas with relatively low concentrations of organics. Given the relatively low concentrations and the limited nature of the contamination in far downgradient areas, the mass of additional contaminants treated under Alternatives 4A, 4B, 5A, and 5B is not significantly higher than Alternatives 2 and 3.

Alternatives 2 and 3 have a higher degree of implementability and will have the least impact on the community, as access is only required to one adjacent property. Alternatives 4A, 4B, 5A and 5B would require multiple access agreements and alternatives 4A and 4B would have the highest impact on the community. Alternatives that utilize ISCO (3, 4B and 5B) will have the greatest potential for short term risks to workers and the community due to the handling of substantial volumes of strong oxidants.

Alternative 1 is the most cost-effective followed by Alternatives 2 and 3. The cost of Alternatives 4A and 5A are similar and approximately \$3.0 to \$4.2 million dollars higher than Alternative 2. Costs for Alternatives 4B and 5B are comparable and are approximately \$3.0 to \$4.2 million dollars higher than Alternative 3. In general, the costs for alternatives that utilize ISCO are the least certain, due to the potential variability in oxidant quantities.

In summary, Alternative 2 is superior over Alternative 3 as it provides a higher short-term and long-term effectiveness, is more readily implementable and will address a greater area of contamination at a lower cost. Accordingly, Alternatives 4A and 5A that utilize AS/SVE are superior to Alternatives 4B and 5B that utilize ISCO. Alternatives 4A and 5A offer minimal additional protectiveness compared to Alternative 2, will result in significant long term community disruption, and will not efficiently treat the low mass of contaminants in downgradient “hot spots”.

9.0 REFERENCES

Bradley, P.M., and F.H. Chapelle, 1998. Microbial mineralization of VC and DCE under different terminal electron accepting conditions. *Anaerobe* 4(2): 81-87, 1998.

Brown, R.A. 2003. In Situ Chemical Oxidation: Performance, Practice, and Pitfalls. AFCEE Technology Transfer Workshop, February 24-27, 2003, San Antonio, TX. http://www.afcee.brooks.af.mil/products/techtrans/workshop/postworkshop03/Tuesday/pm/sourcezoneremediation/4_brown.pdf

Dekard, L.A., Willis, J.C., and Rivers, D.B. 1994. Evidence for the aerobic degradation of tetrachloroethylene by a bacterial isolate. Biotechnology Letters. 16:11, 1221-1224.

Dilling W.L., Tefertiller, N.B. and Kallos, G.J. 1975. Evaporation rates and reactivity of methylene chloride, chloroform, 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene and other chlorinated compounds in dilute aqueous solutions. Environ. Sci. Technol. 9, 833-838.

Domenico, P.A. and F.W. Schwartz, 1990. Physical and Chemical Hydrogeology, 506pp., John Wiley & Sons, Inc., New York, 1990.

Field, A. et al. ART System Performance Enhanced by Effective Site Assessment; Technology News and Trends, July 2007. http://www.clu-in.org/products/newsltrs/tnandt/view.cfm?issue=0707.cfm

Gerritse, J., Renard, V., Gottschal, J.C. and Visser, J. 1995. Complete degradation of tetrachloroethene by combining anaerobic dechlorinating and aerobic methanotrophic enrichment cultures. Applied Microbiology and Biotechnology. 43:5, 920-928.

Golder Associates Inc., 2002. Remedial Investigation/Feasibility Study Work Plan, Lightman Drum Company Site, Winslow Township, New Jersey, July 2002.

Golder Associates Inc., 2004a. Remedial Investigation Update, Lightman Drum Company Site, Winslow Township, New Jersey, January 2004.

Golder Associates Inc., 2004b. Addendum To Remedial Investigation Update, Lightman Drum Company Site, Winslow Township, New Jersey, September 2004.

Golder Associates Inc., 2005a. Candidate Technologies Memorandum, Lightman Drum Company Site, Winslow Township, New Jersey, June 2005.

Golder Associates Inc., 2005b. Revised Work Plan Nano-Scale Zero-Valent Iron Pilot Test, Lightman Drum Company Site, Winslow Township, New Jersey, February 2005.

Golder Associates Inc., 2006a. Revised Addendum Remedial Investigation/Feasibility Study Work Plan, Lightman Drum Company Site, Winslow Township, New Jersey, May 2006.

Golder Associates Inc., 2006b. Remedial Investigation Report, Lightman Drum Company Site, Winslow Township, New Jersey, August 2006.

Golder Associates Inc., 2006c. Remedial Action Objectives And Remedial Alternatives Screening Memorandum, Lightman Drum Company Site, Winslow Township, New Jersey, October 2006.

Golder Associates Inc., 2007a. Revised RI/FS Work Plan Addendum #2, Lightman Drum Company Site, Winslow Township, New Jersey, May 2007.

Golder Associates Inc., 2007b. Addendum To Remedial Investigation Report, Lightman Drum Company Site, Winslow Township, New Jersey, September 2007.

Golder Associates Inc., 2007c. Feasibility Study Progress Report, Lightman Drum Company Site, Winslow Township, New Jersey, September 2007.

Golder Associates Inc., 2007d. Soil Source Area Removal Work Plan Lightman Drum Superfund Site, Winslow Township, New Jersey, October 2007.

Golder Associates Inc., 2008a. Work Plan for Delineation of Un-Naturally Colored Soils, March 2008.

Golder Associates Inc., 2008b. Addendum to Remedial Investigation Report – Un-naturally Colored Soils Investigation, June 2008.

Golder Associates Inc., 2008c; Revised Remedial Investigation Report, October 2008.

Golder Associates Inc., 2008d. Revised Feasibility Study, September 2008.

Golder Associates Inc., 2008e. Revised Baseline Human Health Risk Assessment and Screening Level Ecological Risk Assessment, October 2008.

Golder Associates Inc., 2008f. Draft Construction Completion Report Soil Source Area Removal, June 2008.

Hardt, W.F., and Hilton, G.S., 1969. Water Resources and Geology of Gloucester County, New Jersey: New Jersey Department of Conservation and Economic Development Special Report 30, 130 p.

Howard, P.H., Boethling, R.S., Jarvis, W.F., Meylan, W.M., Michalenko, E.M., 1991. Handbook of Environmental Degradation Rates, 776pp., CRC Press, 1991.

Huling, S.G. and Pivetz, B.E. In-site Chemical Oxidation. USEPA Engineering Issue. USEPA/600/R-06/072. August 2006

INTEX 1989. Remedial Investigation, Lightman Drum Company, Winslow Township, NJ, September 1989

INTEX 1990. Phase II Remedial Investigation, Lightman Drum Company, Winslow Township, NJ, October 1990

ITRC. 2005. Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater, Second Edition. Interstate Technology and Regulatory Cooperation Work Group, In Situ Chemical Oxidation Work Team.

Markley, Marco. Soil Survey of Camden County, New Jersey. U.S. Department of Agriculture, April 1966.

McConnell G., Ferguson D.M. and Pearson, C.R. 1975. Chlorinated hydrocarbons and the environment. Endeavour. 34, 13-18.
Montgomery, J. H. Groundwater Chemicals Desk Reference, 3rd Edition, CRC Press, 1995.

Rooney, J.G., 1971. Groundwater Resources of Cumberland County, New Jersey Department of Environmental Protection, Division of Water Resources Special Report 34, 83.

Ryoo, D., Shim, H., Canada, K., Barbieri, P and Wood, T. 2000. Aerobic degradation of tetrachloroethylene by toluene-o-xylene monooxygenase of Pseudomonas stutzeri OX1. Nature Biotechnology. 18, 775-778.

Siegrist, R.L., M.A. Urynowicz, O.R. West, M.L. Crimi, and K.S. Lowe. 2001. Principles and Practices of In Situ Chemical Oxidation Using Permanganate. 367 pp. Battelle Press, Columbus, OH.

Shim, H., Ryoo, D., Barbieri, P. and Wood, T. 2001. Aerobic degradation of mixtures of tetrachloroethylene, trichloroethylene, dichloroethylenes, and vinyl chloride by toluene-o-xylene monooxygenase of Pseudomonas stutzeri OX1. Applied Microbiology and Biotechnology. 56:1-2, 265-269.

Sorenson, K.S., Peterson, L.N., Hinchee, R.H. and Ely, R.L. 2000. An Evaluation of Aerobic Trichloroethene Attenuation Using First-Order Rate Estimation. Bioremediation Journal. 4:4, 337-357.

Sperry, K.L., and J. Cookson, Jr. 2002. In Situ Chemical Oxidation: Design & Implementation. ITRC Presentation to New Jersey Department of Environmental Protection, October 30, 2002. http://www.state.nj.us/dep/srp/training/sessions/insitu200210c.pdf

USEPA, 1999. State, Tribal, and Site Identification Center, NPL Site Narrative at Listing, Lightman Drum Company, Winslow Township, New Jersey, July 22, 1999.

USEPA, 1999. Use of Monitored Natural Attenuation at Superfund RCRA Corrective Action, and Underground Storage Tank Sites. USEPA OSWER Directive 9200.4-17.

USEPA, 2000. Superfund Contract Support Team Sampling Report, Lightman Drum Company Site, Winslow Township, New Jersey, November 2000.

USEPA, 2000. Administrative Order on Consent, USEPA Index No. CERCLA-02-2000-2034, November 2000.

Zapecza, Otto S. Hydrogeologic Framework of the New Jersey Coastal Plan, Regional Aquifer-System Analysis; U.S. Geologic Survey Professional Paper 1404-B; 1989.

TABLE 2-1A
SUMMARY OF COPCS AND RISKS TO HUMAN RECEPTORS
LIGHTMAN DRUM RI/FS

		Groundwater			
Risk Driving Constituents	**On-Property Supply Well**	**Monitoring Wells**	**On-Property Vapor Intrusion**	**Maximum Detection (µg/L)**	**GW Criteria (1)**
VOCs		*VOCs*			
1,1,2-Trichloroethane		X	-	2.7	2
1,2,3-Trichlorobenzene		X	-	280 (J)	NA
1,2,4-Trichlorobenzene		X	-	590	1
1,2-Dichlorobenzene		X	-	87 (J)	5
1,4-Dichlorobenzene		X	-	130 (J)	5
Benzene		X	X	140	1
Chlorobenzene		X	-	86 (J)	1
Chloroform		X	-	2.7	1
cis-1,2-Dichloroethene		X	X	1400	1
Ethylbenzene		X	X	3100	2
Isopropylbenzene		-	X	54 (J)	1
Tetrachloroethene		X	X	4200	1
Toluene		X	-	630	1
Trichloroethene		X	X	2100	1
Vinyl Chloride		X	X	6.6 (J)	1
Xylenes (total)	*none*	X	X	90000	2
SVOCs		*SVOCs*			
2,4-Dimethylphenol		X	-	300	20
4-Methylphenol		X	-	1100	NA
bis(2-Ethylhexyl)Phthalate		X	-	17	3
Naphthalene		X	-	17	2
Inorganics		*Inorganics*			
Antimony		X	**-**	7.5 (J)	3
Arsenic		X	**-**	3.3 (J)	3
Cadmium		X	**-**	102	0.5
Chromium		X	**-**	28.2	**2.3 B**
Iron		X	**-**	55700	**932**
Lead		X	**-**	22	5
Manganese		X	**-**	229	**5.3 B**
Nickel		X	**-**	26.1 (B)	**1.2 B**
Thallium		X	**-**	8.6 (J)	2
Vanadium		X	**-**	8.2 (B)	**1.7 B**

Scenario Timeframe	Receptor Population	Receptor Age		RME Scenario	CT Scenario
Future	Resident	Adult	Cancer Risk	2.60E-02	1.74E-03
			Non-cancer Health Hazard	186	113
Future	Resident	Child	Cancer Risk	3.8E-02	1.16E-02
			Non-cancer Health Hazard	1250	385
Future	Industrial/Commercial Worker	Adult	Cancer Risk	6.9E-02	2.55E-03
			Non-cancer Health Hazard	557	57

Notes:
1) The Site falls within the New Jersey Pinelands protected area and so the groundwater is classified as Class I-PL by the NJDEP and the groundwater quality standards correspond to background values or the practical quantitation limit (PQL), whichever is higher. **BOLD** values are from background well MW-1. NA indicates that the compound was non-detect in background and there is no available NJ Class IIA PQL.

TABLE 2-1B
SUMMARY OF ECOLOGICAL RISKS
Lightman Drum Superfund Site

Environmental Medium	COPECs	Receptor	Hazard Quotient (NOAEL/LOAEL)
Surface Water	Aluminum Arsenic Barium Copper Iron Lead Selenium	Green Frog	(NOAEL only) Aluminum HQ = 5.676 Arsenic HQ = 2.037 Lead HQ = 0.228
Soil	Methyl acetate 2-Chloronaphthalene **4,4'-DDD** **4,4'-DDE** **4,4'-DDT** 4-Methylphenol Aluminum Antimony	Meadow Vole	Aluminum HQ = 10.802/1.189 Selenium HQ = 1.005/0.363
	Barium Benzaldehyde **Benzo(a)Pyrene** Benzo(b)Fluoranthene **beta-BHC** Beryllium bis(2-Ethylhexyl)Phthalate	American Robin	4,4'-DDD HQ = 2.205/0.220 4,4'-DDT HQ = 6.557/0.656 Aluminum HQ = 8.067/0.807 Chromium HQ = 45.596/2.280 Lead HQ = 7.118/0.712 Selenium HQ = 1.253/0.626
	Cadmium Caprolactam Carbazole Chromium Cobalt Copper **Dieldrin** Di-n-butylphthalate	Red Fox	Aluminum HQ = 275.385/27.513 Chromium HQ = 1.687/0.169 Dieldrin HQ = 3.750/0.389 Mercury HQ = 5.563/0.556 Selenium HQ = 2.209/0.221
	Endrin **gamma-BHC (Lindane)** **gamma-Chlordane** **Hexachlorobenzene** Iron Lead **Mercury** Selenium Vanadium Zinc	Red-tailed Hawk	4,4'-DDT HQ = 6.249/0.670 Aluminum HQ = 1.382/0.138 Chromium HQ = 2.101/0.210 Mercury HQ = 1.203/0.120

COPEC = Chemical of potential ecological concern
NOAEL = No observable adverse effects level
LOAEL = Lowest observable adverse effects level
Bold COPECs indicate those that are bioaccumulative

Potential ARARs
Lightman Drum Feasibility Study
Winslow Township, NJ

Regulator	Criteria	Citation	Description	Comments
Potential Chemical Specific ARARs				
Federal Safe Drinking Water Act	National Primary Drinking Water Standards - Maximum Contaminant Level Goals (MCLGs)	40 CFR 141	The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.	The NJ groundwater quality standards for Class I-PL are applicable for the remediation of groundwater
Federal Safe Drinking Water Act	National Secondary Drinking Water Standards - Maximum Contaminant Levels (MCLs)	40 CFR 143	The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.	Excepting thallium, these standards are less stringent than applicable state standards
Federal Resource Conservation and Recovery Act	Groundwater Protection Standards and Maximum Concentration Limits	40 CFR 264 subpart F	Establishes standards for groundwater protection	These standards are less stringent than applicable state standards
State of New Jersey Statutes and Rules	Drinking Water Standards - MCLs	N.J.A.C. 7:10 Safe Drinking Water Act	Establishes MCLs that are generally equal to or more stringent than the Safe Drinking Water Act MCLs	
State of New Jersey Statutes and Rules	National Secondary Drinking Water Standards -Secondary MCLs	N.J.A.C. 7:10-7 Safe Drinking Water Act	Establishes standards for public drinking water systems for those contaminants which impact the aesthetic qualities of drinking water	Contaminants Of Potential Concern (COPCs) not addressed in 7:10-7.2 Recommended upper limits and optimum ranges for physical, chemical, and biological characteristics in drinkingwater. There is no current exposure pathway to contaminated groundwater, and new developments in the vicinity of the Site are required by municipal ordinance to connect to the municipal water supply system.
State of New Jersey Statutes and Rules	Groundwater Quality Standards	N.J.A.C. 7:9C Groundwater Quality Standards	Establishes standards for the protection of ambient groundwater quality. Used as the primary basis for setting numerical criteria for groundwater cleanups	Includes standards for groundwater protected by the Pinelands Protection Act, N.J.S.A. 13:18A-1 et seq.

Table 3-1
Potential ARARs
Lightman Drum Feasibility Study
Winslow Township, NJ

Regulator	Criteria	Citation	Description	Comments
Potential Location Specific ARARs				
New Jersey Flood Hazard Control Act	Floodplain Use and Limitations	N.J.A.C. 7:13 Flood Hazard Area Control		Western Plume source area and portions of downgradient plumes lie within 100-year floodplain
Federal National Environmental Policy Act	Statement of Procedures on Floodplain Management and Wetlands Protection	40 CFR 6, Appendix A	Establishes policy and guidance for carrying out Executive Order 11988 - to avoid to the extent possible the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development.	Western Plume source area and portions of downgradient plumes lie within 100-year floodplain
New Jersey Freshwater Wetlands Protection Act		N.J.A.C. 7:7A N.J.S.A. 13:9B-1	Require permits for regulated activity disturbing wetlands	Potentially applicable for construction activities performed in the vicinity of a wetland or waterway (Pump Branch Creek)
Federal National Environmental Policy Act	Statement of Procedures on Floodplain Management and Wetlands Protection	40 CFR 6, Appendix A	Executive Order 11990 - Protection of Wetlands - to avoid to the extent possible the long and short term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or Indirect support of new construction in wetlands	portions of downgradient plumes lie in the vicinity of a wetland or waterway
Federal Endangered and Non-Game Species Act	Protection of threatened and endangered species	N.J.S.A. 23:2A-1	Standards for the protection of threatened and endangered species	Swamp pink was identified as potentially occurring on or adjacent to the Site; A survey found no evidence of the plant
Federal Endangered Species Act	Protection of threatened and endangered species	16 USC 1531 et seq. 40 CFR 400	Standards for the protection of threatened and endangered species	Swamp pink was identified as potentially occurring on or adjacent to the Site; A survey found no evidence of the plant
Endangered Plant Species List Act	Protection of threatened and endangered species	N.J.S.A. 13:1B et seq.	To develop and adopt a list of plant species that are endangered in New Jersey	Swamp pink was identified as potentially occurring on or adjacent to the Site; A survey found no evidence of the plant

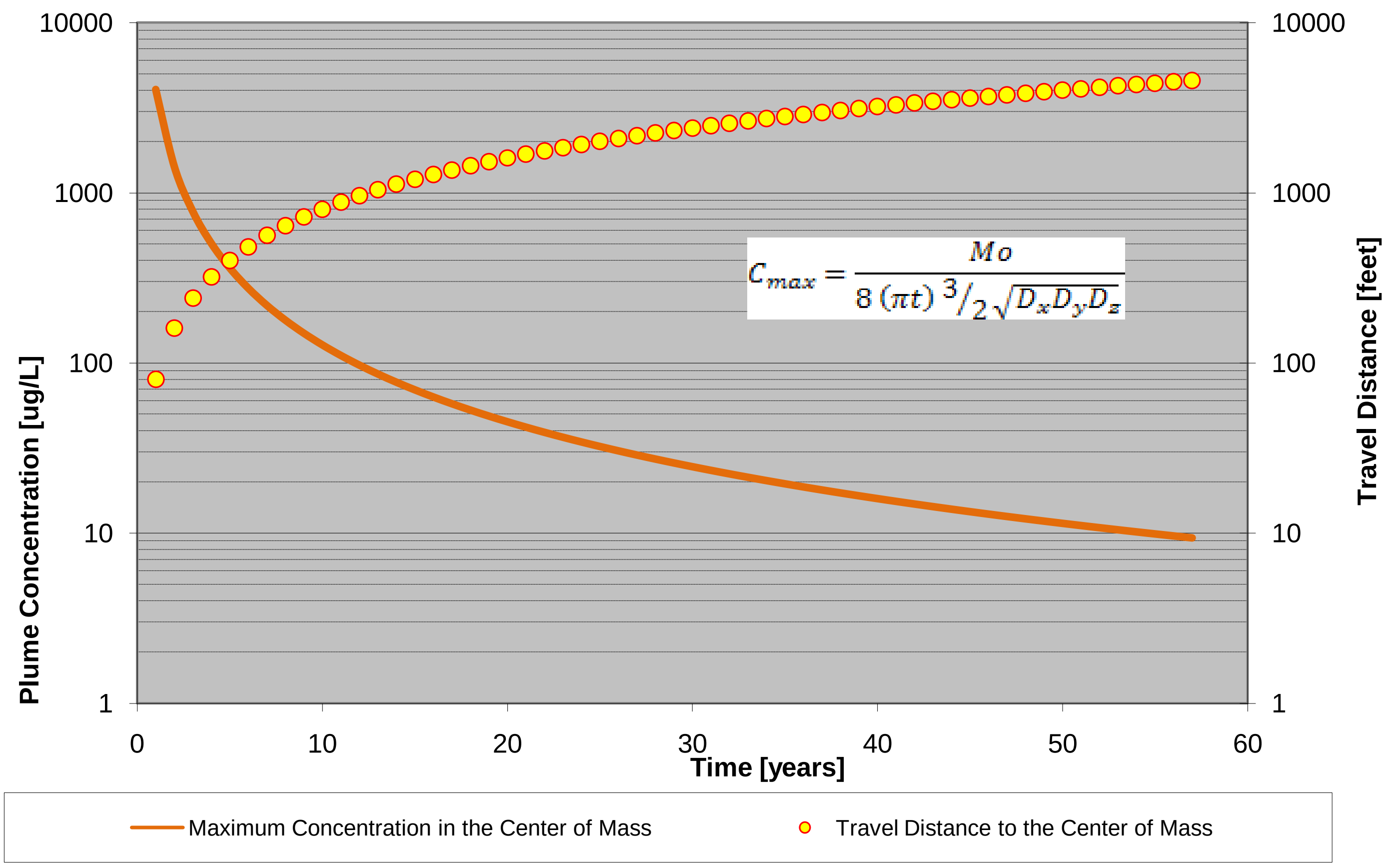
Potential ARARs
Lightman Drum Feasibility Study
Winslow Township, NJ

Regulator	Criteria	Citation	Description	Comments
Potential Location Specific ARARs (con't)				
Federal Fish and Wildlife Conservation Act	Statement of Procedures for non-game Fish and Wildlife Protection	16 USC 2901 et seq.	Established EPA policy and guidance for promoting the conservation of non-game fish and wildlife and their habitats.	Potentially applicable for construction activities performed which may impact non-game fish and wildlife and their habitats
Federal National Historic Preservation Act	Procedures for preservation of historical and archaeological data	16 USC 469 et seq. 40 CFR 6301 ('c)	Establishes procedures to provide for preservation of historical and archaeological data that might be destroyed through alteration of terrain as a result of a Federally licensed activity or program	A Stage IA Cultural Resources Survey indicated low to moderate potential for pre-historic archaeological remains and a low potential for historic archeological remains.
Potential Action Specific ARARs				
New Jersey Soil Erosion and Sediment Control Act	Procedures for controlling erosion and sediment movement	N.J.S.A. 4:24-39 et seq.	to establish soil erosion and sediment control standards for Department of Transportation certification of its projects to the Soil Conservation Districts	Potentially applicable for construction activities
Clean Water Act (CWA)	Procedures to preserve surface water quality	33 USC 151 et seq.	to sharply reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff.	Potentially applicable if water is discharged to surface water
Water Quality Standards	Procedures for State development of water quality standards under the CWA	40 CFR 131		Potentially applicable if water is discharged to surface water
The New Jersey Pollutant Discharge Elimination System		N.J.A.C. 7:14A	Establishes standards for discharge of pollutants to surface and groundwaters	Potentially applicable if water is discharged to surface or groundwaters
Surface Water Quality Standards		N.J.A.C. 7:9B	Establishes standards for the protection and enhancement of surface water resources	Potentially applicable if water is discharged to surface water
Toxic Pollutant Effluent Standards		40 CFR 129	Establishes effluent standards or prohibitions for certain toxic pollutants	Pollutants regulated not identified as COPCs
Resource Conservation and Recovery Act		42 USC 6901 et seq.	to manage hazardous and non-hazardous waste	
Identification and Listing of Hazardous Wastes		40 CFR 261	Identifies solid wastes which are subject to regulation as hazardous wastes	Potentially applicable to waste streams from treatment options
Standards for Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities		40 CFR 263	Establishes the responsibilities regarding the handling, transportaion, and management of hazardous waste	
Land Disposal Restrictions (LDRs)		40 CFR 268	Establishes Treatment Standards for land disposal of hazardous wastes.	

Table 3-1
Potential ARARs
Lightman Drum Feasibility Study
Winslow Township, NJ

Regulator	Criteria	Citation	Description	Comments
Hazardous Waste Permit Program		40 CFR 270	Establishes provisions covering basic EPA permitting requirements	
Hazardous Materials Transportation Act (HMTA)		49 USC 1801-1813		
Hazardous Material Transportation Regulations		49 CFR 107, 171-177	Regulates transportation of hazardous materials	Potentially applicable for removal of treatment waste streams
Clean Air Act (CAA)		42 USC 7401	To preserve air quality and to reduce air pollution	Potentially applicable to waste streams from AS/SVE alternative
National Ambient Air Quality Standards		40 CFR 50	Establishes primary and secondary standards for six pollutants to protect the public health and welfare.	Potentially applicable to waste streams from AS/SVE alternative
National Emission Standards for Hazardous Air pollutants		40 CFR 63	Establishes regulations for specific air pollutants (such as benzene and PCE)	Potentially applicable to waste streams from AS/SVE alternative
State of New Jersey Statutes and Rules	Air Pollution Control	N.J.A.C. 7:27 (Subchapters 8 & 16)	Regulates Air Pollution	
Technical Requirements for Site Remediation		N.J.A.C. 7:26E (Subchapter 8)	Establishes institutional controls for contaminated groundwater	
Fish and Wildlife Coordination Act		16 USC 661-666	Requires consultation when a federal department or agency proposes or authorizes any modification of any stream or other water body and adequate provision for protection of fish and wildlife resources	Potentially applicable if water is discharged to surface water
Occupational Safety and Health Act (OSHA)		29 USC 651-678	Regulates worker health and safety	
Safe Drinking Water Act (SDWA)	Underground injection control regulations	40 CFR 144-147	provides for the protection of underground sources of drinking water	Potentially applicable if water is re-injected following treatment
Federal Clean Water Act	General Pretreatment Regulations for Existing and New Sources of Pollution	40 CFR 403	Prohibits discharge of pollutants to a Publically Operated Treatment Works (POTW) which cause or may cause pass-through or interference with operations of the POTW	Potentially applicable if water is discharged to a POTW

Total VOC Concentration Reduction as a Result of Dispersion (Mo = 76 kg)
Lightman Drum Feasibility Study
Winslow Township, NJ



Initial Mass	Average Solute Velocity		Plume Length		Longitudinal Dynamic Dispersivity	
$m_0 = V_0 C_0$	v		L		$\alpha_x = 3.28 * 0.82 [\log (L/3.28)]^{2.446}$	
[kg]	[ft/day]	[m/year]	[ft]	[m]	[ft]	[m]
76	0.22	24.48	4500	1372	44.084	13.44

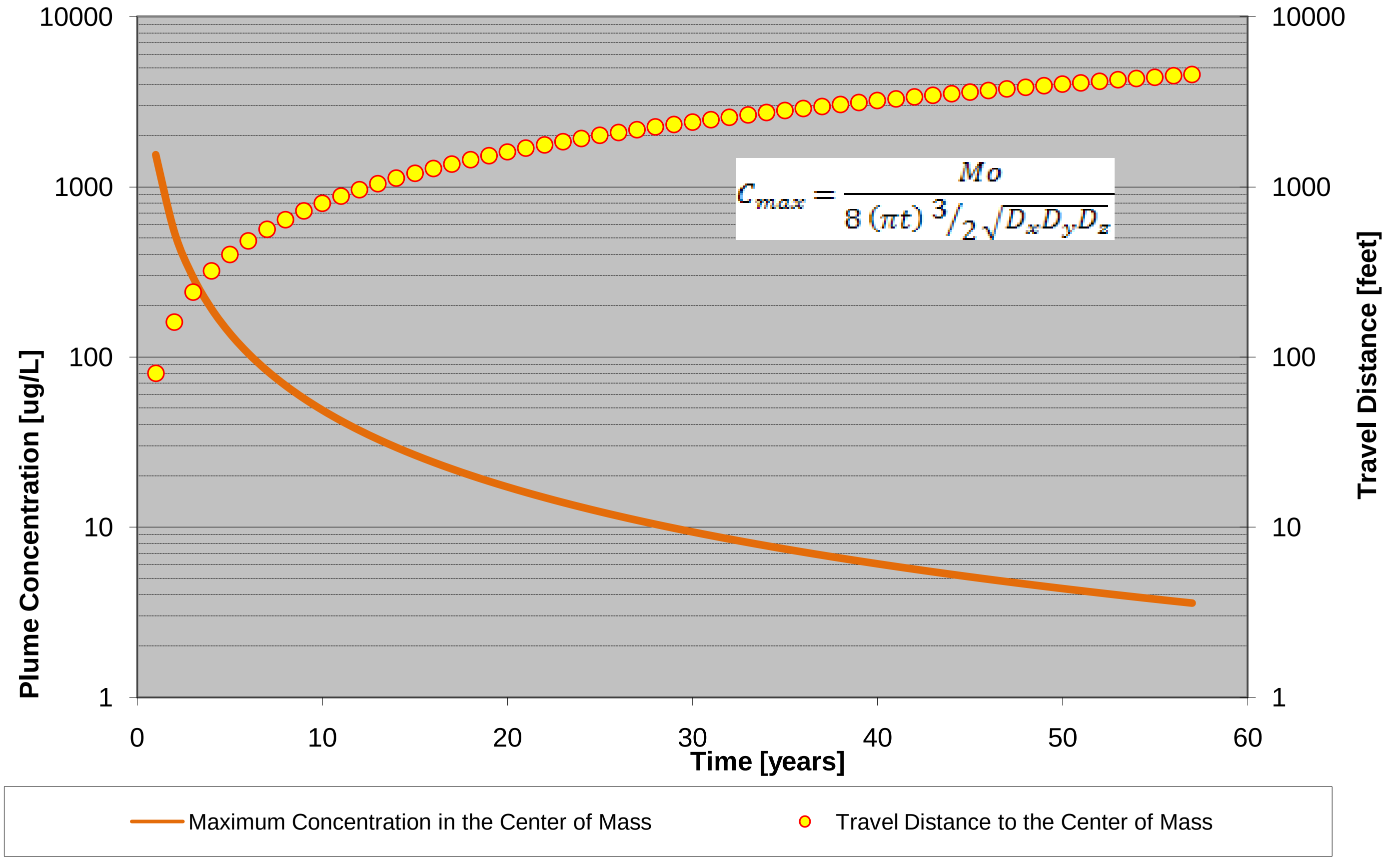
Transverse Dynamic Dispersivity	
$\alpha y = 0.1\ \alpha x$	
[ft]	[m]
4.41	1.34
Vertical Dynamic Dispersivity	
$\alpha z = 0.05\ \alpha x$	
[ft]	[m]
2.20	0.67

