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October 11, 2016

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Division of Environmental Remediation
625 Broadway, 12th Floor
Albany, NY 12233-7017

Re: Corrective Measures Study Report Addendum
Former Philips Display Components Facility
Seneca Falls, New York

Dear Mr. Magee:

The enclosed report is an addendum to the June 2013 *Corrective Measures Study (CMS) Report* for the former Philips Display Components facility. The corrective measures alternatives presented in the *CMS Report* were revised because the New York State Department of Environmental Conservation changed the soil cleanup objectives (SCO) for Areas of Concern (AOC) 1, 2, and 3 (Buildings 2, 7, and 11 Areas, respectively) from Restricted Use - Commercial SCOs to Protection of Groundwater SCOs.

The addendum to the *CMS Report* presents revised corrective measures alternatives for AOCs 1, 2, and 3 using the Protection of Groundwater SCOs. Corrective measures presented in the 2013 *CMS Report* that are applicable to site-wide conditions and those specific to AOCs 4 (Soil Vapor Intrusion Pathways) and 5 (Historical Outfalls) remain unchanged.

Please call me at (908) 559-3691 if you have any questions.

Sincerely,

Matthew T. Walsh
Manager – Corporate Workplace Safety & Environmental Compliance

Enclosure

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CORRECTIVE MEASURES STUDY REPORT ADDENDUM

Former Philips Display Components Facility Seneca Falls, New York

Facility EPA ID # NYD002246015

NYSDEC ID # 850003

October 2016

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CORRECTIVE MEASURES STUDY REPORT ADDENDUM

Former Philips Display Components Facility

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ACRONYMS AND ABBREVIATIONS

AOC	Area of Concern
AOC 1	Building 2 Area
AOC 2	Building 7 Area
AOC 3	Building 11 Area
AOC 4	Soil Vapor Intrusion Pathways
AOC 5	Historical Outfalls
bgs	below ground surface
C	Celsius
CAO	Corrective Action Objectives
CMS	Corrective Measures Study
COPC	contaminant of potential concern
COPEC	contaminant of potential ecological concern
CSM	conceptual site model
DCE	dichloroethene
DNAPL	dense non-aqueous phase liquid
ERH	electrical resistance heating
ft/yr	feet per year
GTEOSI	GTE Operations Support Incorporated
ISTR	in situ thermal remediation
kg/L	kilograms per liter
L/kg	liters per kilogram
µg/L	micrograms per liter
mg/L	milligrams per liter
MNA	monitored natural attenuation
MPE	multi-phase extraction
NYCRR	New York Code of Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
O&M	operations and maintenance
RCRA	Resource Conservation and Recovery Act

RFI	RCRA Facility Investigation
SCO	soil cleanup objective
SGVs	Standards and guidance values
SMP	Site Management Plan
TCE	trichloroethene
TCH	thermal conductance heating
USEPA	U.S. Environmental Protection Agency
UV	ultraviolet
VC	vinyl chloride
VOC	volatile organic compound

EXECUTIVE SUMMARY

GTE Operations Support Incorporated has updated its approach to the Resource Conservation and Recovery Act (RCRA) corrective measures at the former Philips Display Components Facility in Seneca Falls, New York (site). The corrective measures alternatives presented in the *Corrective Measures Study (CMS) Report* (Arcadis 2013) for the site were revised because the New York State Department of Environmental Conservation (NYSDEC) changed the soil cleanup objectives (SCO) for Areas of Concern (AOC) 1, 2, and 3 (Buildings 2, 7, and 11 Areas, respectively) from commercial SCOs to protection of groundwater SCOs. This addendum to the 2013 *CMS Report* updates the conceptual site model and presents revised corrective measures alternatives for AOCs 1, 2, and 3 using the protection of groundwater SCOs. Data gathered from almost thirty years of closure activities, RCRA facility investigations, and interim corrective measures indicate that the revised corrective measures alternative for Areas of Concern (AOC) 1, 2, and 3 (described below) meet RCRA corrective action objectives.

The updated conceptual site model summarizes the delineation of potential dense non-aqueous phase liquid (DNAPL), migration and natural attenuation of COPC, and definition of potential COPC source areas. Arcadis used a hierarchical lines-of-evidence approach (Kueper and Davies 2009) to identify and determine the extent of DNAPL at the site. The lines of evidence outlined in this addendum to the *CMS Report* indicate that DNAPL is isolated. The DNAPL was a source of TCE to groundwater and, if present, will be actively remediated.

Decreases in parent (TCE) and daughter product (cis-1,2-dichloroethene and vinyl chloride) concentrations in groundwater have been observed. These site-wide decreases in concentration were used to calculate site-specific attenuation half-lives in AOCs 1, 2, and 3. Coupled with the evidence of reductive dechlorination and extremely low groundwater velocity (about 2 feet per year), the updated monitored natural attenuation (MNA) assessment shows that dissolved-phase TCE concentrations will attain the NYSDEC Class GA standard before reaching the site boundary. The site-specific attenuation half-lives were calculated using pre-remediation data; remediation of DNAPL will result in even shorter attenuation half-lives (i.e., faster attenuation) for TCE and daughter products.

An integrated strategy that includes removing DNAPL and MNA will achieve the corrective action objectives. The recommended corrective measures alternative for AOCs 1, 2, and 3 includes the following steps:

- implementing in situ thermal remediation to treat DNAPL,
- monitoring the natural attenuation of COPC in groundwater over the long term and comparing results to predicted concentrations,
- excavating unsaturated soil in AOCs 1, 2, and 3 with concentrations greater than commercial SCOs,
- implementing a Site Management Plan to include institutional controls,
- restricting groundwater use, and
- recording an environmental covenant to restrict future site use to warehousing and distribution.

Corrective measures presented in the *CMS Report* (Arcadis 2013) that are applicable to site-wide conditions and those specific to AOCs 4 (Soil Vapor Intrusion Pathways) and 5 (Historical Outfalls) remain unchanged.

1 INTRODUCTION

GTE Operations Support Incorporated (GTEOSI) submitted a *Corrective Measures Study (CMS) Report* (Arcadis 2013) for the former Philips Display Components Facility (site) in Seneca Falls, New York (Figure 1) to the New York State Department of Environmental Conservation (NYSDEC) on June 28, 2013. The purpose of the CMS was to outline a plan to comply with Resource Conservation and Recovery Act (RCRA) corrective action regulations and enable the beneficial reuse of the site. NYSDEC conditionally approved the *CMS Report* in a December 19, 2013, letter indicating that GTEOSI will need to attain the commercial soil cleanup objectives (SCOs) outlined in 6 New York Code of Rules and Regulations (NYCRR) Subpart 375-6. In a January 31, 2014 letter to NYSDEC, GTEOSI agreed to apply the commercial SCOs for the site. NYSDEC formally approved the *CMS Report* in a July 31, 2014 letter.

In January 2016, NYSDEC changed SCOs for Areas of Concern (AOC) 1, 2, and 3 (Building 2, 7, and 11 Areas, respectively) to the protection of groundwater SCOs. Following discussions with NYSDEC, GTEOSI agreed to submit a *CMS Report Addendum* to present revised corrective measures alternatives for AOCs 1, 2, and 3 using the protection of groundwater SCOs.

The *CMS Report Addendum* is organized in the following sections:

- Section 2 presents the refined Conceptual Site Model (CSM).
- Section 3 provides soil Corrective Action Objectives (CAOs).
- Section 4 evaluates applicable remedial technologies and corrective measure alternatives that meet the CAOs.
- Section 5 recommends corrective measures alternatives for AOCs 1, 2 and 3.
- Section 6 lists source documents cited in the text.

The *CMS Report Addendum* presents revised corrective measures alternatives for AOCs 1, 2, and 3 only. Corrective measures that are applicable to site-wide conditions and those specific to AOCs 4 (Soil Vapor Intrusion Pathways) and 5 (Historical Outfalls) are discussed in the *CMS Report* (Arcadis 2013) and are unchanged by this addendum.

2 CONCEPTUAL SITE MODEL

The *CMS Report* (Arcadis 2013) included a CSM based on the nature and extent of contaminants of potential concern (COPC) in soil, groundwater, and soil vapor outlined in the figures and Section 4 of the *CMS Report* (Arcadis 2013). The CSM summarized historical site information and geologic, hydrogeologic, geochemical, and anthropogenic data. As defined in the *CMS Report* (Arcadis 2013), the primary COPC is trichloroethene (TCE), with concentrations reported in soil, groundwater and soil vapor. TCE degrades into cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride (VC) through reductive dechlorination. Cis-1,2-DCE and VC were reported primarily in groundwater and are, therefore, considered secondary COPC.

Historical data, as well as data collected since the submission of the *CMS Report* (Arcadis 2013), have been evaluated to update the CSM, including COPC distribution, migration pathways, fate, and potential exposures. Section 2 presents the updated CSM and incorporates groundwater analytical data from samples collected since the *CMS Report* (Arcadis 2013) was submitted. The updated CSM summarizes the delineation of dense non-aqueous phase liquid (DNAPL), migration and natural attenuation of COPC, and definition of potential COPC source areas.

2.1 DNAPL

During active manufacturing from at least 1914 to 1986, fluids and chlorinated solvents containing trichloroethene (TCE) may have been used in industrial processes. TCE is the primary COPC in AOCs 1, 2, and 3 (Building 2, 7, and 11 Areas, respectively), and is the driver for soil and groundwater remediation in these AOCs (Arcadis 2013). TCE breakdown products, cis-1,2-DCE and VC, were also in groundwater samples collected from AOCs 1, 2, and 3 and are secondary COPC.

A hierarchical lines-of-evidence approach (Kueper and Davies 2009) was used to identify and determine the extent of DNAPL at the Site. The lines of evidence used to identify the presence of DNAPL are:

- The observation of DNAPL in monitoring wells or soil cores;
- Groundwater TCE concentrations near or above the solubility limit of 1,280,000 micrograms per liter (µg/L); and
- Soil TCE concentrations near or above the soil saturation limit of 492 milligrams per kilogram (mg/kg).

DNAPL was reported in soil cores in either 2001 or 2005 in four borings: two in AOC 1 (B2-PH05 and MW-BI-01) and two in AOC 3 (B11-PH-07 and B11-PH08) (Figure 2). DNAPL was observed in a soil sample from 25 to 30 feet below ground surface (bgs) at MW-BI-01 using an ultraviolet (UV) light field-screening tool (URS 2002). Globules of DNAPL were observed in soil cores between 29 and 30 feet bgs at B2-PH05, 28 and 30 feet bgs at B11-PH07, and 21 and 24 feet bgs at B11-PH08 (Arcadis 2013).

Using the law of equilibrium partitioning for saturated zone soil, the site-specific soil saturation limit for TCE was calculated using Equation 1 below, from the United States Environmental Protection Agency (USEPA) Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA 2002a).

$$C_{sat} = \frac{S}{\rho_b}(K_d\rho_b + \theta_w) \quad (1)$$

Where

C_{sat} = the site-specific soil saturation concentration for TCE (mg/kg)

S = the TCE solubility in water in milligrams per liter (mg/L)

ρ_b = the dry soil bulk density in kilograms per liter (kg/L)

K_d = the soil-water partition coefficient in liters per kilogram (L/kg), calculated using the formula $K_d = K_{oc}\ x\ f_{oc}$, where K_{oc} is the TCE organic carbon partition coefficient (L/kg) and f_{oc} is the fraction of organic carbon in site soil (dimensionless)

θ_w = the total water filled soil porosity (effective plus immobile porosity, dimensionless)

The calculated site-specific soil saturation limit for TCE at which DNAPL may be present is 492 mg/kg. This concentration was calculated using Equation 1, assuming ρ_b = 1.7255 kg/L, f_{oc} = 0.003, θ_w = 0.35 (glacial till), and K_{oc} = 60.7 L/kg (USEPA 2016).

TCE concentrations in soil samples co-located with observed DNAPL were greater than the soil saturation limit at MW-BI-01 (930 mg/kg at 25 feet bgs and 1,200 mg/kg at 30 feet bgs), B2-PH05 (1,500 mg/kg at 29.5 feet bgs), and B11-PH08 (8,100 mg/kg at 22 feet bgs), confirming the visual observations of DNAPL at these locations.

Groundwater samples were collected from temporary monitoring wells installed at borings B11-PH-07 and B11-PH08, where DNAPL was observed. A groundwater sample from B11-PH-07 contained a dissolved-phase TCE concentration of 1,000,000 µg/L, near the TCE aqueous solubility limit of 1,280,000 µg/L. Laboratory analysis of a DNAPL sample collected from the temporary monitoring well installed at B11-PH-08 indicated that TCE comprised about 100% of the DNAPL (Arcadis 2013).

With the exception of B2-06 and B11-PH09, there is no evidence of DNAPL in soil borings advanced nearest to the four borings where DNAPL was observed, including boring (B11-09), which is less than five feet from B11-PH07. DNAPL was not observed in soil cores from any of these borings, soil concentrations were less than the soil saturation limit of TCE, and groundwater concentrations were less than the solubility limit of TCE.

Soil TCE concentrations approached the soil saturation limit at B2-06 (340 mg/kg), about 20 feet north of B2-PH-05, and at B11-PH09 (470 mg/kg), about 40 feet east of B11-PH08. These observations and the laboratory analytical data indicate that DNAPL is isolated to the four borings where DNAPL was observed, and is potentially present at B2-06 and B11-PH09. There is no evidence of DNAPL in AOC 2 (Building 7 Area) because DNAPL was not observed, groundwater TCE concentrations (at or below 1,200 µg/L) are much less than the TCE solubility limit and soil TCE concentrations (at or below 48 mg/Kg) are much less than the soil saturation limit.

2.2 COPC Transport

The historical distribution of COPC and concentration data were used to update the migration pathway conceptual model.

2.2.1 Groundwater Dynamics

The source of the soil and groundwater COPC concentrations was the DNAPL. The dominant COPC migration mechanism is diffusion from the DNAPL into groundwater. Movement of groundwater (advection) is limited by the low hydraulic conductivity of the saturated till.

The primary and secondary COPC (TCE, cis-1,2-DCE, and VC) are dissolved in groundwater in AOCs 1, 2, and 3 within the till, which is the upper water-bearing hydrostratigraphic unit. The COPC are soluble in water and volatile; therefore, they can migrate in both groundwater and soil vapor. COPC also absorb or adsorb onto soil particles and organic matter, and become incorporated into the soil matrix. In the saturated zone, the law of equilibrium governs COPC mass partitioning between the groundwater and saturated soil. The COPC also readily biodegrade when conditions are amenable. These processes collectively attenuate the migration of COPC. Attenuation of COPC concentrations in the saturated zone also occurs as a result of dispersion and dilution.

Groundwater advection is very slow because of the low hydraulic conductivity and relatively flat hydraulic gradient in the saturated till. The groundwater velocity at AOCs 1, 2, and 3 is about 2 to 3 feet per year (ft/yr), based on hydraulic conductivity values obtained from historical investigations at monitoring wells in AOCs 1, 2, and 3 (Chester Environmental 1994), and an estimated effective porosity of 0.18 (the specific yield of a silt matrix [Fetter 1994]). A groundwater velocity of 2 to 3 ft/yr is conservative and close to the upper limit of calculated values; slug test data indicate groundwater velocities may be as low as 0.3 ft/yr at select locations across the site (Chester Environmental 1994).

The slow advection has resulted in minimal COPC migration and enabled the decay of COPC by decreasing the mass flux. For example, the following October 2000 groundwater TCE concentration data from ACOs 1, 2, and 3 show concentrations decreasing by at least two orders of magnitude over relatively short groundwater flow paths (80 to 110 feet):

- from 2,400 to 8 micrograms per liter (µg/l) over a 110-foot flow path between B2-08 and B2-11 southeast of Building 2 (AOC 1);
- from 12,000 to 17 µg/l over an 80-foot flow path between MW-23 and B7-05 southeast of Building 7 (AOC 2); and
- from 12,000 to 60 µg/l over a 94-foot flow path between B11-02 and MW-25 southeast of Building 11 (AOC3 3).

Significant decreases in groundwater TCE concentrations over short distances support the hydraulic data indicating groundwater flow velocities are very slow at the site. The detection of cis-1,2-DCE and VC concomitant with decreases in TCE concentrations at the above and other sampling locations shows that COPC migration is further limited by biodegradation.