Mo = Initial contaminant mass [M]
t = Time [T]
D_n = ($D_n = \alpha_n V + D^*$) Coefficient of dispersion in coordinate direction n [L^2/T]
α_n = Dynamic dispersivity or dispersivity in direction n [L]
values estimated from Biochlor documentation (USEPA, 2002)
V = Solute velocity [L/T]
D* = Coefficient of molecular diffusion [L^2/T] (negligible)

Total VOC Concentration Reduction as a Result of Dispersion (Mo = 76 kg)
Lightman Drum Feasibility Study
Winslow Township, NJ

Travel Distance	Time	Maximum Plume Concentration (i.e., Center of Mass)
D = t V	*t*	*C*
[ft]	[years]	[ug/L]
80	1	4045.58
161	2	1430.33
241	3	778.57
321	4	505.70
402	5	361.85
482	6	275.27
562	7	218.44
642	8	178.79
723	9	149.84
803	10	127.93
883	11	110.89
964	12	97.32
1044	13	86.31
1124	14	77.23
1205	15	69.64
1285	16	63.21
1365	17	57.72
1445	18	52.98
1526	19	48.85
1606	20	45.23
1686	21	42.04
1767	22	39.21
1847	23	36.68
1927	24	34.41
2008	25	32.36
2088	26	30.52
2168	27	28.84
2248	28	27.31
2329	29	25.90
2409	30	24.62
2489	31	23.44
2570	32	22.35
2650	33	21.34
2730	34	20.41
2811	35	19.54
2891	36	18.73
2971	37	17.98
3051	38	17.27
3132	39	16.61
3212	40	15.99
3292	41	15.41
3373	42	14.86
3453	43	14.35
3533	44	13.86
3614	45	13.40
3694	46	12.97
3774	47	12.56
3854	48	12.17
3935	49	11.79
4015	50	11.44
4095	51	11.11
4176	52	10.79
4256	53	10.48
4336	54	10.20
4417	55	9.92
4497	56	9.65
4577	57	9.40

Table 5-2
Total VOC Concentration Reduction as a Result of Dispersion (Mo = 29 kg)
Lightman Drum Feasibility Study
Winslow Township, NJ



Initial Mass	Average Solute Velocity		Plume Length		Longitudinal Dynamic Dispersivity	
$m_0 = V_0 C_0$	v		L		$\alpha_x = 3.28 * 0.82\,[\log(L/3.28)]^{2.446}$	
[kg]	[ft/day]	[m/year]	[ft]	[m]	[ft]	[m]
29	0.22	24.48	4500	1372	44.084	13.44

Transverse Dynamic Dispersivity	
$\alpha y = 0.1\ \alpha x$	
[ft]	[m]
4.41	1.34

Vertical Dynamic Dispersivity	
$\alpha z = 0.05\ \alpha x$	
[ft]	[m]
2.20	0.67

Mo = Initial contaminant mass [M]
t = Time [T]
D_n = ($D_n = \alpha_n V + D^*$) Coefficient of dispersion in coordinate direction n [L^2/T]
α_n = Dynamic dispersivity or dispersivity in direction n [L]
values estimated from Biochlor documentation (USEPA, 2002)
V = Solute velocity [L/T]
D* = Coefficient of molecular diffusion [L^2/T] (negligible)

Table 5-2
Total VOC Concentration Reduction as a Result of Dispersion (Mo = 29 kg)
Lightman Drum Feasibility Study
Winslow Township, NJ

Travel Distance	Time	Maximum Plume Concentration (i.e., Center of Mass)
D = t V	*t*	*C*
[ft]	[years]	[ug/L]
80	1	1543.71
161	2	545.78
241	3	297.09
321	4	192.96
402	5	138.07
482	6	105.04
562	7	83.35
642	8	68.22
723	9	57.17
803	10	48.82
883	11	42.31
964	12	37.14
1044	13	32.93
1124	14	29.47
1205	15	26.57
1285	16	24.12
1365	17	22.02
1445	18	20.21
1526	19	18.64
1606	20	17.26
1686	21	16.04
1767	22	14.96
1847	23	14.00
1927	24	13.13
2008	25	12.35
2088	26	11.64
2168	27	11.00
2248	28	10.42
2329	29	9.88
2409	30	9.39
2489	31	8.94
2570	32	8.53
2650	33	8.14
2730	34	7.79
2811	35	7.46
2891	36	7.15
2971	37	6.86
3051	38	6.59
3132	39	6.34
3212	40	6.10
3292	41	5.88
3373	42	5.67
3453	43	5.47
3533	44	5.29
3614	45	5.11
3694	46	4.95
3774	47	4.79
3854	48	4.64
3935	49	4.50
4015	50	4.37
4095	51	4.24
4176	52	4.12
4256	53	4.00
4336	54	3.89
4417	55	3.78
4497	56	3.68
4577	57	3.59

Table 6-1
Summary of NCP Evaluation of Remedial Alternatives
Lightman Drum Feasibility Study
Winslow Township, NJ

NCP Criteria	Alternative						
	Alternative 1	Alternative 2	Alternative 3	Alternative 4A	Alternative 4B	Alternative 5A	Alternative 5B
	No Further Action	AS/SVE + IC + MNA	ISCO + IC + MNA	Alternative 2 + Downgradient P&T	Alternative 3 + Downgradient P&T	Alternative 2 + Downgradient ISCO	Alternative 3 + Downgradient ISCO
Overall Protection of Human Health and the Environment	Protective of human health under current conditions. VOC contamination remains in groundwater within the source area; no additional measures for long-term protection of human health and the environment.	Protective of human health and the environment. • addresses remaining groundwater source contaminants in and immediate downgradient areas of the source areas • MNA further downgradient • institutional controls protects potential receptors until groundwater cleanup has been completed	Protective of human health and the environment. • addresses remaining groundwater source contaminants in and immediate downgradient areas of the source areas • MNA further downgradient • institutional controls protects potential receptors until groundwater cleanup has been completed	Protective of human health and the environment. • addresses remaining groundwater source contaminants in and downgradient of the source areas • far downgradient contaminant "hot spots" may be addressed, although this would not significantly enhance the protectiveness of the remedy, it may accelerate the restoration of groundwater quality through additional mass removal • MNA in remaining downgradient areas. • institutional controls protects potential receptors until groundwater cleanup has been completed	Protective of human health and the environment. • addresses remaining groundwater source contaminants in and downgradient of the source areas • far downgradient contaminants ("hot spots") may be addressed, although this would not significantly enhance the protectiveness of the remedy, it may accelerate the restoration of groundwater quality through additional mass removal • MNA in remaining downgradient areas. • institutional controls protects potential receptors until groundwater cleanup has been completed	Protective of human health and the environment. • addresses remaining groundwater source contaminants in and downgradient of the source areas • far downgradient contaminants ("hot spots") may be addressed, although this would not significantly enhance the protectiveness of the remedy, it may accelerate the restoration of groundwater quality through additional mass removal • MNA in remaining downgradient areas. • institutional controls protects potential receptors until groundwater cleanup has been completed	Protective of human health and the environment. • addresses remaining groundwater source contaminants in and downgradient of the source areas • far downgradient contaminants ("hot spots") may be addressed, although this would not significantly enhance the protectiveness of the remedy, it may accelerate the restoration of groundwater quality through additional mass removal • MNA in remaining downgradient areas. • institutional controls protects potential receptors until groundwater cleanup has been completed
Compliance with ARARs	Not expected to achieve groundwater ARARs in a reasonable time frame.	This alternative is expected to comply with groundwater ARARs in a reasonable time frame.	This alternative is expected to comply with groundwater ARARs in a reasonable time frame.	This alternative is expected to comply with groundwater ARARs in a reasonable time frame.	This alternative is expected to comply with groundwater ARARs in a reasonable time frame.	This alternative is expected to comply with groundwater ARARs in a reasonable time frame.	This alternative is expected to comply with groundwater ARARs in a reasonable time frame.
Short-term Effectiveness	No further actions taken that would result in impact to the local community or the environment. Appropriate health and safety measures were implemented during the soil source removal and will be implemented during the un-naturally colored soil removal activities, mitigating short-term risk to construction workers.	Construction activities could pose significant restrictions to current businesses operating in the treatment area including the Lightman and adjacent property. With appropriate health and safety measures during the construction activities, short-term risk to construction workers and Site workers is low.	Construction activities could pose significant restrictions to current businesses operating in the treatment area including the Lightman and adjacent property. Strong oxidants may increase groundwater concentrations of some metals during implementation. Injection could enable movement of contaminants and contaminants may migrate into the vapor phase. The by-product of permanganate treatment, MnO2, can accumulate and inhibit flow through the aquifer. Oxidants used pose a short-term hazard; precautions must be taken to mitigate this threat to Site workers and proper storage and handling would be necessary.	Construction activities could pose significant restrictions to current businesses operating in the treatment area and significant short-term negative impacts involving construction of pipelines, wells and treatment systems on private property With appropriate health and safety measures during the construction activities, short-term risk to construction workers and Site workers is low.	Construction activities could pose significant restrictions to current businesses operating in the treatment area and significant short-term negative impacts involving construction of pipelines, wells and treatment systems on private property. Strong oxidants may increase groundwater concentrations of some metals during implementation. Injection could enable movement of contaminants and contaminants may migrate into the vapor phase. The by-product of permanganate treatment, MnO2, can accumulate and inhibit flow through the aquifer. Oxidants used pose a short-term hazard; precautions must be taken to mitigate this threat to Site workers and proper storage and handling would be necessary.	Construction activities could pose significant restrictions to current businesses operating in the treatment area and significant short-term negative impacts on private property. Strong oxidants may increase groundwater concentrations of some metals during implementation. Injection could enable movement of contaminants and contaminants may migrate into the vapor phase. The by-product of permanganate treatment, MnO2, can accumulate and inhibit flow through the aquifer. With appropriate health and safety measures during construction activities, mitigating short-term risk to construction workers is low for AS/SVE. Oxidants used pose a short-term hazard; precautions must be taken to mitigate this threat to Site workers and proper storage and handling would be necessary.	Injection activities could pose significant restrictions to current businesses operating in the treatment area and on private property and short-term negative impacts due to injection points Strong oxidants may increase groundwater concentrations of some metals during implementation. Injection could enable movement of contaminants and contaminants may migrate into the vapor phase. The by-product of permanganate treatment, MnO2, can accumulate and inhibit flow through the aquifer. Oxidants used pose a short-term hazard; precautions must be taken to mitigate this threat to Site workers and proper storage and handling would be necessary.
Reduction of Toxicity, Mobility, or Volume	Saturated soil source removal action has significantly addressed the toxicity, mobility and volume of source contaminants in the area of the former waste storage tanks.	Saturated soil source removal action has significantly addressed the toxicity, mobility and volume of source contaminants in the area of the former waste storage tanks. Would directly address remaining sources and a large area of the plumes downgradient of the source areas and thereby would be effective in reducing the toxicity, mobility and volume of contaminants.	Saturated soil source removal action has significantly addressed the toxicity, mobility and volume of source contaminants in the area of the former waste storage tanks. Would directly address remaining sources and higher concentration contamination areas of the plumes downgradient of the source areas and thereby would be effective in reducing the toxicity, mobility and volume of contaminants.	Saturated soil source removal action has significantly addressed the toxicity, mobility and volume of source contaminants in the area of the former waste storage tanks. Would directly addresses remaining source and a large area of the plumes downgradient of the source areas and thereby would be effective in reducing the toxicity, mobility and volume of contaminants. Limited additional reduction in toxicity, mobility, and volume with pump and treat, given the low concentrations of VOCs and the limited nature of the far downgradient contamination.	Saturated soil source removal action has significantly addressed the toxicity, mobility and volume of source contaminants in the area of the former waste storage tanks. Would directly addresses remaining source and a large area of the plumes downgradient of the source areas and thereby would be effective in reducing the toxicity, mobility and volume of contaminants. Limited additional reduction in toxicity, mobility, and volume with pump and treat, given the low concentrations of VOCs and the limited nature of the far downgradient contamination.	Saturated soil source removal action has significantly addressed the toxicity, mobility and volume of source contaminants in the area of the former waste storage tanks. Would directly addresses remaining source and a large area of the plumes downgradient of the source areas and thereby would be effective in reducing the toxicity, mobility and volume of contaminants. Limited additional reduction in toxicity, mobility, and volume with ISCO given the low concentrations of VOCs and the limited nature of the far downgradient contamination.	Saturated soil source removal action has significantly addressed the toxicity, mobility and volume of source contaminants in the area of the former waste storage tanks. Would directly addresses remaining source and a large area of the plumes downgradient of the source areas and thereby would be effective in reducing the toxicity, mobility and volume of contaminants. Limited additional reduction in toxicity, mobility, and volume with ISCO given the low concentrations of VOCs and the limited nature of the far downgradient contamination.
Long-term Effectiveness and Permanence	Substantial source mass in the vicinity of the former waste storage tanks has been removed and will no longer contribute as a source to groundwater contamination. Contamination remaining in other areas will remain a source for the foreseeable future.	Substantial source mass in the vicinity of the former waste storage tanks has been removed and will no longer contribute as a source to groundwater contamination. Would permanently treat remaining sources and large area of the plumes downgradient of the source areas. Treatment of the source areas and downgradient groundwater would expedite the clean-up of downgradient groundwater by MNA.	Substantial source mass in the vicinity of the former waste storage tanks has been removed and will no longer contribute as a source to groundwater contamination. Would permanently treat remaining sources and large area of the plumes downgradient of the source areas. Treatment of the source areas and downgradient groundwater would expedite the clean-up of downgradient groundwater by MNA.	Substantial source mass in the vicinity of the former waste storage tanks has been removed and will no longer contribute as a source to groundwater contamination. Would permanently treat remaining sources and a large area of the plumes downgradient of the source areas. Would treat far downgradient "hot spot", additional effectiveness would be minimal due to low concentrations of VOCs in localized areas. Effectiveness of pump and treat would be dependent on accurate delineation of "hot-spots".	Substantial source mass in the vicinity of the former waste storage tanks has been removed and will no longer contribute as a source to groundwater contamination. Would permanently treat remaining sources and a large area of the plumes downgradient of the source areas. Would treat far downgradient "hot spot", additional effectiveness would be minimal due to low concentrations of VOCs in localized areas .Effectiveness of pump and treat would be dependent on accurate delineation of "hot-spots".	Substantial source mass in the vicinity of the former waste storage tanks has been removed and will no longer contribute as a source to groundwater contamination. Would permanently treat remaining sources and a large area of the plumes downgradient of the source areas. Would treat far downgradient "hot spot", additional effectiveness would be minimal due to low concentrations of VOCs in localized areas. Effectiveness of ISCO would be dependent on accurate delineation of "hot-spots".	Substantial source mass in the vicinity of the former waste storage tanks has been removed and will no longer contribute as a source to groundwater contamination. Would permanently treat remaining sources and a large area of the plumes downgradient of the source areas. Would treat far downgradient "hot spot", additional effectiveness would be minimal due to low concentrations of VOCs in localized areas. Effectiveness of ISCO would be dependent on accurate delineation of "hot-spots".

Table 6-1
Summary of NCP Evaluation of Remedial Alternatives
Lightman Drum Feasibility Study
Winslow Township, NJ

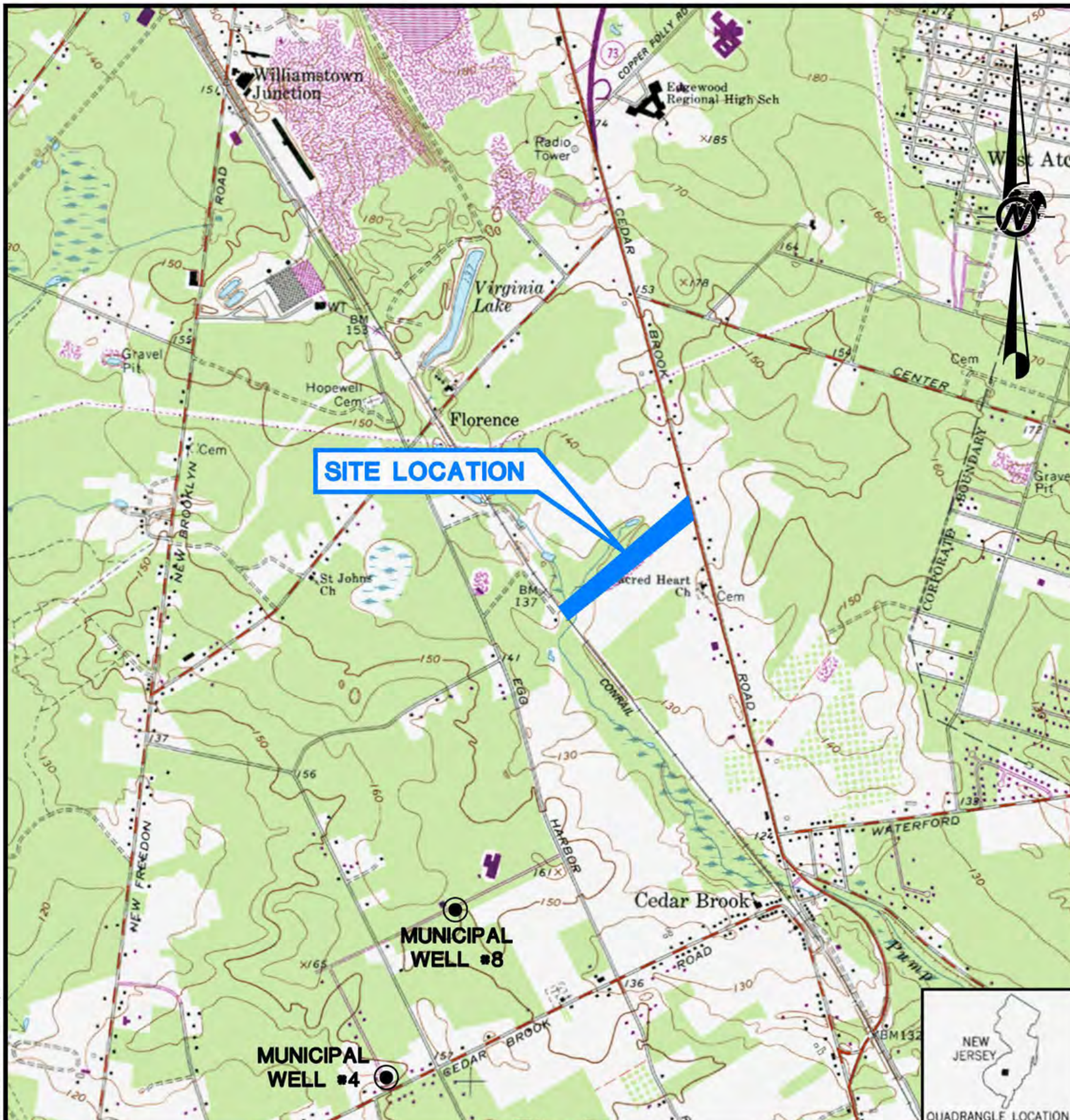
NCP Criteria	**Alternative**						
	Alternative 1	Alternative 2	Alternative 3	Alternative 4A	Alternative 4B	Alternative 5A	Alternative 5B
	No Further Action	AS/SVE + IC + MNA	ISCO + IC + MNA	Alternative 2 + Downgradient P&T	Alternative 3 + Downgradient P&T	Alternative 2 + Downgradient ISCO	Alternative 3 + Downgradient ISCO
Implementability	This alternative is readily implementable	Readily implementable using standard equipment, services, and materials. AS/SVE would be directly applicable to the contaminants and subsurface conditions at the site. Would require access agreement with one adjacent property	Readily implementable using standard equipment and services but would require additional precautions due to the high volume of oxidants that would be necessary to treat the VOC mass. Would require access agreement with one adjacent property	Readily implementable using standard equipment, services and materials. AS/SVE is directly applicable to the contaminants and subsurface conditions at the site. Would require extensive construction of pipelines, wells and treatment systems on multiple private properties that would require access and will be a long term disruption to the properties. Significant access limitations due to railroad tracks and wetlands and residential development west of the railroad tracks.	Readily implementable using standard equipment and services but would require additional precautions due to the high volume of oxidants that would be necessary to treat the VOC mass. Would require extensive construction of pipelines, wells and treatment systems on multiple private properties that would require access and would be a long term disruption to the properties. Significant access limitations due to railroad tracks and wetlands and residential development west of the railroad tracks.	Readily implementable using standard equipment and services. ISCO would require additional precautions due to the high volume of oxidants that would be necessary to treat the VOC mass. Would require access agreements for multiple private properties. Significant access limitations due to railroad tracks and wetlands and residential development west of the railroad tracks.	Readily implementable using standard equipment and services but would require additional precautions due to the high volume of oxidants that would be necessary to treat the VOC mass. Would require access agreements for multiple private properties. Significant access limitations due to railroad tracks and wetlands and residential development west of the railroad tracks.
Cost	None	AS/SVE: $5,450,000 MNA: $1,880,000 **Total:** $7,330,000 (NPW)	ISCO: $8,150,000 MNA: $1,880,000 **Total:** $10,030,000 (NPW)	AS/SVE: $5,450,000 Downgradient P&T: $2,810,000 MNA: $1,880,000 **Total:** $10,140,000 (NPW)	ISCO: $8,150,000 Downgradient P&T: $2,810,000 MNA: $1,880,000 **Total:** $12,840,000 (NPW)	AS/SVE: $5,450,000 Downgradient ISCO: $4,190,000 MNA: $1,880,000 **Total:** $11,520,000 (NPW)	ISCO: $8,150,000 Downgradient ISCO: $4,190,000 MNA: $1,880,000 **Total:** $14,220,000 (NPW)

Notes:
AS/SVE = Air Sparge / Soil Vapor Extraction
SC = Soil Source Control
IC = Institutional Controls
MNA = Monitored Natural Attenuation
ISCO - In-Situ Chemical Oxidation
NPW - Net Present Worth

Table 7-1
Comparative Summary of Remedial Alternatives
Lightman Drum Feasibility Study
Winslow Township, NJ

NCP Criteria	Alternative						
	Alternative 1	Alternative 2	Alternative 3	Alternative 4A	Alternative 4B	Alternative 5A	Alternative 5B
	No Further Action	AS/SVE + IC + MNA	ISCO+ IC + MNA	Alternative 2 + Downgradient P&T	Alternative 3 + Downgradient P&T	Alternative 2 + Downgradient ISCO	Alternative 3 + Downgradient ISCO
Overall Protection of Human Health and the Environment	Yes (Current use)	Yes	Yes	Yes	Yes	Yes	Yes
Compliance with ARARs	No	Yes	Yes	Yes	Yes	Yes	Yes
Short-term Effectiveness	Moderate	High	Moderate	High	Moderate	Moderate	Moderate
Reduction of Toxicity, Mobility, or Volume	Low	High	High	High	High	High	High
Long-term Effectiveness and Permanence	Low	High	High	High	High	High	High
Implementability	High	High	High	Low	Low	Moderate	Moderate
Cost (NPW)	$0	$7,330,000	$10,030,000	$10,140,000	$12,840,000	$11,520,000	$14,220,000

Notes:
AS/SVE = Air Sparge / Soil Vapor Extraction
SC = Soil Source Control
IC = Institutional Controls
MNA = Monitored Natural Attenuation
ISCO - In-Situ Chemical Oxidation
NPW - Net Present Worth



REFERENCES

1.) MAP TAKEN FROM U.S.G.S. 7.5 MINUTE QUADRANGLE OF WILLIAMSTOWN, NEW JERSEY, DATED 1981.

2.) NEAREST PUBLIC WELL LOCATIONS ARE BASED ON NJDEP IMAP COORDINATES.

2000 0 2000
SCALE FEET

Golder Associates
Philadelphia USA

SCALE	AS SHOWN	TITLE	SITE LOCATION MAP
DATE	09/29/08		
DESIGN	HAL		
CADD	GLS		
FILE No. 0136054S001	CHECK	RJI	
PROJECT No. 013-6054 REV. 1	REVIEW	PSF	LIGHTMAN DRUM SITE — FIGURE 2-1

Drawing file: 0136054S001 Rev 1 – 2-1.dwg Feb 17, 2009 – 12:15pm

LEGEND

WOODED AREA

UNWOODED AREA

TREELINE

PROPERTY LINE

MW-4 GROUNDWATER MONITORING WELL LOCATION

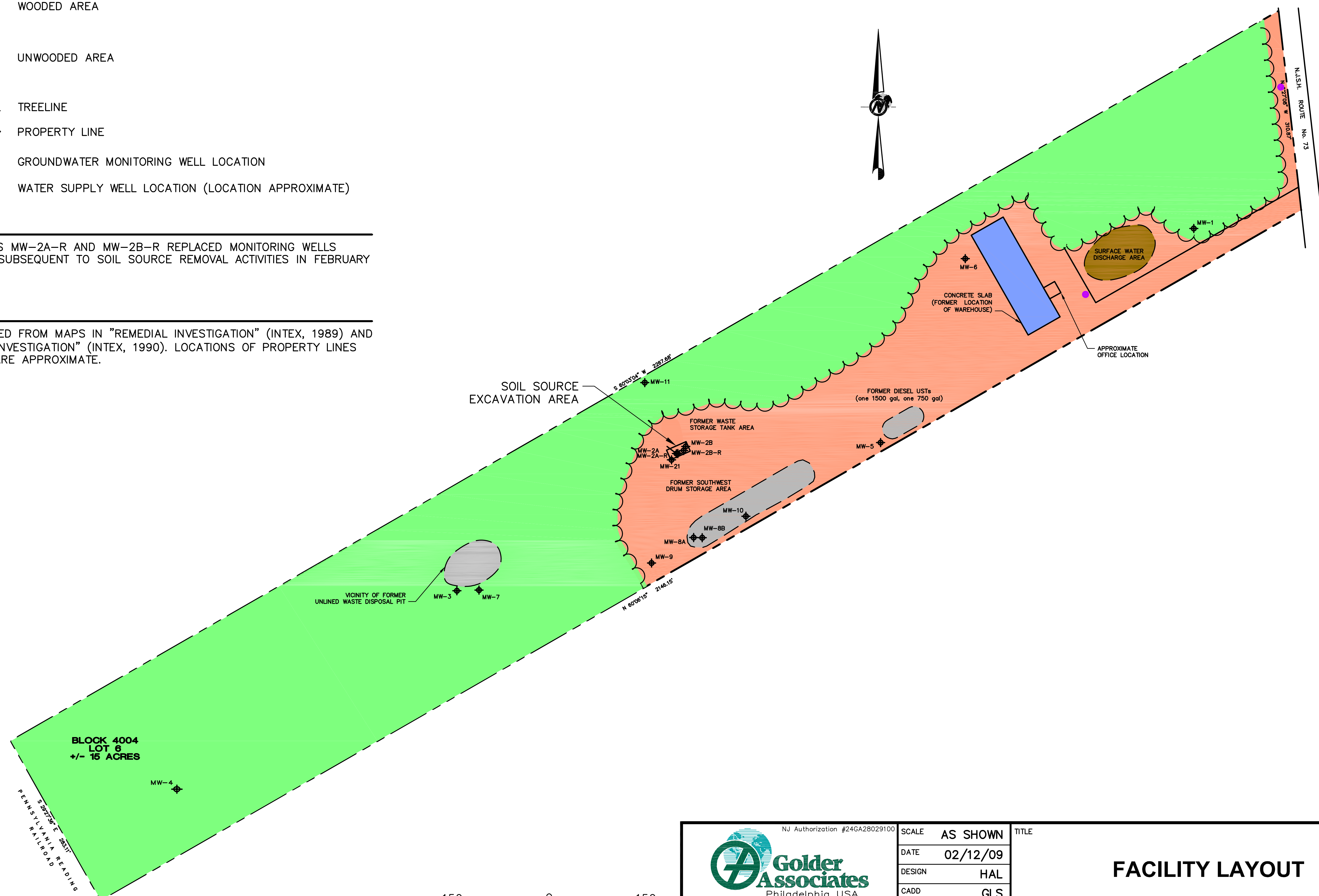
WATER SUPPLY WELL LOCATION (LOCATION APPROXIMATE)

NOTE

1.) MONITORING WELLS MW-2A-R AND MW-2B-R REPLACED MONITORING WELLS MW-2A AND MW-2B SUBSEQUENT TO SOIL SOURCE REMOVAL ACTIVITIES IN FEBRUARY 2008.

REFERENCE

1.) BASE MAP DIGITIZED FROM MAPS IN "REMEDIAL INVESTIGATION" (INTEX, 1989) AND "PHASE II REMEDIAL INVESTIGATION" (INTEX, 1990). LOCATIONS OF PROPERTY LINES AND ALL FEATURES ARE APPROXIMATE.

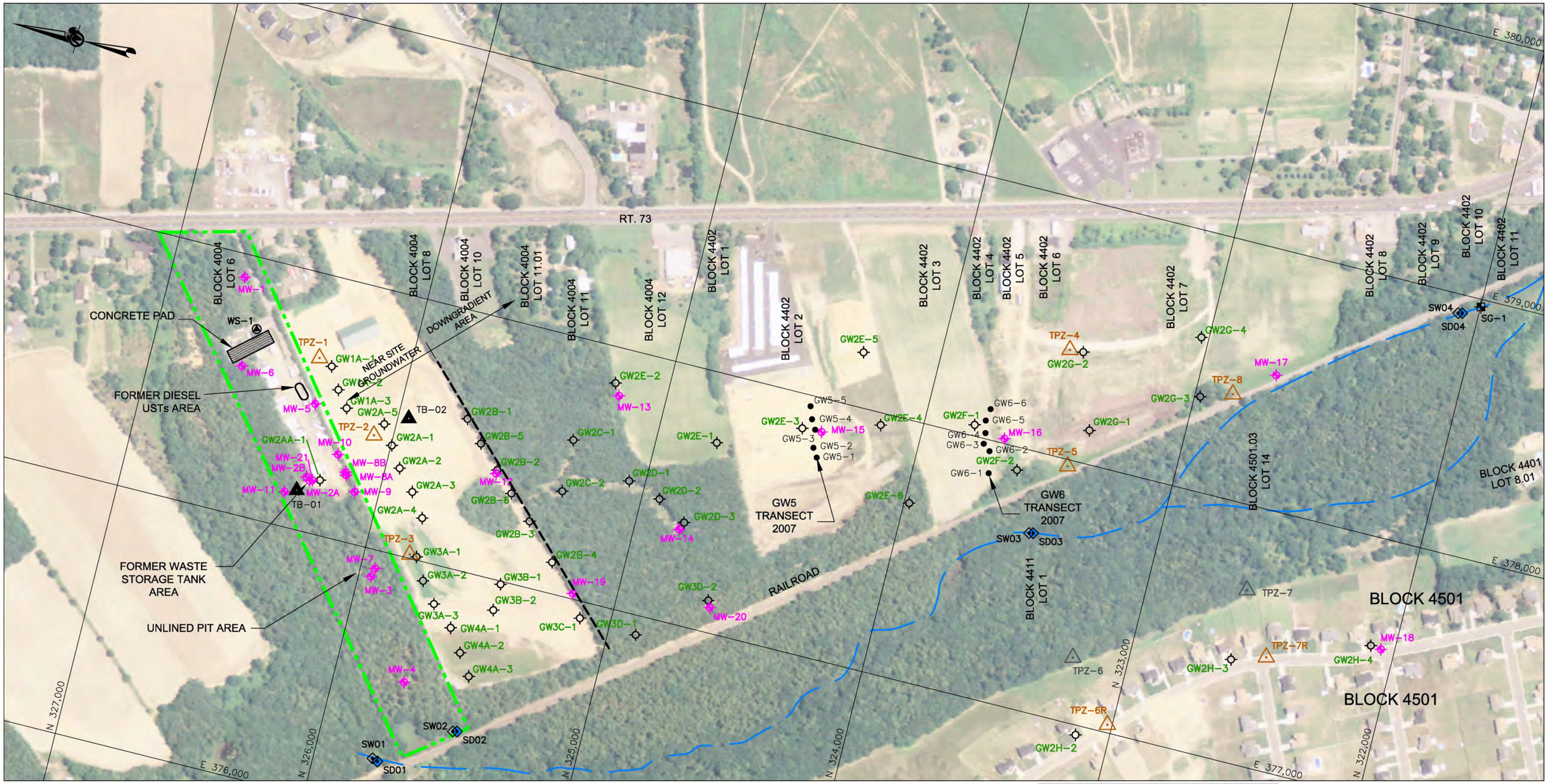


150 0 150

SCALE FEET

NJ Authorization #24GA28029100	SCALE AS SHOWN	TITLE	
Golder Associates Philadelphia USA	DATE 02/12/09	FACILITY LAYOUT	
	DESIGN HAL		
	CADD GLS		
FILE No. 0136054S002	CHECK HAL		
PROJECT No. 013-6054 REV. 1	REVIEW PSF	LIGHTMAN DRUM SITE	FIGURE 2-2

Drawing file: 0136054S002 Rev 1 - 2-2.dwg Feb 17, 2009 - 12:16pm



WELL I.D.	Ground Surface	Top of Screen	Bottom of Screen
	(ft MSL)	(ft MSL)	(ft MSL)
MW-1	136.23	122.23	112.23
MW-2A	134.85	123.85	113.85
MW-3	131.51	122.51	112.51
MW-4	125.22	97.22	77.22
MW-5	136.12	123.12	113.12
MW-6	136.45	122.45	112.45
MW-2B	134.51	104.51	94.51
MW-7	131.75	128.75	115.75
MW-8A	135.34	126.34	119.34
MW-8B	135.28	107.28	119.28
MW-9	134.31	125.31	118.31
MW-10	135.67	126.67	116.67
MW-11	135.67	120.67	110.67
MW-12	132.49	97.49	87.49
MW-13	135.06	90.06	80.06
MW-14	131.09	86.09	76.09
MW-15	128.92	78.92	68.92
MW-16	123.30	68.30	58.30
MW-17	118.81	63.81	53.81
MW-18	135.50	52.50	42.50
MW-19	131.04	96.04	86.04
MW-20	128.40	83.40	73.40
MW-21	135.37	124.37	114.37
TPZ-1	134.73	129.73	109.73
TPZ-2	135.73	130.73	110.73
TPZ-3	132.41	127.41	107.41
TPZ-4	126.60	111.60	101.60
TPZ-5	120.92	105.92	95.92
TPZ-6	132.81	117.81	107.81
TPZ-7	130.55	115.55	105.55
TPZ-8	120.59	110.59	100.59
TPZ-6R	135.70	117.70	107.70
TPZ-7R	136.11	118.11	108.11

LEGEND

- APPROXIMATE PROPERTY LINE – LIGHTMAN DRUM SITE
- WS-1 — ONSITE WATER SUPPLY WELL (LOCATION APPROXIMATE)
- MW-11 — MONITORING WELL
- PIEZOMETER
- DECOMMISSIONED PIEZOMETER
- GW3B-1 — GEOPROBE AQUIFER PROFILE BORINGS (LOCATION APPROXIMATE)
- SG-1 — STAFF GAUGE
- SW01 — SURFACE WATER SAMPLE (LOCATION APPROXIMATE)
- SD01 — SEDIMENT SAMPLE (LOCATION APPROXIMATE)
- TEST BORING (LOCATION APPROXIMATE)
- PUMP BRANCH CREEK (SEE NOTE 1)

NOTE

1.) APPROXIMATE CREEK LOCATION ESTIMATED FROM 1995 AERIAL PHOTO, EPHEMERAL IN VICINITY OF LIGHTMAN PROPERTY.

REFERENCES

1.) AERIAL PHOTOGRAPH TAKEN FROM USDA GEOSPATIAL DATA GATEWAY, DATED 2006.

2.) MONITORING WELLS, STAFF GAUGE AND PIEZOMETERS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

3.) GEOPROBE PROFILE BORINGS AND SURFACE WATER/SEDIMENT SAMPLING LOCATIONS WERE LOCATED IN THE FIELD BY GOLDER ASSOCIATES, INC. PERSONNEL USING A HANDHELD GPS UNIT AND ARE APPROXIMATE ONLY.

300 0 300
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
1	02/13/09	HAL	UPDATE PER REMEDIAL INVESTIGATION FIGURES	AM	HAL	PSF

PROJECT

LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

TITLE

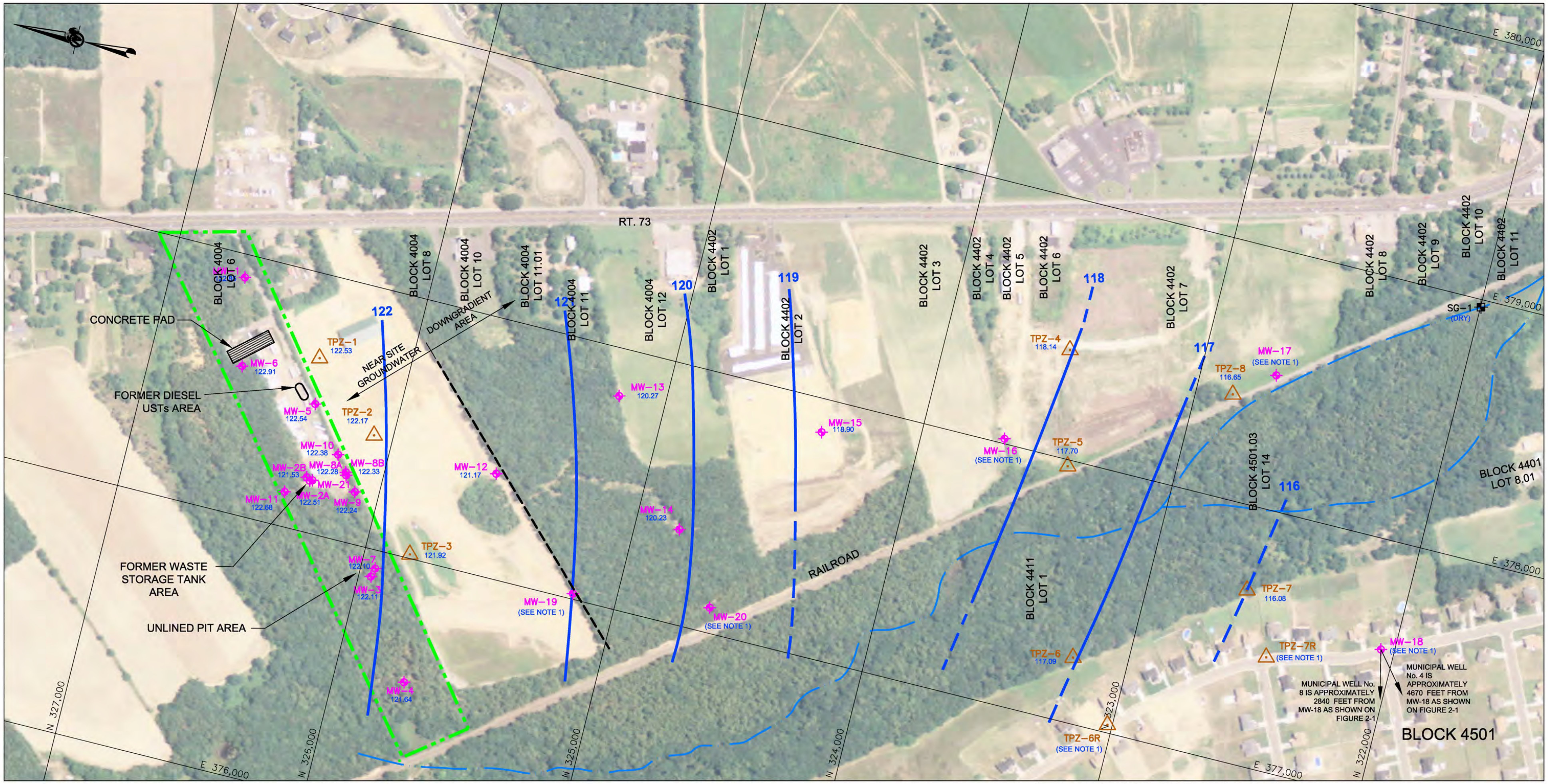
GROUNDWATER, SURFACE WATER & SEDIMENT SAMPLING LOCATIONS

Golder Associates
Philadelphia USA

PROJECT No.		013-6054	FILE No.	0136054S003
DESIGN	HAL	12/20/07	SCALE AS SHOWN	REV. 1
CADD	GLS	12/20/07		
CHECK	HAL	12/20/07		
REVIEW	PSF	12/20/07		

FIGURE 2-3

Drawing file: 0136054S003 Rev 1 – 2-3.dwg Feb 17, 2009 – 12:17pm



WELL I.D.	Ground Surface	Top of Screen	Bottom of Screen
	(ft MSL)	(ft MSL)	(ft MSL)
MW–1	136.23	122.23	112.23
MW–2A	134.85	123.85	113.85
MW–3	131.51	122.51	112.51
MW–4	125.22	97.22	77.22
MW–5	136.12	123.12	113.12
MW–6	136.45	122.45	112.45
MW–2B	134.51	104.51	94.51
MW–7	131.75	128.75	115.75
MW–8A	135.34	126.34	119.34
MW–8B	135.28	107.28	119.28
MW–9	134.31	125.31	118.31
MW–10	135.67	126.67	116.67
MW–11	135.67	120.67	110.67
MW–12	132.49	97.49	87.49
MW–13	135.06	90.06	80.06
MW–14	131.09	86.09	76.09
MW–15	128.92	78.92	68.92
MW–16	123.30	68.30	58.30
MW–17	118.81	63.81	53.81
MW–18	135.50	52.50	42.50
MW–19	131.04	96.04	86.04
MW–20	128.40	83.40	73.40
MW–21	135.37	124.37	114.37
TPZ–1	134.73	129.73	109.73
TPZ–2	135.73	130.73	110.73
TPZ–3	132.41	127.41	107.41
TPZ–4	126.60	111.60	101.60
TPZ–5	120.92	105.92	95.92
TPZ–6	132.81	117.81	107.81
TPZ–7	130.55	115.55	105.55
TPZ–8	120.59	110.59	100.59
TPZ–6R	135.70	117.70	107.70
TPZ–7R	136.11	118.11	108.11

LEGEND

- APPROXIMATE PROPERTY LINE – LIGHTMAN DRUM SITE
- GROUNDWATER CONTOUR – DASHED WHERE INFERRED
- MONITORING WELL
- PIEZOMETER
- 122.38 GROUNDWATER ELEVATION (FEET) BASED ON WATER LEVEL MEASUREMENTS COLLECTED NOVEMBER 6, 2003
- SG–1 STAFF GAUGE
- PUMP BRANCH CREEK (SEE NOTE 2)

NOTES

1.) TPZ–6R AND TPZ–7R REPLACED TPZ–6 AND TPZ–7 IN JANUARY 2005. MW–16 THROUGH MW–21 WERE INSTALLED IN JANUARY 2005. THEREFORE NO WATER LEVEL MEASUREMENTS TAKEN IN NOVEMBER, 2003.

2.) APPROXIMATE CREEK LOCATION ESTIMATED FROM 1995 AERIAL PHOTO, EPHEMERAL IN VICINITY OF LIGHTMAN PROPERTY.

3.) MW–2B WAS NOT USED FOR CONTOURING BECAUSE OF AN ANOMALOUSLY LOWER GROUNDWATER ELEVATION COMPARED TO OTHER MONITORING WELLS IN THE VICINITY.

REFERENCES

1.) AERIAL PHOTOGRAPH TAKEN FROM USDA GEOSPATIAL DATA GATEWAY, DATED 2006.

2.) MONITORING WELLS, STAFF GAUGE AND PIEZOMETERS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

300 0 300
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
1	02/13/09	HAL	UPDATE PER REMEDIAL INVESTIGATION FIGURES	AM	HAL	PSF

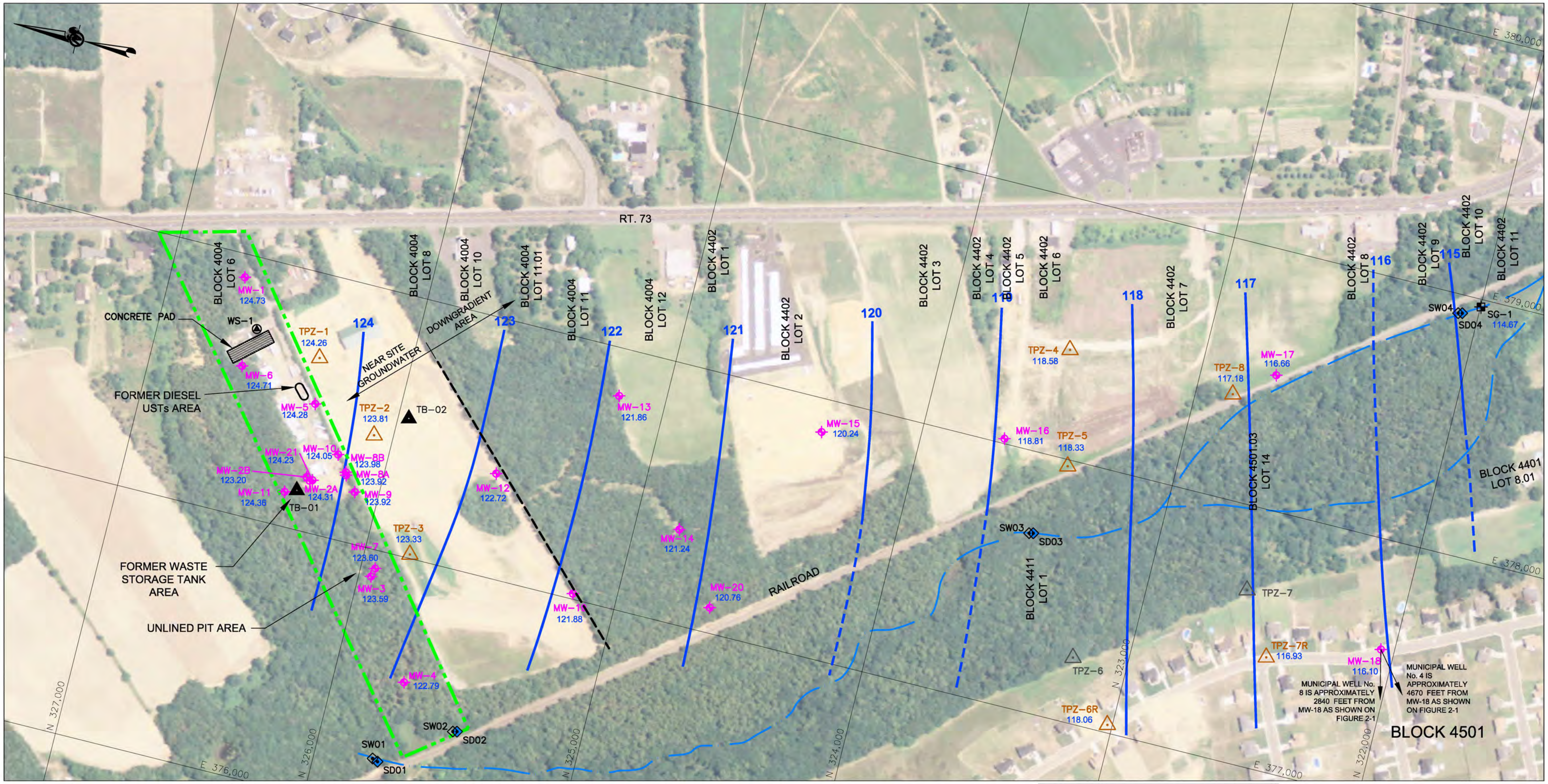
PROJECT
LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

TITLE
INTERPRETED GROUNDWATER CONTOUR MAP - NOVEMBER 6, 2003

Golder Associates
Philadelphia USA

PROJECT No.		013–6054	FILE No.	0136054S004
DESIGN	HAL	12/20/07	SCALE AS SHOWN	REV. 1
CADD	GLS	12/20/07		
CHECK	HAL	12/20/07		
REVIEW	PSF	12/20/07		

FIGURE 2-4



LEGEND

- APPROXIMATE PROPERTY LINE – LIGHTMAN DRUM SITE
- GROUNDWATER CONTOUR – DASHED WHERE INFERRED
- WS-1 ONSITE WATER SUPPLY WELL (LOCATION APPROXIMATE)
- MW-11 MONITORING WELL
- PIEZOMETER
- DECOMMISSIONED PIEZOMETER
- SG-1 STAFF GAUGE
- SW01 SURFACE WATER SAMPLE (LOCATION APPROXIMATE)
- SD01 SEDIMENT SAMPLE (LOCATION APPROXIMATE)
- TEST BORING (LOCATION APPROXIMATE)
- 122.38 GROUNDWATER ELEVATION (FEET) BASED ON WATER LEVEL MEASUREMENTS COLLECTED MAY 3, 2005
- PUMP BRANCH CREEK (SEE NOTE 2)

NOTES

1.) MW-2B WAS NOT USED FOR CONTOURING BECAUSE OF AN ANOMALOUSLY LOWER GROUNDWATER ELEVATION COMPARED TO OTHER MONITORING WELLS IN THE VICINITY.

2.) APPROXIMATE CREEK LOCATION ESTIMATED FROM 1995 AERIAL PHOTO, EPHEMERAL IN VICINITY OF LIGHTMAN PROPERTY.

REFERENCES

1.) AERIAL PHOTOGRAPH TAKEN FROM USDA GEOSPATIAL DATA GATEWAY, DATED 2006.

2.) MONITORING WELLS, STAFF GAUGE AND PIEZOMETERS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

WELL I.D.	Ground Surface	Top of Screen	Bottom of Screen
	(ft MSL)	(ft MSL)	(ft MSL)
MW-1	136.23	122.23	112.23
MW-2A	134.85	123.85	113.85
MW-3	131.51	122.51	112.51
MW-4	125.22	97.22	77.22
MW-5	136.12	123.12	113.12
MW-6	136.45	122.45	112.45
MW-2B	134.51	104.51	94.51
MW-7	131.75	128.75	115.75
MW-8A	135.34	126.34	119.34
MW-8B	135.28	107.28	119.28
MW-9	134.31	125.31	118.31
MW-10	135.67	126.67	116.67
MW-11	135.67	120.67	110.67
MW-12	132.49	97.49	87.49
MW-13	135.06	90.06	80.06
MW-14	131.09	86.09	76.09
MW-15	128.92	78.92	68.92
MW-16	123.30	68.30	58.30
MW-17	118.81	63.81	53.81
MW-18	135.50	52.50	42.50
MW-19	131.04	96.04	86.04
MW-20	128.40	83.40	73.40
MW-21	135.37	124.37	114.37
TPZ-1	134.73	129.73	109.73
TPZ-2	135.73	130.73	110.73
TPZ-3	132.41	127.41	107.41
TPZ-4	126.60	111.60	101.60
TPZ-5	120.92	105.92	95.92
TPZ-6	132.81	117.81	107.81
TPZ-7	130.55	115.55	105.55
TPZ-8	120.59	110.59	100.59
TPZ-6R	135.70	117.70	107.70
TPZ-7R	136.11	118.11	108.11

300 0 300
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
1	02/13/09	HAL	UPDATE PER REMEDIAL INVESTIGATION FIGURES	AM	HAL	PSF

PROJECT

LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

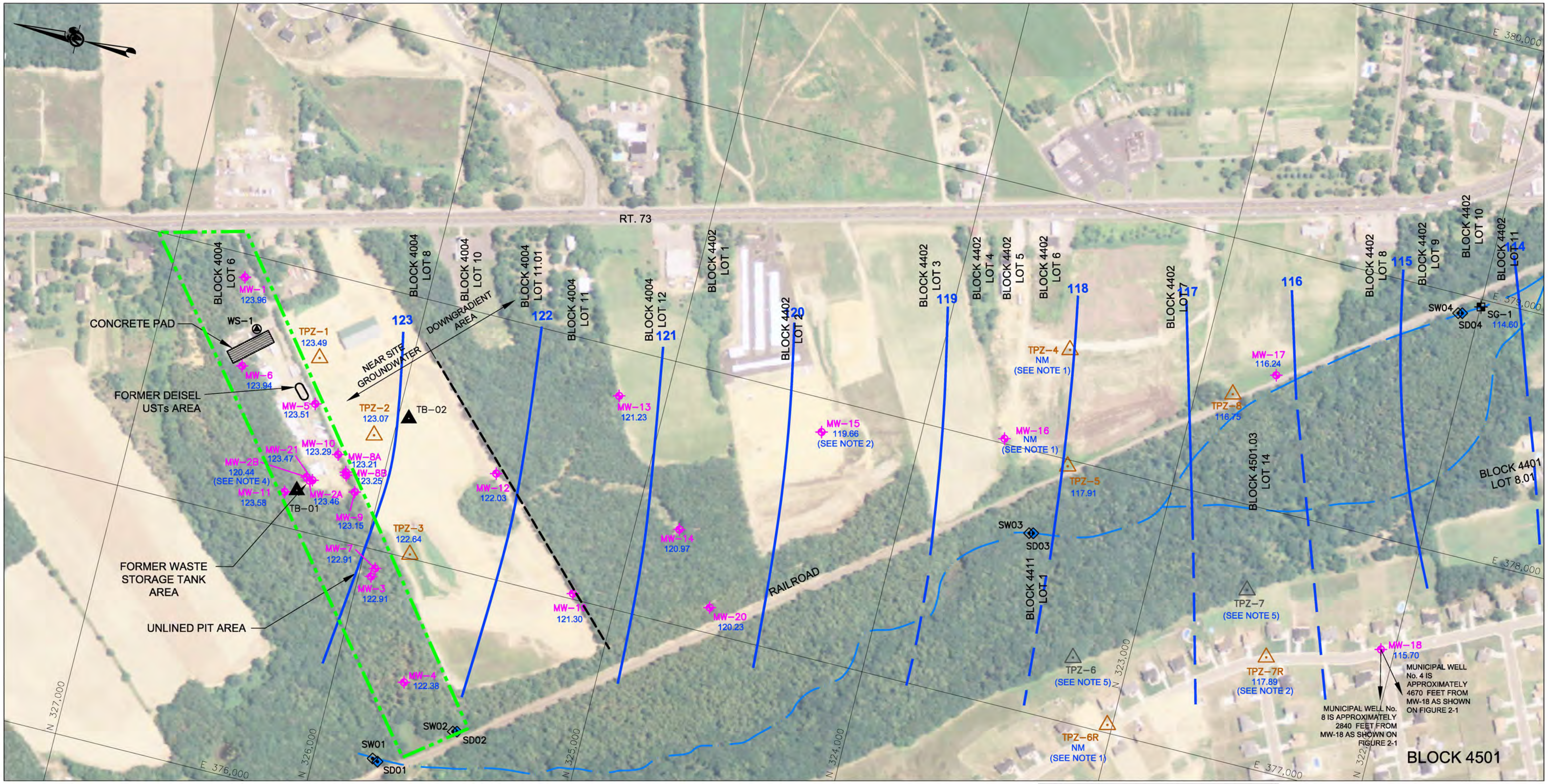
TITLE

INTERPRETED GROUNDWATER CONTOUR MAP - MAY 3, 2005

Golder Associates
Philadelphia USA

PROJECT No.		013-6054	FILE No. 0136054S005
DESIGN	CM	12/20/07	SCALE AS SHOWN / REV. 1
CADD	GLS	12/20/07	
CHECK	HAL	12/20/07	**FIGURE 2-5**
REVIEW	PSF	12/20/07	

Drawing file: 0136054S005 Rev 1 – 2-5.dwg Feb 17, 2009 – 12:19pm



LEGEND

- APPROXIMATE PROPERTY LINE – LIGHTMAN DRUM SITE
- GROUNDWATER CONTOUR – DASHED WHERE INFERRED
- WS-1 — ONSITE WATER SUPPLY WELL (LOCATION APPROXIMATE)
- MW-11 — MONITORING WELL
- PIEZOMETER
- DECOMMISSIONED PIEZOMETER
- SG-1 — STAFF GAUGE
- SW01 — SURFACE WATER SAMPLE (LOCATION APPROXIMATE)
- SD01 — SEDIMENT SAMPLE (LOCATION APPROXIMATE)
- TEST BORING (LOCATION APPROXIMATE)
- 122.38 — GROUNDWATER ELEVATION (FEET) BASED ON WATER LEVEL MEASUREMENTS COLLECTED MARCH 13, 2006
- PUMP BRANCH CREEK (SEE NOTE 3)

NOTES

1.) MW-16 AND TPZ-4 WERE DAMAGED PRIOR TO SYNOPTIC WATER LEVEL MEASUREMENTS, AND WATER LEVEL WAS NOT TAKEN. TPZ-6R PIEZOMETER HAD BEEN COVERED WITH SOD AND COULDN'T BE LOCATED DURING SYNOPTIC WATER LEVEL MEASUREMENTS, AND WATER LEVEL WAS NOT TAKEN.

2.) TPZ-7R AND MW-15 WAS NOT USED FOR CONTOURING BECAUSE OF AN ANOMALOUSLY HIGH READING.

3.) APPROXIMATE CREEK LOCATION ESTIMATED FROM 1995 AERIAL PHOTO, EPHEMERAL IN VICINITY OF LIGHTMAN PROPERTY.

4.) MW-2B WAS NOT USED FOR CONTOURING BECAUSE OF AN ANOMALOUSLY LOWER GROUNDWATER ELEVATION COMPARED TO OTHER MONITORING WELLS IN THE VICINITY.

5.) TPZ-6 AND TPZ-7 WERE REPLACED BY TPZ-6R AND TPZ-7R, RESPECTIVELY, IN JANUARY 2005.

REFERENCES

1.) AERIAL PHOTOGRAPH TAKEN FROM USDA GEOSPATIAL DATA GATEWAY, DATED 2006.