Based on measured groundwater levels, the hydraulic gradient direction in AOCs 1, 2, and 3 is generally south to southeast towards the southern property boundary (Figure 3). Groundwater in AOCs 2 and 3 (Building 7 and Building 11 Areas) and parts of AOC 1 (Building 2 Area) flows south to a steep embankment, where it evaporates or transpires when it reaches the embankment (Arcadis 2013 and USEPA 2003). COPC were not reported in groundwater sampled in March 2016 from bedrock wells MW-BR-04 and MW-BR-05, downgradient of AOCs 2 and 3 (Figure 4), indicating that COPC in groundwater are not migrating to bedrock.

2.2.2 Groundwater Elevation Fluctuations and Capillary Zone Contact with COPC

On-site groundwater level measurements vary seasonally and typically fluctuate between 2 and 4 feet bgs in AOCs 1, 2, and 3. The water table has been measured as shallow as 0.5 feet bgs. The fluctuating groundwater table results in contact between unsaturated zone soils and dissolved-phase TCE in groundwater. TCE concentrations in groundwater outside of DNAPL locations are above the concentration that could, through capillary zone contact, result in soil TCE concentrations above the protection of groundwater SCO (about 1.2 mg/L, based on equilibrium calculations and the assumed bulk density, total porosity, and soil-water partition coefficient outlined in Section 2.1). This natural process influences the evaluation of alternatives for unsaturated soils because treated soils could be re-contaminated by fluctuating groundwater levels.

TCE concentrations in groundwater outside of DNAPL locations are below the level that could result in soil concentrations above the commercial SCO of 200 mg/kg (520 mg/L, based on equilibrium calculations outlined in Section 2.1). Only one unsaturated zone soil sample (above 4 ft bgs), collected in 2005, had a TCE concentration slightly greater than the corresponding commercial SCO (230 mg/kg at 1.5 feet bgs at B2-PH04) (Figure 5). TCE concentrations in soil samples collected below the water table at B2-PH04 (15 to 36 mg/kg) were far below the soil saturation limit, indicating DNAPL was not present at this location. This is supported by groundwater sampling results indicating 29,000 µg/l TCE at boring B2-PH04, far below the TCE solubility limit.

2.3 COPC Decay (Natural Attenuation)

Groundwater monitoring has been ongoing for more than 20 years. Since the completion of a natural attenuation assessment that was presented in the *CMS Report* (Arcadis 2013), additional groundwater samples have been collected as part of the semi-annual groundwater sampling program. TCE concentrations from groundwater samples collected since submittal of the *CMS Report* (Arcadis 2013) are provided in the *March 2016 Semiannual Groundwater Sampling Event Report* (Arcadis 2016) and are shown on the graphs in Appendix A. TCE and cis-1,2-DCE concentrations in groundwater sampled in the fall of 2015 and spring of 2016 are shown on Figure 4.

2.3.1 Revised MNA Assessment

Over the past two decades, decreases in TCE concentrations and associated cis-1,2-DCE and VC concentrations have been observed. Concentration versus time degradation rates were calculated using the molecular weight of chlorinated ethenes as part of the natural attenuation assessment presented in the *CMS Report* (Arcadis 2013). Exponential regressions of individual chlorinated volatile organic compound (VOC) concentrations were calculated to determine point first-order degradation rates. Additionally, total molecular COPC concentrations over time were plotted to determine the total molar concentration trends.

The 2013 natural attenuation assessment identified MW-23 and MW-25 as the only wells having statistically significant decreasing concentration trends. Data collected since the *CMS Report* (Arcadis 2013), along with the USEPA guidance on evaluating monitored natural attenuation (MNA) (USEPA 2011), were used to revise the assessment as part of the *CMS Report Addendum*. The revised assessment resulted in better statistical evidence for decreasing COPC concentration trends, and greater confidence in the calculated COPC attenuation half-lives in AOCs 1, 2, and 3. The monitoring well data that were used to calculate COPC attenuation half-lives have decreasing concentration trends with confidence levels of at least 98%.

Appendix B presents the revised MNA assessment and results, and includes a description of changes to the assessment procedures from the original MNA assessment (Arcadis 2013), and updated conclusions. Key factors that influenced the outcome of the revised MNA assessment are:

- Additional COPC concentration data collected after the CMS Report (Arcadis 2013) were evaluated, and seasonal concentration variability was reduced by using only the seasonal high COPC concentrations in the analysis.
- The revised analysis resulted in acceptable correlation factors (R^2) and confidence levels (p-values) for regression lines used to calculate COPC attenuation half-lives.

A summary of these factors and the updated conclusions regarding MNA are provided below. Details and calculations are in Appendix B.

One of the main limitations encountered in the 2013 MNA assessment when correlating data points to linear regression lines with statistical confidence was seasonal fluctuations in groundwater concentrations between the spring and fall sampling events. Water table elevations fluctuate by as much as 3 feet between the spring and fall semiannual sampling events (hydrographs provided in Appendix A), with seasonal low concentrations occurring in the spring that are likely caused by dilution from elevated water levels.

The updated MNA assessment limits the evaluated data to groundwater concentrations from the fall sampling events, representing seasonal high groundwater COPC concentrations. By removing the seasonal variability, changes in concentrations over time more accurately represent site-specific natural attenuation processes, and concentration variability caused water level changes is reduced.

Regression analysis of the concentration data was performed to determine the direction and statistical significance of trends. Concentration trends were accepted as statistically significant if the confidence level was 90% or greater. All of the data sets analyzed, except for cis-1,2-DCE at MW-23 and vinyl chloride at MW-24 and MW-26, had decreasing trends with a confidence level of at least 98% (Appendix B, Table B-1). Furthermore, the evaluation of total COPC molar concentrations in groundwater in AOCs 1, 2 and 3 (Appendix B) shows that total molar concentrations are decreasing over time. The decreasing total molar concentration trends demonstrate complete degradation of COPC at the site.

Peak COPC concentrations at each well in ACOs 1, 2, and 3 were identified and used as starting points for calculating representative first-order degradation rate constants. The peak TCE concentrations coincide with the point in time when reductions from natural attenuation processes began to exceed the mass flux from residual sources, such as potential DNAPL. For the daughter products cis-1,2-DCE and vinyl chloride, peak concentrations coincide with the point in time when reductions from natural attenuation processes began to exceed rates of production by reductive dehalogenation of parent compounds (TCE and cis-1,2-DCE, respectively).

Revised attenuation half-lives were calculated for TCE and cis-1,2-DCE at monitoring wells MW-25 and MW-22 in AOC 3 (Building 11 Area), and MW-24 and MW-26 in AOC 1 (Building 2 Area). A revised attenuation half-life for TCE was calculated for MW-23 in AOC 2 (Building 7 Area). The attenuation half-lives were estimated from linear regression analyses using natural log normalized concentration data, conducted following USEPA guidance (USEPA 2002b & 2009).

The closeness-of-fit of the linear regression line to the site data is represented by the value R^2. Values of R^2 close to zero indicate weak model fits, while R^2 values close to one indicate strong model fits. R^2 values less than 0.5, indicating variability in the data, were defined as not statistically significant in the CMS Report (Arcadis 2013 Based on the guidance provided in the 2011 USEPA *Approach for Evaluation the Progress of Natural Attenuation in Groundwater,* R^2 values less than 0.1 indicate a weak fit of the linear model to groundwater concentration data. For regression lines with R^2 values greater than 0.1, the decision criteria for the appropriate fit of a regression line has changed from the correlation factor (R^2) to the confidence level (p-value, described below). The R^2 values for linear regressions used to calculate attenuation half-lives ranged between 0.8 and 0.4 (Appendix B, Table B-1).

The p-value of the correlation is a measure of the level of significance of the statistical test. Correlations were accepted as statistically significant for p-values less than or equal to 0.1 (i.e., 90% confidence level). All of the data sets analyzed, except for cis-1,2-DCE at MW-23 and vinyl chloride at MW-24 and MW-26, had decreasing trends with p-values of 0.02 or less (confidence levels of at least 98%).

The calculated attenuation half-lives for TCE (Appendix B, Table B-1) are similar in AOCs 1, 2, and 3, ranging between 1,960 and 2,796 days (5.4 and 7.4 years) at monitoring wells MW-22 through MW-25. Although TCE concentrations are clearly decreasing at MW-26, the calculated attenuation half-life (4,592 days, or 12.6 years) is an outlier.

The calculated attenuation half-lives for cis-1,2-DCE are similar at MW-22 and MW-25 in AOC 3, between 1,181 and 1,898 days (3.2 and 5.2 years). Calculated attenuation half-lives for MW-24 and MW-26 in AOC 1, between 6,054 and 6,692 days (16.6 and 18.3 years), are three to six times higher than the attenuation half-lives calculated for AOC 3. With the further depletion of TCE concentrations in AOC 1, the formation of cis-1,2-DCE is expected to decrease and the attenuation half-life will improve with time. An attenuation half-life for cis-1,2-DCE was not calculated at MW-23 because of the limited number of reported concentrations, but a clear decreasing concentration trend exists.

VC concentrations are reported at MW-24 and MW-26 in AOC 1 (Arcadis 2016), and concentrations are below the reporting limit or are reported at concentrations less than the NYSDEC Class GA Standard (2 µg/L) at monitoring wells in AOCs 2 and 3. Attenuation half-lives could not be calculated for VC at MW-24 and MW-26 because concentration trends were not statistically significant (confidence levels less than 80%); however, concentrations appear to be decreasing.

The calculated attenuation half-lives for AOCs 1, 2, and 3 are considered to be a conservative assessment of the natural attenuation processes for COPC. The attenuation half-lives were calculated based on site-specific conditions using seasonal high groundwater COPC concentrations. Furthermore, the calculated attenuation half-lives lump several transport and attenuation processes into a single rate constant (e.g., advection, dispersion, adsorption, biodegradation, transformation, partitioning from unsaturated soils, and diffusion from potential DNAPL sources). Concentration decreases estimated using attenuation half-lives from AOCs 1 and 3 are also conservative because an integrated corrective measures strategy, including source removal, will be implemented.

The MNA assessment shows decreasing concentration trends for both primary and secondary COPC. Groundwater and soil COPC concentrations are likely near equilibrium because groundwater movement is very slow. Thus, as groundwater COPC concentrations have decreased, it is assumed that the adsorbed COPC concentrations in saturated and unsaturated zone soil have also decreased (fluctuating groundwater levels result in contact between unsaturated zone soils and dissolved-phase COPC in groundwater).

The most recent soil investigation was conducted in 2005, so groundwater concentrations in 2016 are a better indicator of the soil concentrations within AOC 1, 2, and 3 than the 2005 soil sampling data. Additionally, because groundwater COPC concentrations in AOCs 1, 2 and 3 are decreasing, it is clear that adsorbed COPC within the soil matrix are not adversely affecting natural attenuation.

2.3.2 COPC Migration Distance

To evaluate the influence of site-specific natural attenuation processes on COPC transport, the calculated COPC travel distance before achieving standards and guidance values (SGVs) is compared to the travel distance to the downgradient site boundary to determine the potential for offsite migration. The calculated attenuation half-lives were used to predict the maximum COPC migration distance before the respective NYSDEC Class GA standard is attained, using recent concentration data from groundwater monitoring wells and historical concentration data from temporary wells sampled in 2000 or 2005. The monitoring wells and historical borings are depicted on Figure 6.

COPC travel distance calculations were performed by solving Equation 2 for the migration distance to attain the corresponding NYSDEC Class GA standards (*d*) using the site-specific groundwater velocities and COPC attenuation half-lives.

$$d = \frac{-\ln\left(\frac{C_{goal}}{C_0}\right)}{0.693} * v\lambda \qquad (2)$$

Where

d = COPC travel distance before attaining the standard (feet)

C_{goal} = the concentration standard (µg/l)

C_0 = the initial COPC concentration (µg/l)

V = groundwater velocity (feet/day)

λ = attenuation half-life (days), related to the first-order degradation rate (*k*) through the relationship

$$k = \frac{0.693}{\lambda}$$

Groundwater samples from wells MW-23 (AOC 2) and MW-24 (AOC 1) have the highest TCE concentrations at 1,700 µg/l (reported in September 2010) and 1,200 µg/L, respectively. Based on the calculated TCE attenuation half-life (5.4 years) and groundwater velocities (2.6 ft/yr at MW-23 and 2.0 ft/yr at MW-24 calculated from slug test results [Chester Environmental 1994]), TCE is predicted to travel 109 feet from MW-23 and 91 feet from MW-24 before concentrations reach the NYSDEC Class GA standard. Monitoring wells MW-23 and MW-24 are about 227 and 288 feet upgradient of the site boundary, respectively; therefore, TCE concentrations at MW-23 and MW-24 are predicted to attenuate below the Class GA standard within the site boundary. Similar migration distance calculations yield the same results for TCE concentrations at MW-25 in AOC 3 and MW-26 in AOC 1 (Table 1); concentrations reach the Class GA standard within the site boundary. TCE concentrations are below the Class GA standard at MW-22.

TCE attenuation half-lives calculated for MW-23, MW-24, MW-25, and MW-26 were also used to estimate maximum possible migration distances from historical boring locations where groundwater concentrations were measured in 2000 or 2005 in AOCs 1, 2, and 3. The maximum travel distance from a sampling location not associated with a potential DNAPL source is approximately 235 feet, from boring B2-01 in AOC 1 (Table 1). This travel distance is shorter than the distance to the site boundary (Figure 6).

The potential travel distances for cis-1,2-DCE, a product of TCE degradation, from monitoring wells and historical borings in AOCs 1, 2, and 3 were also evaluated using calculated attenuation half-lives for MW-24, MW-25, and MW-26. The cis-1,2-DCE concentrations and estimated travel distances to attain the Class GA standard for sampling locations are summarized in Table 2. Cis-1,2-DCE travel distances above the Class GA groundwater standard in AOCs 2 and 3 are shorter than the distances to the site boundary.

Several locations within AOC 1 (B2-04, B2-05, B2-06, B2-10, B2A-04, B2-PH03, IS-02, MW-24, and MW-26) had cis-1,2-DCE concentrations with the potential to reach the site boundary based on the current estimated attenuation half-lives (Table 2). The approximate attenuation half-lives calculated for AOC 1 are conservative because, as discussed in Section 2.3.1, they are based on conditions where TCE is biodegrading to form cis-1,2-DCE, but TCE concentrations are also decreasing. With the further depletion of TCE concentrations in AOC 1, the formation of cis-1,2-DCE is expected to decrease and the attenuation half-life will improve with time. Additionally, most of the initial concentration data for AOC 1 sampling locations (Table 2) were collected about 16 years ago. Due to the age of these data, Section 4 outlines a plan to obtain updated groundwater and attenuation half-life data during a pre-design investigation.

2.4 Potential Source Areas

TCE is the primary COPC in groundwater at AOCs 1, 2, and 3, and TCE DNAPL was observed at four isolated locations in AOCs 1 and 3 (Figure 2). The identification of DNAPL during sampling in 2000 and 2005 is based on the following hierarchical lines of evidence, where:

- DNAPL was observed;
- Groundwater TCE concentrations approach 100 percent solubility (1,280,000 µg/L); and
- Soil TCE concentrations approach or exceed the soil saturation limit (492 mg/kg).

TCE concentrations approached or exceeded the soil saturation or solubility limits at locations in AOCs 1 and 3 where DNAPL was observed in 2000 or 2005. DNAPL was not observed in AOC 2 (Building 7 Area) and the historical soil and groundwater analytical data indicate that DNAPL is not present in AOC 2.

As stated in the preceding sections, the source of the soil and groundwater COPC concentrations was the DNAPL. The CPOC dissolved in groundwater resulted from slow migration of TCE from the observed DNAPL locations (B2-PH05, MW-BI-01, B11-PH-07, and B11-PH08). The CMS data indicate that the four isolated locations where DNAPL was observed are the source of COPC at the site. Pre-design investigative activities will determine if DNAPL is present in these areas through observations and analytical results. If DNAPL is present, it can be addressed using source removal corrective measures, as discussed further in Section 4.

2.5 Updated Conceptual Site Model Summary

Potential TCE source areas are confined to four locations where DNAPL was observed (B2-PH05, MW-BI-01, B11-PH-07, and B11-PH08), and adjacent borings where DNAPL was potentially present (B2-06 and B11-PH09). The tight and dense nature of the till and slow groundwater velocity have limited the migration of COPC. The dissolved-phase TCE and cis-1,2-DCE concentration at AOCs 1, 2 and 3 wells are decreasing, as indicated by the reductions in concentrations in groundwater during the past two decades of monitoring (Appendix B). Dissolved-phase TCE concentrations show decreasing trends at monitoring locations across the site. TCE breakdown products (cis-1,2-DCE, VC) have been measured, indicating that natural attenuation is occurring, and total molar concentrations of COPC are decreasing, demonstrating complete degradation of COPC at the site.