2.) MONITORING WELLS, STAFF GAUGE AND PIEZOMETERS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

WELL I.D.	Ground Surface (ft MSL)	Top of Screen (ft MSL)	Bottom of Screen (ft MSL)
MW-1	136.23	122.23	112.23
MW-2A	134.85	123.85	113.85
MW-3	131.51	122.51	112.51
MW-4	125.22	97.22	77.22
MW-5	136.12	123.12	113.12
MW-6	136.45	122.45	112.45
MW-2B	134.51	104.51	94.51
MW-7	131.75	128.75	115.75
MW-8A	135.34	126.34	119.34
MW-8B	135.28	107.28	119.28
MW-9	134.31	125.31	118.31
MW-10	135.67	126.67	116.67
MW-11	135.67	120.67	110.67
MW-12	132.49	97.49	87.49
MW-13	135.06	90.06	80.06
MW-14	131.09	86.09	76.09
MW-15	128.92	78.92	68.92
MW-16	123.30	68.30	58.30
MW-17	118.81	63.81	53.81
MW-18	135.50	52.50	42.50
MW-19	131.04	96.04	86.04
MW-20	128.40	83.40	73.40
MW-21	135.37	124.37	114.37
TPZ-1	134.73	129.73	109.73
TPZ-2	135.73	130.73	110.73
TPZ-3	132.41	127.41	107.41
TPZ-4	126.60	111.60	101.60
TPZ-5	120.92	105.92	95.92
TPZ-6	132.81	117.81	107.81
TPZ-7	130.55	115.55	105.55
TPZ-8	120.59	110.59	100.59
TPZ-6R	135.70	117.70	107.70
TPZ-7R	136.11	118.11	108.11

300 0 300
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
1	02/13/09	HAL	UPDATE PER REMEDIAL INVESTIGATION FIGURES	AM	HAL	PSF

PROJECT

LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

TITLE

INTERPRETED GROUNDWATER CONTOUR MAP - MARCH 13, 2006

Golder Associates
Philadelphia USA

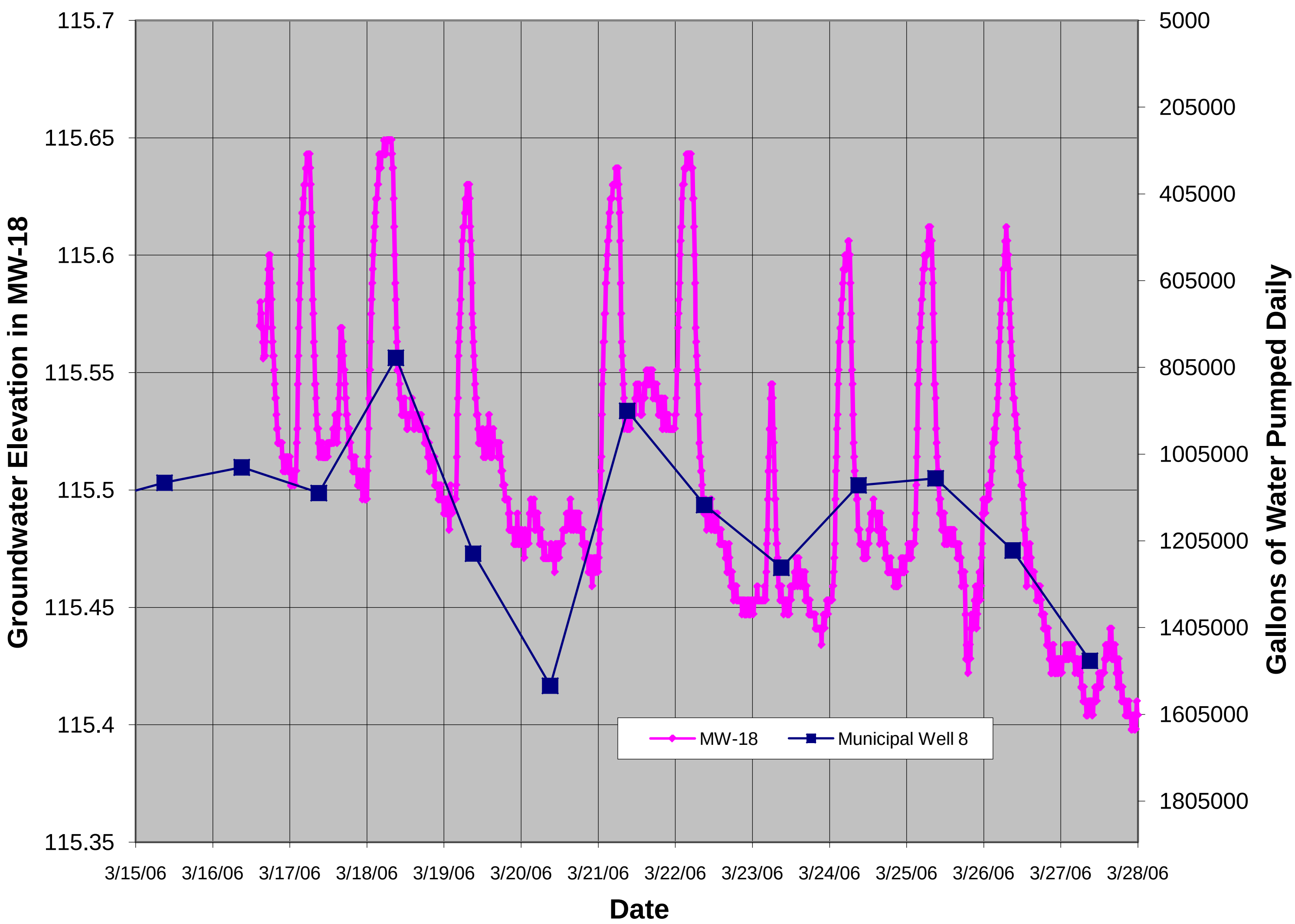
PROJECT No.		013-6054
DESIGN	HAL	12/20/07
CADD	GLS	12/20/07
CHECK	HAL	12/20/07
REVIEW	PSF	12/20/07

FILE No. 0136054S006
SCALE AS SHOWN REV. 1

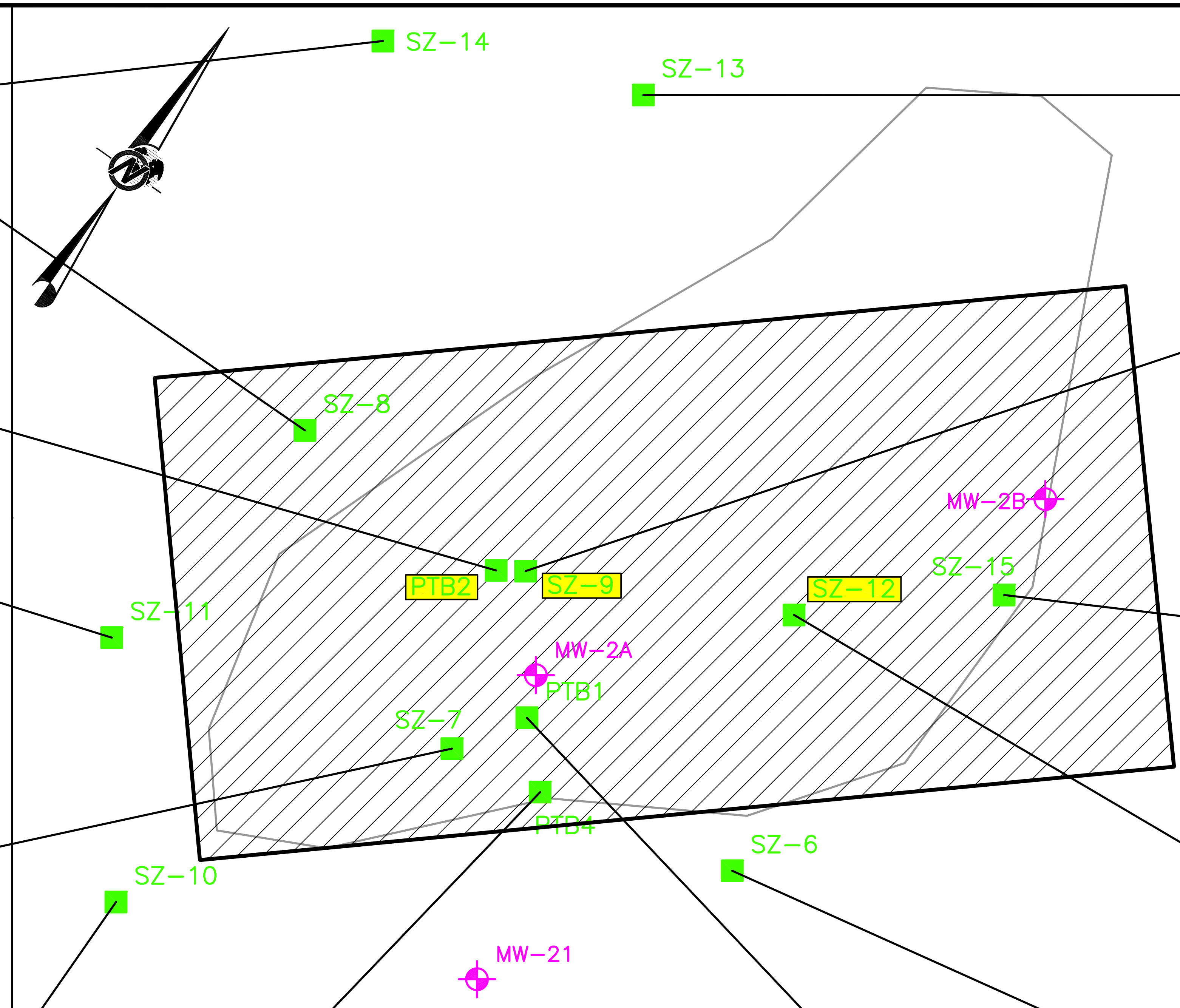
FIGURE 2-6

Drawing file: 0136054S006 Rev 1 – 2-6.dwg Feb 17, 2009 – 12:19pm

Figure 2-7
Water Levels and Pumping Record
Municipal Well 8 and MW-18
Lightman Yard Feasibility Study
Winslow Township, NJ



Location	Depth	Parameter	Result
SZ-14	14'-16'	TOTAL VOCs	0.009
		PCE	0.005
		TCE	0.004
	24'-26'	TOTAL VOCs	ND
	34'-36'	TOTAL VOCs	0.004
SZ-8	14'-16'	TCE	0.190
		TOTAL VOCs	2.71
		BTEX	2.29
	16'-18'	TOTAL VOCs	1.25
		BTEX	1.07
	34'-36'	TOTAL VOCs	ND
PTB2	12'-14'	TOTAL VOCs	705.30
		BTEX	669.00
		PCE	20.00
	14'-16'	TOTAL VOCs	408.10
		BTEX	398.00
SZ-11	14'-16'	PCE	0.007
		TCE	0.003
		TOTAL VOCs	0.010
	20'-22'	PCE	0.004
		TCE	0.002
		TOTAL VOCs	0.006
	34'-36'	TOTAL VOCs	ND
SZ-7	14'-16'	TOTAL VOCs	803.20
		BTEX	783.09
		PCE	17.00
		TCE	0.08
	18'-20'	TOTAL VOCs	1,895.60
		BTEX	1,856.60
		PCE	39.00
	34'-36'	TOTAL VOCs	ND
SZ-10	14'-16'	BTEX	2.40
		TOTAL VOCs	2.40
	18'-20'	BTEX	0.72
		PCE	0.01
		TCE	0.006
		TOTAL VOCs	0.75
	34'-36'	TOTAL VOCs	ND



Location	Depth	Parameter	Result
SZ-13	14'-16'	BTEX	10.90
		PCE	0.28
		TOTAL VOCs	11.18
	16'-18'	BTEX	4.22
		TOTAL VOCs	4.22
	30'-32'	TOTAL VOCs	ND
SZ-9	14'-16'	BTEX	35.00
		PCE	0.93
		TCE	0.22
		TOTAL VOCs	36.15
	16'-18'	BTEX	0.395
		PCE	0.05
		TCE	0.01
		TOTAL VOCs	0.51
	34'-36'	TOTAL VOCs	ND
SZ-15	14'-16'	BTEX	3.34
		PCE	0.24
		TCE	0.87
		TOTAL VOCs	4.52
	18'-20'	BTEX	1.39
		PCE	0.31
		TCE	0.410
		TOTAL VOCs	2.13
	30'-32'	TOTAL VOCs	ND
SZ-12	12'-14'	BTEX	27.10
		PCE	0.85
		TOTAL VOCs	27.95
	14'-16'	BTEX	7.99
		TCE	0.32
		TOTAL VOCs	8.31
	16'-18'	NOT SAMPLED FOR LAB ANALYSIS	
	18'-20'	NOT SAMPLED FOR LAB ANALYSIS	
	30'-32'	TOTAL VOCs	ND
SZ-6	14'-16'	TOTAL VOCs	1.45
		BTEX	1.26
		PCE	0.04
		TCE	0.01
	16'-18'	TOTAL VOCs	0.85
		BTEX	0.51
		PCE	0.03
		TCE	0.003
	30'-32'	TOTAL VOCs	ND

Location	Depth	Parameter	Result
PTB4	14'-16'	TOTAL VOCs	2.94
		BTEX	2.67

Location	Depth	Parameter	Result
PTB1	14'-16'	TOTAL VOCs	2.08
		BTEX	1.90

LEGEND

- SOIL BORING LOCATION
- SURFACE SOIL SAMPLING LOCATION
- SATURATED SOIL BORING LOCATIONS
- EXISTING MONITORING WELL
- BORING LOCATION AND DEPTH WITH A POSITIVE "OIL RED O" RESULT
- EXCEEDS NJDEP IGW SCC
- APPROXIMATE LIMITS OF EXCAVATION

NOTE

1.) SATURATED SOIL BORING LOCATIONS BASED ON MEASUREMENTS TO SURVEYED MONITORING WELLS.

2.) CONCENTRATIONS ARE EXPRESSED IN mg/kg.

5 0 5
SCALE FEET

REFERENCES

1.) BASE MAP TAKEN FROM FILE 2702-01.DWG, TITLED "PLAN OF SURVEY", PROVIDED BY JAMES M. STEWART, INC.

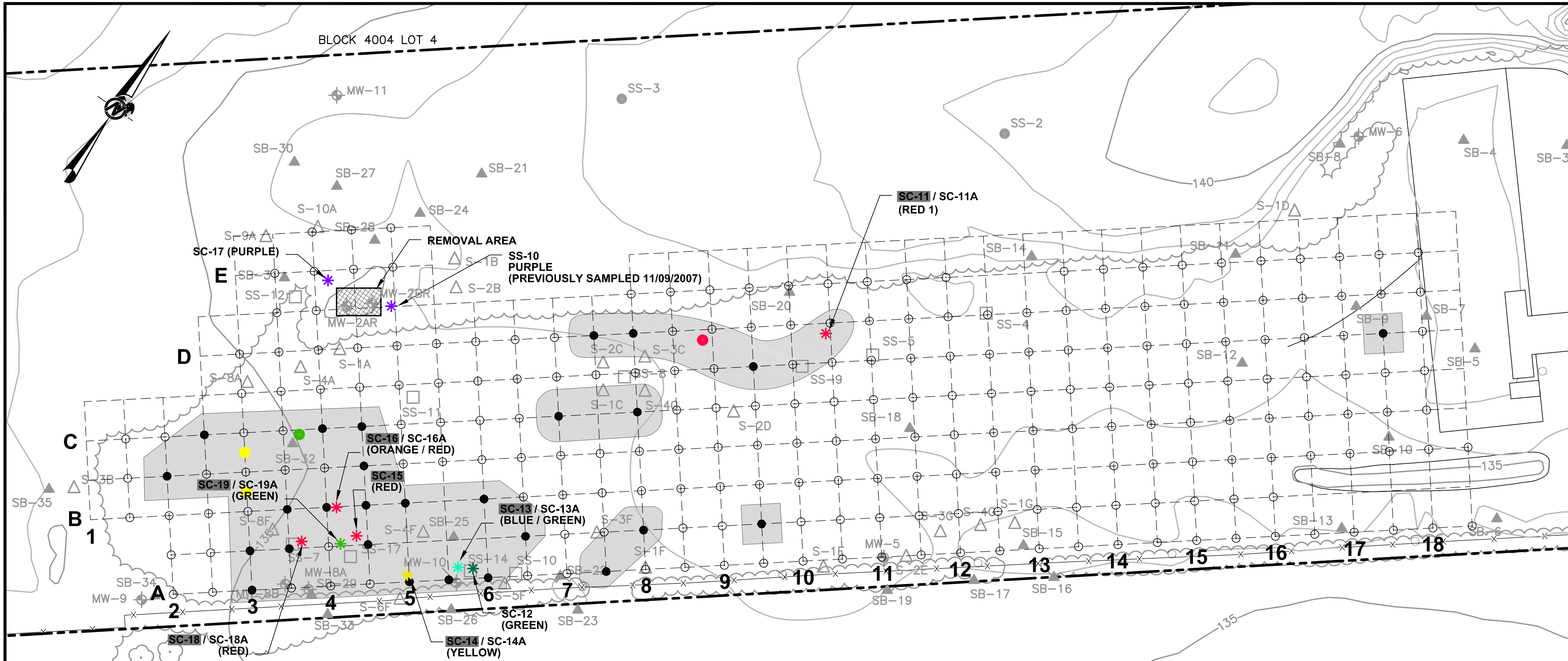
2.) UNSATURATED SOIL BORING AND SOIL SAMPLE LOCATIONS SURVEYED BY JAMES M. STEWART, INC., NOVEMBER 2002.

3.) MONITORING WELLS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

Golder Associates
Philadelphia USA

SCALE	AS SHOWN	TITLE	SATURATED SOURCE AREA SOIL RESULTS
DATE	02/13/09		
DESIGN	HAL		
CADD	AM		
FILE No.	0136054S007	CHECK	HAL
PROJECT No.	013-6054 REV. 2	REVIEW	PSF
			LIGHTMAN DRUM SITE
		FIGURE	2-8

Drawing file: 0136054S007 REV 2 - 2-8.dwg Feb 17, 2009 - 12:20pm



LEGEND

SOIL BORING LOCATION (UNSATURATED SOIL)

SHALLOW SOIL SAMPLING LOCATION (UNSATURATED SOIL)

MONITORING WELL

PHASE II REMEDIAL INVESTIGATION SOIL SAMPLE LOCATION

PHASE I REMEDIAL INVESTIGATION SOIL SAMPLE LOCATION

UN-NATURALLY COLORED SOIL SAMPLE LOCATION (SEE NOTE 5)

UN-NATURALLY COLORED SOIL DELINEATION LOCATION

UN-NATURALLY COLORED SOIL FOUND AT DELINEATION LOCATION

UN-NATURALLY COLORED SOIL FOUND BETWEEN DELINEATION LOCATIONS

HORIZONTAL EXTENT OF UN-NATURALLY COLORED SOIL (SEE NOTE 6)

NOTES

1.) SOIL SAMPLES SC-11 THROUGH SC-19 COLLECTED JANUARY 17, 2008 AND SOIL SAMPLES SC-11A, SC-13A, SC-14A, SC-16A, SC-18A, AND SC-19A COLLECTED MARCH 26, 2008.

2.) UN-NATURALLY COLORED SOIL DELINEATION PERFORMED MARCH 26, 2008 THROUGH MARCH 28, 2008.

3.) COLORED SOIL SAMPLE LOCATIONS SC-11, SC-13, SC-14, SC-16, SC-18, SC-19, AND SELECT DELINEATION LOCATIONS WITH UN-NATURALLY COLORED SOIL WERE SURVEYED APRIL 10, 2008 BY JAMES M. STEWART, INC. SURVEY DATA PROVIDED IN APPENDIX C OF ADDENDUM TO THE REMEDIAL INVESTIGATION REPORT, DATED JUNE 6, 2008.

4.) NON-SURVEYED LOCATIONS ARE APPROXIMATE.

5.) SOIL SAMPLE LOCATIONS WHERE ANALYTES WERE DETECTED ABOVE NEW JERSEY NON-RESIDENTIAL DIRECT CONTACT SOIL CLEANUP CRITERIA AND/OR IMPACT TO GROUNDWATER SOIL CLEANUP CRITERIA (NJSCC) ARE SHADED GRAY.

6.) THE HORIZONTAL EXTENT OF UN-NATURALLY COLORED SOIL SHOWN ON THE FIGURE IS THE INTERPRETED EXTENT OF SOIL WITH DETECTIONS ABOVE NJSCC.

REFERENCE

1.) BASE MAP TAKEN FROM FILE 2702-01.DWG, TITLED "PLAN OF SURVEY", PROVIDED BY JAMES M. STEWART, INC.

50 0 50

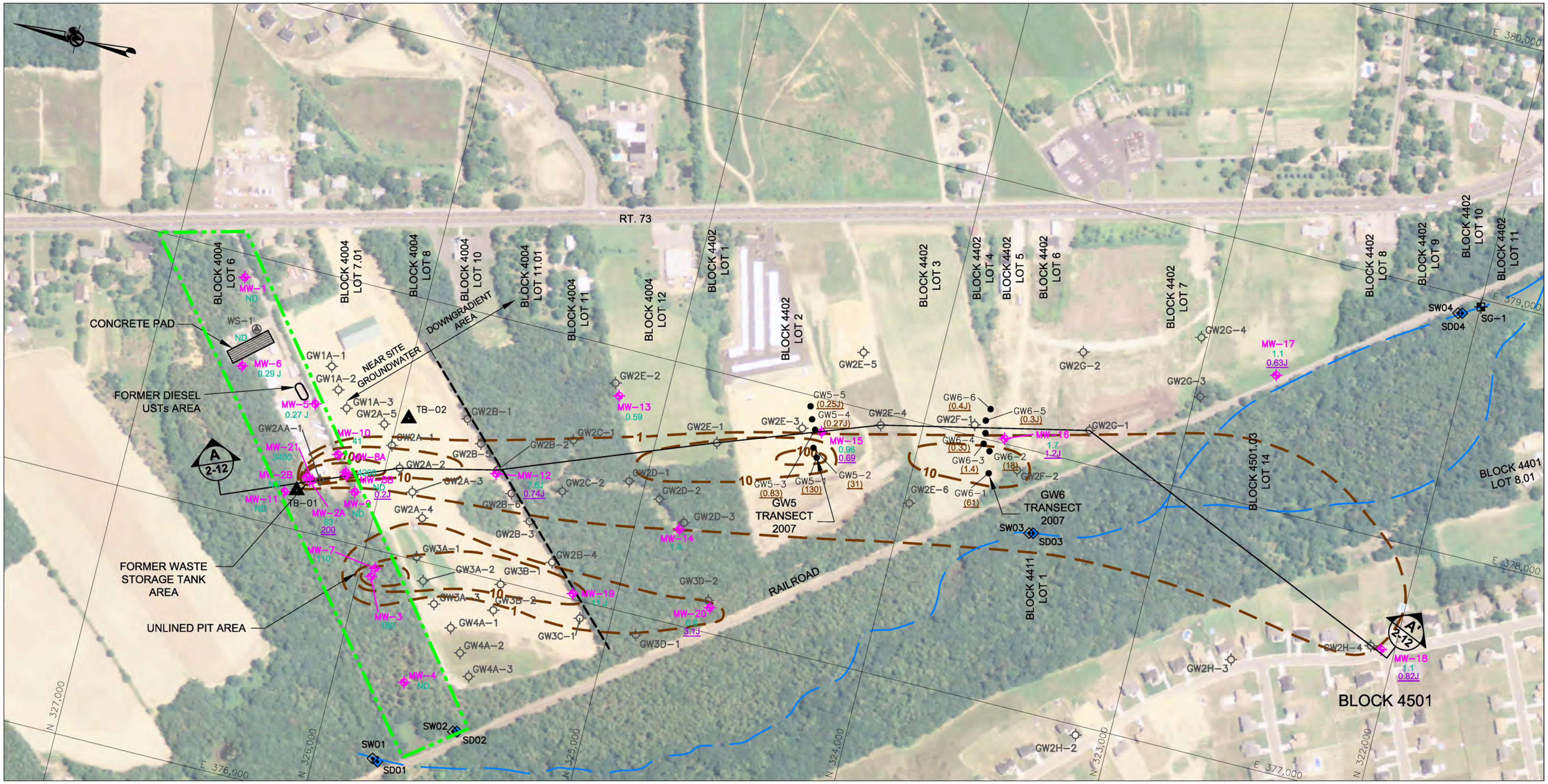
SCALE FEET

NJ Authorization #24GA28029100

Golder Associates
Philadelphia USA

SCALE	AS SHOWN	TITLE	UN-NATURALLY COLORED SOIL DELINEATION
DATE	09/29/08		
DESIGN	HAL		
CADD	RG		
FILE No. 0136054S032	CHECK	RJI	LIGHTMAN DRUM SITE
PROJECT No. 013-6054 REV. 1	REVIEW	PSF	FIGURE 2-9

Drawing file: 0136054S032.dwg Feb 17, 2009 - 1:34pm



LEGEND

(green dash-dot line)	APPROXIMATE PROPERTY LINE – LIGHTMAN DRUM SITE
(brown dashed line)	PCE ISOCONCENTRATION CONTOUR (SEE NOTE 3)
WS-1	ONSITE WATER SUPPLY WELL (LOCATION APPROXIMATE)
MW-11	MONITORING WELL
GW3B-1	GEOPROBE AQUIFER PROFILE BORINGS (LOCATION APPROXIMATE)
SG-1	STAFF GAUGE
A / 2-12	DETAIL OR CROSS SECTION DESIGNATION; FIGURE No. WHERE DETAIL OR CROSS SECTION IS PRESENTED
(blue dashed line)	PUMP BRANCH CREEK (SEE NOTE 3)
SW01	SURFACE WATER SAMPLE (LOCATION APPROXIMATE)
SD01	SEDIMENT SAMPLE (LOCATION APPROXIMATE)
▲	TEST BORING (LOCATION APPROXIMATE)
30	PCE CONCENTRATIONS (ug/L) FOR MARCH 2006
1.4	PCE CONCENTRATIONS (ug/L) FOR FEBRUARY 2007
(31)	GEOPROBE PCE CONCENTRATIONS (ug/L) FOR JULY 2007

NOTE

1.) ND = NOT DETECTED

2.) ISOCONCENTRATION CONTOURS BASED ON GEOPROBE AND MONITORING WELL DATA COLLECTED 2006–2007. DATA FROM MW–2B AND MW–8B WERE NOT CONTOURED AS THEY ARE SCREENED BELOW THE PLUME. WHERE MONITORING WELL DATA FROM 2006 AND 2007 WERE AVAILABLE, 2007 DATA WAS USED.

3.) APPROXIMATE CREEK LOCATION ESTIMATED FROM 1995 AERIAL PHOTO, EPHEMERAL IN VICINITY OF LIGHTMAN PROPERTY.

REFERENCES

1.) AERIAL PHOTOGRAPH TAKEN FROM USDA GEOSPATIAL DATA GATEWAY, DATED 2006.

2.) MONITORING WELLS, STAFF GAUGE AND PIEZOMETERS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

3.) GEOPROBE PROFILE BORINGS AND SURFACE WATER/SEDIMENT SAMPLING LOCATIONS WERE LOCATED IN THE FIELD BY GOLDER ASSOCIATES, INC. PERSONNEL USING A HANDHELD GPS UNIT AND ARE APPROXIMATE ONLY.

4.) PARCEL BOUNDARIES FROM GIS DATABASE OF NEW JERSEY.

300 0 300
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
2	02/13/09	HAL	UPDATED PER REMEDIAL INVESTIGATION FIGURES	AM	HAL	PSF
1	09/29/08	HAL	REVISED PER USEPA COMMENTS DATED JUNE 26, 2008	AM	RJI	PSF

PROJECT
LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

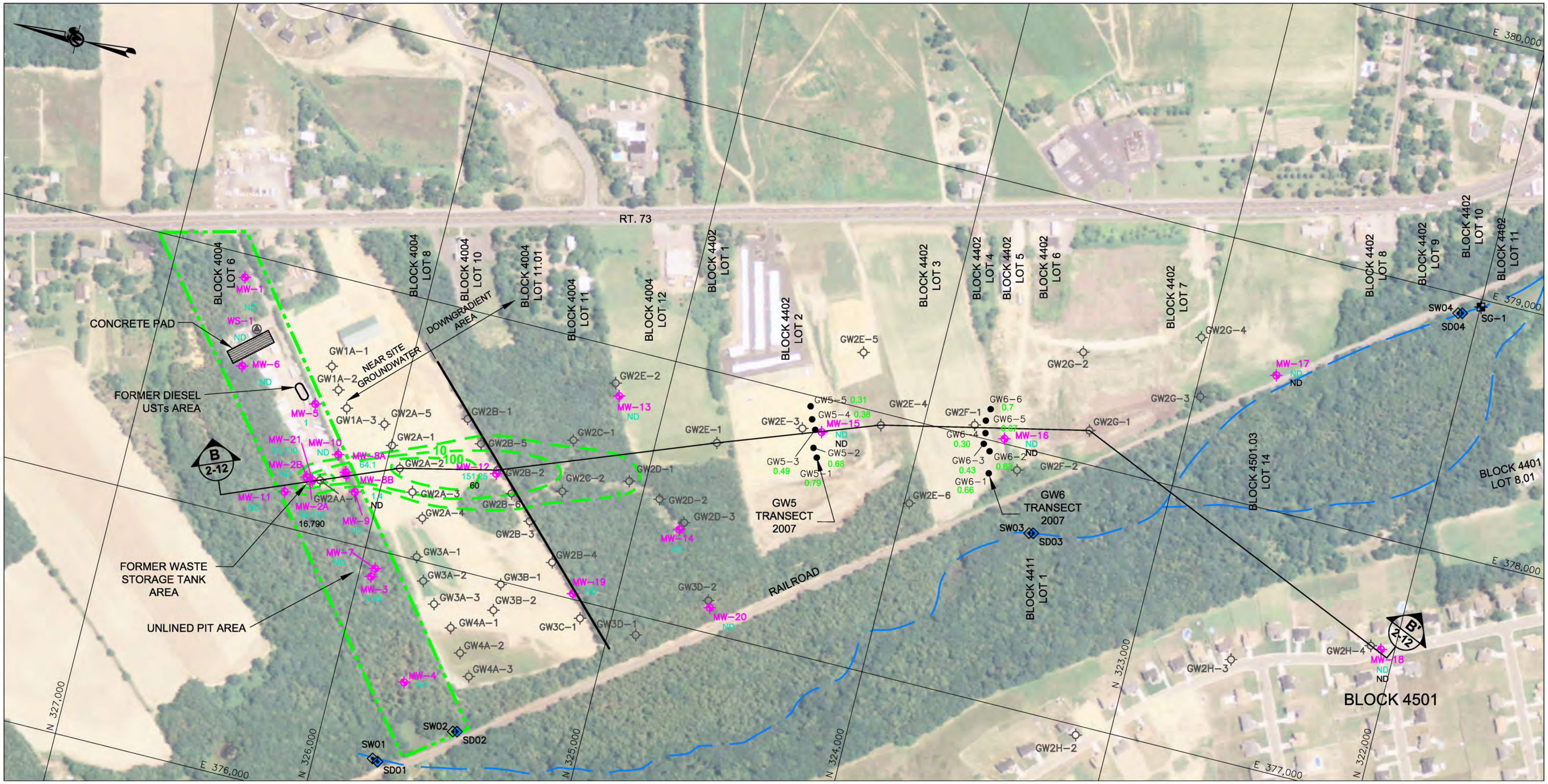
TITLE
PCE ISOCONCENTRATIONS 2006-2007

PROJECT No.	013-6054		FILE No.	0136054S008
DESIGN	HAL	12/20/07	SCALE AS SHOWN	REV. 2
CADD	GLS	12/20/07		
CHECK	HAL	12/20/07		
REVIEW	PSF	12/20/07		

Golder Associates
Philadelphia USA

FIGURE 2-10

Drawing file: 0136054S008 REV 2 – 2-10.dwg Feb 17, 2009 – 12:21pm



LEGEND

	APPROXIMATE PROPERTY LINE – LIGHTMAN DRUM SITE
	BTEX CONTOUR (SEE NOTE 3)
WS-1	ONSITE WATER SUPPLY WELL (LOCATION APPROXIMATE)
MW-11	MONITORING WELL
GW3B-1	GEOPROBE AQUIFER PROFILE BORINGS (LOCATION APPROXIMATE)
A	DETAIL OR CROSS SECTION DESIGNATION
2-11	FIGURE No. WHERE DETAIL OR CROSS SECTION IS PRESENTED
	PUMP BRANCH CREEK (SEE NOTE 3)
SG-1	STAFF GAUGE
SW01	SURFACE WATER SAMPLE (LOCATION APPROXIMATE)
SD01	SEDIMENT SAMPLE (LOCATION APPROXIMATE)
1.4	BTEX CONCENTRATIONS (ug/L) FOR MARCH 2006
0.7	BTEX CONCENTRATIONS (ug/L) FEBRUARY 2007
0.7	GEOPROBE BTEX CONCENTRATIONS (ug/L) JULY 2007

NOTE

1.) ND = NOT DETECTED

2.) ISOCONCENTRATION CONTOURS BASED ON GEOPROBE AND MONITORING WELL DATA COLLECTED 2006–2007. DATA FROM MW–2B AND MW–8B WERE NOT CONTOURED AS THEY ARE SCREENED BELOW THE PLUME. WHERE MONITORING WELL DATA FROM 2006 AND 2007 WERE AVAILABLE, 2007 DATA WAS USED.

3.) APPROXIMATE CREEK LOCATION ESTIMATED FROM 1995 AERIAL PHOTO, EPHEMERAL IN VICINITY OF LIGHTMAN PROPERTY.

4.)BTEX IS THE SUM OF DETECTED CONCENTRATIONS OF BENZENE, TOLUENE, ETHYL BENZENE, AND TOTAL XYLENES.

300 0 300
SCALE FEET

REFERENCES

1.) AERIAL PHOTOGRAPH TAKEN FROM USDA GEOSPATIAL DATA GATEWAY, DATED 2006.

2.) MONITORING WELLS, STAFF GAUGE AND PIEZOMETERS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

3.) GEOPROBE PROFILE BORINGS AND SURFACE WATER/SEDIMENT SAMPLING LOCATIONS WERE LOCATED IN THE FIELD BY GOLDER ASSOCIATES, INC. PERSONNEL USING A HANDHELD GPS UNIT AND ARE APPROXIMATE ONLY.