In addition, calculated attenuation half-lives indicate that TCE concentrations in AOCs 1, 2, and 3, and cis-1,2-DCE concentrations in ACOs 2, and 3 will attenuate below the NYSDEC Class GA standard within the site boundary. Some locations within AOC 1 had cis-1,2-DCE concentrations with the potential to reach the site boundary based on the current estimated attenuation half-lives (Table 2). As discussed in Section 2.3, the estimated attenuation half-lives for cis-1,2-DCE are conservative, and are expected to improve over time as the parent compound, TCE, becomes depleted.

Strong evidence of natural attenuation at the site suggests that the decay of COPC is occurring and will continue under the existing site conditions; however, the MNA assessment suggests that an integrated corrective measure approach (source control and ongoing attenuation half-life calculations) is needed to assure that corrective measures goals are met.

3 CORRECTIVE ACTION OBJECTIVES

This section presents the objectives and requirements of corrective measures as a preparatory step to developing and screening corrective measure alternatives. The CAOs are chemical-, location-, and action-specific cleanup objectives established for protecting human health and the environment, based on the nature and extent of COPC, potential exposure pathways and receptors, and remediation goals (USEPA 1990). The CAOs for soil (SCOs) for AOCs 1, 2, and 3 (Building 2, 7, and 11 Areas, respectively) were revised to the protection of groundwater SCOs. CAOs for groundwater and soil vapor/air are summarized in Table 3. CAOs were also developed for addressing DNAPL because DNAPL is considered separately from dissolved COPC in groundwater.

The CAO for DNAPL is:

- To remove, to the extent practicable, DNAPL from the site.

The CAOs for soil are:

- To minimize, to the extent practicable, the potential for exposure (ingestion, inhalation, and direct contact) with COPC in soil above commercial use standards.
- To minimize, to the extent practicable, the potential for exposure to chemicals of potential ecological concern (COPECs) in soil with concentrations that may result in population-level effects for ecological receptors.
- To achieve, to the extent practicable, protection of groundwater SCOs in AOCs 1, 2, and 3.

4 CORRECTIVE MEASURES ALTERNATIVES

Section 7 of the *CMS Report* (Arcadis 2013) presented the preliminary screening of corrective measures technologies. The revised CAO for soil in AOCs 1, 2, and 3 is to achieve, to the extent practicable, the protection of groundwater SCOs; therefore, the general response actions and technology screening for soil and groundwater have been updated using the following site-specific conditions described by the CSM:

- The updated natural attenuation assessment (Section 2 and Appendix B) shows that natural attenuation processes are capable of attaining CAOs in AOCs 1, 2, and 3; and
- DNAPL can be addressed using a source removal corrective action objective, managed as a separate corrective measure.

The *CMS Report* defines corrective measure technologies as general categories of actions under each general response action (e.g., *barrier* is a corrective measure technology under the general response action of *containment*). Process options are specific remedial processes used to apply each corrective measure technology (e.g., a *groundwater recovery trench* is a process option under the *barrier* corrective measure technology).

Target treatment areas in each media are defined in Section 4.1 and screening of the corrective measure technologies are discussed in subsequent sections. Sections 4.2 through 4.9 present the general response actions, corrective measures technologies, common components of the corrective measures alternatives, and the evaluation of corrective measures alternatives for AOCs 1, 2, and 3.

4.1 Media Specific Target Areas

Based on the CAOs identified in Section 3, corrective measures for DNAPL, groundwater, and soil are needed. The areas targeted for corrective measures for each media are discussed in this section.

4.1.1 DNAPL

As identified on Figure 2, two areas where DNAPL was observed are AOC 1 (Building 2 Area) and AOC 3 (Building 11 Area). DNAPL was not observed in AOC 2 (Building 7 Area) and historical information (laboratory analytical data and boring logs) indicate that DNAPL is not present in AOC 2. The DNAPL target areas are shown on Figures 7, 8, and 9.

4.1.2 Groundwater

Six monitoring wells (MW-22, MW-23, MW-24, MW-25, and MW-26) are within AOCs 1, 2, and 3 (Figure 4). Though COPC concentrations in groundwater at these wells are decreasing as discussed in Section 2.3, groundwater from each of the wells contains COPC concentrations greater than applicable standards and guidance values (SGVs). Data from monitoring wells and temporary wells indicate that groundwater COPC concentrations exceed SGVs throughout AOCs 1, 2, and 3. As such, the target areas for groundwater are AOCs 1, 2, and 3.

4.1.3 Soil

Soil investigations were completed at the site between 1999 and 2001 as part of the *RCRA Facility Investigation* (*RFI)* (URS 2002). Additional soil investigations were completed in 2005 as part of the CMS (Arcadis 2013). The nature and extent of COPC in soil were defined in the *CMS Report* (Arcadis 2013). As identified in Section 3, the CAO for soils has been modified from achieving the Restricted Use – Commercial SCOs to achieving the Protection of Groundwater SCOs. The CAO of minimizing exposure to soils greater than the Restricted Use – Commercial SCOs also applies, because of the potential exposure to unsaturated soils during construction activities such as subsurface utility maintenance.

During the historical soil investigations conducted within AOCs 1, 2, and 3, samples were collected from both saturated and unsaturated soils. As discussed in Section 2.2.2, the water table in AOCs 1, 2, and 3 is generally less than 4 feet bgs; therefore, unsaturated zone soils are above 4 feet bgs and saturated zone soils are below.

COPC within the saturated soil matrix are assumed to be in equilibrium with groundwater COPC because groundwater movement is very slow. Thus, as discussed in Section 2.3.1, reductions in groundwater COPC concentrations likely represent proportional reductions in soil COPC concentrations. The protection of groundwater SCOs were established by NYSDEC based on groundwater SGVs for each COPC and assuming local equilibrium. It is therefore assumed that the target area for saturated soils to reach the protection of groundwater SCO matches the target area for groundwater above SGVs.

As discussed in Section 2.2.2, unsaturated soils above 4 feet bgs become saturated during high water table conditions. During periods of saturation, COPC in unsaturated zone soils equilibrate with groundwater. Section 2.3.1 describes how contact between unsaturated zone soils and dissolved-phase COPC in groundwater is represented in the attenuation half-lives that were calculated for AOCs 1, 2, and 3 in the natural attenuation assessment (Appendix B). It is therefore assumed that the target area for unsaturated soils to reach the protection of groundwater SCO matches the target area for groundwater above SGVs.

Concentrations of COPC in unsaturated zone soils were compared to the commercial SCOs to provide protection to workers at the site. Only one unsaturated zone soil sample, collected in 2005, had a TCE concentration slightly above the commercial SCO (230 mg/kg at 1.5 feet bgs at B2-PH04) (Figure 5).

4.2 General Response Actions

General response actions are categories of corrective measures that can reduce the chemical concentration in various media (e.g. DNAPL, groundwater, and soil) in each AOC and the potential for COPC exposure. They provide the basis for identifying specific corrective measure technologies and process options for each medium. General response actions for soil and groundwater were provided in Section 7.1 the *CMS Report*. General response actions for DNAPL in AOCs 1 and 3 include:

- no action
- monitoring
- physical removal
- ex situ treatment
- institutional controls
- containment
- in situ treatment
- disposal

Corrective measures may be used independently or in combination to satisfy CAOs. As presented in the *CMS Report* (Arcadis 2013), the general responses identified for each media are divided into remedial technologies and process options for preliminarily screening. Preliminary screening is explained in detail in Section 4.3.

The remedial technologies and process options retained from the preliminary screening are screened further for effectiveness, implementability, and relative cost (Section 4.4). Corrective measures that will be implemented regardless of which corrective measures alternatives are selected are presented in Section 4.5.

The remedial technologies retained after further screening discussed in Section 4.4 are combined into corrective measures alternatives for each AOC designed to achieve the CAOs (Section 4.6). Corrective measures alternatives are evaluated against balancing criteria (long-term effectiveness, reduction in toxicity, mobility, and volume, short-term effectiveness, implementability, sustainability, and cost) in Sections 4.7, 4.8, and 4.9. The corrective measures alternatives for each AOC are comparatively evaluated and one recommended corrective measure is identified for each targeted media for implementation at AOCs 1, 2, and 3 (Section 4.10).

4.3 Technology Screening

The technology screening conducted in the *CMS Report* was updated based on the revised CAO for soils and the updated CSM, and includes an evaluation of technologies for addressing DNAPL. Technical implementability is the first preliminary screening criteria. Preliminary technical implementability screening considers the site-specific CAOs, site-specific conditions (geologic setting and contaminant distribution), and contaminant characteristics. The preliminary screening process consists of reviewing available technologies and listing retained technologies and process options capable of addressing the contaminants in each medium.

Table 4 presents the preliminary evaluation of technologies for DNAPL. Tables 5 and 6 present the preliminary evaluation of technologies for soil and groundwater, respectively. Technologies and process options eliminated from further consideration based on the preliminary evaluation are shaded gray in Tables 4, 5, and 6.

After the preliminary screening, the retained corrective measure technologies and process options were further evaluated using the following criteria:

- effectiveness
- cost
- implementability

The effectiveness of corrective measure technologies and process options is based on the following criteria:

- potential effectiveness in meeting CAOs for the contaminant types, site conditions, and estimated areas and volumes of affected media
- potential human exposures, adverse environmental effects, and nuisance conditions resulting from implementation

Implementability primarily refers to the administrative aspects of using a process option, such as obtaining necessary permits, the availability and capacity of treatment, storage, and disposal services, and the availability of necessary equipment. Cost is not heavily weighted in the evaluation of process options during the initial screening. General capital and operations and maintenance (O&M) costs are used instead of detailed estimates.

Table 7 presents the screening and qualitative evaluation of process options for DNAPL corrective measure process options. Tables 8 and 9 present the screening and qualitative evaluation of process options for soil and groundwater, respectively. Each process option was given a “low”, “moderate”, or “high” rating for effectiveness, implementability, and cost. Technologies and process options eliminated from further consideration are shaded grey in Tables 7, 8, and 9.

4.4 Technologies Retained

The following process options were retained in whole or in part as potential corrective measure alternatives.

DNAPL (AOCs 1 and 3)

- no action
- institutional controls (Site Management Plan)
- long-term gauging
- infiltration control/capping
- physical removal of DNAPL from recovery wells
- excavation of DNAPL for off-site disposal
- treat DNAPL using thermal heating and extraction
- disposal of recovered DNAPL off site

Soil (AOCs 1 and 3)

- no action
- institutional controls (Site Management Plan)
- infiltration control/capping
- soil removal
- disposal of soil off site

Groundwater (AOCs 1, 2, and 3)

- no action
- institutional controls (Site Management Plan)
- monitored natural attenuation

Remedial technologies retained for AOCs 1, 2, and 3 during technical implementability and process-option screenings are summarized in Table 10. Technologies and process options eliminated from further consideration based on effectiveness, implementability, or cost are shaded grey.

4.4.1 DNAPL Options

The technologies and process options for addressing DNAPL are briefly described below and were evaluated by comparing effectiveness, implementability, and cost (Table 7).

4.4.1.1 No Action

The “no action” option is retained and examined as a baseline for comparison to other corrective measures (Table 7).

4.4.1.2 Institutional Controls

Institutional controls affect site management and use. Institutional controls do not physically alter site conditions and are not intended to reduce the mobility, toxicity, or volume of COPC as part of the corrective measures alternative. Institutional controls limit the potential for exposure to COPC through deed notifications, deed restrictions, and site management and health and safety plans.

Deed notifications are descriptions about the property recorded using an environmental covenant to prohibit certain uses. The covenant could include land use restrictions and preclude residential use of the property. The covenant could prohibit facilities with sensitive populations and prohibit the extraction or use of groundwater. Institutional controls received “moderate” effectiveness, “high” implementability, and “low” cost ratings (Table 7). Institutional controls do not affect the presence or amount of DNAPL, and would be used in combination with other process options (Table 7).

4.4.1.3 Long-Term Monitoring

Long-term monitoring, including periodic gauging of wells with an interface probe, provides information on the presence and recoverability of DNAPL. Because DNAPL is not present in the groundwater monitoring wells at the site, DNAPL monitoring and recovery wells could be installed in areas where DNAPL was observed and monitored with an interface probe to evaluate the presence, thickness, and recoverability of DNAPL, if present.

Long-term monitoring received “low” effectiveness, “high” implementability, and “low to moderate” cost ratings (Table 7). The effectiveness of long-term monitoring may increase to “moderate” if implemented in conjunction with other process options.

4.4.1.4 Manual DNAPL Removal

Manual removal of DNAPL from wells is a common practice typically implemented using bailers or absorbent materials. Manual removal of DNAPL is possible when the DNAPL thickness in a well is sufficient to allow collection (generally greater than 1 foot). Bailing DNAPL is conducted by repeatedly lowering a bailer to the bottom of the well and emptying the contents into a container at the surface until the DNAPL volume recovered is no longer measurable.

Alternatively, absorbent materials are placed in wells where less than 1 foot of DNAPL accumulates or where DNAPL thickness recovers slowly after removal. The absorbent material is removed and replaced periodically depending on the rate of DNAPL accumulation in the well. Manual removal received “moderate” effectiveness, “high” implementability, and “low” cost ratings (Table 7).

4.4.1.5 Mechanical Removal

Mechanical removal of DNAPL from wells is a common practice implemented when the accumulation of DNAPL is greater than can be reasonably recovered manually, and when the capital costs for a mechanical system can be offset by lower labor costs compared to manual removal. Floats calibrated to the DNAPL density control a pump or skimmer and, ultimately, pump operation. The pump or skimmer is connected to a collection unit consisting of a secondary containment unit with internal storage containers, typically one or two 55-gallon drums, where the recovered fluid is stored prior to off-site disposal.

Mechanical recovery is powered by either solar panels or a standard 120-volt a/c electrical connection. Depending on the rate of DNAPL accumulation, collection units may be emptied weekly, monthly or quarterly. Mechanical removal received “moderate to high” effectiveness, “moderate to high” implementability, and “low” cost ratings (Table 7).

4.4.1.6 Excavation

Excavation involves the physical removal of targeted media. Typical equipment used includes backhoes, draglines, clamshells, vacuum trucks, and front-end loaders. Because of the limited footprint of the targeted area and the depth of historical observations of DNAPL (varying from 22 to 30 feet bgs), augers may also be appropriate for excavation. Soil and groundwater sampling and field observations would be used to confirm the presence of DNAPL and to define the extent before excavation. Excavation and removal of soil containing DNAPL eliminates the source of VOCs in soil and groundwater.

Soil and groundwater near DNAPL would be removed along with the DNAPL during excavation. As discussed in Section 2, areas of historically observed DNAPL are co-located with elevated COPC concentrations in soil and groundwater. Thus, removal of soil and groundwater near potential DNAPL areas will result in decreased COPC migration from potential source areas.

Excavation of soil containing DNAPL is considered an aggressive remediation method because it disturbs the soil and could potentially mobilize DNAPL vertically or horizontally. Because soil at the site is tight till with low permeability, the backfill should be low permeability material similar to the native soil to avoid creating more permeable zones where dissolved COPC could migrate preferentially. Excavation received “moderate” effectiveness, “low to moderate” implementability, and “high” cost ratings (Table 7).

4.4.1.7 In Situ Thermal Remediation

In situ thermal remediation (ISTR) is an aggressive treatment option that heats the subsurface to volatilize COPC. Heating technologies include electrical resistance heating (ERH), thermal conductance heating (TCH), or steam-enhanced extraction. Thermal remediation by injecting steam is not feasible in low permeability soils, but ERH and TCH are retained as viable treatment options.

4.4.1.7.1 Electrical Resistance Heating

ERH is typically used to heat low permeability saturated and unsaturated zone soils. ERH passes three-phase electrical current between subsurface electrodes. The natural electrical resistance of soil and groundwater causes the temperature to rise in response to the applied current. The ERH process requires water to remain in soil pores to prevent the soils from desiccating and becoming overly resistive; therefore, the upper temperature threshold of the heating process is the boiling point of water (i.e., 100°Celsius [C] at atmospheric pressure). Though the groundwater does not boil, steam produced during heating moves volatile contaminants to the surface where they are recovered using vacuum extraction.

The rate of heating in an ERH application depends on the resistive properties of the formation and the amount of energy delivered to the subsurface; however, subsurface temperatures approaching the boiling point of water are typically achieved in about one to two months.

4.4.1.7.2 Thermal Conductive Heating

TCH is effective in low permeability soils. The TCH process uses electrically powered in situ heater wells that span the vertical treatment interval and are heated to 500 to 800°C. Heat conducts from the heater wells into the soil formation at a uniform and predictable rate. The thermal conductivity of different soil types has little variability. During the heating process, soils adjacent to the heater wells achieve temperatures higher than the boiling point of water, which will vaporize pore water and VOCs. Although conduction is TCH’s primary heat transfer mechanism, convection also occurs (steam and hot groundwater mobilize in heated parts of the soil column).

4.4.1.7.3 Thermal Remediation and Extraction

The high soil temperature created in thermal treatment areas raises the VOC vapor pressure, which increases volatilization from soil and groundwater. Volatilized VOCs and dissolved-phase compounds are recovered using either multi-phase extraction (MPE) or soil vapor extraction. MPE consists of recovery wells that can recover both vapor and liquid phases and increase the net effective drawdown. Soil vapor extraction removes vapor phase only.

MPE well-screen intervals span both the saturated and unsaturated zones, thereby removing volatile organic vapors in soil gas (vapor extraction) and groundwater, which lowers the water table and exposes more of the subsurface to vapor extraction. Groundwater extraction also removes dissolved contaminants from the subsurface. For soil vapor extraction, the wells may span both the saturated and unsaturated zones but the operation is controlled to achieve vapor recovery while limiting the extraction of groundwater. The results of MPE pilot testing, conducted in 2012 and discussed in the *CMS Report* in Section 3.4 and Appendix B, indicate that hydraulic and vapor control can be established and sustained with relatively low extraction rates. MPE effectiveness is limited by soil permeability and the ability to move water and vapor through the subsurface. Because of technology limitations, MPE was not considered as a stand-alone technology, but may be applicable in conjunction with ISTR.

MPE would not be implemented with ERH because the soil needs to stay moist for ERH to be effective. ERH would be implemented with soil vapor extraction.

4.4.1.7.4 Thermal Remediation Benefits

Increased vapor pressure is the predominant thermal remediation mechanism. Thermal remediation benefits include:

- Vapor, groundwater, and DNAPL viscosities are reduced at elevated temperatures, resulting in improved mobility and recoverability of vapors and liquids.
- The steam generated within pore space during TCH can enhance effective porosity and improve vapor- and liquid-phase recovery.
- VOC adsorption coefficients are reduced when soil temperatures are increased, resulting in an increased rate of desorption from soil particles.
- The azeotropic boiling point of TCE (73.4 °C) is lower than the pure compound boiling point (86.9 °C) and the boiling point of water (100 °C). As such, DNAPL within the saturated treatment zone will undergo azeotropic boiling at the DNAPL/water interface, which will expedite the transfer and recovery of DNAPL from the liquid to the vapor phase.

ISTR would include MPE to remove volatilized VOCs. Soil and groundwater within the ISTR treatment footprint would be treated along with the DNAPL. As discussed in Section 2, areas of historically observed DNAPL are co-located with elevated concentrations of COPC in soil and groundwater. Thus, ISTR treatment of soil and groundwater near potential DNAPL areas will result in decreased COPC migration from potential source areas. Thermal treatment received “high” effectiveness, “moderate” implementability, and “high” cost ratings (Table 7).

4.4.2 Soil Options

The technologies and process options for addressing the target area for unsaturated soils that exceed the commercial SCO are described below and evaluated based on effectiveness, implementability, and cost in Table 8. The technologies and process options for addressing saturated and unsaturated soil target areas that exceed the protection of groundwater SCOs are evaluated in conjunction with the technologies and process options for addressing the groundwater target areas, discussed below in Section 4.4.3.

4.4.2.1 No Action

The final NYSDEC DER-10 guidance for selecting a corrective measures alternative specifies that a “no action” alternative be developed and examined as a potential corrective measure. The “no action” option, which would not be effective but would be easy to implement with no costs, is retained and examined as a baseline against other corrective measures (Table 8).

4.4.2.2 Institutional Controls

Institutional controls affect site management and/or use and would include the components discussed in Section 4.3.1.2. Institutional controls received “moderate” effectiveness, “high” implementability, and “low” cost evaluations (Table 8). Institutional controls do not affect the COPC concentration in soil, and are considered in combination with other process options (Table 8).

4.4.2.3 Excavation

Excavation and dewatering involves the physical removal of targeted media. Typical equipment used includes backhoes, draglines, clamshells, vacuum trucks, and front-end loaders. Soil sampling would confirm the removal of contaminants before backfilling. Excavation and removal of soil greater than commercial SCOs eliminates the potential for exposure during site construction work.

Excavated material is typically characterized and disposed off-site at an approved waste management facility. Off-site transportation of wastes must comply with applicable shipping and manifesting regulations. Disposal cost depends on the amount of soil removed and the soil characteristics (hazardous or non-hazardous).

Excavation of source zone mass is considered an aggressive remediation method. Excavation received “moderate to high” effectiveness, “moderate” implementability, and “high” cost evaluations (Table 8).

4.4.2.4 Elimination of in situ Thermal Remediation

ISTR was previously retained as a treatment technology for soil in the CMS Report (Arcadis 2013). However, as part of the revised treatment technology screening, ISTR was not retained as a soil corrective measure technology. This change to the technology screening results was largely influenced by the following factors:

1. The CAO for saturated and unsaturated soils in AOCs 1, 2, and 3 was revised from the commercial SCO to the protection of groundwater SCO.
2. The soil target area expanded significantly because the target areas for achieving the protection of groundwater SCO in unsaturated and saturated soils matches the target area for groundwater above SGVs, as discussed in Section 4.1.3.
3. Because saturated and unsaturated soils in ACOs 1, 2, and 3 are in contact with groundwater with COPC concentrations above SGVs, technologies evaluated for treatment of soil must be considered in conjunction with treatment of groundwater within AOCs 1, 2, and 3.

ISTR was not retained as a corrective measure for the protection of groundwater SCO because of the low implementability and very high cost associated with applying ISTR (Table 8). The very large footprint of the target area would include all of AOCs 1, 2, and 3, resulting in significant impact to business operations at the facility. The cost for applying ISTR over such a large area is very high cost compared to the other corrective measures that are considered.

ISTR was not retained as a corrective measure for the unsaturated soil commercial SCO target area because of the high cost and low implementability compared to other retained technologies for soil (Table 8). With only a single unsaturated zone soil sample from 1.5 feet bgs at B2-PH04 exceeding the commercial SCO, the capital cost to mobilize a thermal treatment system greatly exceeds costs for the other technologies considered, such as excavation.

4.4.3 Groundwater Options

The technologies and process options for addressing COPC in groundwater are briefly described below and evaluated by comparing effectiveness, implementability, and cost (Table 9). The technologies and process options discussed in this section also apply to unsaturated soils in ACOs 1, 2, and 3 that exceed the protection of groundwater SCOs because unsaturated soils are in contact with groundwater with COPC concentrations above SGVs.

4.4.3.1 No Action

The “no action” option is retained and examined as a baseline for comparison to other corrective measures (Table 9).

4.4.3.2 Institutional Controls

Institutional controls affect site management and use and would include the components discussed in Section 4.3.1.2. Institutional controls received “moderate” effectiveness, “high” implementability, and “low” cost evaluations (Table 9). Institutional controls do not affect the VOC concentration in groundwater, and are considered in combination with other process options (Table 9).

4.4.3.3 Monitored Natural Attenuation

As discussed in Section 2, the MNA assessment conducted as part of the CMS Report (Arcadis 2013) was updated to include data collected since the submittal, and the evaluation was revised to improve the data quality for assessing the feasibility of applying MNA as a corrective measure. The revised MNA assessment resulted in better statistical evidence for decreasing COPC concentration trends, and greater confidence in the calculated COPC attenuation half-lives in AOCs 1, 2, and 3 (Appendix B).

Groundwater throughout AOCs 1, 2, and 3 is included in the target area because COPC concentrations at each of the monitoring wells in AOCs 1, 2, and 3 exceeded the SGVs. The evidence for decreasing COPC concentrations and complete degradation of COPC in ACOs 1, 2, and 3 presented in Appendix B shows that groundwater SGVs will be achieved through MNA. As COPC concentrations in groundwater achieve SGVs, concentrations in the surrounding soil, which are in equilibrium with groundwater, will also achieve the protection of groundwater SCOs. COPC concentrations in unsaturated soil will also achieve the protection of groundwater SCOs through contact between unsaturated zone soils and attenuating COPC in groundwater.

MNA would be implemented through routine monitoring of select parameters as part of a long-term monitoring program. MNA received “low” effectiveness, “high” implementability, and “low to moderate” cost ratings (Table 9). The effectiveness of MNA would increase to “moderate” if implemented in combination with other options (e.g., source removal).

4.4.3.4 Elimination of Excavation and in situ Thermal Remediation

Excavation and ISTR were previously retained groundwater in the *CMS Report* (Arcadis 2013) as source treatment technologies targeting the areas of highest groundwater COPC concentrations in AOCs 1, 2, and 3. The *CMS Report Addendum* evaluates excavation and ISTR as corrective measures in potential source areas where DNAPL was historically observed. The revised groundwater target area is outside the potential source areas. Excavation and ISTR are not retained as corrective measures for the groundwater target area because of the very high cost and low implementability compared to other retained technologies for groundwater (Table 9).

4.5 Components Common to Each Alternative

The *CMS Report Addendum* focuses on the updated conceptual site model and corrective measures alternatives evaluation for AOCs 1, 2, and 3. Corrective measures components identified for soil vapor intrusion mitigation, historical outfall soil, and site management are unchanged from the *CMS Report* (Arcadis 2013). Therefore, some components of the final corrective measure alternative will be common to each of the alternatives identified because of this evaluation. Components common to each of the AOC 1, 2, and 3 corrective measures alternatives will include:

- implementation of a Site Management Plan (SMP) for groundwater monitoring and institutional controls;
- restricting groundwater use; and
- implementing an environmental covenant to restrict future site use to warehousing and distribution;

The above components common to each corrective measures alternative are presented in the *CMS Report* (Arcadis 2013). H.P. Neun (now Seneca Falls Specialists and Logistics) and the Seneca County Industrial Development Agency have agreed to collaborate on the selected corrective measures, and will remain key stakeholders during the design and implementation of corrective measures.

Because TCE concentrations in and near the potential source areas (areas of historically observed DNAPL) are near the solubility limit, and TCE concentrations in groundwater throughout the remainder of the site are orders of magnitude less, a comprehensive remedial approach is planned for the site involving an integrated site strategy. The strategy for an integrated approach to address DNAPL is outlined in the *Technical/Regulatory Guidance: Integrated DNAPL Site Strategy* developed by the Interstate Technology & Regulator Council (ITRC 2011). The strategy includes targeting the source areas for active remediation, integrated with monitored natural attenuation (MNA).

The natural attenuation assessment (Appendix B) and the evaluation presented in Section 4.4 show that implementing MNA at the site will allow concentrations of COPC in groundwater to meet CAOs established in the *CMS Report* (Arcadis 2013). Additionally, because of equilibrium partitioning between the soil matrix and groundwater, COPC concentrations in soil at the site will reach the protection of groundwater SCO as concentrations of COPC in groundwater attain the SGVs.

Concentrations of COPC in unsaturated zone soils were compared to worker exposure scenarios as part of the *CMS Report* (Arcadis 2013). Based on the technology screening conducted in Section 4.4, excavation is the only technology retained that would treat unsaturated soils for construction worker scenarios. To address potential worker exposure scenarios and achieve CAOs for soil, unsaturated zone soil (less than 4 feet bgs) with COPC concentrations greater than commercial SCOs will be excavated and disposed of off-site. Unsaturated zone soil with COPC concentrations greater than commercial SCOs was reported in only one soil sample during the RCRA Facility Investigation (RFI) and CMS (at boring B2-PH-04, located about 5 feet south of Building 2) (Figure 5).

Seasonal fluctuations of groundwater elevations result in contact between groundwater COPC and soils in the capillary fringe and unsaturated zone. However, as discussed in Section 2, groundwater TCE levels outside the potential DNAPL areas are below the concentration (520 mg/L) that could, by contact and partitioning during water level fluctuations, result in soil concentrations above the commercial SCO for TCE (200 mg/Kg). The target areas for DNAPL and unsaturated zone soil active remediation will be refined following pre-design investigations.

Following source removal, a MNA program will be implemented to monitor the natural attenuation of COPC and reductions in concentrations toward the SGVs. Periodic reassessment of the calculated attenuation half-lives will be performed to evaluate the performance of the MNA remedy. It is anticipated that COPC half-lives will decrease over time, resulting in shorter COPC travel distances to achieve SGVs after the source mass is removed and parent COPC are depleted.

Based on the above, the following two components are also common to each of the corrective measures alternatives presented in the following sections:

- MNA (with periodic reassessment of the calculated attenuation half-lives to evaluate remedy performance); and
- Excavation of unsaturated soil (less than 4 feet below ground surface) with concentrations that exceed commercial SCOs.

4.6 Corrective Measures Alternatives for AOCs 1, 2, and 3

The process options retained during the technical implementability and process option screenings (Table 10) were assembled into corrective measure alternatives for each AOC (AOC 1-Building 2 Area, AOC 2-Building 7 Area, and AOC 3 – Building 11 Areas). Descriptions of each alternative include a conceptual design and assumptions for implementation as a basis for detailed analysis and comparison to other alternatives. Each alternative for AOCs 1, 2, and 3 is summarized in Table 11.

Corrective measure technologies retained in the *CMS Report* (Arcadis 2013) are similar to those included in the *CMS Report Addendum*. No change was made to the Alternatives evaluated for AOC 2 because DNAPL was not observed within the Building 7 area and soil or groundwater data do not indicate the presence of DNAPL. The alternatives previously considered for AOC 2 are supported by the updated conceptual site model that includes MNA, as discussed in Section 2. As part of performance monitoring, monitoring results from the MNA program will be used to predict groundwater concentrations and evaluate the effectiveness at achieving CAOs in AOC 2. Soil COPC concentrations will decrease to the protection of groundwater SCOs through natural degradation and as groundwater COPC concentrations decrease over time.

The corrective measures alternatives for AOCs 4 and 5 presented in the *CMS Report* are still applicable and are, therefore, not discussed in the *CMS Report Addendum*. The proposed alternatives for AOCs 1, 2 and 3 were evaluated using the threshold and balancing criteria outlined in the *CMS Report* (Arcadis 2013). Results of the evaluation are provided in Tables 12, 13 and 14 for AOCs 1, 2, and 3, respectively.

4.7 Area of Concern 1 (Building 2 Area) Alternatives

The following corrective measure alternatives were evaluated for the AOC 1 – Building 2 area that contained DNAPL, groundwater COPC concentrations in excess of SGVs, saturated soil COPC concentrations in excess of protection of groundwater and commercial SCOs, and unsaturated soil concentrations in excess of protection of groundwater SCOs:

- Alternative 1A – No Action
- Alternative 1B – Physical Removal of DNAPL and MNA
- Alternative 1C – Thermal Treatment and MNA
- Alternative 1D – Excavation and MNA

The no action alternative and SMP were considered for each AOC and are discussed in the *CMS Report* (Arcadis 2013). The groundwater and site use restrictions will be recorded in an environmental covenant. The conceptual design assumptions for each corrective measures alternative appear in Table 11. Sections 4.7.1 through 4.7.3 present an analysis of corrective measures for the various alternatives considered for AOC 1 using the balancing criteria (Table 12).

4.7.1 Alternative 1B: Physical Removal and MNA

Alternative 1B combines the physical removal of DNAPL from recovery wells either through manual or mechanical methods with MNA and the SMP (including institutional controls). For costing purposes, it is assumed that one recovery well would be installed in each of the two locations where DNAPL was observed in AOC 1. The locations where DNAPL was observed within the Building 2 area are depicted on Figure 2. The conceptual design assumptions for Alternative 1B are in Table 11. Implementing Alternative 1B would involve the installation of recovery wells in the area of observed DNAPL, as presented on Figure 7, for manual or mechanical removal of DNAPL. This alternative is estimated to require more than 10 years of DNAPL recovery and more than 50 years for MNA to attain SGVs.

An analysis of Alternative 1B relative to the balancing criteria is provided in Table 12.

4.7.2 Alternative 1C: Thermal Remediation and MNA

Alternative 1C combines ISTR with MNA and the SMP (including institutional controls). Additional investigation would be required to verify the target treatment area before designing the thermal remediation system. The approximate extent of the ISTR area in ACO 1 based on existing data is shown on Figure 8. The ISTR area encompasses borings in AOC 1 where DNAPL was historically observed (B2-PH05 and MW-BI-01), and where soil analytical results indicate DNAPL was potentially present (B2-06). ISTR would volatilize and remove DNAPL resulting in the removal of COPC sorbed to soil and dissolved in groundwater. The conceptual design assumptions for Alternative 1C are in Table 11.