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
2	02/13/09	HAL	UPDATE PER REMEDIAL INVESTIGATION FIGURES	AM	HAL	PSF
1	02/10/09	HAL	REVISED PER USEPA COMMENTS DATED JUNE 26, 2008	AM	RJI	PSF

PROJECT
LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

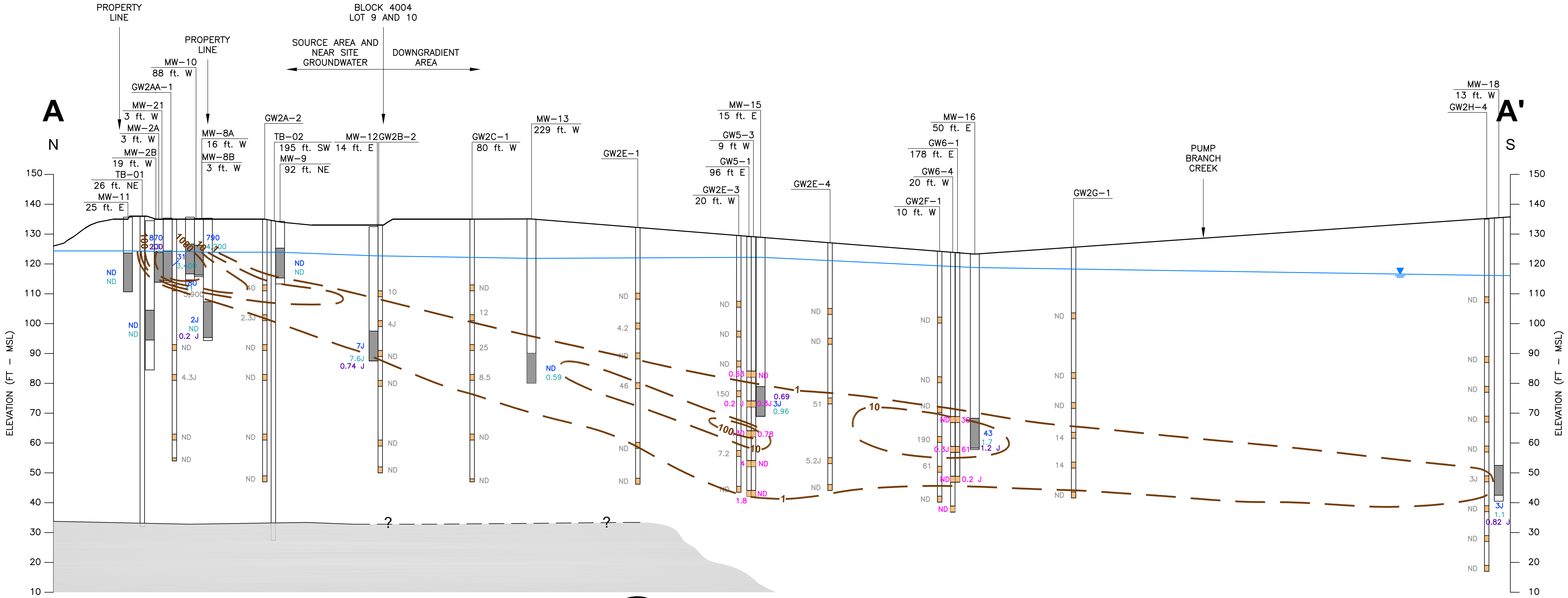
TITLE
TOTAL BTEX ISOCONCENTRATIONS 2006-2007

PROJECT No.	013-6054		FILE No.	0136054S009
DESIGN	HAL	12/20/07	SCALE AS SHOWN	REV. 2
CADD	GLS	12/20/07		
CHECK	HAL	12/20/07		
REVIEW	PSF	12/20/07		

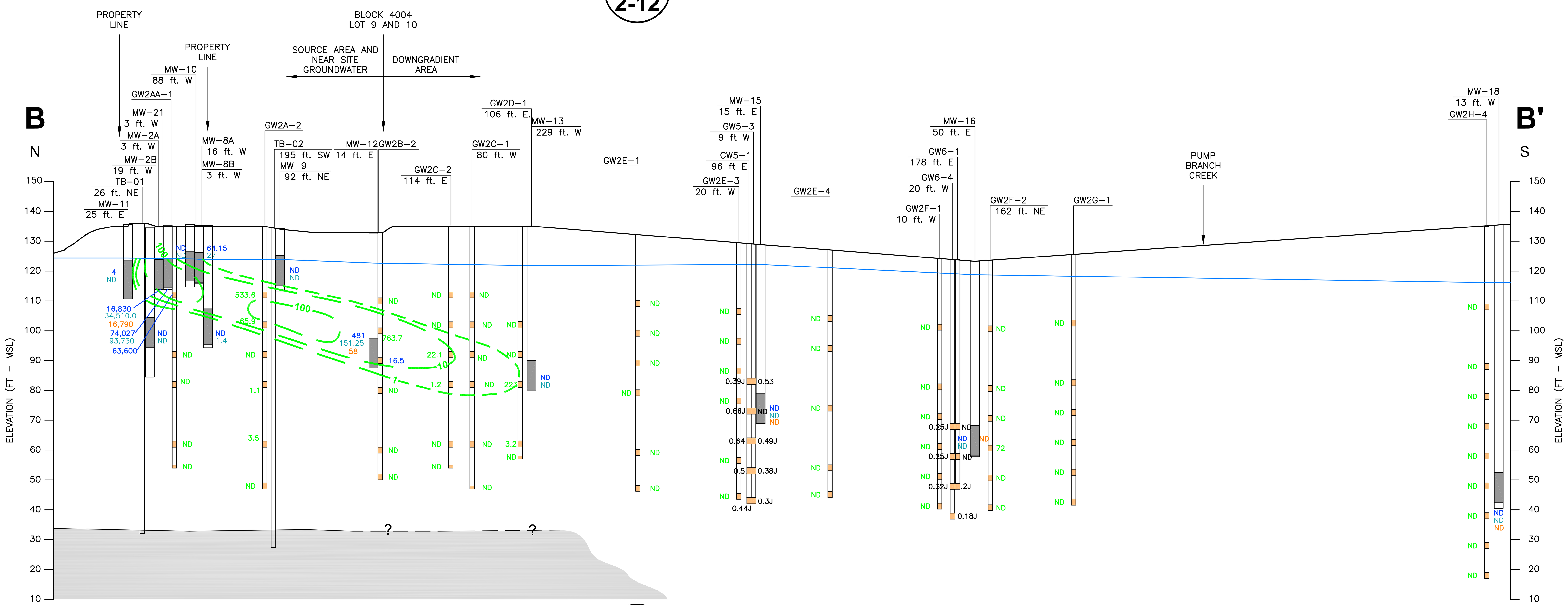
Golder Associates
Philadelphia USA

FIGURE 2-11

Drawing file: 0136054S009 REV 2 – 2-11.dwg Feb 17, 2009 – 12:21pm



A
CROSS SECTION A-A'
2-12



B
CROSS SECTION A-A'
2-12

LEGEND

- MW–8A — BOREHOLE LABEL
- 16 ft. W — PROJECTED DISTANCE AND DIRECTION
- TOP OF BOREHOLE
- SAMPLING INTERVAL
- BOTTOM OF BOREHOLE
- 43 — PCE CONCENTRATIONS (ug/L) 2002–2004
- 43 — PCE CONCENTRATIONS (ug/L) FEBRUARY 2005
- 1.7 — PCE CONCENTRATIONS (ug/L) MARCH 2006
- ND — BTEX CONCENTRATIONS (ug/L) 2002–2004
- ND — PCE CONCENTRATIONS (ug/L) JULY 2007
- ND — BTEX CONCENTRATIONS (ug/L) JULY 2007
- 1 — BTEX CONCENTRATIONS (ug/L) FEBRUARY 2007
- 1.7 — PCE CONCENTRATIONS (ug/L) FEBRUARY 2007
- 10 — PCE CONTOUR
- 10 — BTEX CONTOUR
- WATER TABLE (MAY 3, 2005)
- COHANSEY SAND FORMATION
- KIRKWOOD FORMATION

NOTE

1.) ND = NON DETECT

2.) GEOPROBE DATA (BORINGS DESIGNATED WITH THE PREFIX GW–2) WERE TAKEN BETWEEN AUGUST 2002 AND DECEMBER 2004.

3.) GEOPROBE DATA BORING GW5–3 & GW6–4 WERE TAKEN JULY 2007.

4.) ISOCONCENTRATION CONTOURS BASED ON GEOPROBE AND MONITORING WELL DATA COLLECTED 2006–2007.

200 0 200 400
HORIZONTAL SCALE FEET

20 0 20 40
VERTICAL SCALE FEET

VERTICAL EXAGGERATION 10X

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
2	02/13/09	HAL	UPDATE SECTION CALLOUTS	AM	RJI	PSF
1	09/29/08	HAL	REVISED PER USEPA COMMENTS DATED JUNE 26, 2008	AM	RJI	PSF

PROJECT

LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

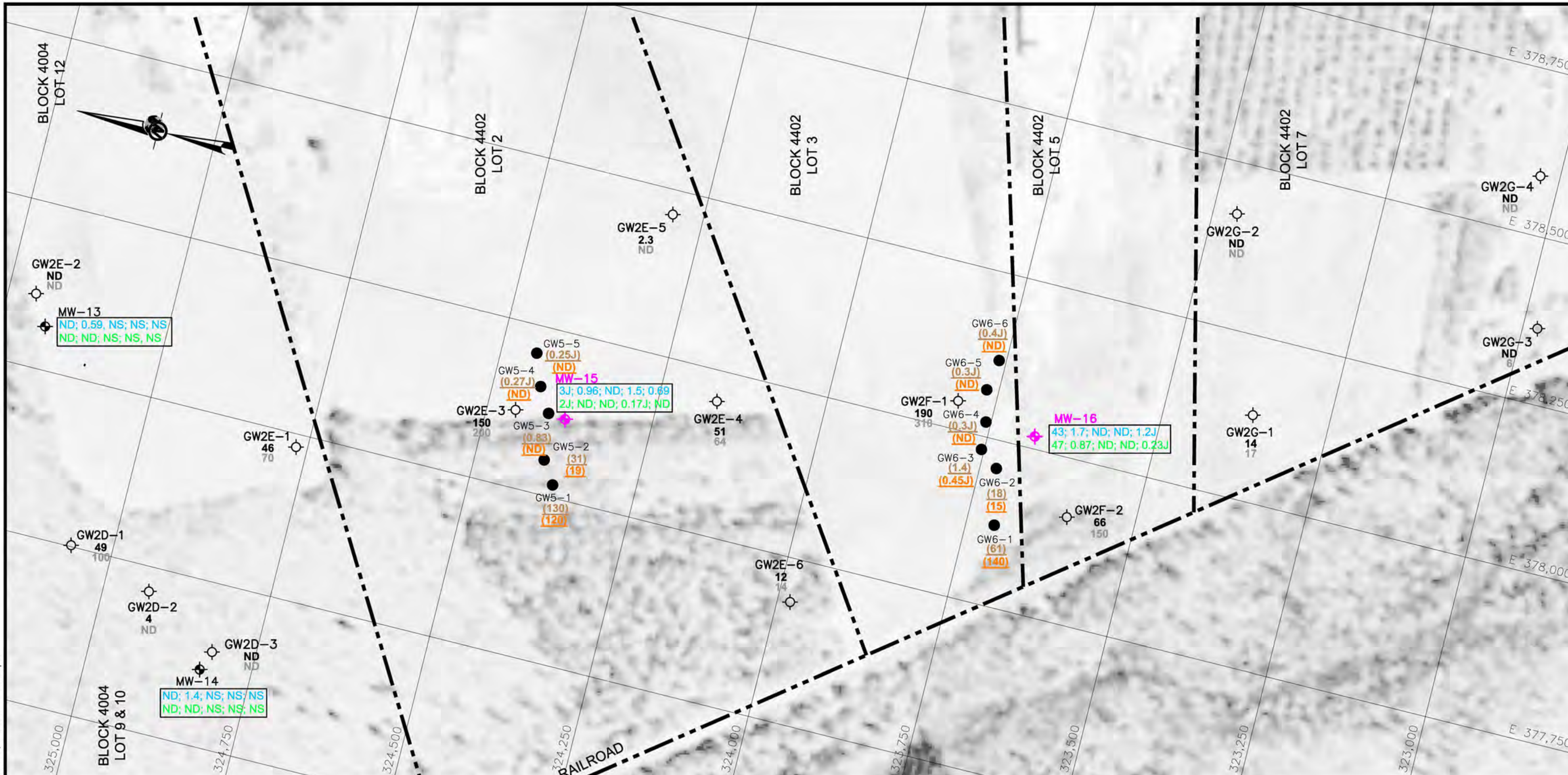
TITLE

PCE & BTEX ISOCONCENTRATION CONTOURS CROSS SECTION VIEW

NJ Authorization #24GA28029100

Golder Associates
Philadelphia USA

PROJECT No.	013–6054		FILE No.	0136054S010
DESIGN	HAL	12/20/07	SCALE AS SHOWN	REV. 2
CADD	GLS	12/20/07		
CHECK	HAL	12/20/07	FIGURE 2-12	
REVIEW	PSF	12/20/07		



LEGEND

— - - —	APPROXIMATE PROPERTY LINE
MW-11	MONITORING WELL
MW-12	FEBRUARY 2007 SAMPLING LOCATIONS
GW3B-1	GEOPROBE AQUIFER PROFILE BORINGS (LOCATION APPROXIMATE)
ND	MAXIMUM PCE CONCENTRATIONS (ug/L) 2002-2004
18	MAXIMUM TCE CONCENTRATIONS (ug/L) 2002-2004
(1.4)	MAXIMUM PCE CONCENTRATIONS (ug/L) JULY 2007
(0.4J)	MAXIMUM TCE CONCENTRATIONS (ug/L) JULY 2007
3J	PCE CONCENTRATIONS (ug/L) FOR: FEB. 2005; MAR. 2006; AUG. 2006; NOV. 2006; FEB. 2007
2J	TCE CONCENTRATIONS (ug/L) FOR: FEB. 2005; MAR. 2006; AUG. 2006; NOV. 2006; FEB. 2007
●	AQUIFER PROFILE BORING (JULY 2007)

NOTES

1.) ND = NOT DETECTED

2.) NS = NOT SAMPLED

REFERENCES

1.) AERIAL PHOTOGRAPH TAKEN FROM TERRAIN NAVIGATOR PRO BY MAPTECH, OF WILLIAMSTOWN NJ, DATED MARCH 25, 1995.

2.) MONITORING WELLS, STAFF GAUGE AND PIEZOMETERS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

3.) GEOPROBE PROFILE BORINGS AND SURFACE WATER/SEDIMENT SAMPLING LOCATIONS WERE LOCATED IN THE FIELD BY GOLDER ASSOCIATES, INC. PERSONNEL USING A HANDHELD GPS UNIT AND ARE APPROXIMATE ONLY.

150 0 150
SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
1	09/29/08	HAL	REVISED PER USEPA COMMENTS DATED JUNE 26, 2008	RG	RJI	PSF

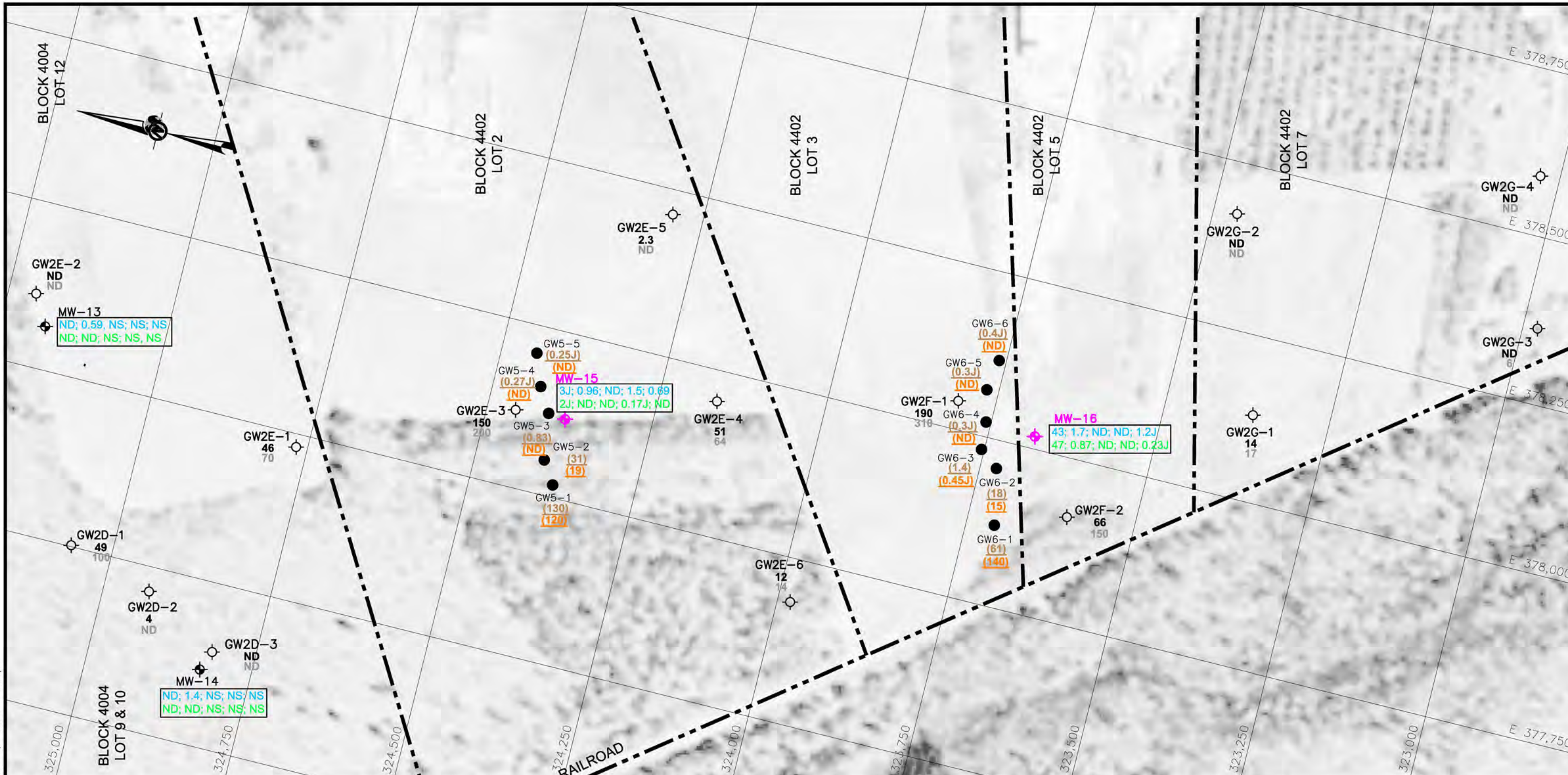
PROJECT
LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

TITLE
2007 AQUIFER PROFILE MAXIMUM DETECTIONS

NJ Authorization #24GA28029100
Golder Associates
Philadelphia USA

PROJECT No.	013-6054	FILE No.	0136054S011
DESIGN	HAL	12/20/07	SCALE AS SHOWN REV. 1
CADD	GLS	12/20/07	
CHECK	HAL	12/20/07	FIGURE 2-13
REVIEW	PSF	12/20/07	

Drawing file: 0136054S011 REV 1 - 2-13.dwg Feb 17, 2009 - 12:23pm



LEGEND

	APPROXIMATE PROPERTY LINE	3J	PCE CONCENTRATIONS (ug/L) FOR: FEB. 2005; MAR. 2006; AUG. 2006; NOV. 2006; FEB. 2007
MW-11	MONITORING WELL	2J	TCE CONCENTRATIONS (ug/L) FOR: FEB. 2005; MAR. 2006; AUG. 2006; NOV. 2006; FEB. 2007
MW-12	FEBRUARY 2007 SAMPLING LOCATIONS		AQUIFER PROFILE BORING (JULY 2007)
GW3B-1	GEOPROBE AQUIFER PROFILE BORINGS (LOCATION APPROXIMATE)		
ND	MAXIMUM PCE CONCENTRATIONS (ug/L) 2002-2004		
18	MAXIMUM TCE CONCENTRATIONS (ug/L) 2002-2004		
(1.4)	MAXIMUM PCE CONCENTRATIONS (ug/L) JULY 2007		
(0.4J)	MAXIMUM TCE CONCENTRATIONS (ug/L) JULY 2007		

NOTES

1.) ND = NOT DETECTED

2.) NS = NOT SAMPLED

REFERENCES

1.) AERIAL PHOTOGRAPH TAKEN FROM TERRAIN NAVIGATOR PRO BY MAPTECH, OF WILLIAMSTOWN NJ, DATED MARCH 25, 1995.

2.) MONITORING WELLS, STAFF GAUGE AND PIEZOMETERS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

3.) GEOPROBE PROFILE BORINGS AND SURFACE WATER/SEDIMENT SAMPLING LOCATIONS WERE LOCATED IN THE FIELD BY GOLDER ASSOCIATES, INC. PERSONNEL USING A HANDHELD GPS UNIT AND ARE APPROXIMATE ONLY.

150 0 150

SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
1	09/29/08	HAL	REVISED PER USEPA COMMENTS DATED JUNE 26, 2008	RG	RJI	PSF

PROJECT

LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

TITLE

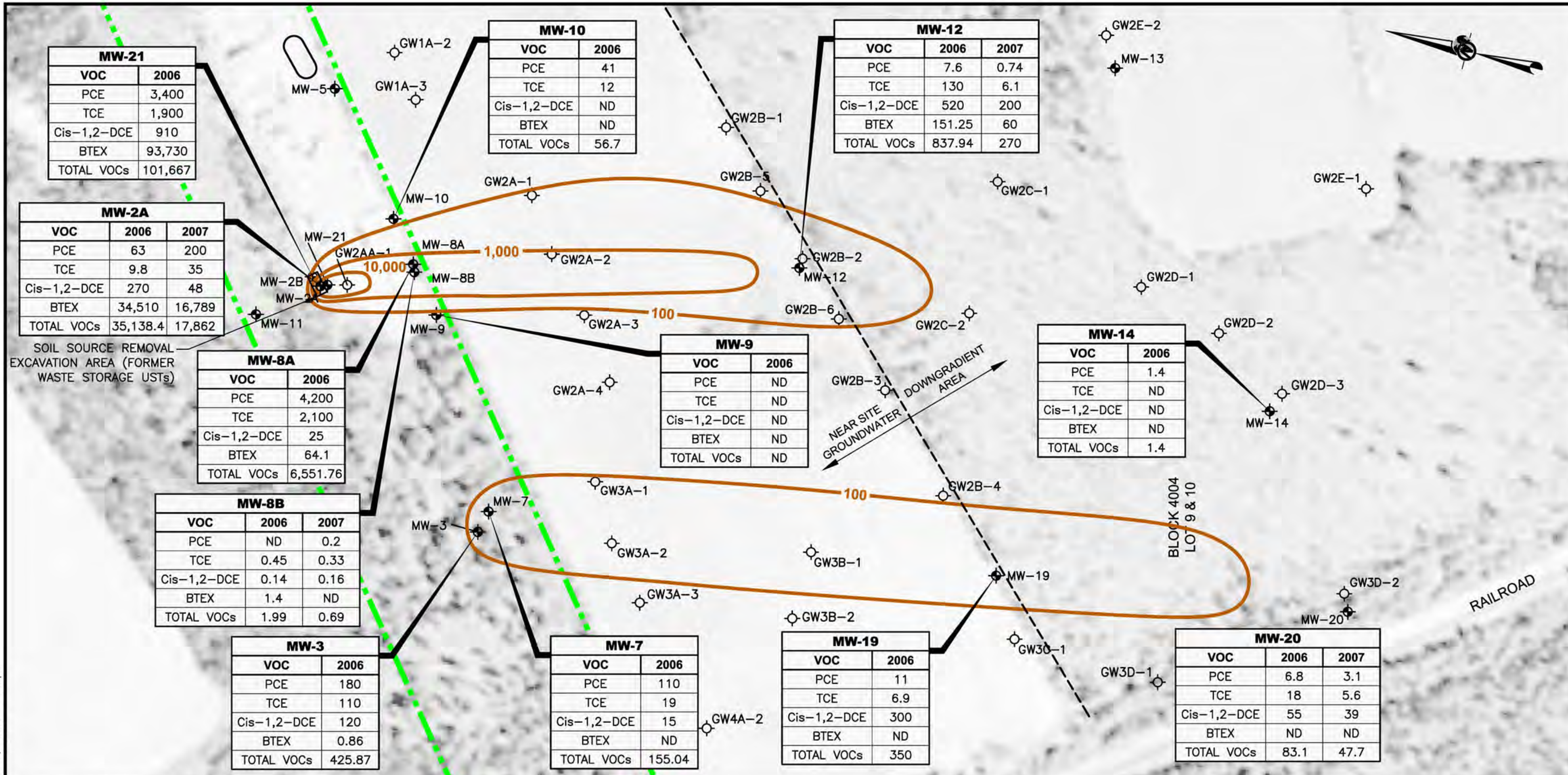
2007 AQUIFER PROFILE MAXIMUM DETECTIONS

NJ Authorization #24GA28029100

Golder Associates
Philadelphia USA

PROJECT No.	013-6054		FILE No.	0136054S011
DESIGN	HAL	12/20/07	SCALE AS SHOWN	REV. 1
CADD	GLS	12/20/07		
CHECK	HAL	12/20/07	**FIGURE 2-13**	
REVIEW	PSF	12/20/07		

Drawing file: 0136054S011 REV 1 - 2-13.dwg Feb 17, 2009 - 1:29pm



MW-21

VOC	2006
PCE	3,400
TCE	1,900
Cis-1,2-DCE	910
BTEX	93,730
TOTAL VOCs	101,667

MW-10

VOC	2006
PCE	41
TCE	12
Cis-1,2-DCE	ND
BTEX	ND
TOTAL VOCs	56.7

MW-12

VOC	2006	2007
PCE	7.6	0.74
TCE	130	6.1
Cis-1,2-DCE	520	200
BTEX	151.25	60
TOTAL VOCs	837.94	270

MW-2A

VOC	2006	2007
PCE	63	200
TCE	9.8	35
Cis-1,2-DCE	270	48
BTEX	34,510	16,789
TOTAL VOCs	35,138.4	17,862

MW-8A

VOC	2006
PCE	4,200
TCE	2,100
Cis-1,2-DCE	25
BTEX	64.1
TOTAL VOCs	6,551.76

MW-9

VOC	2006
PCE	ND
TCE	ND
Cis-1,2-DCE	ND
BTEX	ND
TOTAL VOCs	ND

MW-14

VOC	2006
PCE	1.4
TCE	ND
Cis-1,2-DCE	ND
BTEX	ND
TOTAL VOCs	1.4

MW-8B

VOC	2006	2007
PCE	ND	0.2
TCE	0.45	0.33
Cis-1,2-DCE	0.14	0.16
BTEX	1.4	ND
TOTAL VOCs	1.99	0.69

MW-3

VOC	2006
PCE	180
TCE	110
Cis-1,2-DCE	120
BTEX	0.86
TOTAL VOCs	425.87

MW-7

VOC	2006
PCE	110
TCE	19
Cis-1,2-DCE	15
BTEX	ND
TOTAL VOCs	155.04

MW-19

VOC	2006
PCE	11
TCE	6.9
Cis-1,2-DCE	300
BTEX	ND
TOTAL VOCs	350

MW-20

VOC	2006	2007
PCE	6.8	3.1
TCE	18	5.6
Cis-1,2-DCE	55	39
BTEX	ND	ND
TOTAL VOCs	83.1	47.7

LEGEND

LIGHTMAN PROPERTY BOUNDARY

100 TOTAL VOC ISOCONCENTRATION CONTOUR (ppb)

MW-11 MONITORING WELL

GW3B-1 GEOPROBE AQUIFER PROFILE BORINGS (LOCATION APPROXIMATE)

150 0 150

SCALE FEET

NOTE

1.) ALL CONCENTRATIONS IN ug/L (ppb). TOTAL VOC IS TOTAL CONCENTRATION OF ALL DETECTED VOCs. BASED ON MARCH 2006 AND FEBRUARY 2007 SAMPLING RESULTS.

REFERENCES

1.) AERIAL PHOTOGRAPH TAKEN FROM TERRAIN NAVIGATOR PRO BY MAPTECH, OF WILLIAMSTOWN NJ, DATED MARCH 25, 1995.

2.) MONITORING WELLS WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

3.) GEOPROBE PROFILE BORINGS WERE LOCATED IN THE FIELD BY GOLDER ASSOCIATES, INC. PERSONNEL USING A HANDHELD GPS UNIT AND ARE APPROXIMATE ONLY.

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
2	02/13/09	HAL	CORRECTING MW-7 VALUES	AM	RJI	PSF
1	09/12/08	HAL	REVISED PER USEPA COMMENTS DATED JUNE 26, 2008	AM	RJI	PSF

PROJECT

LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

TITLE

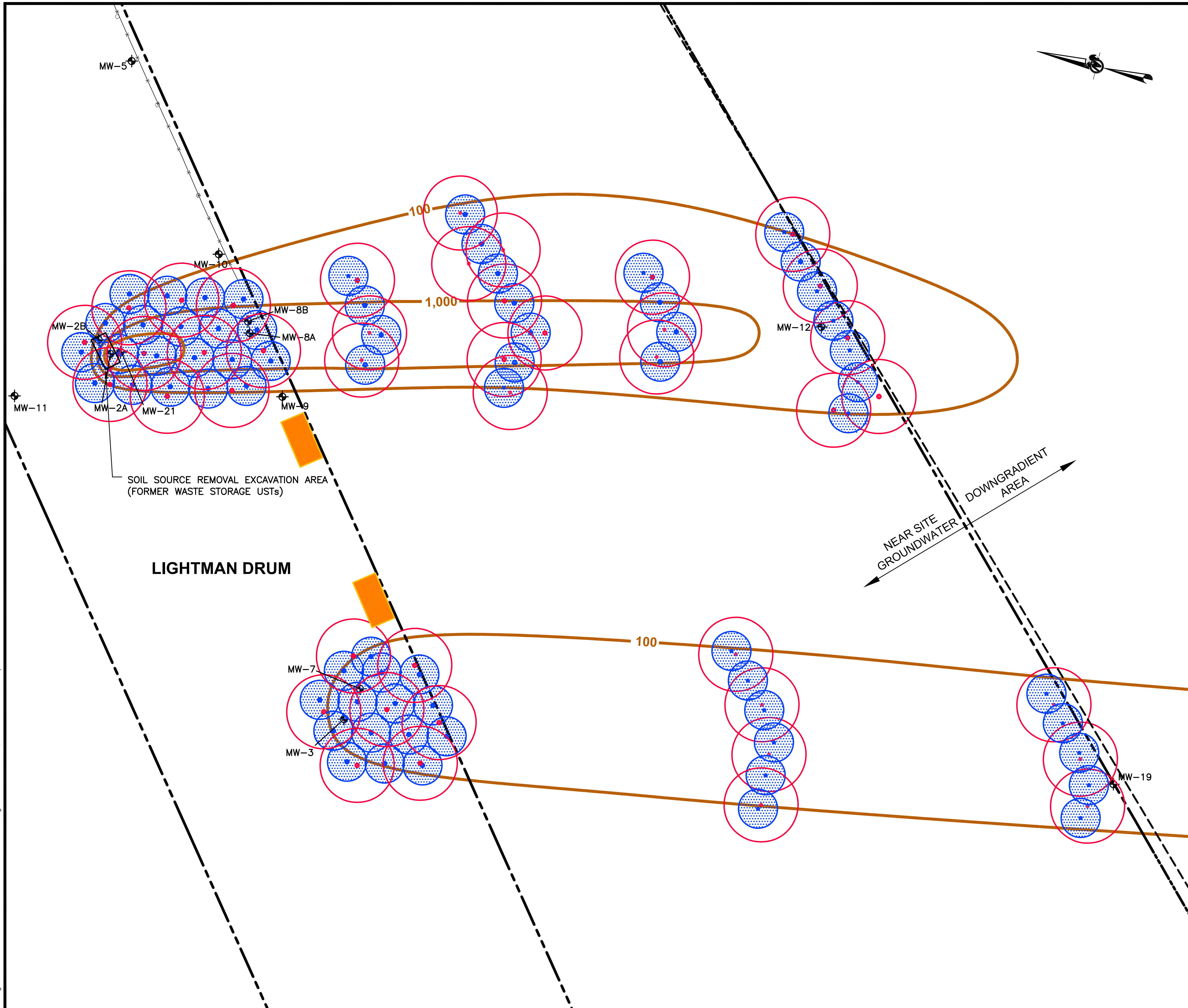
TOTAL VOC INTERPRETED ISOCONCENTRATION CONTOURS AND WELL CHEMISTRY DATA

Golder Associates Philadelphia USA

PROJECT No.	013-6054	FILE No.	0136054S015	
DESIGN	MJB	12/20/07	SCALE AS SHOWN	REV. 2
CADD	RG	12/20/07		
CHECK	HAL	12/20/07		
REVIEW	PSF	12/20/07		

FIGURE 5-1

Drawing file: 0136054S015 REV 2 - 5-1.dwg Feb 17, 2009 - 1:31pm



LEGEND

PROPERTY BOUNDARY

MONITORING WELL

100 TOTAL VOCs ISOCONCENTRATION CONTOUR (ppb)

AIR SPARGE WELL (ESTIMATED (20 FT ZOI)

SOIL VAPOR EXTRACTION WELL (ESTIMATED (40 FT ZOI)

TREATMENT BUILDING

REFERENCES

1.) BASE MAP TAKEN FROM FILE 2702-01.DWG, TITLED "PLAN OF SURVEY", PROVIDED BY JAMES M. STEWART, INC.