If Alternative 1C is implemented, the estimated time for groundwater concentrations to attain SGVs is more than 30 years. Implementing Alternative 1C would include installing the following equipment:

- electrodes or heater wells within the treatment area,
- vapor-liquid extraction and sensor wells bordering and within the treatment area, and
- a temporary vapor and water treatment system.

During ISTR, DNAPL and COPC in soil and groundwater turn to vapor as they are heated. The vapor and groundwater would be extracted and treated prior to discharge. Implementing ISTR would take about 12 months.

An analysis of Alternative 1C relative to the balancing criteria is provided in Table 12.

4.7.3 Alternative 1D: Excavation and MNA

Alternative 1D combines soil excavation with MNA and the SMP (including institutional controls). Additional investigation would be required to verify the excavation area prior to starting the design. The excavation would target the areas of DNAPL. Because of the depth of the potential DNAPL (28 to 30 feet bgs), and the potential for sheeting and shoring to cause DNAPL mobilization, the excavation footprint may be significantly larger than the extent of DNAPL. The conceptual design assumptions for Alternative 1D are in Table 11.

Implementing Alternative 1D would involve the excavation and off-site disposal of soil from an area about 3,800 square feet down to a maximum depth of 33 feet bgs. Excavation is estimated to take about one month. The approximate excavation footprint is depicted on Figure 9. The estimated time for groundwater concentrations to attain SGVs is more than 30 years.

An analysis of Alternative 1D relative to the balancing criteria is provided in Table 12.

4.8 Area of Concern 2 (Building 7 Area) Alternatives

As discussed in Section 4.6, corrective measure alternatives for AOC 2 are the same as those presented in the *CMS Report* with the modification of long term monitoring to MNA, which will include long-term groundwater monitoring and periodic reassessment of the calculated attenuation half-lives to evaluate remedy performance and reductions in COPC concentrations toward the SGVs. The alternatives considered for AOC 2 are supported by the updated conceptual site model that includes the natural attenuation processes discussed in Section 2. An additional groundwater monitoring well may be needed to monitor the area downgradient of AOC 2 (Figure 7). Base on the revised MNA assessment, MNA is an acceptable standalone technology in AOC 2 for groundwater to achieve SGVs.

An analysis of AOC 2 Alternatives relative to the balancing criteria is provided in Table 13.

4.9 Area of Concern 3 (Building 11 Area) Alternatives

The following corrective measure alternatives were evaluated for the AOC 3 – Building 11 area that contained DNAPL, groundwater COPC concentrations in excess of SGVs, saturated soil COPC concentrations in excess of protection of groundwater and commercial SCOs, and unsaturated soil concentrations in excess of protection of groundwater SCOs:

- Alternative 3A - No Action,

- Alternative 3B – Physical Removal of DNAPL and MNA,
- Alternative 3C – Thermal Treatment and MNA, and
- Alternative 3D - Excavation and MNA.

The no action alternative and SMP are discussed in the *CMS Report* (Arcadis 2013). The groundwater and site use restrictions will be recorded in an environmental covenant. The conceptual design assumptions for each corrective measure alternative appear in Table 11. Sections 4.9.1 through 4.9.3 present an analysis of corrective measures for the various alternatives considered for AOC 3 using the balancing criteria (Table 14).

4.9.1 Alternative 3B: Physical Removal and MNA

Alternative 3B combines the physical removal of DNAPL from recovery wells either through manual or mechanical methods with MNA and the SMP (including institutional controls). For costing purposes, it is assumed that one recovery well would be installed in each of the two locations where DNAPL was observed in AOC 3. The conceptual design assumptions for Alternative 3B are in Table 11. Implementing Alternative 3B would involve installing recovery wells in the area of observed DNAPL, as presented on Figure 7, for manual or mechanical removal of DNAPL. This alternative is estimated to require more than 10 years of DNAPL recovery and more than 50 years for MNA to attain SGVs.

An analysis of Alternative 3B relative to the balancing criteria is provided in Table 14.

4.9.2 Alternative 3C: Thermal Remediation and MNA

Alternative 3C combines ISTR with MNA and the SMP (including institutional controls). Additional investigation would be required to verify the target treatment area prior to the designing the thermal remediation system. The approximate extent of the ISTR area in AOC 3 based on existing data is shown on Figure 8. The ISTR area encompasses borings in AOC 3 where DNAPL was historically observed (B11-PH-07 and B11-PH08), and where soil analytical results indicate DNAPL was potentially present (B11-PH09). ISTR would volatize and remove DNAPL resulting in the removal of COPC sorbed to soil and dissolved in groundwater. The conceptual design assumptions for Alternative 1D are in Table 11.

If Alternative 3C is implemented, the estimated time for groundwater concentrations to attain SGVs is more than 30 years. Implementing Alternative 3C would include installing of the following equipment:

- electrodes or heater wells within the treatment area,
- vapor-liquid extraction and sensor wells bordering and within the treatment area, and
- a temporary vapor and water treatment system.

During ISTR, DNAPL and COPC in soil and groundwater turn to vapor as they are heated. The vapor and groundwater would be extracted and treated prior to discharge. Implementing ISTR would take about 12 months.

An analysis of Alternative 3C relative to the balancing criteria is provided in Table 14.

4.9.3 Alternative 3D: Excavation and MNA

Alternative 3D combines soil excavation with MNA and the SMP (including institutional controls). As discussed in Section 4.9.2 above, additional investigation would be required to verify the excavation area prior starting the design. The excavation would target the DNAPL areas. Because of the depth of the potential DNAPL and the potential for sheeting and shoring to cause DNAPL mobilization, the excavation footprint may be significantly larger than the extent of DNAPL. Additionally, the proximity of the excavation to Building 11 may require substantial shoring of the excavation to protect the Building 11A foundation, or razing of Building 11A. The conceptual design assumptions for Alternative 3D are in Table 11.

Implementing Alternative 3D would involve excavating and off-site disposal of about 3,200 square feet of soil to a maximum depth of 33 feet bgs, which is estimated to take about one month. The approximate excavation footprint is depicted on Figure 9. The estimated time for groundwater concentrations to attain SGVs is more than 30 years.

An analysis of Alternative 3D relative to the balancing criteria is provided in Table 14.

4.10 Comparative Analysis

A comparative analysis was completed using the balancing criteria in Tables 12, 13, and 14 to identify the recommended corrective measure alternatives. The “no action” alternative was removed from consideration because it did not achieve the threshold criteria or the balancing criteria. Because of the similar nature of alternatives 1B and 3B, they are considered jointly for AOCs 1 and 3 as the “B Alternative” (physical DNAPL removal and MNA). Similarly, 1C and 3C along with 1D and 3D are considered as the “C Alternative” (ISTR and MNA) and “D Alternative” (excavation and MNA), respectively. Because the ‘no action alternative was removed from consideration, Alternative 2B is the recommended corrective measure alternative for AOC 2.

4.10.1 Long-Term Effectiveness

Each of the recommended corrective measure alternatives would remove source area COPC mass, and reduce COPC concentrations in soil and groundwater to meet protection of groundwater SCOs and groundwater SGVs, respectively. Because the recommended alternatives are expected to achieve long-term effectiveness, the differentiator between each alternative in the comparative analysis is reliability. The reliability and effectiveness of ISTR and excavation are very high because both measures will remove the COPC mass within the treatment area. However, the potential exists for DNAPL to be mobilized during excavation.

Physical removal of observed DNAPL may be a reliable alternative and effective in terms of implementation, but the long-term reliability and effectiveness is dependent on the recoverability of DNAPL, and. the chance of success is unknown. ISTR and MNA appear to be the most reliable corrective measures for long-term effectiveness.

4.10.2 Reduction of Toxicity, Mobility, or Volume of Wastes

Physical removal, ISTR, and excavation reduce the mobility, toxicity, and volume of VOCs in soil and groundwater. The statutory preference for treatment as a principal element would be satisfied.

4.10.3 Short-Term Effectiveness

This criterion evaluates the potential effects that the alternative will have on human health and the environment during construction and implementation. Short-term effectiveness of alternatives is affected by the amount of activities performed to implement the alternative. The C and D alternatives would pose marginally higher risks to the community, workers, and the environment than the B alternative because of increased site activity and traffic. During installation of thermal treatment equipment identified in the C alternative, risks from electrical and thermal hazards would be limited to construction workers and operators. Engineering controls would be used to reduce potential site-worker exposure to fugitive vapors produced during thermal treatment. CAOs and soil protectiveness could be achieved in about 12 months.

Similarly, excavation of soils including the creation of pits and possible use of caissons would increase risk during implementation. Using construction area barricades and signage, risks would be limited to construction workers and operators but could still pose a larger risk than an in-situ process with a contained system. Also, there is a potential risk of DNAPL mobilization with excavation if the excavation boundary is not effectively contained during removal activities or if the DNAPL is not completely removed. Assuming no mobilization, CAOs and soil protectiveness could be achieved in less than 6 months.

The B alternative requires less construction for implementation. Recovery well installation to facilitate physical removal of DNAPL would pose a limited risk to construction workers. However, the time needed to achieve CAOs could be up to 5 years.

With only a marginal increase in short term risk but a large reduction in the timeframe to achieve CAOs and soil protectiveness, ISTR has the most favorable short-term effectiveness.

4.10.4 Implementability

Each of the alternatives considered are technically and administratively feasible and would not interfere with site operations. However, because of onsite utilities, implementing either the C or D alternatives could require relocating utilities, or using engineering controls or modifying the treatment footprint to avoid utilities. The smaller footprint of the B alternative poses fewer challenges and would likely be the most implementable alternative.

4.10.5 Sustainability

The sustainability of each alternative was judged based on the natural resource consumption and the environmental burden of implementing an alternative (consistent with the green remediation practices and strategies in Subsection 1.14 of the DER-10). Qualitative sustainability was assessed based on the following five green remediation metrics:

1. energy use,
2. air emissions,
3. water consumption,
4. land impact, and
5. material consumption and waste generation.

Factors in the evaluation of sustainability for each of the alternatives include the initial implementation and the long-term operation and maintenance demand. Implementing sustainability best management practices during the design phase for each alternative can lead to improved sustainability.

The B alternative (physical removal of DNAPL) requires monitoring and institutional controls resulting in long-term fuel consumption contributing to energy use and air emissions. Additionally, waste will be generated during site visits as DNAPL is physically removed. The relative quantities of energy used and waste generated are small compared to both ISTR and excavation, making the B alternative the most sustainable alternative.

Energy use is the predominant green remediation metric impacted by the C alternative (ISTR). The duration of energy use is short, but the amount of energy consumed is large. Hydroelectric power generation within upstate New York reduces the air emissions compared to regions where power is generated using coal or natural gas. Waste will also be generated during ISTR; however, the amount of waste generated will be much less than from excavation because COPC will be concentrated on activated carbon or in the form of recovered DNAPL. The use of fuel-powered equipment with air emissions would be limited to the construction phase, and is expected to be less than emissions during excavation.

The D alternative (excavation) uses large fuel-powered equipment, with higher energy requirements and air emissions than alternative B, but less than the C alternative. Excavation would generate significantly more waste (several thousand tons of excavated soil) than the B or C alternatives and require resources for restoration. Although the implementation time is shorter for excavation, the operations intensity and the amount of waste generated may make the D alternative the least sustainable alternative.

4.10.6 Cost

The costs for each corrective measure alternative evaluated for AOCs 1, 2, and 3 are summarized in Table 15 and Appendix C. Factors that affect the costs for each alternative are the capital cost and the operation and maintenance (O&M) costs.

The B alternative is the only source area treatment alternative that has O&M costs. The other alternatives' O&M costs are associated with the common corrective measures. Although O&M costs for the B alternative are cumulative over 30 years, the total costs are still the lowest because of the low capital cost.

The D alternative (excavation) has the highest capital cost and the highest overall costs. The costs are driven by the labor and equipment to perform the excavation and the cost for waste disposal.

The C alternative (thermal treatment) has median capital and overall project costs. The cost for thermal treatment is driven by installation and operation of the thermal remediation wells and system.

4.10.7 Recommended Alternatives

The recommended alternatives for AOCs 1, 2, and 3 are the 1C (ISTR and MNA), 2B (Site Management Plan and MNA), and 3C (ISTR and MNA) alternatives, respectively.

5 CONCLUSIONS

Revised corrective measure alternatives for AOCs 1, 2, and 3 were developed following accepted USEPA and NYSDEC guidance and are based on an updated evaluation of data summarized in the *CMS Report* (Arcadis 2013), and data collected since the *CMS Report* was submitted in 2013. H.P. Neun (now Seneca Falls Specialists and Logistics) and Seneca County Industrial Development Agency have agreed to collaborate on the selected corrective measures, and will remain key stakeholders during the design and implementation of corrective measures.

The former DNAPL areas are believed to be the source of TCE to groundwater and are proposed to be targeted for active remediation. Natural attenuation of groundwater COPC concentrations has been documented for more than two decades and DNAPL treatment will accelerate the natural attenuation of COPC. Site-specific attenuation half-lives show that TCE concentrations will decrease to below NYSDEC Class GA standards before reaching the site boundary. Based on the evaluation of RCRA performance standards and criteria, and on the continued integration of corrective measures with beneficial site use, the corrective measures recommended for AOCs 1, 2, and 3 include the following steps:

- implementing in situ thermal remediation to treat DNAPL,
- monitoring the natural attenuation of COPC in groundwater over the long term and comparing results to predicted concentrations,
- excavating unsaturated soil in AOCs 1, 2, and 3 with concentrations greater than commercial SCOs,
- implementing a Site Management Plan to include institutional controls,
- restricting groundwater use, and
- recording an environmental covenant to restrict future site use to warehousing and distribution.

Corrective measures applicable to site-wide conditions and those specific to AOCs 4 (Soil Vapor Intrusion Pathways) and 5 (Historical Outfalls) remain unchanged and are discussed in the *CMS Report* (Arcadis 2013).

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TABLES

Table 1
TCE Fate and Transport

Former Philips Components Facility
Seneca Falls, New York

Well/Boring	TCE concentration (µg/L)	Sampling date	Sampling depth (ft bgs)	Attenuation half-life (yrs)[b]	Travel distance to class GA standard[c] (ft)	Distance to property boundary (ft)
Building 2 Area						
B2-01	3,200	Oct-00	2-12	12.58	235	302
B2-02	2,300	Oct-00	6-16	12.58	223	257
B2-03	1,100	Oct-00	6-16	12.58	196	302
B2-04	370	Oct-00	6-16	12.58	156	241
B2-05	45,000	Oct-00	16-26	5.42	142	309
B2-06	230,000	Oct-00	16-26	5.42	168	264
B2-07	3	Oct-00	16-26	5.42	Achieved	138
B2-09	1,200	Oct-00	12-22	5.42	86	220
B2-10	650	Oct-00	16-26	5.42	76	104
B2-11	8	Oct-00	16-26	5.42	7	156
B2A-04	98	Oct-00	16-26	5.42	47	99
B2-PH01	18	Jul-05	29-34	5.42	20	163
B2-PH02	10	Jul-05	0-10	12.58	25	321
B2-PH03	11,000	Aug-05	15-20	5.42	120	224
B2-PH04	29,000	Aug-05	23-33	5.42	136	304
B2-PH08	310	Jul-05	28-35.5	5.42	65	104
IS-02	13	Oct-00	<12	12.58	35	102
IS-03	8	Oct-00	<12	12.58	17	207
MW-24[a]	1,700	Sep-10	14.5-24.5	5.42	91	288
MW-26	110	Sep-15	5-15	12.58	112	154
Building 7 Area						
IS-01	170	Oct-00	<12	5.37	70	233
B7-01	0	Oct-00	16-26	5.37	Achieved	291
B7-05	17	Oct-00	4-14	5.37	24	152
IS-06	1	Oct-00	4-14	5.37	Achieved	120
MW-23	1,200	Sep-15	9-19	5.37	109	227
Building 11 Area						
B11-02	12,000	Oct-00	6-16	5.91	133	295
B11-03	870	Oct-00	6-16	5.91	88	206
B11-04	3,500	Oct-00	<14	5.91	112	228
B11-09	230,000	Oct-00	16-26	5.91	183	255
B11-10	570	Oct-00	14-24	5.91	81	202
B11-PH06	61,000	Jul-05	23-25	5.91	161	273
B11-PH07	1,000,000	Jul-05	27-30	5.91	208	237
B11-PH08	120,000,000	Jul-05	22	5.91	290	294
B11-PH09	64,000	Jul-05	<32	5.91	161	230
MW-22	4	Sep-15	5-15	7.66	Achieved	185
MW-25	10	Sep-15	6-16	5.91	11	235

Notes and acronyms:

bgs = below ground surface

ft = feet

TCE = trichloroethene

yrs = years

µg/L = micrograms per liter

[a] Most recent reported TCE concentration during a fall groundwater sampling event.