2.) MONITORING WELLS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

100 0 100

SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
1	09/28/08	HAL	REVISED PER USEPA COMMENTS DATED JUNE 26, 2008	AM	RJI	PSF

PROJECT

LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

TITLE

AIR SPARGE / SOIL VAPOR EXTRACTION CONCEPTUAL LAYOUT

NJ Authorization #24GA28029100

Golder Associates
Philadelphia USA

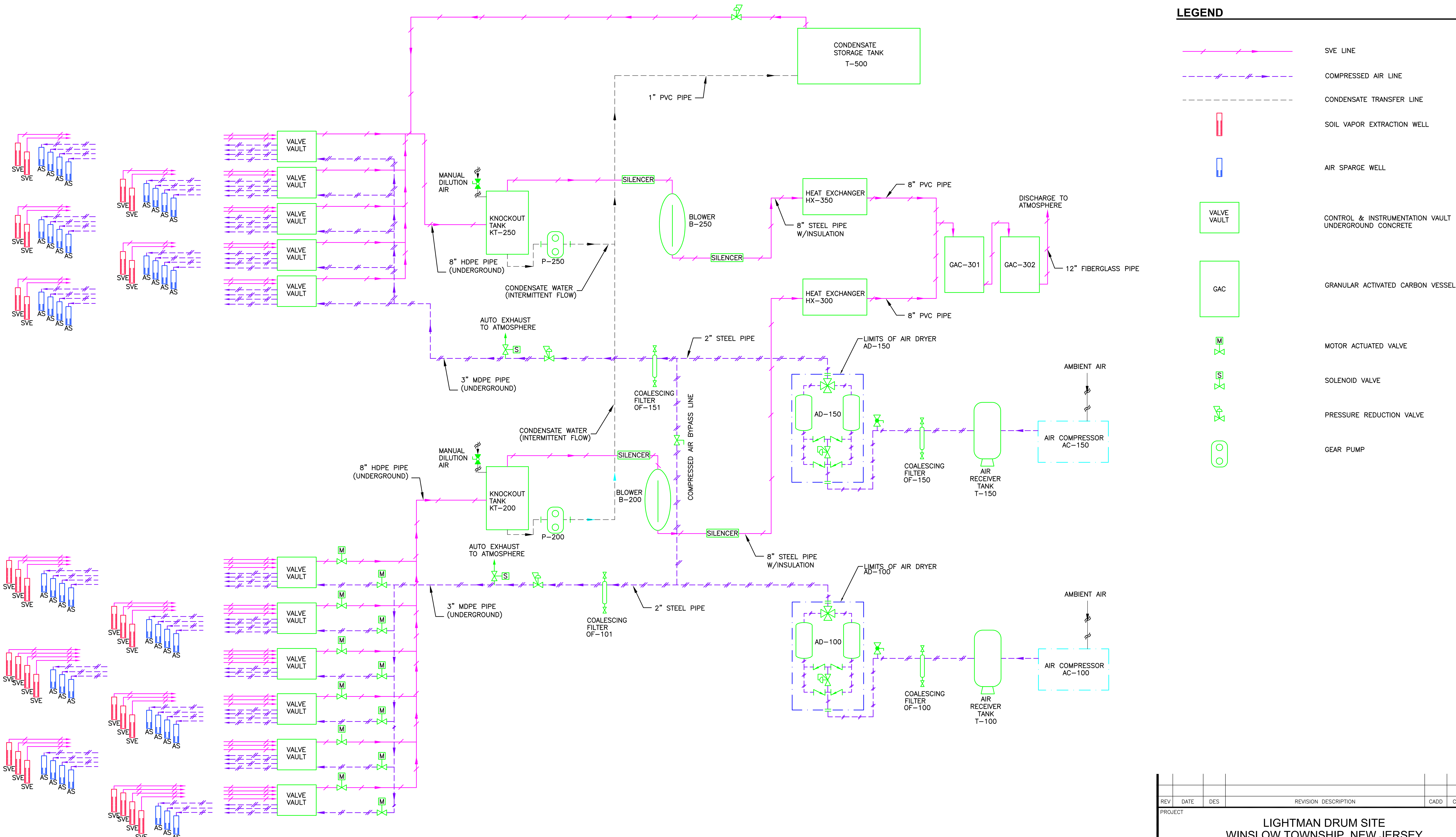
PROJECT No.		013-6054
DESIGN	SDG	12/20/07
CADD	YPW	12/20/07
CHECK	HAL	12/20/07
REVIEW	PSF	12/20/07

FILE No. 0136054S016

SCALE AS SHOWN REV. 1

FIGURE 5-2

Drawing file: 0136054S016 REV 1 - 5-2.dwg Feb 17, 2009 - 1:32pm



REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

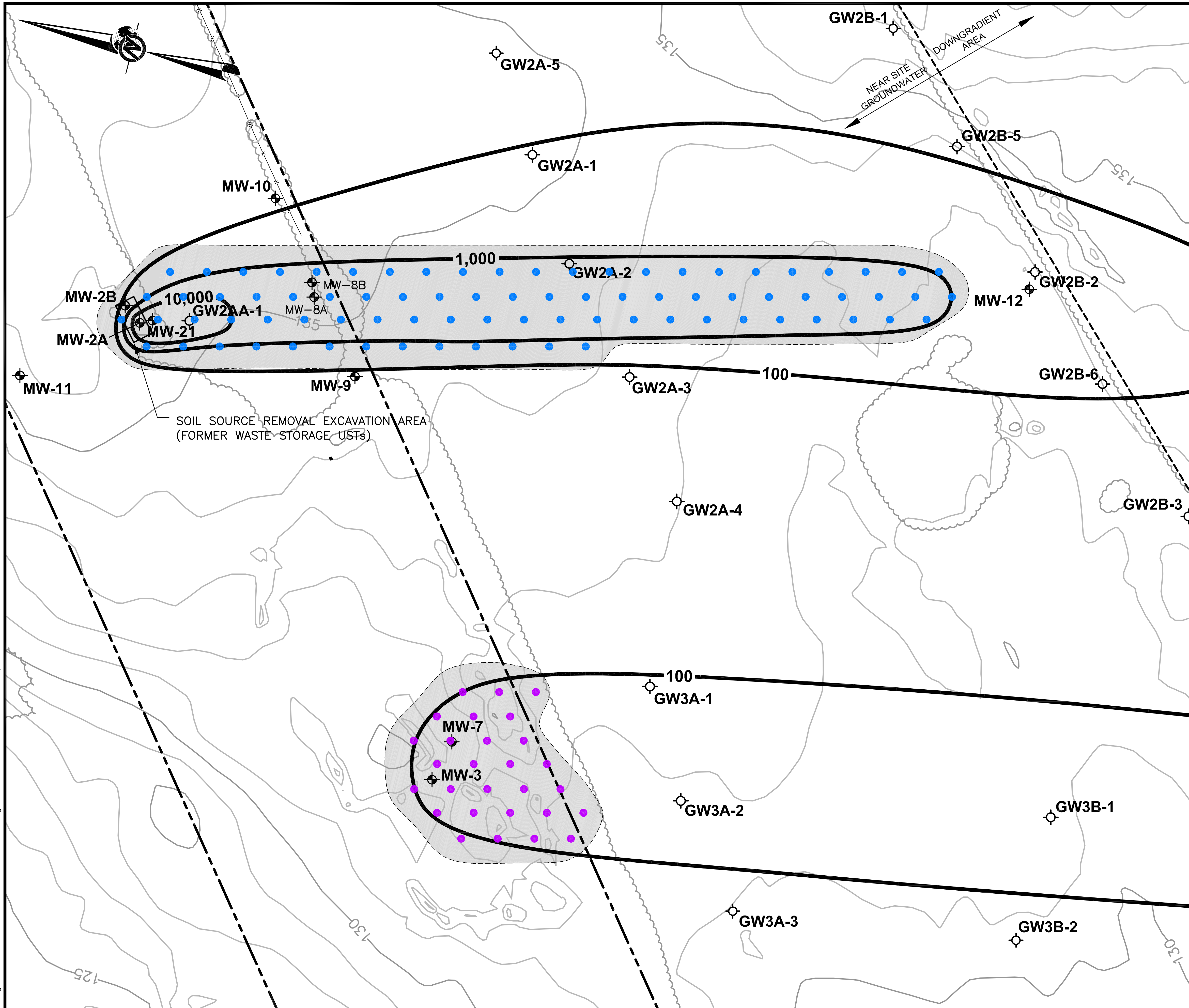
TITLE

AIR SPARGE / SOIL VAPOR EXTRACTION CONCEPTUAL PROCESS FLOW DIAGRAM

NJ Authorization #24GA28029100

Golder Associates
Philadelphia, PA

PROJECT No.		013-6504	FILE No.	0136504S017
DESIGN	SDG	12/20/07	SCALE NONE	REV. 0
CADD	YPW	12/20/07		
CHECK	HAL	12/20/07	FIGURE 5-3	
REVIEW	PSF	12/20/07		



LEGEND

LIGHTMAN PROPERTY BOUNDARY

MONITORING WELL

GEOPROBE AQUIFER PROFILE BORING (LOCATION APPROXIMATE)

100 TOTAL VOCs ISOCONCENTRATION CONTOUR (ppb)

FENTON'S REAGENT INJECTION POINT

PERMANGANATE INJECTION POINT

TREATMENT AREA

REFERENCES

1.) BASE MAP TAKEN FROM FILE 2702-01.DWG, TITLED "PLAN OF SURVEY", PROVIDED BY JAMES M. STEWART, INC.

2.) MONITORING WELLS SHOWN WERE BASED ON SURVEY INFORMATION SUPPLIED BY JAMES M. STEWART, INC.

80 0 80

SCALE FEET

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
1	09/23/08	HAL	REVISED PER USEPA COMMENTS DATED JUNE 26, 2008	AM	RJI	PSF

PROJECT

LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

TITLE

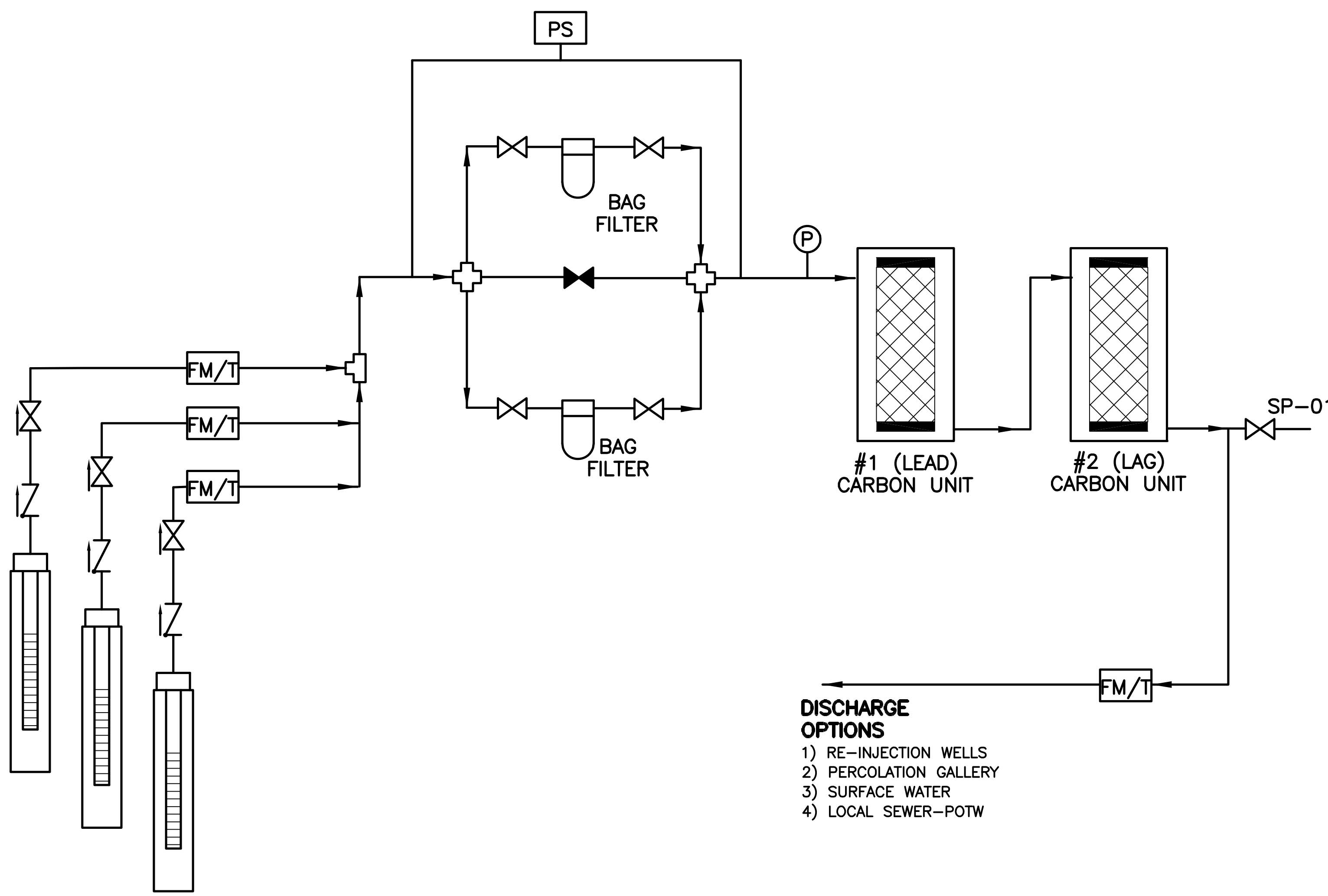
ISCO CONCEPTUAL DESIGN

NJ Authorization #24GA28029100

Golder Associates
Philadelphia USA

PROJECT No.		013-6054	FILE No. 0136054S018
DESIGN	MJB	12/20/07	SCALE AS SHOWN REV. 1
CADD	RG	12/20/07	
CHECK	HAL	12/20/07	**FIGURE 5-4**
REVIEW	PSF	12/20/07	

Drawing file: 0136054S018 REV 1 - 5-4.dwg Feb 17, 2009 - 1:33pm



LEGEND

- GATE VALVE
- BALL VALVE
- CHECK VALVE
- FM/T — FLOW METER/TOTALIZER
- PS — DIFFERENTIAL PRESSURE SWITCH
- SP — SAMPLE PORT
- (P) — PRESSURE GAUGE
- – – – – ELECTRICAL SIGNAL CONNECTION

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW

PROJECT

LIGHTMAN DRUM SITE
WINSLOW TOWNSHIP, NEW JERSEY

TITLE

GROUNDWATER EXTRACTION & TREATMENT CONCEPTUAL PROCESS FLOW DIAGRAM

Golder Associates
Philadelphia USA
NJ Authorization #24GA28029100

PROJECT No.		013-6054	FILE No.	0136054S019
DESIGN	SDG	12/20/07	SCALE AS SHOWN	REV. 0
CADD	YPW	12/20/07	**FIGURE 5-5**	
CHECK	HAL	12/20/07		
REVIEW	PSF	12/20/07		

APPENDIX A

MUNICIPAL WELL PUMPING DATA

SWitch Mon.

Date	Initials	Time	Comments WELL 8	RCA Hours	Well Pumps Hours	Booster Pumps #1	Booster Pumps #2	Meter Reading 24 Hours	Total Used GALS	Well Tank Level	HYPO Rate	HYPO Wt.	HYPO Pump No.
Month March			Year 06										
1	RD	924	SWITCHED HypoTANK # 2(Klenflow Del)	16.3	9160.8	324344	188800	18437721	10460	80	50/60	78	#1
2	RD	852	Hypo Del.	16.7	9177.1	324344	18897.5	18448191	10833	100	50/60	75	#1
3	RD	920		17.2	9193.8	324344	18915.7	18459014	10996	77	50/60	~~105~~ 104	#1
4	RD	840		20.8	9211.0	324344	18934.3	18470010	13264	90	60/60	100	#1
5	RD	1057		20.6	9231.8	32434.4	18956.7	18483274	10839	75	50/50	95	#1
6	RD	805		17.4	92524	324344	18976.1	18496113	1112.7	75	50/60	91	#1
7	RD	805		16.1	9269.8	324521	18998.1	18507290	11553	93	70/60	85	#1
8	RD	850	BLED HYPO	19.0	92879	[illegible]	18976.9	18518843	12020	71	60/60	85	#1
9	RD	800	SWITCHED HYPO TANKS & BLED	19.3	9306.9	324933	18976.9	18530868	[illegible]	75	60/60	84	#1
10	RD	815		17.9	9326.2	325147	18976.4	18543097	1133.6	77	60/60	~~120~~ 114	#1
11	RD	825	BACKWASHED LIME PUMP	19.8	9344.1	325323	18978.4	18554433	12534	97	60/60	109	#1
12	RD	800	BACKWASHED LIME PUMP	23.9	9363.9	32556.0	18976.4	18566967	1500.3	100	60/60	104	#1
13	RH	1035	SWITCHED BOOSTERS (SEE LOG - LIME TANK)	17.4	9387.8	325822	18978.9	18581970	1119.1	96	50/60	95	#1
14	RH	935		16.7	9405.2	325822	18997.8	18593161	1070.9	85	50/60	93	#1
15	RH	1000		16.2	9421.9	32582.2	19015.9	18603870	1035.5	73	50/60	89	#1
16	RH	855	LOWERED LIME PUMP	16.7	9438.1	32582.2	19033.4	18614225	1094.5	71	50/60	85	#1
17	RH	955		12.0	9454.8	32582.2	19051.5	18625170	782.9	86	50/60	87	#1
18	RH	650		19.4	9466.8	32582.2	19064.5	18632999	1234.3	101	50/60	80	#1
19	RH	835		24.7	9486.7	32582.2	19085.3	18645342	15390	89	50/60	75	#1
20	JV	10:30		19.0	9510.9	32582.2	19111.9	18660732	9050	92	50/60	70	#1
21	JV	9:00		17.5	9524.9	325927	19111.9	18669782	11820	74	50/60	65	#1
22	JV	9:40	NEW RATE LIME 50%	20.0	9542.4	326171	19111.9	18681602	12666	92	50/60	60	1#
23	JV	9:30	NEW RATE LIME 40%	16.8	9562.4	32639.2	1911.9	18693668	10768	97	50/60	57	1#
24	JV	9:20		16.6	9579.2	326577	1911.9	18704436	10608	89	50/60	54	1#
25	JV	9:40		19.3	9595.8	32675.8	1911.9	18715044	12270	88	50/60	50	1#
26	JV	9:30		23.4	9615.1	326971	1911.9	18727314	14816	91	50/60	45	1#
27	JS	1030	Switched Boost		9638.8	327230	19111.9	18742130		91	50/60	40	#1
28													
29													
30													
31													

WINSLOW TOWNSHIP WATER DEPARTMENT

Month March Year 06

Date	Initials	Time	Comments Well 4	Ran Hours	Well Pumps Hours	Booster Pumps #1	Booster Pumps #2	Meter Reading 24 Hours	Total Used GALS	2MG Tank Level	HYPO Rate	HYPO Wt.	HYPO Pump No.
1	RO	10:50		0	5802.6			111044	0		30/60	27	#1
2	RO	9:53	Ran Well	2.1	5802.6			111044	328		50/60	27	#1
3	RO	9:05		0	5804.7			111372	0		50/60	26	#1
4	RO	10:32		0	5804.7			111372	0		30/60	26	#1
5	RO	10:23	WELL OFF	0	5804.7			111372	0		50/60	26	#1
6	PO	8:30		0	5804.7			111372	0		50/60	26	#1
7	PO	8:00		0	5804.7			111372	0		70/60	26	#1
8	PO	8:30	WELL ON HAND	2	5804.7			111372	280		50/60	26	#1
9	PO	8:15		0	5806.7			111652	0		50/60	28	#1
10	PO	8:00		0	5806.7			111652	0		50/60	28	#1
11	PO	8:10		0	5806.7			111652	0		50/60	28	#1
12	PO	8:05		0	5806.7			111652	0		50/60	28	#1
13	RH	10:00		0	5806.7			111652	0		50/60	28	#1
14	RH	9:20	RAN WELL	2.0	5806.7			111652	281		50/60	28	#1
15	RH	9:55		0	5808.7			111933	0		50/60	27	#1
16	RH	9:30		0	5808.7			111933	0		50/60	27	#1
17	RH	9:50		0	5808.7			111933	0		50/60	27	#1
18	RH	7:20		0	5808.7			111933	0		50/60	27	#1
19	RH	8:00		0	5808.7			111933	0		50/60	27	#1
20	VZ	10:30		0	5808.7			11193.3	0		50/60	27	#1
21	VZ	11:00		1.5	5808.7			11193.3	200		50/60	27	#1
22	VZ	11:00		0	5810.2			11213.3	0		50/50	26	#1
23	[illegible]	9:50		0	5810.2			11213.3	0		50/50	26	#1
24	VZ	9:30		0	5810.2			11213.3	0		50/50	26	#1
25	VZ	9:00		0	5810.2			11213.3	0		50/50	26	#1
26	VZ	9:30		0	5810.2			11213.3	0		50/50	26	#1
27	[illegible]	10:35			5810.2			11213.3			50/50	26	#1
28													
29													
30													
31													

Table A-1
Summary of Public Water Supply Well Withdrawal Data

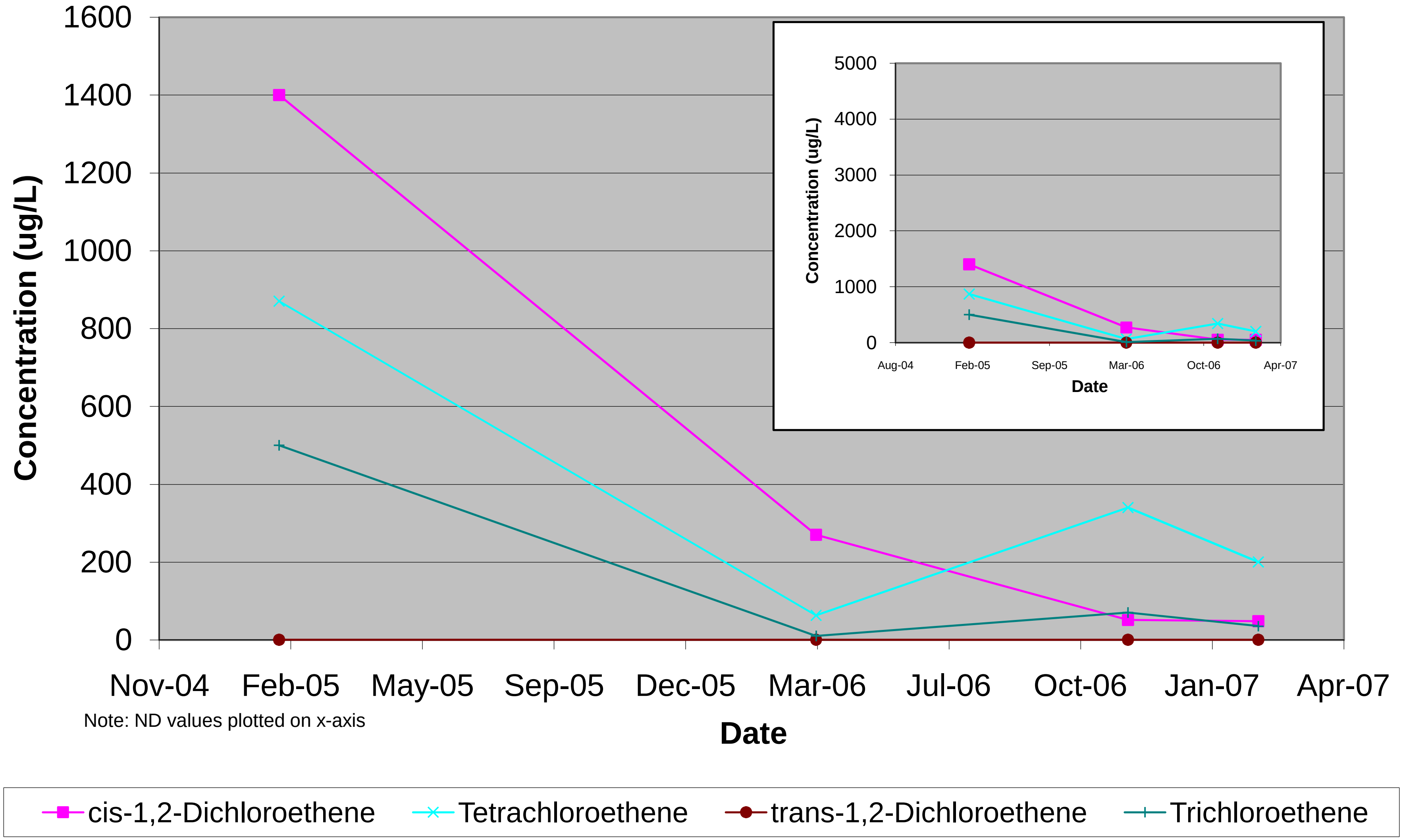
Owner and Well Designation	Well Permint No.	Year	Gallons Pumped per Year [gal/year]	Month [gal/month]	Day [gal/day]	Minute [gpm]
Winslow Twp MUA Sicklerville Well 3	31-06874	2003	1.05E+08	8.74E+06	287,192	199
	31-06874	2004	4.41E+07	3.68E+06	120,937	84
	31-06874	2005	9.29E+07	7.74E+06	254,521	177
	31-06874	2006	1.69E+08	1.41E+07	463,068	322
	31-06874	2007	2.88E+08	2.40E+07	788,822	548
Winslow Twp MUA Sicklerville Well 8	31-51329	2003	4.08E+08	3.40E+07	1,117,137	776
	31-51329	2004	3.49E+08	2.90E+07	955,005	663
	31-51329	2005	4.37E+08	3.64E+07	1,197,151	831
	31-51329	2006	4.67E+08	3.89E+07	1,278,901	888
	31-51329	2007	6.85E+07	5.71E+06	187,658	130
Winslow Twp MUA Sicklerville Well 9	31-47169	2003	6.22E+07	5.18E+06	170,460	118
	31-47169	2004	4.67E+07	3.89E+06	128,033	89
	31-47169	2005	8.20E+07	6.83E+06	224,603	156
	31-47169	2006	9.99E+07	8.32E+06	273,696	190
	31-47169	2007	7.06E+07	5.88E+06	193,321	134
Winslow Twp MUA Sicklerville Well 7	31-47168	2003	1.55E+08	1.29E+07	425,745	296
	31-47168	2004	1.51E+08	1.26E+07	413,989	287
	31-47168	2005	1.47E+08	1.23E+07	403,370	280
	31-47168	2006	1.36E+08	1.14E+07	373,238	259
	31-47168	2007	1.28E+08	1.07E+07	351,660	244
Winslow Twp MUA Sicklerville Well 2	31-05543	2003	4.00E+03	3.33E+02	11	0
	31-05543	2004	0.00E+00	0.00E+00	0	0
	31-05543	2005	0.00E+00	0.00E+00	0	0
	31-05543	2006	3.95E+07	3.29E+06	108,315	75
	31-05543	2007	1.88E+08	1.57E+07	515,255	358
Winslow Twp MUA Sicklerville Well 1	31-05542	2003	2.50E+08	2.09E+07	686,036	476
	31-05542	2004	2.50E+08	2.08E+07	684,759	476
	31-05542	2005	2.05E+08	1.71E+07	562,164	390
	31-05542	2006	1.58E+07	1.32E+06	43,271	30
	31-05542	2007	1.79E+07	1.49E+06	49,079	34
Winslow Twp MUA Sicklerville Well 4	31-05578	2003	3.92E+06	3.26E+05	10,726	7
	31-05578	2004	4.23E+06	3.52E+05	11,581	8
	31-05578	2005	4.61E+06	3.84E+05	12,625	9
	31-05578	2006	4.90E+06	4.08E+05	13,411	9
	31-05578	2007	2.77E+06	2.31E+05	7,595	5

Source : NJDEP Preliminary data

APPENDIX B

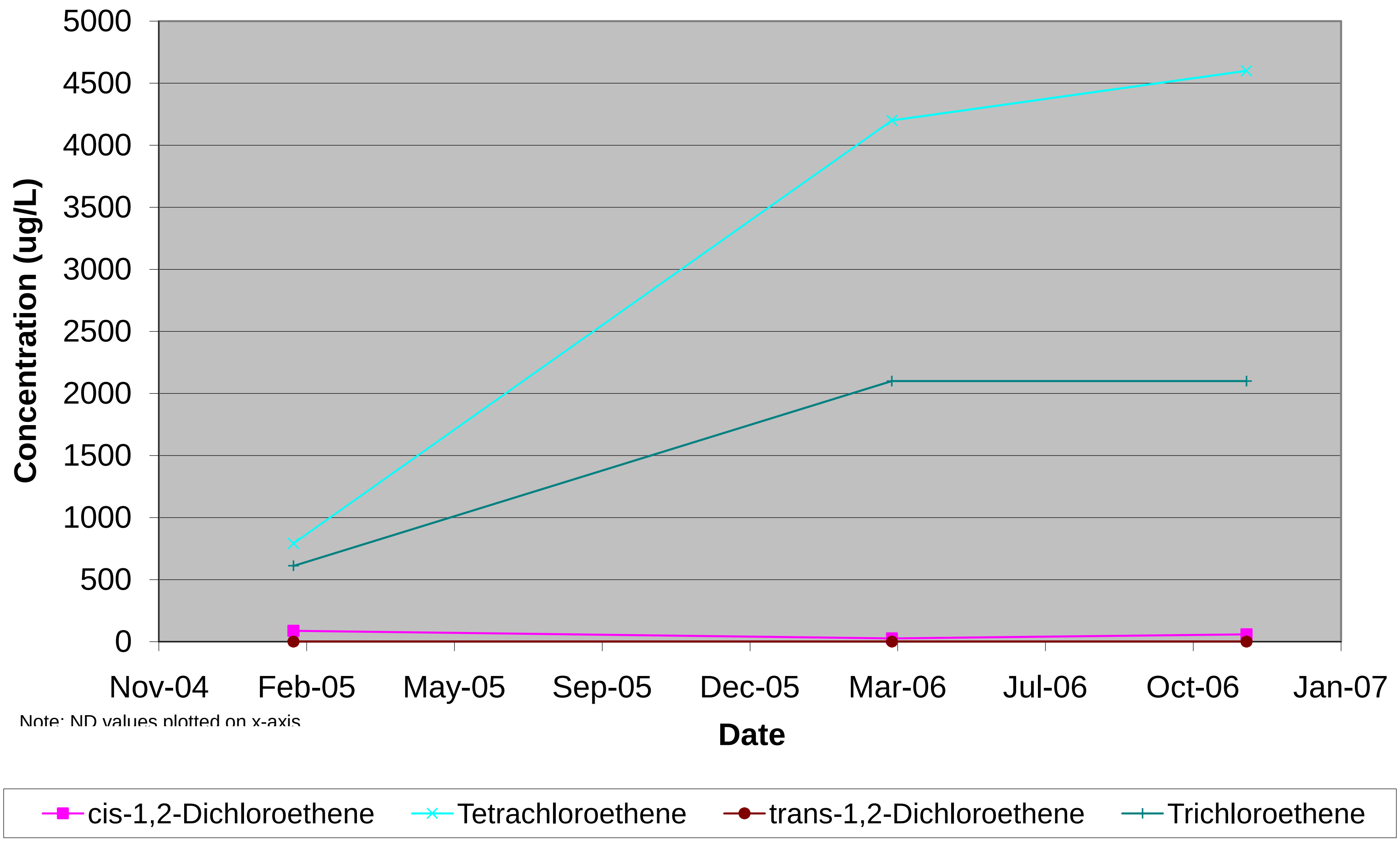
GROUNDWATER CONCENTRATION TIME TRENDS

MW-2A

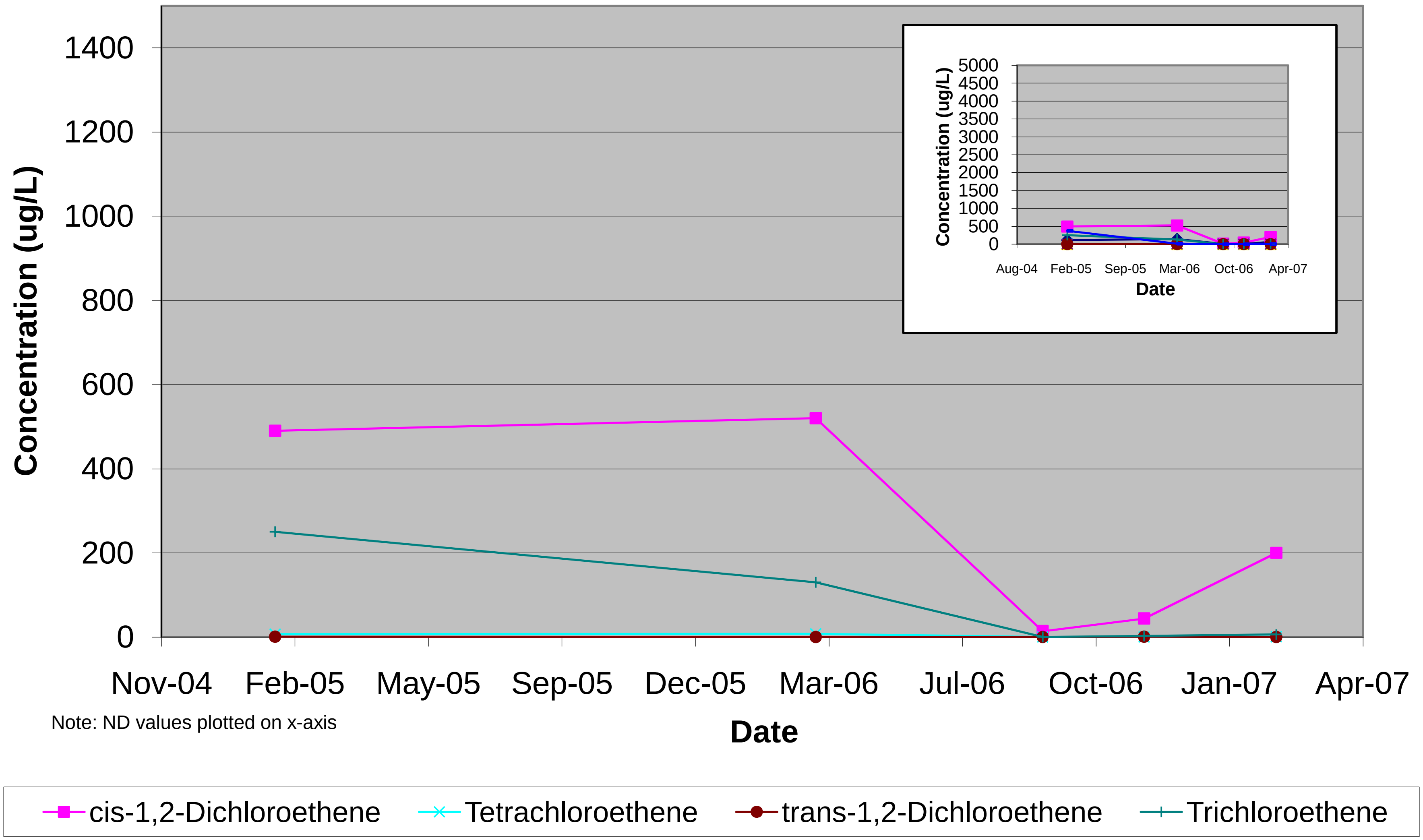


Note: ND values plotted on x-axis

MW-8A

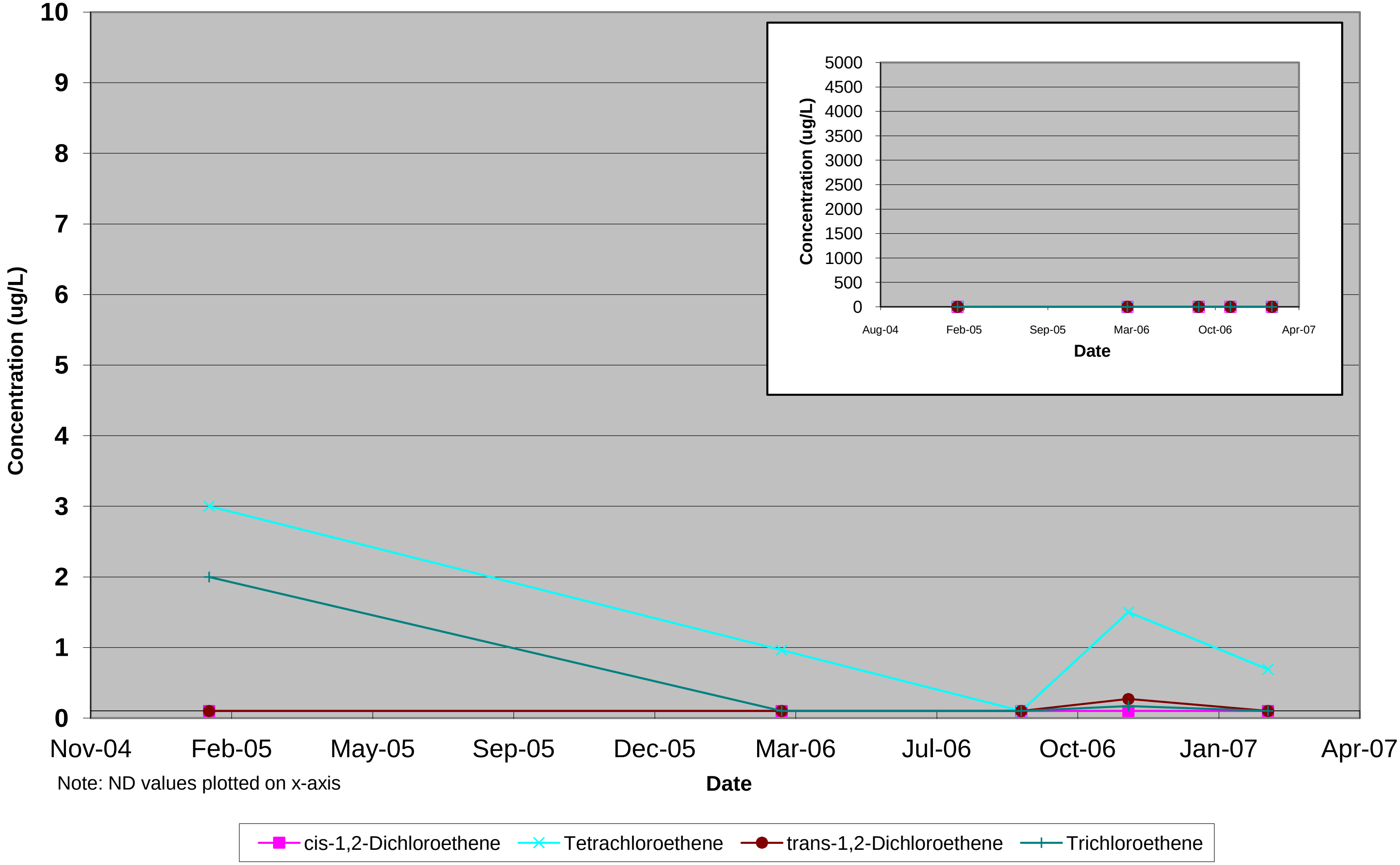

5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Concentration (ug/L)
Nov-04
Feb-05
May-05
Sep-05
Dec-05
Mar-06
Jul-06
Oct-06
Jan-07
Note: ND values plotted on x-axis
Date
cis-1,2-Dichloroethene
Tetrachloroethene
trans-1,2-Dichloroethene
Trichloroethene

MW-12



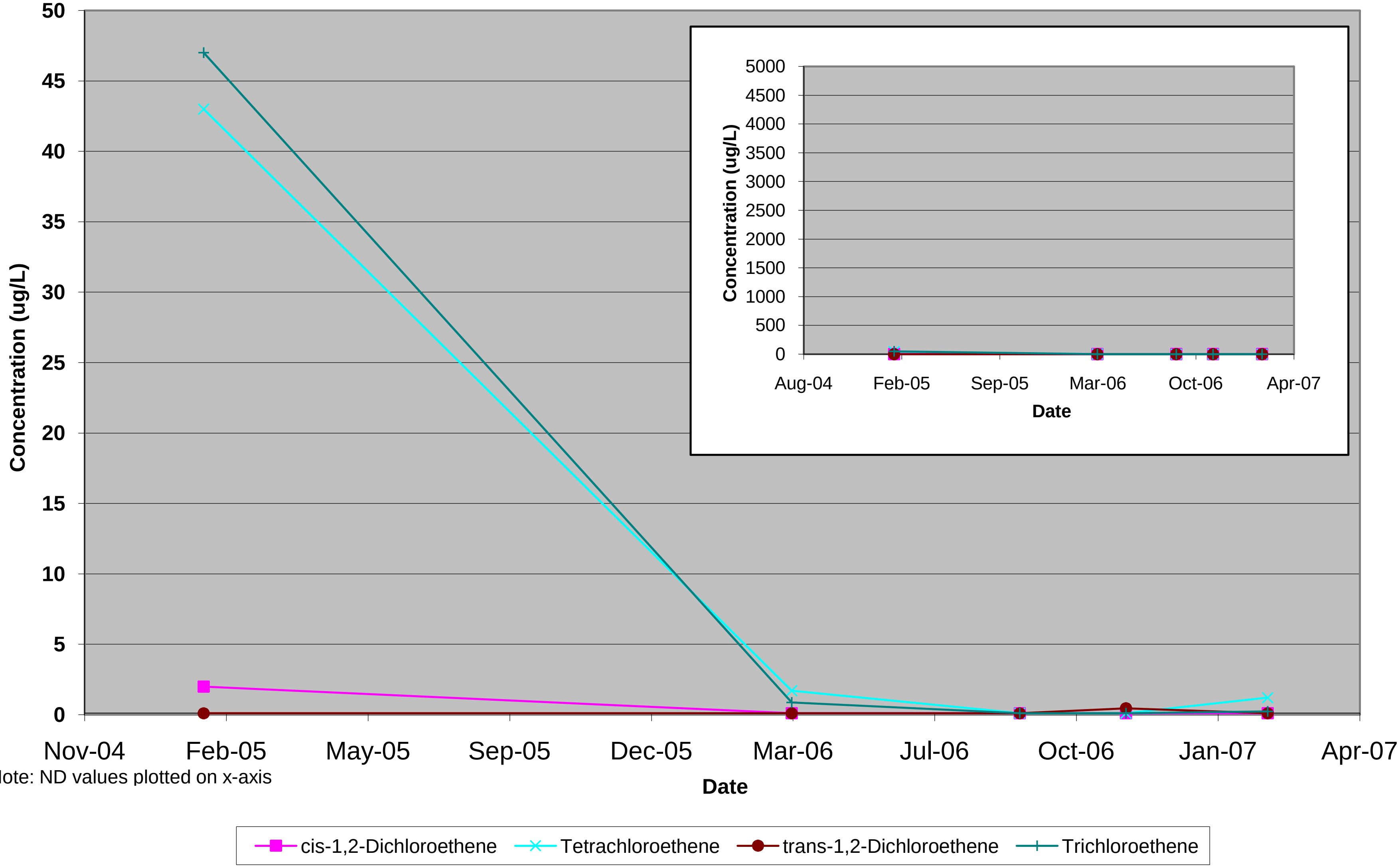
Note: ND values plotted on x-axis

MW-15



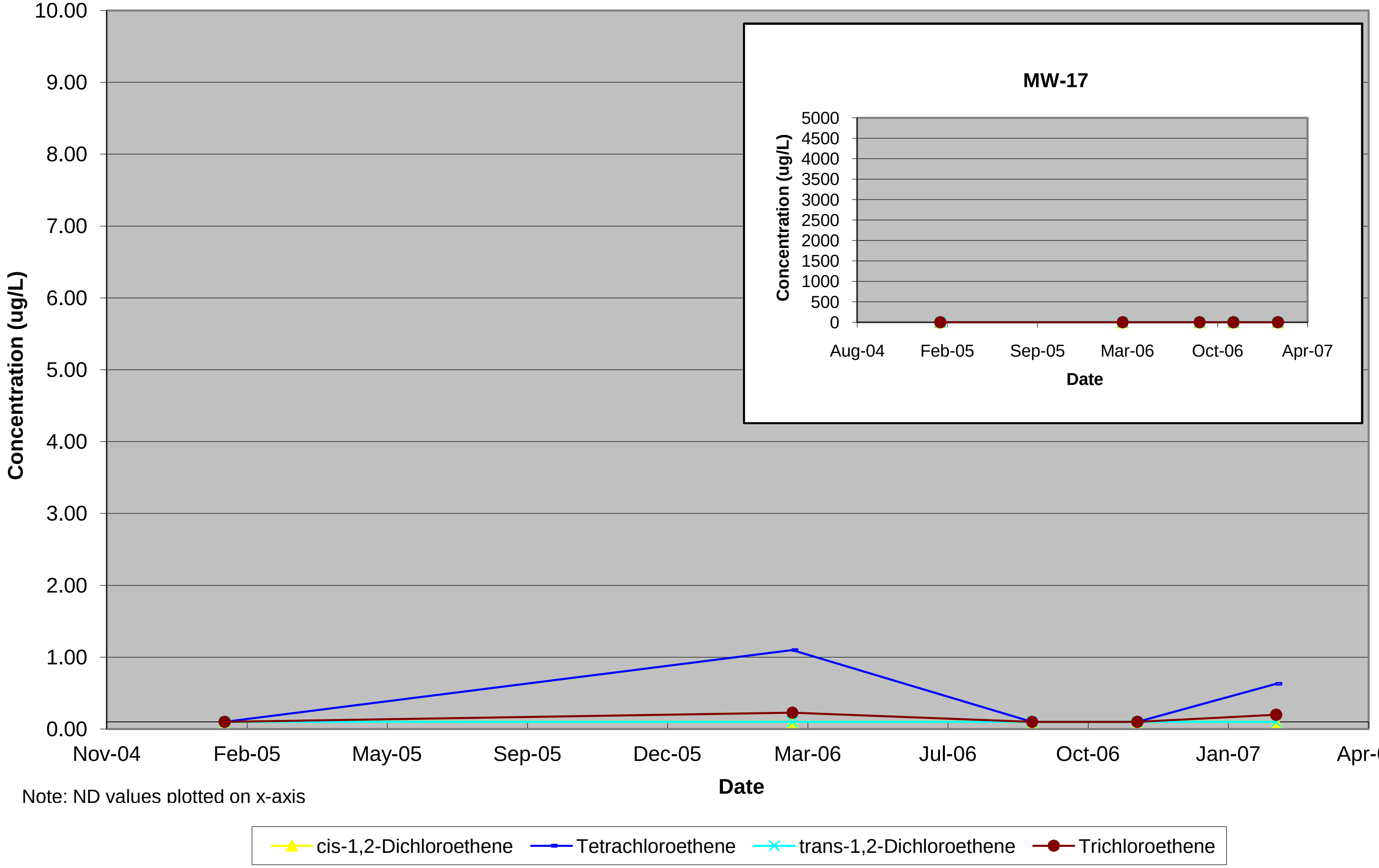
Note: ND values plotted on x-axis

MW-16

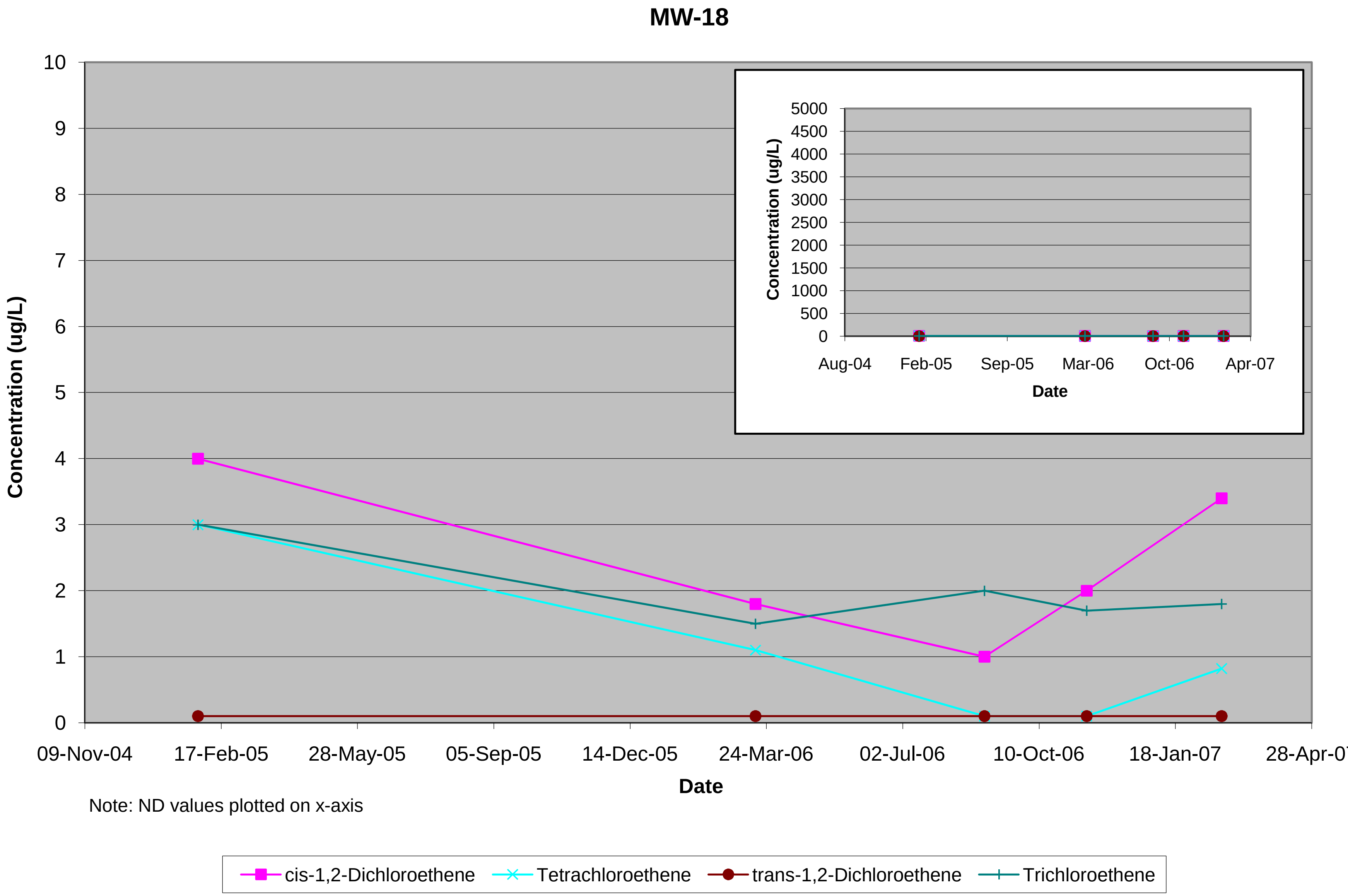


Note: ND values plotted on x-axis

MW-17



Note: ND values plotted on x-axis



Note: ND values plotted on x-axis

APPENDIX C

AS/SVE CONCEPTUAL DESIGN CALCULATIONS

Golder Associates	SUBJECT Lightman Drum – Conceptual (FS) AS/SVE		
	Job No. 013-6054 Ref.	Made by S.D. GLAZ Checked DNB 12/20/07 Reviewed APJ 12/21/07	Date 12/10/2007 Sheet 1 of 5

Plume defined as within 100 ug/L total VOCs in GW

Known Parameters

- Depth to Groundwater 10-12 ft bgs
- Soil = Sandy – No Know len's
- maximum depth to bottom of plume. = 40 ft

Assumed Parameters – No Field Data Available

- Airsparge
  - Radius of Influence @ 10ft above injection screen is 20 ft Based upon guidance of
    1/2 (psi – hydraulic head) + (depth below plume @ injection x Tan (θ))

    or $1/2(10) + (10)(\tan(53)) = 18.3$ say 20 ft
  - Soil Density = 2.70
  - Pore space ratio = 35% (0.35)
  - Air injection rate (5-30 norm)
    SAY 20 scfm (independent of head)
  - minimum injection Depth = 30 ft

Soil Vapor Extraction

- Radius of influence = 40 ft
  Reduced for sandy soil due to shallow depth
- ID of Wells = 4" min
- Surface is considered 90% impervious
- Ratio of SVE Extraction Rate to Air Sparge is 2:1 (scfm)
- friction loss in piping = 30" wc

Golder Associates	SUBJECT Lightman Drum - Conceptual design AS/SVE		
	Job No. 013-6054 Ref.	Made by SGlazier Checked DNB 12/20/07 Reviewed APJ 12/21/07	Date 12/11/07 Sheet 2 of 5

Air Sparge

Minimum Air pressure @ injection (max depth: 50 bgs)

= hydraulic head + 5 psig
= ((50-10)(62.34)/144) + 5 = 22.3 psig

Maximum Air pressure @ injection pt (depth = 40 ft)
(prevent liquification)

= wt of soil column
40 (2.70)(62.34)(1-0.35) /144 = 30.4 psi
= wt of water column
= (40-10)(1)(62.34)(0.35) /144 = 4.6 psi
Total = 35 psig

∆ Assume Average injection pressure is 30 psig

Air useage per well

- Avg flow rate = 20 scfm
- Avg injection pressure = 30 psig

flow = 20 scfm @ 0 psig

$$= \frac{20\,(14.7)}{(30+14.7)} = 6.6 \text{ cfm @ } 30 \text{ psig}$$

Total Injection volume

	#wells	Rate	Operation	Net
Source Area (West Plume)	= 20	20	100%	= 400
Down gradient (West plume)	= 11	20	35%	= 77
Source Area (East plume)	= 15	20	100%	= 300
Down gradient (East plume	= 22	20	35%	= 154
Total				931 scfm

Total @ all wells 100% operation = 931
77 / (1-0.35) = 143
154 / (1-0.35) = 286
1360 scfm

Golder Associates	SUBJECT Lightman Drum - Conceptual Design AS/SVE		
	Job No. 013-6054 Ref. Feasibility Study	Made by SGLAZIER Checked DNB 12/20/07 Reviewed APJ 12/21/07	Date 12/11/07 Sheet 3 of 5

Air Sparge Equipment

Air Compressor - 75% on-off

Flow Rating @ 100 psig

$$= \frac{931}{.75} \times \left(\frac{14.7}{100+14.7}\right) \times 1.15\,(\text{loss}) \cong 185 \text{ cfm@100 psig}$$

Horsepower requirement (1/4 hp/scfm @ 100 psig)

= 185 (1/4) = 46 Hp say 50 Hp

Soil Vapor Extraction

- Extraction Rate (2x injection Rate)

  Assume 100% operation

  Total Rate = 1360 scfm x 2 = 2720 scfm

- Extraction Rate from single well

  Assume worst Ration Air Sparge wells to SVE wells

  = 4/3 (west plume down gradient)

  - Injection Rate = 20 scfm x 4 wells = 80 scfm
  - Extraction Rate, per well = 80 (2) / 3 wells = 53.3 scfm

  Extraction Rate per lin ft of well screen =

  $$= \frac{53.3}{5 \text{ ft/well}} \cong \cancel{1.08}\ 10.8 \text{ DNB scfm per screen}$$

  (on high end of range)

Assume Horizontal Trench

$$\text{Rate per lin ft} = \frac{53.3}{130 \text{ ft}} = 0.41$$

evaluate Trenches for pilot

Golder Associates			
SUBJECT Lightman Drum - Conceptual (FS)(AS/SVE)			
Job No. Ref. 013-6054	Made by SGLAZER Checked DNB 12/21/07 Reviewed APJ 12/21/07	Date 12/17/07	Sheet 4 of 5

Soil Vapor Extraction

Equipment requirements

- Assume 24 inch wc @ wellhead (limit upswelling)
- Assume 24 inch wc friction losses

therefore Total Requirements are 2720 Scfm @ at 50" wc

$$= \text{approx } 2720 \Big/ \left[\frac{(14.7 - 1.0 - 0.5)}{14.7}\right] = 3030 \text{ icfm @ } 50'' \text{wc}$$

Horsepower estimate = 175 Hp
(vendor cutsheet)

Carbon Vessels

Assume 2 systems @ 60/40 ration East/West

Flow rate = (2720 * 0.60) = 1600 scFm

Based upon flow rate vessel is approx 8,000 # capacity

- Carbon changeout - undeterminable with information available

Golder Associates	SUBJECT Lightman Drum - Conceptual (FS) Air Sparge/SVE		
	Job No. 013-6054 Ref.	Made by SGLAZIER Checked DWB 12/20/07 Reviewed APJ 12/21/07	Date 12/17/07 Sheet 5 of 5

O&M items

Utility

Electric

- Air Sparge = 50 Hp @ 75% operat = 37.5 Hp
- SVE blowers = 75 Hp
- Air Dryers = 5 Kw = 10 Hp equivalent
- Building Misc = 3 kw = 5 Hp equivalent
- Building Vent/Heat = 5 Kw = 10 Hp equivalent
- Heat Exchanger = 3 Kw = 5 Hp equivalent

Total = 142.5 Hp say 140

Kwh = 140 (0.747 x 1) = 105 Kwh

Cost = 105 x 24 x 365 x 10¢ x 85% operation

≅ $78,000

APPENDIX D

ISCO CONCEPTUAL DESIGN CALCULATIONS

Appendix D
ISCO Conceptual Design Calculations
Revised Lightman Drum Feasibility Study
Winslow Township, NJ

Calculation	Value	Units	Assumptions	Notes
Oxidant Requirements				
		Eastern Plume		
Surface Area of Eastern Plume >1000 ppb	71,610	square feet		contours based on 2006 well concentrations for total VOCs
Pore Volume of Eastern Plume >1000 ppb	358,050	cubic feet	0.20	porosity, 25 feet thick in vertical
Pore Volume of Eastern Plume >1000 ppb	10,139,976	L	28.32	L/cubic foot
Volume of 100% H2O2 needed	506,999	L	0.05	amount of pore volume represents NOD
Mass of 100% H2O2 needed	727,543	kg	1.44	kg/L density of 100% H2O2
Mass of 35% H2O2 needed	2,078,695	kg	0.35	kg H2O2 per kg of 35% H2O2
		Western Plume		
Surface Area of Western Plume	22,205	square feet		contours based on 2006 well concentrations for total VOCs
Pore Volume of Western Plume	111,025	cubic feet	0.20	porosity, 25 feet thick in vertical
Pore Volume of Western Plume	3,144,228	L	28.32	L/cubic foot
Volume of Permanganate needed	157,211	L	0.05	amount of pore volume represents SOD
Mass of Permanganate needed	9,433	kg	0.06	kg/L volume to mass converson

Table made by MJB
Checked by HAL

APPENDIX E

GROUNDWATER EXTRACTION MODEL

APPENDIX E

CONCEPTUAL GROUNDWATER EXTRACTION SYSTEM

A conceptual groundwater extraction system was developed based on capture zone calculations using the method described by Todd (Todd, D.K., Groundwater Hydrology, 1980, pp. 121-123):

$x = Q / (2p\ T\ I)$

$2y = 2Q / (2\ T\ I)$,

where:

x = stagnation point measured from the pumping well in the downgradient direction [feet];
y = half width of the capture zone [feet];
2y= capture zone width [feet]
T = aquifer transmissivity [$feet^2$/day], calculated by multiplying the aquifer hydraulic conductivity (K measured in feet/day) by aquifer thickness (B measured in feet)
T = K B;
I = Horizontal hydraulic gradient [feet/foot]; and,
Q = groundwater pumping rate [feet3/day].

Table E-1 presents the input variables and the results of these calculations.

The following input parameters were used for these calculations:

- The horizontal hydraulic conductivity value of $2.1x10^{-2}$ cm/s is based on the slug test results;
- The aquifer thickness was selected to be 35 feet, corresponding the maximum estimated plume thickness;
- The horizontal hydraulic gradient was $2.1x10^{-3}$ feet/foot, based on groundwater elevation data;
- Groundwater pumping rates for individual extraction wells are estimated to range from 5 gpm to 10 gpm, respectively.

This evaluation includes some simplifying assumptions. For example, the evaluation cannot account for partially penetrating wells; therefore, the aquifer thickness was estimated to be equal to the plume thickness (35 feet).

The calculation results indicate that for a pumping rate of 10 gpm the capture zone width of an individual pumping well is in excess of 400 feet, while the capture zone width corresponding to 5 gpm is in excess of 200 feet (see Tables E-1 and E-2). Based on this evaluation it is estimated that one well capable of extracting groundwater at rates ranging from 5 gpm to 10 gpm can be used to control the "hot spots" identified within the plume area.