[b] AOC 1 Point attenuation half-lives estimated using the half-lives calculated for MW-24 or MW-26 depending on on the groundwater flow path and the depth of samples. If neither MW-24 nor MW-26 are screened in the same depth along the flow path, then the depth of sample was used to select between the MW-24 or MW-26 half-life.

[c] Class GA Standard for TCE is 5 µg/L.

Table 2
cis-1,2-DCE Fate and Transport

Former Philips Components Facility
Seneca Falls, New York

Well/Boring	cDCE concentration (µg/L)	Sampling date[a]	Sampling depth (ft bgs)	Attenuation half-life (yrs)[b]	Travel distance to class GA standard (ft)	Distance to property boundary (ft)
Building 2 Area						
B2-01	1,000	Oct-00	2-12	18.33	280	302
B2-02	430	Oct-00	6-16	18.33	236	257
B2-03	430	Oct-00	6-16	18.33	236	302
B2-04	710	Oct-00	6-16	18.33	262	241
B2-05	10,000	Oct-00	16-26	16.59	364	309
B2-06	100,000	Oct-00	16-26	16.59	474	264
B2-07	10	Oct-00	16-26	16.59	33	138
B2-09	520	Oct-00	12-22	16.59	222	220
B2-10	330	Oct-00	16-26	16.59	201	104
B2-11	1	Oct-00	16-26	16.59	Achieved	156
B2A-04	150	Oct-00	16-26	16.59	163	99
B2-PH01	19	Jul-05	29-34	16.59	64	163
B2-PH02	150	Jul-05	0-10	18.33	180	321
B2-PH03	1,800	Aug-05	15-20	16.59	282	224
B2-PH04	920	Aug-05	23-33	16.59	250	304
B2-PH08	27	Aug-05	28-35.5	16.59	81	104
IS-02	63	Oct-00	<12	18.33	134	102
IS-03	99	Oct-00	<12	18.33	158	207
MW-24	30,000	Sep-15	14.5-24.5	16.59	417	288
MW-26	180	Sep-15	5-15	18.33	190	154
Building 7 Area						
B7-01	0	Oct-00	<12	NA	Achieved	291
B7-05	0	Oct-00	4-14	NA	Achieved	152
IS-06	1	Oct-00	4-14	NA	Achieved	120
MW-23	310	Sep-15	9-19	NA	NA	227
Building 11 Area						
B11-02	530	Oct-00	6-16	3.24	44	295
B11-03	84	Oct-00	6-16	3.24	26	206
B11-04	1,600	Oct-00	<14	3.24	54	228
B11-09	3,200	Oct-00	16-26	3.24	60	255
B11-10	440	Oct-00	14-24	3.24	42	202
B11-PH06	2,500	Jul-05	23-25	3.24	58	273
B11-PH07	1,300,000	Jul-05	37-30	3.24	117	237
B11-PH08	1,200	Jul-05	19[a]	3.24	51	294
B11-PH09	100	Jul-05	<32	3.24	28	230
MW-22	11	Sep-15	5-15	5.20	12	185
MW-25	200	Sep-15	6-16	3.24	34	235

Notes and acronyms:
cDCE = cis-1,2-dichloroethene
bgs = below ground surface
ft = feet
yrs = years
µg/L = micrograms per liter

[a] Most recent reported cDCE concentration during a fall groundwater sampling event.

[b] AOC 1 Point attenuation half-lives estimated using the half-lives calculated for MW-24 or MW-26 depending on on the groundwater flow path and the depth of samples. If neither MW-24 nor MW-26 are screened in the same depth along the flow path, then the depth of sample was used to select between the MW-24 or MW-26 half-life.

[c] Class GA Standard for cDCE is 5 µg/L.

Table 3
Summary of Corrective Action Objectives

Former Philips Display Components Facility
Seneca Falls, New York

Medium	Corrective Action Objectives	AOC Applicability					Related Numerical Standards
		AOC 1 Building 2 Area	AOC 2 Building 7 Area	AOC 3 Building 11 Area	AOC 4 Soil Vapor Intrusion Pathways	AOC 5 Historical Outfalls	
Soil	• Minimize potential for exposure (ingestion, inhalation and direct contact) with COPCs in soil above commercial use standards • Minimize the potential for exposure to COPECs in soil with concentrations that may result in population-level effects for ecological receptors. • Achieve, to the extent practicable, protection of groundwater SCOs in AOCs 1, 2, and 3.	Yes	Yes	Yes	No	Yes	NYSDEC Commercial SCOs and Protection of Groundwater SCOs
Groundwater	• Mitigate exposure to COPC in groundwater that exceed the NYSDEC SGVs. • Mitigate exposure to COPC by restricting groundwater use. • Manage potential exposure to COPC in groundwater under worker scenarios. • Control or limit off-site flux of COPC mass from the site.	Yes	Yes	Yes	No	No	NYSDEC SGVs
Dense Non-Aqueous Phase Liquid	• Remove, to the extent practicable, DNAPL from the site.	Yes	No	Yes	No	No	Not Applicable
Soil Vapor and Indoor Air	• Mitigate soil vapor intrusion into buildings where sub-slab vapor and indoor air COPC concentrations fall in the mitigate category on the NYSDOH Soil Vapor/Indoor Air Matrices.	No	No	No	Yes	No	NYSDOH Air Guideline Values; NYSDOH Soil Vapor/Indoor Air Matrix 1

Notes:
NYSDEC - New York State Department of Environmental Conservation
DNAPL - Dense non-aqueous phase liquid
SCOs - NYSDEC Subpart 375-6: Remedial Program Restricted Use — Soil Cleanup Objectives
SGVs - Standards and Guidance Values
COPC - Contaminant of potential concern
COPECs - Contaminant of potential ecological concern

Table 4
Preliminary Evaluation of Corrective Measure Technologies for DNAPL

Former Philips Display Components Facility
Seneca Falls, New York

Response Actions	Remedial Technologies	Process Options	Description	Retained: Yes or No	Decision Rationale
No Action	Not Applicable	Not Applicable	Not Applicable	Yes	Use as a baseline for comparison to other alternatives.
Institutional Control	Not Applicable	Deed Restrictions	Deed restrictions to limit the property use. Implement a Site Management Plan.	Yes	Minimize potential for exposure to residual COPC.
Monitoring	DNAPL Monitoring	Long-Term DNAPL Gauging	Monitor wells for the presence of free phase DNAPL and measure the thickness.	Yes	Will identify if free phase DNAPL is present and the fraction recoverable. Minimize potential for exposure to DNAPL.
Containment	Infiltration Control or Capping	Impermeable Cover	Impermeable cover (concrete and asphalt) to minimize infiltration.	Yes	Asphalt and concrete over much of the site reduces infiltration.
	Barriers (Horizontal or Vertical)	Grout Injection	Pressure Injection of grout to provide a low permeability confining unit.	No	Low effectiveness in low permeability soils. Has the potential to mobilize DNAPL, if present.
		Trenched Cut-off Wall	Low permeability wall to prevent horizontal migration of DNAPL. May be combined with groundwater extraction and treatment or similar technology.	No	Low effectiveness in low permeability soils. Has the potential to mobilize DNAPL, if present.
		Sheet Piling	Sheet pile wall preventing horizontal migration of DNAPL. May be combined with groundwater extraction and treatment or similar technology.	No	Low effectiveness in low permeability soils. Has the potential to mobilize DNAPL, if present.
		Permeable Reactive Barrier or Funneling Gate	A passive treatment wall across the groundwater flow path.	No	Low effectiveness in low permeability soils. Has the potential to mobilize DNAPL, if present.
In Situ Treatment	Physical	Thermal Treatment	Subsurface heating. May require total fluids recovery, including vapor extraction and treatment of vapor stream.	Yes	Effective but requires treatment of vapor stream.
		Soil Vapor Extraction	Volatilize DNAPL using stripping of VOCs through movement of air through the vadose zone.	No	The water level at the site is too shallow to allow for high vacuum application to achieve air flows. Additionally, DNAPL was observed at depth and stripping at the air/water interface would have minimal effect. Soil vapor extraction could potentially be used in conjunction with other technologies.
		In-well Air Stripping	Strip VOCs in a dual-screened well that controls groundwater flow.	No	Ineffective in low permeability soils where the flow of groundwater cannot move a large enough portion of the mass through the target area.
	Chemical	Oxidation	Oxidize contaminants.	No	Ineffective in low permeability soils because of the difficulty in distributing reagents by injection and limited contact with COPC.
		Chemical Reduction	Use a reductant or reductant generating material (i.e., zero valent iron) to degrade contaminants.	No	Ineffective in low permeability soils because of the difficulty in distributing reagents by injection and limited contact with COPC.
	Biological	Enhanced Reductive Dechlorination	Inject a degradable substrate to facilitate biodegradation of chlorinated compounds by microorganisms.	No	Ineffective in low permeability soils because of the difficulty in distributing reagents by injection and limited contact with COPC.

Table 4
Preliminary Evaluation of Corrective Measure Technologies for DNAPL

Former Philips Display Components Facility
Seneca Falls, New York

Response Actions	Remedial Technologies	Process Options	Description	Retained: Yes or No	Decision Rationale
Removal	Removal	Excavation/ Dewatering	Remove DNAPL, soil, and groundwater through excavation and dewatering.	Yes	Applicable in areas where the DNAPL, soil, and groundwater COPC concentrations are co-located and above standards. Depth of observed DNAPL influences the feasibility. Excavation of soils could increase the mobility of DNAPL. Additionally, because the site soils are of low permeability, more permeable backfilled soils could result in increased recharge and mobilize groundwater COPC.
		Manual Recovery	Removal of DNAPL from recovery wells via manual methods such as bailers or absorbent pads	Yes	Applicable in areas where the DNAPL is observed in wells at a thickness that allows removal.
		Mechanical Recovery	Removal of DNAPL from recovery wells via mechanical methods such as skimmers.	Yes	Applicable in areas where the DNAPL is observed in wells at a thickness and mobility that allows periodic removal.
		Multi-Phase Extraction	Apply a vacuum to a series of extraction wells for enhanced total fluids recovery. Requires ex situ treatment and disposal of extracted fluids.	Yes	Not effective in low permeable soils but may be used in combination with other remedial technologies to improve effectiveness.
Ex Situ DNAPL Separation	Physical	Separation	Transfer contaminants to a settling location where DNAPL can separate from residual liquid and liquid can be decanted off. Remaining DNAPL will require disposal.	Yes	Effective and implementable technology for handling of recovered DNAPL.
Disposal/ Discharge	Disposal	Treatment Facility	Off-site disposal of liquids to be containerized and treated by a second party.	Yes	Effective and implementable technology for ex-situ handling of DNAPL.
	Reuse	Reuse/ Recycling	Transfer of recovered DNAPL for off-site reuse/recycling.	Yes	Effective and implementable technology for ex-situ handling of DNAPL if the recovered DNAPL is of good enough quality. Quality is unknown since recent observation has not been made. Technology retained for possible implementation if DNAPL is recovered and is of high enough quality.

Notes:

COPC	Contaminants of Potential Concern
VOCs	Volatile Organic Compounds
DNAPL	Dense Non-Aqueous Phase Liquid
Shaded cells	Technologies not retained

Table 5
Preliminary Evaluation of Corrective Measure Technologies for Soil

Former Philips Display Components Facility
Seneca Falls, New York

Response Actions	Remedial Technologies	Process Options	Description	Retained: Yes or No	Decision Rationale
No Action	Not Applicable	No Action	Not Applicable	Yes	Use as a baseline for comparison to other alternatives.
Institutional Control	Not Applicable	Deed Restrictions	Deed restrictions to limit the property use and implementation of a SMP.	Yes	Minimize potential for exposure to residual concentrations.
Engineering Control	Not Applicable	Access Restrictions	Place access restrictions along the property boundary (i.e., fencing and signage).	Yes	Minimize potential for exposure to residual concentrations.
Containment	Infiltration Control or Capping	Soil, Asphalt and Concrete Cover	Prevent direct contact through the use of cover.	Yes	Most of the area with soil concentrations greater than industrial soil cleanup objectives is covered by asphalt or concrete.
	Barriers (Horizontal or Vertical)	Grout Injection	Pressure Inject grout at depth to provide a low permeability confining unit and prevent migration	No	Ineffective in low permeability soils because of the difficulting in injecting grout into the subsurface.
Removal	Excavation	Excavation	Remove soil through mechanical methods.	Yes	Applicable in areas where the DNAPL and groundwater concentrations are co-located with soil concentrations above cleanup levels or for shallow unsaturated soils that limit alternate treatment methods.
	Removal	SVE	Apply a vacuum to extraction wells to enhance the VOC volatilization. Recover and treat vapor.	Yes	Limited effectiveness in low permeability soils, but feasible in conjunction with other process options.
		Mulit-Phase Extraction	Apply a vacuum to extraction wells to enhance fluids recovery. Treat and dispose of extracted fluids.	Yes	Limited effectiveness in low permeability soils, but feasible in conjunction with other process options.
Disposal	Disposal	On-site	Disposal or reuse of soil on-site. Generally requires treatment prior to disposal - See ex situ treatment options below.	Yes	Feasible in conjuction with other process options. Requires treatment of soil and approval from regulators and site owner.
		Off-site	Disposal of soil or remediation process residuals off-site.	Yes	Effective. Disposal location will depend on soil concentrations. May be combined with other process options.

Table 5
Preliminary Evaluation of Corrective Measure Technologies for Soil

Former Philips Display Components Facility
Seneca Falls, New York

Response Actions	Remedial Technologies	Process Options	Description	Retained: Yes or No	Decision Rationale
In Situ Treatment	Physical	Soil Flushing	Flush soil with liquid to desorb contaminants.	No	Ineffective in lower permeability soils because of distribution and injection challenges and the need to have direct contact with the contaminant mass.
		Surfactant Flushing	Flush soil with surfactant solution to promote the desorption and solubilization of hydrophobic contaminants.	No	Ineffective in lower permeability soils because of distribution and injection challenges and the need to have direct contact with the contaminant mass.
		Thermal Treatment	Heat the subsurface. May require extraction and treatment of vapor stream.	Yes	Applicable in areas where the DNAPL and groundwater COPC concentrations are co-located with soil concentrations above cleanup levels. Effective for chlorinated VOCs. Requires collection and treatment of volatilized VOCs
	Chemical	Oxidation (Injection)	Use oxidizing agent to oxidize contaminants.	No	Ineffective in lower permeability soils because of distribution and injection challenges and the need to have direct contact with the contaminant mass.
		Stabilization/ Solidification	Treatment/Fixation of soil and contaminants by mixing.	No	Ineffective in lower permeability soils because of distribution and injection challenges and the need to have direct contact with the contaminant mass.
	Biological	Enhanced Reductive Dechlorination	Inject a substrate to facilitate biodegradation of chlorinated compounds by microorganisms.	No	Ineffective in lower permeability soils because of distribution and injection challenges and the need to have direct contact with the contaminant mass.
		Bio-venting	Add oxygen to vadose zone to stimulate aerobic microorganisms for the catabolization of contaminants.	No	Ineffective in lower permeability soils because of distribution challenges. PCE and TCE do not have a viable aerobic pathway to ethane and ethene.
Ex Situ Treatment	Physical	Soil Washing	Move high quantities of liquids through soil to desorb contaminants.	No	Ineffective in lower permeability soils because of distribution challenges (i.e., mass being trapped in interior pore space and the need for intense mixing and breaking down of soils).
		Low-Temperature Thermal Treatment	Heat soil using a conveyor and burner system to promote the volatilization of VOCs and some SVOCs. Heat of hydration [heat generated when water mixes with calcium oxide (e.g., quicklime)] can also promote volatilization.	Yes	Effective. Requires collection and treatment of VOCs.
		On-site Incineration	Heat soil using a conveyor and burner system to thermally oxidize VOCs.	No	Although effective for on-site soil treatment for VOCs, the cost per unit volume of treated soil would make incineration infeasible.
	Chemical	Stabilization/ Solidification	Fixation of soil and contaminants by mixing.	Yes	Difficult to create enough plasticity in tight clays.
		Oxidation	Oxidize contaminants	Yes	Difficult to create enough plasticity in tight clays.
	Biological	Land Farming	Stockpile and till soils to promote aerobic biodegradation.	No	Not effective for contaminants that degrade under anaerobic conditions (e.g., chlorinated solvents) or metals.