An estimation of the plume mass is provided in Table E-3 based on a conservative representation of the groundwater contamination on Figure E-1. This Figure combines the highest measured concentrations at all locations irrespective of the timing of the measurements. As such, it represents an overestimate of the plume mass. The mass calculation was made by measuring the area between adjacent isoconcentration contours and multiplying the area by the plume thickness. The thickness was estimated to be about 25 feet for the core of the plume (see plume cross section included on Figure 2-12) and 35 feet for the remainder of the plume, respectively. The calculated total plume mass is approximately 175 kg. Downgradient of the source treatment area the estimated plume mass is approximately 76 kg.

The mass removal rate of the "hot spot" extraction well was estimated based on the average plume concentration in the downgradient area and extraction well pumping rates as shown on Table E-4. On average the extraction well would remove about 1 kg to 2 kg of total VOCs per year (see Table E-4).

The actual mass removal rate of the extraction well is expected to be more variable for the following reasons:

- Plume concentrations are expected to decrease with time as a result of addressing the source area. As a result, the extraction system initial mass removal rates of 1 kg to 2 kg per year is expected to decrease with time to lower levels;
- Historic mass transfer from the source area to the aquifer did not take place at a constant rate resulting in contaminant slug releases from the source area. As a result, VOC "hot spots" are observed downgradient of the source. This will in turn result in variable concentrations at the location of the extraction wells; and,
- Although reductive dechlorination is not a dominant process downgradient of the source, other biotic and abiotic processes will degrade chlorinated solvents. Contaminant mass within the aquifer is expected to be reduced at a low rate[1] (see Section 2.6.4 for

[1]Contaminant degradation with a half-life of 13 years is an estimated slow degradation rate for aerobic TCE degradation referenced in the literature (see Section 5.1.3). At this rate, degradation will reduce the downgradient plume mass by ~25 percent in 5 years, ~45 percent in 10 years, and ~65 percent in 20 years.

additional details) which in turn will result in a continuous decrease in concentration of extracted groundwater.

Based on the above, it is expected that the concentration of extracted groundwater will decrease with time and an asymptotic level may be reached. In addition, it is expected that the location of the higher plume concentration areas ("hot spots") may vary over time. The efficiency of the extraction system would need to be re-evaluated on an annual basis and pumping rates of extraction well might be modified to respond to "hot-spot" position changes or the system operation might be terminated because of low VOC concentrations resulting in a *de minimis* mass removal rate.

Estimated Drawdown for Conceptual Extraction System Design

Steady State Radial Flow to a Well in Unconfined Aquifer with Uniform Recharge and Pumping Interference between Two Wells

Hydraulic head as a function of radial distance for
1) unconfined aquifer and radius of influence (R) from Todd, D.K., 1980, pp. 120.

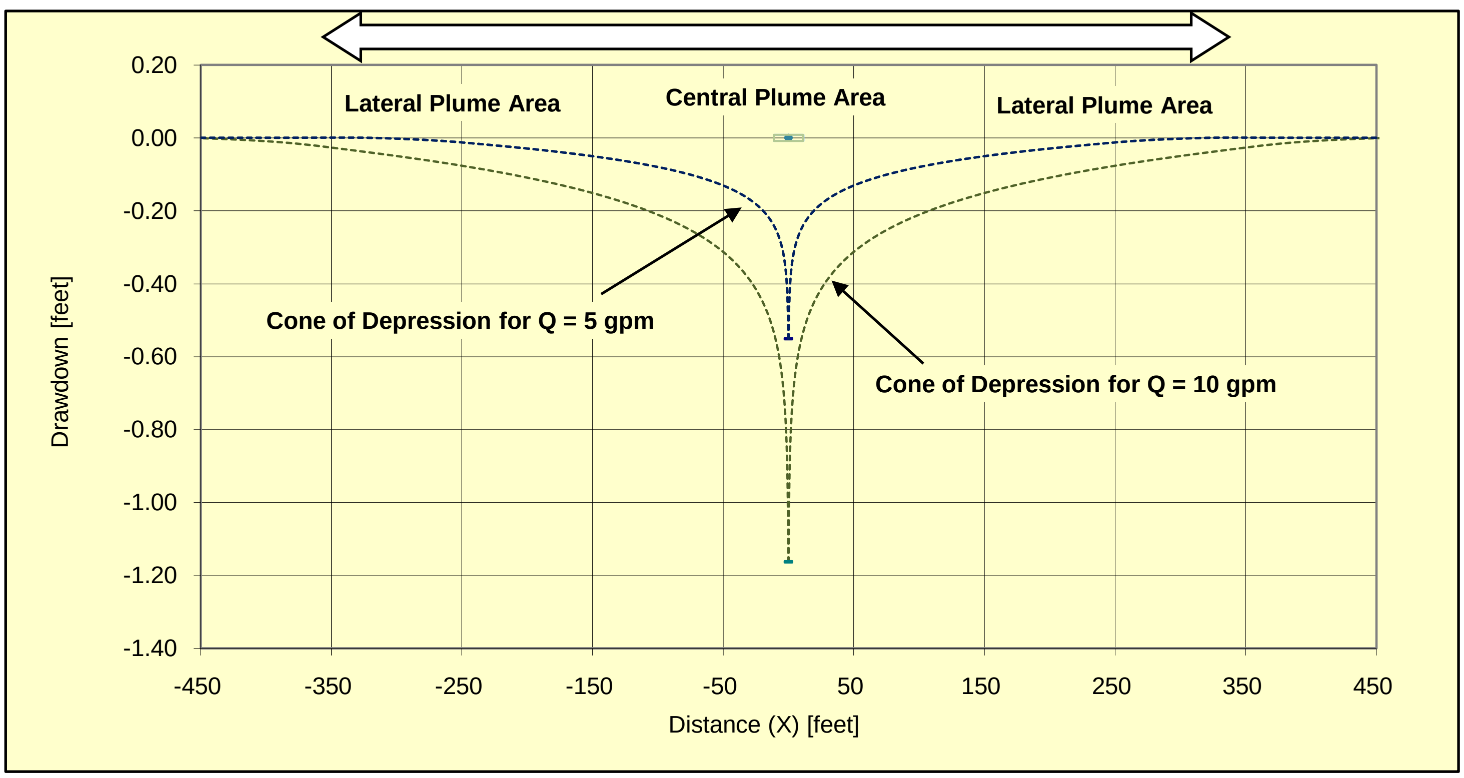
$$h = \left(H^2 - \frac{Q}{\pi K} \ln \frac{R}{r} \right)^{1/2} \qquad R = \left(\frac{Q}{\pi W} \right)^{1/2}$$

2) unconfined aquifer with uniform recharge (W) from Todd, D.K., 1980, pp. 120.

$$h = \left(H^2 - \frac{W}{2K}\left(r^2 - R^2\right) - \frac{Q}{\pi K} \ln \frac{R}{r} \right)^{1/2}$$

where:
- K = Horizontal hydraulic conductivity [L/T]
- b = Aquifer thickness [L]
- T = Transmissivity [L^2/T]
- I = Hydraulic gradient [L/L]
- H = Initial hydraulic head above reference [L]
- Z = Reference elevation [L]
- W = Infiltration [L/T]
- R = Calculated radius of influence [L]
- r_w = Well radius [L]
- s_w = Drawdown at the well [L]
- Q = Pumping rate [L^3/T]
- h = Calculated hydraulic head [L]
- r = Radial distance [L]

	Aquifer Data				Well Data		
	Zone 1	Zone 2			Well 1	Well 2	
K =	2.1E-02	2.1E-02	[cm/s]	Q =	5.0	10.0	[gpm]
K =	60	60	[ft/day]	Q =	962.5	1925	[ft^3/day]
b =	35.0	35.0	[ft]	r_w =	0.17	0.17	[ft]
T=	2100.0	2100.0	[ft^2/day]	Pumping	Yes	Yes	
I =	2.10E-03	2.10E-03	[ft/day]	Reinjection	No	Yes	
H =	35.00	35.00	[ft]	Well Location Xi=	0.00	0.00	[ft]
W =	15.0	15.0	[in/year]	Well Spacing DX=	0.00		[ft]
W =	3.4E-03	3.4E-03	[ft/day]	R =	299	423	[ft]



Golder Associates

Estimated Drawdown for Conceptual Extraction System Design

Water Level above the Base of the Aquifer		Individual Drawdown		Distance for Well 1		Distance for Well 2	
Well 1	Well 2	Well 1	Well 2	r for x<X1	r for x>X1	r for x<X2	r for x>X2
[5 gpm]	[10 gpm]	[5 gpm]	[10 gpm]				
[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]
34.45	33.84	-0.55	-1.16	-0.17	0.17	-0.17	0.17
34.47	33.87	-0.53	-1.13	-0.21	0.21	-0.21	0.21
34.48	33.91	-0.52	-1.09	-0.26	0.26	-0.26	0.26
34.50	33.94	-0.50	-1.06	-0.33	0.33	-0.33	0.33
34.51	33.97	-0.49	-1.03	-0.40	0.40	-0.40	0.40
34.53	34.00	-0.47	-1.00	-0.49	0.49	-0.49	0.49
34.54	34.03	-0.46	-0.97	-0.60	0.60	-0.60	0.60
34.56	34.06	-0.44	-0.94	-0.73	0.73	-0.73	0.73
34.57	34.09	-0.43	-0.91	-0.89	0.89	-0.89	0.89
34.59	34.12	-0.41	-0.88	-1.08	1.08	-1.08	1.08
34.60	34.15	-0.40	-0.85	-1.31	1.31	-1.31	1.31
34.62	34.17	-0.38	-0.83	-1.58	1.58	-1.58	1.58
34.63	34.20	-0.37	-0.80	-1.91	1.91	-1.91	1.91
34.64	34.23	-0.36	-0.77	-2.30	2.30	-2.30	2.30
34.66	34.26	-0.34	-0.74	-2.77	2.77	-2.77	2.77
34.67	34.29	-0.33	-0.71	-3.33	3.33	-3.33	3.33
34.68	34.31	-0.32	-0.69	-4.01	4.01	-4.01	4.01
34.70	34.34	-0.30	-0.66	-4.82	4.82	-4.82	4.82
34.71	34.37	-0.29	-0.63	-5.80	5.80	-5.80	5.80
34.72	34.40	-0.28	-0.60	-6.97	6.97	-6.97	6.97
34.74	34.42	-0.26	-0.58	-8.37	8.37	-8.37	8.37
34.75	34.45	-0.25	-0.55	-10.06	10.06	-10.06	10.06
34.77	34.48	-0.23	-0.52	-12.08	12.08	-12.08	12.08
34.78	34.50	-0.22	-0.50	-14.51	14.51	-14.51	14.51
34.79	34.53	-0.21	-0.47	-17.42	17.42	-17.42	17.42
34.81	34.56	-0.19	-0.44	-20.91	20.91	-20.91	20.91
34.82	34.59	-0.18	-0.41	-25.11	25.11	-25.11	25.11
34.83	34.61	-0.17	-0.39	-30.14	30.14	-30.14	30.14
34.85	34.64	-0.15	-0.36	-36.18	36.18	-36.18	36.18
34.86	34.67	-0.14	-0.33	-43.43	43.43	-43.43	43.43
34.87	34.69	-0.13	-0.31	-52.12	52.12	-52.12	52.12
34.89	34.72	-0.11	-0.28	-62.56	62.56	-62.56	62.56
34.90	34.75	-0.10	-0.25	-75.08	75.08	-75.08	75.08
34.91	34.77	-0.09	-0.23	-90.10	90.10	-90.10	90.10
34.93	34.80	-0.07	-0.20	-108.13	108.13	-108.13	108.13
34.94	34.83	-0.06	-0.17	-129.77	129.77	-129.77	129.77
34.95	34.85	-0.05	-0.15	-155.74	155.74	-155.74	155.74
34.97	34.88	-0.03	-0.12	-186.90	186.90	-186.90	186.90
34.98	34.91	-0.02	-0.09	-224.28	224.28	-224.28	224.28
34.99	34.93	-0.01	-0.07	-269.15	269.15	-269.15	269.15

Table E-2
Capture Zone Calculation

WELL	HYDRAULIC CONDUCTIVITY		AQUIFER THICKNESS	TRANSMISSIVITY	HYDRAULIC GRADIENT	FLOW RATE		STAGNATION POINT COORDINATES (y=0)	WIDTH OF THE CAPTURE ZONE (2y)	
	K (CM/S)	K (FT/DAY)	B (FT)	T (sqFT/DAY)	I (FT/FT)	Q (GPM)	Q (cuFT/DAY)	x = Q / (2p T I) (FT)	y = Q / (2 T I) (FT)	2y (FT)
Extraction Well Pumping at 5 gpm	2.1E-02	60.0	35.0	2100	2.10E-03	**5.00**	**963**	35	109	218
Extraction Well Pumping at 10 gpm	2.1E-02	60.0	35.0	2100	2.10E-03	**10.00**	**1925**	69	218	437

Table E-3
Calculation of Dissolved Phase Plume Mass and Average Concentration in the Source and Downgradient Areas

Plume	Concentration*	Area	Thickness	Porosity	Volume		Mass	Cumulative Volume	Cumulative Mass	Average Concentration	Treatment System
	C	A	B	n	V = n A B		M = C V	S Vi	S Mi	Ci = S Mi / S Vi	
	[ug/L]	[ft^2]	[ft]	[-]	[ft^3]	[L]	[kg]	[L]	[kg]	[ug/L]	
East Plume Source Area (AS Treatment)	81,930	3,541	25	30.00%	26,558	752,108	61.6	752,108	61.6	81,930.0	Source Area Treatment
	1,533	42,658	25	30.00%	319,935	9,060,559	13.9	9,812,668	75.5	7,695.2	
	860.8	120,884	25	30.00%	906,630	25,675,762	22.1	35,488,429	97.6	2,750.5	
East Plume Downgradient Area	860.8	181,326	25	30.00%	1,359,945	38,513,642	**33.2**	74,002,072	130.8	1,767.0	Downgradient Treatment System Pump&Treat/MNA
	523.4	121,414	25	30.00%	910,605	25,788,334	**13.5**	99,790,405	144.3	1,445.6	
	45.9	160,241	35	30.00%	1,682,531	47,649,264	2.2	147,439,669	146.4	993.3	
	92	925,266	35	30.00%	9,715,293	275,137,098	25.3	422,576,767	171.8	406.5	
	7	902,136	35	30.00%	9,472,428	268,259,161	1.9	690,835,928	**173.6**	251.3	
Total Source							97.6	35,488,429		2,750.5	
Downgradient and Captured by Hot-Spot Extraction Well							**46.7**				
Downgradient not Captured by Hot-Spot Extraction Well							29.4				
Total Downgradient							**76.0**	655,347,498		116.0	
Total East							**173.6**	690,835,928		251.3	

Notes:

* Selected concentration within an isoconcentration contour is based on the highest total VOC concentration over the investigation period within the contour area and distributed over the entire thickness of the plume.

Lighter shaded area shows source area calculations

Darker shaded area shows calculations for areas downgradient of the source area treatment

Table E-4
Calculation of Extraction Systems Mass Removal Rates

Plume	Extraction Well Concentration	Extraction Well Pumping Rates		Extraction Well Mass Removal Rates	
	C_E	Q_E		$M_E = Q_E C_E$	
	[ug/L]	[gpm]	[L/day]	[kg/day]	[kg/year]
East Plume Downgradient Area	116.0	5	27,261	3.16E-03	1.15
	116.0	10	54,522	6.33E-03	2.31

Monitored Natural Attenuation & Institutional Controls				
Activity	**Unit Costs**	**Units**	**Quantity**	**Estimated Cost**
Long Term Access Agreement				
Legal	$50,000	Lump Sum	1	$50,000
TOTAL LONG TERM ACCESS AGREEMENT COST				**$50,000**
Initial Capital Cost				
Workplan	$100	Hrs	250	$25,000
CEA Application	$100	Hrs	150	$15,000
Installation of Sentinel and Plume Wells				
Drilling Costs				
Mobilization & Demobilization	$1,500	Lump Sum	1	$1,500
HAS Daily Rig Rate	$2,000	EA	7	$14,000
Well Material	$42	foot	220	$9,240
Flush mount	$250	EA	1	$250
IDW drums	$50	EA	18	$900
Other Costs				
Oversight	$85	Hrs	80	$6,800
Field Equipment	$3,350	Lump Sum	1	$3,350
Well Logs	$85	Hrs	12	$1,020
Well Permits	$130	EA	3	$390
TOTAL INITIAL CAPITAL COST				**$77,450**
Monitoring - Quarterly Years 1 & 2				
Sampling Costs				
Staffing	$75	Hr.	140	$10,500
Field Equipment	$6,868	Lump Sum	1	$6,868
Shipping	$140	day	7	$980
IDW drums	$50	EA	4	$200
Analytical Costs				
Analysis	$11,377	Event	1	$11,377
Data Validation	$100	Hr.	22	$2,200
Reporting Costs				
Quarterly Monitoring Report	$10,000	Lump Sum	1	$10,000
Annual Costs				$168,496
Reporting Costs				
Annual Monitoring Report	$15,000	Lump Sum	1	$15,000
5-year review (split among years)	$10,000	Lump Sum	0.2	$2,000
Biennial CEA certifications (split among years)	$5,000	Lump Sum	0.5	$2,500
Annual Costs				$19,500
Project Management	$25,000	Lump Sum	1	$25,000
TOTAL ANNUAL MONITORING COST - YEARS 1 & 2 (QUARTERLY MONITORING)				**$212,996**
Monitoring - Semi-Annual Years 3 through 30				
Sampling Costs				
Staffing	$75	Hr.	140	$10,500
Field Equipment	$6,868	Lump Sum	1	$6,868
Shipping	$140	day	7	$980
IDW drums	$50	EA	4	$200
Analytical Costs				
Analysis	$11,377	Event	1	$11,377

Monitored Natural Attenuation & Institutional Controls

Activity	Unit Costs	Units	Quantity	Estimated Cost
Data Validation	$100	Hr.	22	$2,200
Reporting Costs				
Quarterly Monitoring Report	$10,000	Lump Sum	1	$10,000
SUBTOTAL - Single Monitoring Event				*$42,124*
Total Annual Sampling Cost (2 sampling events)	$42,124	Sampling Event	2	$84,248
Reporting Costs				
Annual Monitoring Report	$15,000	Lump Sum	1	$15,000
5-year review (split among years)	$10,000	Lump Sum	0.2	$2,000
Biennial CEA certifications (split among years)	$5,000	Lump Sum	0.5	$2,500
Total Annual Reporting Cost				$19,500
Project Management	$25,000	Lump Sum	1	$25,000
TOTAL ANNUAL MONITORING COST - YEARS 3 TO 30 (SEMI-ANNUAL MONITORING)				**$128,748**
Present Worth - Monitoring				
Quarterly				
Years of Monitoring	2	Years		
Discount Rate	7%	%		
PRESENT WORTH OF QUARTERLY MONITORING			**1.81**	**$385,101**
Semi-Annual				
Years of Monitoring	28	Years	**12.14**	
Years prior to Start	2	Years	**0.87**	
Discount Rate	7%	%		
PRESENT WORTH OF SEMI-ANNUAL MONITORING			**10.60**	**$1,364,862**
PRESENT WORTH - TOTAL MONITORING				**$1,749,963**

TOTAL PRESENT WORTH (ROUNDED TO NEAREST $10,000)	**$1,880,000**

Assumptions
installation of 3 wells, 1 to 100 ft bgs, and 2 to 60 ft bgs, and that one will be flushmount
monitoring of 26 wells, sampling for VOCs and MEEs
Sampling will take 2 people 7 days to sample all 26 wells

Source Area Air Sparge / Soil Vapor Extraction

Activity	Unit Costs	Units	Quantity	Estimated Cost
Long Term Access Agreement				
Legal	$50,000	Lump Sum	1	$50,000
Engineering	$50,000	Lump Sum	1	$50,000
Annual Rental (see Annual Operation and Maintenance)				
TOTAL LONG TERM ACCESS AGREEMENT COST				**$100,000**
Initial Capital Cost				
Engineering				
Design	$160,000	Lump Sum	1	$160,000
Workplans	$170,000	Lump Sum	1	$170,000
Construction Oversight	$180,000	Lump Sum	1	$180,000
System Startup	$50,000	Lump Sum	1	$50,000
Pilot Testing	$170,000	Lump Sum	1	$170,000
Capital Construction				
AS / SVE Well Fields and Piping				
Western plume				
Source Area Wells	$161,000	Lump Sum[1]	1	$161,000
Plume Area Wells	$189,000	Lump Sum[2]	1	$189,000
AS / SVE Main Headers	$106,000	Lump Sum[3]	1	$106,000
Eastern plume				
Source Area Wells	$212,000	Lump Sum[4]	1	$212,000
Plume Area Wells	$283,000	Lump Sum[5]	1	$283,000
AS / SVE Main Headers	$132,000	Lump Sum[3]	1	$132,000
Treatment Buildings	$920,000	Lump Sum	1	$920,000
Access Road / Utilites	$340,000	Lump Sum	1	$340,000
Contractor Overhead items	$290,000	Lump Sum	1	$290,000
Contingency	$3,363,000	percent	25%	$850,000
TOTAL INITIAL CAPITAL COST				**$4,213,000**
Annual Operation & Maintenance (O&M)				
Site Visits	$43,000	Lump Sum	1	$43,000
Maintenance	$20,000	Lump Sum	1	$20,000
Carbon Change outs	$16,500	EA	2	$33,000
Condensate Disposal	$15,000	Lump Sum	1	$15,000
Utility Costs	$100,000	Lump Sum	1	$100,000
Property Lease / Annual improvements	$5,000	Lump Sum	1	$5,000
Reporting	$1,250	Lump Sum	1	$1,250
Contingency	$200,750	percent	25%	$60,000
TOTAL ANNUAL O&M COST				**$277,250**
Years of O&M	5	Years		
Discount Rate	7%	%		
PRESENT WORTH OF ANNUAL O&M COST			**4.10**	**$1,136,780**
TOTAL PRESENT WORTH (ROUNDED TO NEAREST $10,000)				**$5,450,000**

1) Includes: 20 AS wells, 7 SVE wells, 3 piezometers, piping, instrumentation, liner, construction materials
2) Includes: 22 AS wells, 18 SVE wells, 3 piezometers, piping, instrumentation, liner, construction materials
3) Includes: piping and construction materials
4) Includes: 20 AS wells, 10 SVE wells, instrumentation, liner, construction materials
5) Includes: 22 AS wells, 18 SVE wells, instrumentation, liner, construction materials

Source Area ISCO

Activity	Unit Costs	Units	Quantity	Estimated Cost
Long Term Access Agreement				
Legal	$50,000	Lump Sum	1	$50,000
Improvements	$50,000	Lump Sum	1	$50,000
TOTAL LONG TERM ACCESS AGREEMENT COST				**$100,000**
Initial Capital Cost				
Engineering				
Project Management	$20,000	Lump Sum	1	$20,000
Workplans	$15,000	Lump Sum	1	$15,000
Reporting	$20,000	Lump Sum	1	$20,000
Permitting	$10,000	Lump Sum	1	$10,000
Pre-Dresign Investigation				
Bench- and Pilot-scale Testing	$300,000	Lump Sum	1	$300,000
Site improvements for access	$5,000	Lump Sum	1	$5,000
SUBTOTAL - One-time ISCO Design Costs				*$370,000*
Labor				
Injection Technicians (includes per diem)	$85	Hour	1,440	$122,400
Drilling Costs				
Mobilization & Demobilization	$1,000	EA	2	$2,000
Geoprobe Rig and Operator	$2,000	Day	30	$60,000
Materials (bentonite, pad, drums, etc.)	$62,000	Lump Sum		$62,000
Materials				
Safety Equipment	$20,000	Lump Sum	1	$20,000
Mobilization and Demobilization	$8,000	EA	2	$16,000
Analytical Samples	$100	Sample	150	$15,000
Acidity Samples	$50	Sample	300	$15,000
Equipment Rental	$64,100	Lump Sum		$64,100
Stone	$20,000	Lump Sum	1	$20,000
Misc. Supplies	$2,500	Lump Sum	1	$2,500
H&S Supplies - consumables	$40,000	Lump Sum	1	$40,000
Security	$25,000	Lump Sum	1	$25,000
Shipping, Travel, Vehicles	$40,000	Lump Sum	1	$40,000
IDW	$5,000	Lump Sum	1	$5,000
Monitoring				
Performance Monitoring	$15,000	Lump Sum	1	$15,000
Reagent Costs				
Fenton's Reagent*	$0.55	kg	2,078,695	$1,143,282
Permanganate*	$4	kg	9,433	$37,732
SUBTOTAL - Single ISCO Injection Event				*$1,705,014*
Total ISCO cost (multiple injections†)	$1,705,014	Injection Event	3	$5,115,043
Contingency	$5,115,043	Percent	50%	$2,557,521
TOTAL INITIAL CAPITAL COST				**$8,042,564**

TOTAL COST (ROUNDED TO NEAREST $10,000)	**$8,150,000**

Note: Highlighted costs have significantly higher uncertainty
* reagent demand based on 5% pore-volume replacement with oxidant
pore-volume based on areal extent of treatment with 25' aquifer thinkness
† 3 injection events used for cost estimating purposes
Contingency is based on total cost of ISCO injections.

Downgradient Pump, Treat, Re-injection				
Activity	**Unit Costs**	**Units**	**Quantity**	**Estimated Cost**
Long Term Access Agreement				
Legal	$100,000	Lump Sum	1	$100,000
Engineering	$100,000	Lump Sum	1	$100,000
Annual Rental (see Annual Operation and Maintenance)				
TOTAL LONG TERM ACCESS AGREEMENT COST				**$200,000**
Initial Capital Cost				
Additional Subsurface Evaluation				
Workplan	$100	Hrs	100	$10,000
HydroPunch	$3,000	Days	5	$15,000
Field Geologist	$100	Hrs	50	$5,000
Laboratory Analytical	$375	EA	80	$30,000
Reporting	$20,000	Lump Sum	1	$20,000
Engineering				
Design	$40,000	Lump Sum	1	$40,000
Workplans	$50,000	Lump Sum	1	$50,000
Construction Oversight	$45,000	Lump Sum	1	$45,000
System Startup	$15,000	Lump Sum	1	$15,000
Aquifer Testing/Delineation	$130,000	Lump Sum	1	$130,000
Capital Construction				
Extraction Wells / Re-Injection Wells / Monitoring Wells	$110,000	Lump Sum	1	$110,000
Treatment Building	$130,000	Lump Sum	1	$130,000
Access Road / Utilites	$130,000	Lump Sum	1	$130,000
Contractor Overhead items	$70,000	Lump Sum	1	$70,000
Contingency	$800,000	percent	25%	$200,000
TOTAL INITIAL CAPITAL COST				**$1,000,000**
Annual Operation & Maintenance (O&M)				
Site Visits	$45,000	Lump Sum	1	$45,000
Maintenance	$3,000	Lump Sum	1	$3,000
Carbon Change outs	$1,300	Lump Sum	1	$1,300
Analytical (Quarterly)	$3,000	Lump Sum	1	$3,000
Property Lease / Annual improvements	$5,000	Lump Sum	1	$5,000
Utility Costs	$2,400	Lump Sum	1	$2,400
Reporting	$40,000	Lump Sum	1	$40,000
Contingency	$99,700	percent	25%	$30,000
TOTAL ANNUAL O&M COST				**$129,700**
Years of O&M	30	Years		
Discount Rate	7%	%		
PRESENT WORTH OF ANNUAL O&M COST			**12.4**	**$1,609,453**
TOTAL PRESENT WORTH (ROUNDED TO NEAREST $10,000)				**$2,810,000**

Downgradient ISCO

Activity	Unit Costs	Units	Quantity	Estimated Cost
Long Term Access Agreement				
Legal	$100,000	Lump Sum	1	$100,000
Improvements	$100,000	Lump Sum	1	$100,000
TOTAL LONG TERM ACCESS AGREEMENT COST				**$200,000**
Initial Capital Cost				
Engineering				
Project Management	$20,000	Lump Sum	1	$20,000
Workplans	$15,000	Lump Sum	1	$15,000
Reporting	$20,000	Lump Sum	1	$20,000
Permitting	$10,000	Lump Sum	1	$10,000
Pre-Dresign Investigation				
Delineation	$100,000	Lump Sum	1	$100,000
Bench- and Pilot-scale Testing	$300,000	Lump Sum	1	$300,000
Site improvements for access	$5,000	Lump Sum	1	$5,000
SUBTOTAL - One-time ISCO Design Costs				*$470,000*
Labor				
Injection Technicians (includes per diem)	$85	Hour	1,440	$122,400
Drilling Costs				
Mobilization & Demobilization	$1,000	EA	2	$2,000
Geoprobe Rig and Operator	$2,000	Day	20	$40,000
Injection Tooling	$100	Day	20	$2,000
Bentonite Backfill	$20	Bag	50	$1,000
Temporary Decontamination Pad	$150	EA	100	$15,000
Steam Cleaner Rental	$50	Day	20	$1,000
55 Gallon Drums	$60	EA	50	$3,000
Injection Pumps	$2,000	Day	20	$40,000
Materials				
Safety Equipment	$20,000	Lump Sum	1	$20,000
Mobilization and Demobilization	$8,000	EA	2	$16,000
Analytical Samples	$100	per sample	150	$15,000
Storage Container Rental	$100	Week	8	$800
Gator Rental	$500	Week	8	$4,000
Rental of Tool Truck/ Tools / Generator	$400	Week	8	$3,200
Meters rental	$2,000	Week	8	$16,000
Stone	$100,000	Lump Sum	1	$100,000
Misc. Supplies	$2,500	Lump Sum	1	$2,500
H&S Supplies - consumables	$20,000	Lump Sum	1	$20,000
Injection Manifold Rental East	$3,250	Week	8	$26,000
Process and Transfer Pumps and Hose Rental	$5,250	Month	2	$10,500
Mixing Tank Rental	$50	Week	8	$400
Holding Tank and piping Rental	$400	Week	8	$3,200
Security	$5,000	Lump Sum	1	$5,000
Shipping, Travel, Vehicles	$40,000	Lump Sum	1	$40,000

Downgradient ISCO

Activity	Unit Costs	Units	Quantity	Estimated Cost
IDW	$5,000	Lump Sum	1	$5,000
Monitoring				
Performance Monitoring	$15,000	Lump Sum	1	$15,000
Reagent Costs				
Permanganate*	$4	kg	63,117	$252,468
SUBTOTAL - Single ISCO Injection Event				*$781,468*
Total ISCO cost (multiple injections†)	$781,468	Injection Event	3	$2,344,404
Contingency	$2,344,404	Percent	50%	$1,172,202
TOTAL INITIAL CAPITAL COST				**$3,986,606**

TOTAL COST (ROUNDED TO NEAREST $10,000)	**$4,190,000**

Note: Highlighted costs have significantly higher uncertainty
* reagent demand based on 5% pore-volume replacement with oxidant
pore-volume based on areal extent of treatment with 25' aquifer thinkness
† 3 injection events used for cost estimating purposes
Contingency is based on total cost if ISCO injections.