Notes:

VOCs	Volatile Organic Compounds
SVOCs	Semi-Volatile Organic Compounds
SMP	Site Management Plan
SVE	Soil Vapor Extraction

Table 6
Preliminary Evaluation of Corrective Measure Technologies for Groundwater

Former Philips Display Components Facility
Seneca Falls, New York

Response Actions	Remedial Technologies	Process Options	Description	Retained: Yes or No	Decision Rationale
No Action	Not Applicable	Not Applicable	Not Applicable	Yes	Use as a baseline for comparison to other alternatives.
Institutional Control	Not Applicable	Deed Restrictions	Deed restrictions limiting the property use. Implement a SMP.	Yes	Minimize potential for exposure to residual concentrations
Monitoring	Groundwater Monitoring	Long-Term Groundwater Monitoring	Monitor groundwater quality.	Yes	Minimize potential for exposure to residual concentrations
		Monitored Natural Attenuation	Monitor natural attenuation parameters and groundwater quality.	Yes	Degradation daughter products indicate attenuation is occurring.
Containment	Infiltration Control or Capping	Impermeable Cover	Impermeable cover (concrete and asphalt) to minimize infiltration.	Yes	Asphalt and concrete cover used to reduce infiltration.
	Barriers (Horizontal or Vertical)	Grout Injection	Pressure Injection of grout to provide a low permeability confining unit.	No	Ineffective in lower permeability soils because of distribution challenges and the lack of variability between the installed features and the soil.
		Trenched Cut-off Wall	Low permeability wall to prevent horizontal migration of groundwater. May be combined with groundwater extraction and treatment or similar technology.	No	Minimize preferential pathways; however, groundwater extraction and hydraulic control behind the cut-off wall would be difficult to implement. Also, there would be a minimal difference in hydraulic conductivity between the glacial till and the cut-off wall.
		Sheet Piling	Sheet pile wall preventing horizontal migration of groundwater. May be combined with groundwater extraction and treatment or similar technology.	No	Ineffective in lower permeability soils because of the lack of variability between the installed sheet piles and the soils.
		Permeable Reactive Barrier or Funneling Gate	A passive treatment wall across the groundwater flow path.	No	The low groundwater velocity makes for a long treatment time period. Capital cost would be high.
		Groundwater Extraction	Hydraulic containment through the extraction of groundwater from vertical wells.	No	Ineffective in lower permeability soils because of the low recovery and recharge achievable in the aquifer.
		Groundwater Recovery Trenches	Trenches, drains and piping used to passively collect groundwater.	No	Ineffective in lower permeability soils because of the low recovery and recharge achievable in the aquifer and the slow natural movement of groundwater.
In Situ Treatment	Physical	Thermal Treatment	Subsurface heating. May require total fluids recovery, including vapor extraction and treatment of vapor stream.	Yes	Effective but requires collection and treatment of VOCs in vapor.
		Air Sparging	Strip VOCs using air injection wells.	No	Ineffective in lower permeability soils because of distribution challenges and the lack of a verifiable pathway for the air from the injection point to a point of recovery.
		In-well Stripping	Strip VOCs in a dual-screened well that controls groundwater flow.	No	Ineffective in lower permeability soils where the flow of groundwater cannot be relied upon to move a large enough portion of the mass through the target area.
	Chemical	Oxidation	Oxidize contaminants.	No	Ineffective in lower permeability soils because of distribution challenges associated with injecting the oxidant and the need to have direct contact with the chemical of concern.
		Chemical Reduction	Use a reductant or reductant generating material (i.e., zero valent iron) to degrade contaminants.	No	Ineffective in lower permeability soils because of distribution challenges associated with injecting the reagent and the need to have direct contact with the chemical of concern.
	Biological	Enhanced Reductive Dechlorination	Inject a degradable substrate to facilitate biodegradation of chlorinated compounds by microorganisms.	No	Ineffective in lower permeability soils because of distribution challenges associated with injecting the reagent.
Removal	Removal	Excavation/ Dewatering	Remove soil and/or groundwater through excavation and dewatering.	Yes	Applicable in areas where the soil and groundwater concentrations are co-located.
		Multi-Phase Extraction	Apply a moderate to high vacuum (i.e. higher than 10 mmHg) to a series of extraction wells for enhanced total fluids recovery. Requires ex-situ treatment and disposal of extracted fluids.	Yes	Not effective in low permeable soils but may be used in combination with other remedial technologies to improve effectiveness.

Table 6
Preliminary Evaluation of Corrective Measure Technologies for Groundwater

Former Philips Display Components Facility
Seneca Falls, New York

Response Actions	Remedial Technologies	Process Options	Description	Retained: Yes or No	Decision Rationale
Ex Situ Treatment	Physical	Air Stripping	Transfer contaminants from an aqueous to a vapor phase. Off-gas may require additional treatment.	Yes	Effective and implementable technology for ex-situ groundwater treatment of VOCs.
		Carbon Adsorption	Remove contaminants from the aqueous or vapor phase onto activated carbon.	Yes	Effective and implementable technology for ex-situ groundwater treatment of VOCs.
	Chemical	UV/Chemical Oxidation	Destroy VOCs by changing the oxidation state of target contaminants using UV radiation and chemical oxidants.	Yes	Effective and implementable technology for ex-situ groundwater treatment of VOCs.
		Ozone	Oxidize contaminants.	Yes	Effective and implementable technology for ex-situ groundwater treatment of VOCs.
		Oxidation	Oxidize contaminants.	Yes	Effective and implementable technology for ex-situ groundwater treatment of VOCs.
	Biological	Aerobic Bioreactor	Aerobic biodegradation performed in an engineered bioreactor for contaminant removal from a process stream.	No	Ineffective technology for chlorinated VOCs.
		Anaerobic Bioreactor	Biodegradation in the absence of oxygen performed in an engineered bioreactor for contaminant removal from a process stream.	No	Long hydraulic retention times for complete mineralization of chlorinated ethenes require large reactor volumes.
		Phytoremediation/Wetlands Construction	Provide biological treatment for susceptible constituents.	No	Technically impractical because of space requirements.
Disposal/ Discharge	Disposal	POTW	Off-site discharge to a POTW.	Yes	Effective but may require on-site pretreatment and permits with the POTW.
		Treatment Facility	Off-site disposal of liquids to be containerized and treated by a second party.	Yes	Effective and implementable technology for ex-situ groundwater treatment of VOCs.
	Reuse	Facility Use	Non-potable on-site reuse of treated groundwater.	Yes	Effective and implementable technology for ex-situ groundwater treatment of VOCs.
		Reinjections	Reinject treated groundwater.	No	Ineffective in lower permeable soil
	Discharge	Surface Water Discharge	Discharge treated groundwater to the Cayuga and Seneca Canal	Yes	Effective and implementable assuming a SPDES permit can be obtained.
		Air Discharge	Discharge from air treatment system.	Yes	Granular activated carbon or air stripper can be used to achieve regulatory air discharge standards.

Notes:

MNA	Monitored Natural Attenuation
MPE	Multi-Phase Extraction
VOCs	Volatile Organic Compounds
SVOCs	Semi-Volatile Organic Compounds
SMP	Site Management Plan
UV	Ultraviolet
GAC	Granulated Activated Carbon
POTW	Public Owned Treatment Works
SPDES	State Pollutant Discharge Elimination System

Table 7
Process Options Screening for DNAPL

Former Philips Display Components Facility
Seneca Falls, New York

Remedial Technologies	Process Options	Effectiveness Evaluation		Implementability Evaluation		Relative Cost Evaluation		Retained for Consideration	
Not Applicable	No Action	Low	Effectiveness, if any, is attributed to naturally occurring processes.	High	Easily implemented	Low	No additional costs.	Yes	Use as a baseline for comparison to other alternatives
Not Applicable	Deed Restrictions	Moderate	No effect on groundwater concentrations. Maintaining the Site Management Plan will reduce potential exposure to residual concentrations.	High	Easily implemented	Low	Negligible costs.	Yes	May be considered in conjunction with other process options
Groundwater Monitoring	Long-Term DNAPL Gauging	Low	Effectiveness, if any, is attributed to naturally occurring processes.	High	Easily implemented	Low	Low capital cost because of existing monitor well network. Limited long term O & M required.	Yes	May be considered in conjunction with other process options
Capping	Impermeable Cover	Low	Use cover to prevent direct contact and rainwater infiltration.	Moderate	May require extension of impermeable cover (i.e., asphalt, concrete)	Low/ Moderate	Moderate capital cost and low O&M cost since most surface is already covered.	Yes	May be considered in conjunction with other process options. Limited protectiveness in areas not targeted for active remediation.
In Situ Physical Treatment	Thermal Treatment	High	Effective at treating DNAPL through volatilization. Effectively reach treatment goals in a short time frame.	Moderate	Predesign sampling needed to confirm treatment area. Require electrodes or heater wells. Utility conflicts and potential increased vapors during treatment.	High	High capital cost for installation of electrodes and off-gas treatment. High O & M costs.	Yes	May be considered in conjunction with other process options and incorporates the implementation of components of MPE.
Removal	Excavation/ Dewatering	Moderate	Effective for source mass removal in areas where DNAPL has been observed historically and is contributing to groundwater concentrations. Could increase the mobility of DNAPL.	Low/ Moderate	Predesign sampling needed to confirm treatment area. Could require the relocation of some site features. Due to the limited footprint and the depth of DNAPL observance augering may be required or step backs and shoring. Proximity to existing buildings would also pose a design challenge.	High	Relatively high capital cost based on proposed area for treatment .	Yes	May be considered in conjunction with other process options. Poses higher cost than other considered methods and greater design/engineering challenges, such as shoring of a building or rerouting utilities.
	Manual Recovery	Moderate	Effective at removing mobile DNAPL. Effectiveness depends on the drainability (influenced by viscosity, mobility, thickness) of DNAPL and the recovery rate within recovery wells.	High	Easily implemented	Low	Low capital cost requiring installation of recovery wells. Limited long term O & M required.	Yes	May be considered in conjunction with other process options
	Mechanical Recovery	Moderate /High	Effective at removing mobile NAPL. Effectiveness depends on the drainability (influenced by viscosity, mobility, thickness) of DNAPL and the recovery rate within recovery wells.	Moderate /High	Easily implemented within the wells. Could require electrical drop or other means to provide power.	Low	Low capital cost requiring installation of recovery wells. Limited long term O & M required.	Yes	May be considered in conjunction with other process options
	MPE	Low/ Moderate	Low permeability soils will limit the source mass recovery effectiveness. Some increased permeability when used with thermal treatment.	Low/ Moderate	Requires a close well network because of low permeability soil.	Moderate	High capital cost to install MPE wells because of well spacing requirements. Moderate O&M costs.	Yes	May be considered in conjunction with other process options.
Ex Situ Treatment	Physical Separation	Moderate /High	Effective for ex-situ separation of DNAPL from groundwater.	High	Implemented using a baffled and weired tank.	Low	Low capital cost relative to other options considered	Yes	May be considered in conjunction with other process options mainly mechanical recovery of DNAPL.
Disposal	Disposal at Treatment Facility	High	Would be sent offsite without treatment except for separation. Removes the contaminated media from the site.	Moderate	Requires permitting and coordination to find a facility that would accept DNAPL	Moderate /High	Low capital cost and moderate/ high O&M cost depending on DNAPL recovery volume.	Yes	May be considered in conjunction with other process options
	Reuse/ Recycling	High	Would be sent offsite without treatment except for separation. Removes the contaminated media from the site.	Moderate	Requires acceptance from recycling facility	Moderate /High	Low capital cost and moderate/ high O&M cost depending on DNAPL recovery volume.	Yes	May be considered in conjunction with other process options.

Notes:
MPE Multi-Phase Extraction
O&M Operations & Maintenance

Table 8
Process Options Screening for Soil

Former Philips Display Components Facility
Seneca Falls, New York

Remedial Technologies	Process Options	Effectiveness Evaluation		Implementability Evaluation		Relative Cost Evaluation		Retained?	
Not Applicable	No Action	Low	No effect on soil concentrations. Effectiveness is attributed to the naturally occurring processes.	High	Easily implemented.	Low	No additional costs.	Yes	Use as a baseline for comparison to other alternatives
Not Applicable	Deed Restrictions	Moderate	No effect on soil concentrations. Maintaining the Site Management Plan will reduce potential exposure to residual concentrations.	High	Easily implemented.	Low	Negligible costs.	Yes	Considered in conjunction with other process options
	Access Restrictions	Moderate	Limiting site access and maintaining the Site Management Plan will reduce potential for exposure to residual concentrations.	High	Easily implemented.	Low	Negligible costs.	Yes	Considered in conjunction with other process options
Infiltration Control or Capping	Soil, Asphalt and/or Concrete Cover	Low	Prevent direct contact and rainwater infiltration using cover. Does not limit leaching to groundwater traversing the area.	Moderate	Extension of impermeable site cover (asphalt, concrete).	Low/ Moderate	Moderate capital costs and low O & M costs	Yes	Considered in conjunction with other process options. May provide limited protectiveness in areas not targeted for active remediation.
In Situ Physical Treatment	Thermal Treatment	Moderate/ High	Effective at treating concentrations in saturated soil. Unsaturated soil treatment is challenging because of lack of heat conductance.	Low	Implementation would require the installation of electrodes or heater wells. The density of the soil would need to be analyzed to determine spacing. Infeasible to implement over the large area where soil concentrations exceed protection of groundwater soil cleanup objectives.	High	High capital cost for installation of infrastructure and off-gas treatment. High O & M costs.	No	Was previously retained as a treatment technology for soil in the CMS Report. With the revised corrective action objective, the soil target area expanded signficantly and so is no longer retained. High cost and significant disruptions to site operations, based on the large volume of soil to treat, in comparison to other process options. Secondary treatment might be achieved if implemented to treat other media.
Removal	MPE	Low/ Moderate	Low permeability soils will limit the effectiveness of source mass recovery. Some increased permeability when used in connection with thermal treatment.	Low/ Moderate	Implementation would require a close well network because of low permeability soil.	Moderate	High capital cost to install MPE wells because of well spacing requirements. Moderate operations and maintenance costs.	No	Low effectiveness compared to other process options. Was retained only in conjunction with thermal treatment.
	SVE	Low	Low permeability soil and small vadose zone with low concentrations minimizes the effectiveness. Combine with other process option to capture vapors from the saturated zone.	Low/ Moderate	Not easily implementable because of low permeability soil.	High	High capital cost to install SVE wells in very close proximity to each other. Moderate to high operations and maintenance costs.	No	High costs and difficult implementability in comparison to other process options.
	Excavation	Moderate /High	Effective for mass removal in areas where DNAPL is contributing to soil and groundwater concentrations or in shallow unsaturated soils.	Moderate	Implementation would require predesign sampling to confirm treatment area. Could require the relocation of some site features.	High	Relatively high capital cost based on proposed area for treatment and existing site features (asphalt capping and buildings)	Yes	Considered in conjunction with other process options.
Ex Situ Physical Treatment	Low-Temperature Thermal Treatment	High	Effective at treating VOCs.	Low	Requires space for the handling and treatment of excavated soils.	High	High capital cost for installation of infrastructure and off-gas treatment. High O & M costs.	No	High capital cost and difficult implementability in comparison to other process options.
Ex Situ Chemical Treatment	Stabilization/ Solidification	Moderate	Effective for chlorinated solvents and other VOCs. Effectiveness is limited by the ability to achieve full contact with the VOCs.	Low	Implementable. Requires the use of a pug mill and addition of water to create plasticity in tight clays.	High	High capital cost for soil excavation and backfill. Not all of the material would be used as backfill and disposal would be required.	No	High capital cost and difficult implementability in comparison to other process options.
	Oxidation	Moderate	Effective at oxidizing chlorinated solvents and other VOCs. Effectiveness is limited by the ability to achieve full contact with the VOCs.	Low	Implementable. Requires the use of a pug mill and addition of water to create plasticity in tight clays.	High	High capital cost for soil excavation and backfill. Not all of the material would be used as backfill and disposal would be required.	No	High capital cost and difficult implementability in comparison to other process options.
Disposal	Disposal Off-site	High	Removes the contaminants.	Moderate	Used in conjunction with excavation. Requires coordination and acceptance of material at an off-site location.	Moderate /High	Cost dependent on the classification of the soil for disposal.	Yes	Considered in conjunction with other process options.

Notes:

MPE	Multi-Phase Extraction
VOCs	Volatile Organic Compounds
SVE	Soil Vapor Extraction
O&M	Operations & Maintenance

Table 9
Process Options Screening for Groundwater

Former Philips Display Components Facility
Seneca Falls, New York

Remedial Technologies	Process Options	Effectiveness Evaluation		Implementability Evaluation		Relative Cost Evaluation		Retained for Consideration	
Not Applicable	No Action	Low	Effectiveness, if any, is attributed to naturally occurring processes.	High	Easily implemented	Low	No additional costs.	Yes	Use as a baseline for comparison to other alternatives
Not Applicable	Deed Restrictions	Moderate	No effect on groundwater concentrations. Maintaining the Site Management Plan will reduce potential exposure to residual concentrations.	High	Easily implemented	Low	Negligible costs.	Yes	May be considered in conjunction with other process options
Groundwater Monitoring	Long-Term Monitoring	Low	Effectiveness, if any, is attributed to naturally occurring processes.	High	Easily implemented	Low	Low capital cost because of existing monitor well network. Limited long term O & M required.	Yes	May be considered in conjunction with other process options
	MNA	Moderate	Natural attenuation processes would require an extended timeframe to reduce concentrations to cleanup goals. Ongoing monitoring has demonstrated that the MNA process is already occurring. The low permeability of soils means that groundwater travels slowly allowing for longer degradation timeframes during migration. The effectiveness would improve following source removal/treatment.	High	Degradation and bulk attenuation evident in groundwater results.	Low/ Moderate	Low capital cost because of existing monitor well network. Long term O & M required.	Yes	May be considered in conjunction with other process options.
Capping	Impermeable Cover	Low	Use cover to prevent direct contact and rainwater infiltration.	Moderate	May require extension of impermeable cover (i.e., asphalt, concrete)	Low/ Moderate	Moderate capital cost and low O&M cost.	Yes	May be considered in conjunction with other process options. Limited protectiveness in areas not targeted for active remediation.
In Situ Physical Treatment	Thermal Treatment	High	Effective at treating contaminants in groundwater. Effectively reach treatment goals in a short time frame.	Low/ Moderate	Require electrodes or heater wells. Utility conflicts and potential increased vapors during treatment. Would require a large footprint of treatment to target dissolved concentrations.	High	High capital cost for installation of electrodes and off-gas treatment. High O & M costs.	No	High cost and implementation challenges in comparison to other process options. Secondary treatment would be achieve if implemented to treat other media.
Removal	Excavation/ Dewatering	Moderate	Effective for source mass removal in areas where DNAPL, soil concentrations and groundwater concentrations are coincident. Groundwater treatment would be limited to the amount of water entering the excavated area and the transport of dissolved COPC within the groundwater to the excavated area.	Moderate	Predesign sampling needed to confirm treatment area. Could require the relocation of some site features.	High	Relatively high capital cost based on proposed area for treatment.	No	High cost and implementation challenges in comparison to other process options. Secondary treatment would be achieved if implemented to treat other media.
	MPE	Low/ Moderate	Low permeability soils will limit the source mass recovery effectiveness. Some increased permeability when used with thermal treatment.	Low/ Moderate	Require a close well network because of low permeability soil.	Moderate	High capital cost to install MPE wells because of well spacing requirements. Moderate O&M costs.	No	Low effectiveness compared to other process options. Was retained only in conjunction with thermal treatment which has been eliminated.
Ex Situ Physical Treatment	Air Stripping	High	Effective for ex-situ treatment of VOCs in groundwater.	High	Implemented using an air stripping unit.	Low	Low capital cost.	No	Would only be used in conjunction with removal technologies which have been eliminated.
	Carbon Adsorption	Low	Not effective for vinyl chloride.	Low/ Moderate	Carbon can be impregnated with permanganate to improve performance but carbon absorption capacity is reduced.	Moderate /High	High infrastructure costs; moderate long-term O&M cost because of carbon regeneration.	No	Difficult to extract groundwater from low permeability soils. Increased capital and O&M costs without substantial increase in effectiveness.

Table 9
Process Options Screening for Groundwater

Former Philips Display Components Facility
Seneca Falls, New York

Remedial Technologies	Process Options	Effectiveness Evaluation		Implementability Evaluation		Relative Cost Evaluation		Retained for Consideration	
Ex Situ Chemical Treatment	UV/Chemical Oxidation	Moderate /High	Moderately effective for ex situ treatment of VOCs in groundwater	Moderate	Implementability contingent upon addressing health & safety concerns from strong oxidant.	High	Moderate capital cost; high O&M cost	No	Difficult to extract groundwater from low permeability soils. Increased capital and O&M costs without substantial increase in effectiveness.
	Ozone	Moderate /High	Moderately effective for ex situ treatment of VOCs in groundwater. May require longer treatment time compared with other oxidation methods.	Low/ Moderate	Implementability contingent upon addressing health & safety concerns from strong oxidant. Requires production or delivery of ozone in a gaseous state.	High	High capital cost; low to moderate O&M cost	No	Difficult to extract groundwater from low permeability soils. Increased capital and O&M costs without substantial increase in effectiveness.
	Oxidation - Fenton's Reagent/ Hydrogen Peroxide	Moderate /High	Moderately effective for ex situ treatment of VOCs in groundwater.	Moderate	Implementability contingent upon addressing health & safety concerns from strong oxidant.	High	Moderate capital cost; high O&M cost	No	Difficult to extract groundwater from low permeability soils. Increased capital and O&M costs without substantial increase in effectiveness.
	Oxidation - Potassium Permanganate	Moderate /High	Moderately effective for ex situ treatment of VOCs in groundwater.	Moderate	Implementability contingent upon addressing health & safety concerns from strong oxidant.	High	Moderate capital cost; high O&M cost	No	Difficult to extract groundwater from low permeability soils. Increased capital and O&M costs without substantial increase in effectiveness.
Disposal	POTW	High	Requires the lowest level of treatment prior to discharge.	Moderate	Requires permitting and construction of discharge line to discharge to POTW.	Moderate	Moderate capital cost and moderate O&M cost	No	Would only be used in conjunction with removal technologies which have been eliminated.
	Off-Site Disposal	High	Removes the contaminated media from the site.	Moderate	Requires acceptance from disposal facility.	High	High transport cost, disposal cost dependent on the concentrations.	No	Would only be used in conjunction with removal technologies which have been eliminated.
Reuse	Facility Use	Moderate	Effectiveness limited if the property owner needs non-potable water.	Moderate	Implementability is dictated by the property owner needs.	Moderate	Cost contingent upon current property owner's need	No	Does not offer significant benefits compared to current discharge method.
Discharge	Surface Water Discharge	High	Requires high level of treatment to meet discharge standards.	High	Implementability is dictated by SPDES permit requirements.	Low	Negligible capital cost; minimal O&M cost	No	Would only be used in conjunction with removal technologies which have been eliminated.
	Air Discharge	High	If necessary, diverting air stripper gaseous effluent through GAC will remove most VOCs.	High	Carbon vessels can be sized and installed.	Low	Low capital cost; low O&M cost	No	Would only be used in conjunction with removal technologies which have been eliminated.

Notes:

MNA	Monitored Natural Attenuation
MPE	Multi-Phase Extraction
VOCs	Volatile Organic Compounds
UV	Ultraviolet
GAC	Granulated Activated Carbon
POTW	Public Owned Treatment Works
SPDES	State Pollutant Discharge Elimination System
O&M	Operations & Maintenance

Table 10
Summary of Corrective Meaures Technology Options Retained

Former Philips Display Components Facility
Seneca Falls, New York

Corrective Measure Technologies	Process Options	Corrective Measure Retained?						
		AOC 1 Building 2 Area			AOC 2 Building 7 Area	AOC 3 Building 11 Area		
		DNAPL	Soil	Groundwater	Groundwater	DNAPL	Soil	Groundwater
Not Applicable	No Action	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Not Applicable	Deed, Access, and Work Restrictions	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Groundwater Monitoring	Long-term Monitoring/Gauging	Yes	No	Yes	Yes	Yes	No	Yes
	Monitored Natural Attenuation	No	No	Yes	Yes	No	No	Yes
Infiltration Control or Capping	Asphalt and Concrete Cover	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Removal	Excavation/Dewatering	Yes	Yes	No	No	Yes	Yes	No
	Manual Recovery	Yes	No	No	No	Yes	No	No
	Mechanical Recovery	Yes	No	No	No	Yes	No	No
	Mulit-Phase Extraction	Yes	No	No	No	Yes	No	No
Ex Situ Physical Treatment	Air Stripping	Yes	No	No	No	Yes	No	No
	Separation	Yes	No	No	No	Yes	No	No
In Situ Physical Treatment	Thermal Treatment	Yes	No	No	No	Yes	No	No
Disposal	Disposal	Yes	Yes	No	No	Yes	Yes	No
	Reuse	Yes	No	No	No	Yes	No	No

Notes:
AOC - Area of concern

Table 11
Summary of Corrective Measure Alternatives Conceptual Design Assumptions

Former Philips Display Components Facility
Seneca Falls, New York

Area of Concern 1 (Building 2 Area)

Alternative	1A	1B	1C	1D
Title	No Action	DNAPL Physical Removal, with MNA	Thermal remediation of DNAPL Areas, with MNA	Excavate Areas of DNAPL and Unsaturated Soils that Exceed Commercial Standards, with MNA
Administrative	NA	Site Management Plan (30+ Years) • Implement deed and access restrictions and institutional controls to limit site and groundwater use and limit access to soil. • Annual inspections to ensure institutional controls are maintained.		
DNAPL Treatment	NA	Manual/ Mechanical Removal (10 years) • Implement manual removal for 1 year to determine the drainability of DNAPL and frequency of recovery. • Depending on the observance of DNAPL either manual removal will continue or mechanical removal will be implemented. (Cost estimate assumes manual removal will continue)	Thermal Remediation (1 year) • Implement thermal remediation in the areas of soil that exceed the industrial standard.	Excavation (1 year) • Excavate approximately 4,700 cubic yards of soil that contains DNAPL or lies above DNAPL.
Soil Treatment	NA	• Excavate approximately 15 cubic yards of soil that exceed the commercial standard in the unsaturated zone. • Secondary treatment from MNA and general site management	• Excavate approximately 15 cubic yards of soil that exceed the commercial standard in the unsaturated zone. • Secondary treatment from thermal remediation and MNA, general site management	Excavation (1 year) • Excavate approximately 15 cubic yards of soil that exceed the commercial standard in the unsaturated zone. (Secondary treatment from MNA and general site management)
Groundwater Treatment	NA	Monitored Natural Attenuation (30+ Years) • Annual monitoring of site wells (30+ Years)	Monitored Natural Attenuation (30+ Years) • Annual monitoring of site wells (30+ Years) (Secondary treatment from thermal remediation)	Monitored Natural Attenuation (30+ Years) • Annual monitoring of site wells (30+ Years)

Area of Concern 2 (Building 7Area)

Alternative	2A	2B
Title	No Action	Implement a Site Management Plan
Administrative & Soil/ Groundwater Treatment	NA	Site Management Plan (30+ Years) • Implement deed restrictions and institutional controls to limit site and groundwater use and limit access to soil. • Annual monitoring of site wells and MNA implementation (30+ Years) • Annual inspections to ensure institutional controls are maintained.

Area of Concern 3 (Building 11 Area)

Alternative	3A	3B	3C	3D
Title	No Action	DNAPL Physical Removal, with MNA	Thermal remediation of DNAPL Areas, with MNA	Excavate DNAPL, with MNA
Administrative	NA	Site Management Plan (30+ Years) • Implement deed and access restrictions and institutional controls to limit site and groundwater use and limit access to soil. • Annual inspections to ensure institutional controls are maintained.		
DNAPL Treatment	NA	Manual/ Mechanical Removal (10 years) • Implement manual removal for 1 year to determine the drainability of DNAPL and frequency of recovery. • Depending on the observance of DNAPL either manual removal will continue or mechanical removal will be implemented. (Cost estimate assumes manual removal will continue)	Thermal Remediation (1 year) • Implement thermal remediation in the areas of soil that exceed the industrial standard.	Excavation (1 year) • Excavate approximately 3500 cubic yards of soil that contain DNAPL.
Soil Treatment	NA	• Secondary treatment from MNA and general site management	• Secondary treatment from thermal remediation and MNA, general site management	• Secondary treatment from MNA and general site management
Groundwater Treatment	NA	Monitored Natural Attenuation (30+ Years) • Annual monitoring of site wells (30+ Years)	Monitored Natural Attenuation (30+ Years) • Annual monitoring of site wells (30+ Years) (Secondary treatment from thermal remediation)	Monitored Natural Attenuation (30+ Years) • Annual monitoring of site wells (30+ Years)

Notes:
NA - Not Applicable
MNA - Monitored Natural Attenuation
DNAPL - Dense Non-Aqueous Phase Liquid

Table 12
Summary of Alternatives for Area of Concern 1 Building 2 Area

Former Philips Display Components Facility
Seneca Falls, New York

Alternative	Description	Balancing Criteria					
		Long - Term Effectiveness	Reduction in TMV of Wastes	Short - Term Effectiveness	Implementability	Sustainability	Cost
Area of Concern 1							
1A	No Action	Not an effective alternative.	Does not reduce the TMV of wastes.	Not an effective alternative.	Requires no implementation.	Sustainable, but includes no active remediation or monitoring.	No costs.
1B	DNAPL Physical Removal, with MNA	- An effective alternative; should not be affected by site conditions. - Institutional and engineered components of the Site Management Plan have a long useful life with routine operations and maintenance. - Residual risk remains until soil and groundwater COPC concentrations reach standards. - Maintaining Institutional controls reduces potential exposure.	- A passive alternative, recovery of DNAPL at recovery wells. - Has limited effect on groundwater concentrations so reductions in toxicity and volume are attributed to natural degradation. - Natural limitations on mobility exist because of the low hydraulic conductivity of the soil.	- Poses minimal risk to the public, workers, and the environment during implementation. - Not effective in the short-term for achieving standards or guidance values. - Minimal contaminant-related risk of fire, exposure to hazardous substances, and minimal threats associated with remediation.	- Only well construction necessary plus ongoing O&M. - SMP requires minimal administrative activities. - Does not require off-site treatment or storage. - Minimal disposal of purge water associated with annual sampling and DNAPL removal will be required. - Does not require special technologies. - Long timeframe is expected for naturally occurring processes to achieve the standards.	- Requires the extended creation of waste during sampling and DNAPL removal and consumption of fuel for site visits over the long life span of the remedy. - Has the longest useful life (compared to other alternatives) which extends the environmental burden of the remedy (i.e. materials, fuel, etc. are used for a long period of time).	$330,000
1C	Thermal remediation of DNAPL Areas, with MNA	- An effective alternative. - The institutional and engineered components of the SMP have a long useful life with routine operations and maintenance. - Residual risk remains until groundwater concentrations site wide reach standards. - Thermal remediation should shorten the timeframe to reach standards. - The source mass is destroyed or removed as part of thermal remediation. - Maintaining Institutional controls reduces the potential exposure to residual concentrations.	- An active treatment alternative. - Thermal remediation would result in removal of mass, reducing toxicity below the applicable soil cleanup objectives and improving progress toward groundwater standards. - Removal of mass in soils and groundwater eliminates the volume and mobility of the chemicals of concern sorbed to soils and dissolved in the groundwater, and removes residual DNAPL.	- Poses minimal risk to the public and the environment. - Some risk to workers from elevated temperatures and volatilized chemicals of concern in soil vapors. - Risk is minimized by personal protective equipment and engineered controls. - Effective in the short-term for reducing mass and achieving standards. - Minimal contaminant-related risk of fire and exposure to hazardous substances associated with remediation.	- Well and electrode installation and temporary system construction are necessary to implement the thermal treatment. - Requires off-site treatment, storage, or disposal of groundwater removed from the treatment area. - Immediate beneficial results. - No construction is necessary to implement the SMP. - SMP requires minimal administrative activities. Expected wastes include the soil from well installation, purge water during monitoring, and extracted groundwater. - Shorter timeframe is expected for the reduction of contaminants.	- High energy requirements. - Thermal remediation creates water consumption, air emissions, and waste to be managed. - Installation of the system will require the operation of fuel-powered equipment. - The effectiveness of the thermal treatment reduces the expected length of the remedy eliminating long term energy use and water consumption. - SMP requires fuel consumption and waste generation throughout the length of the remedy.	$2,672,000
1D	Excavate Areas of DNAPL and Unsaturated Soils that Exceed Commercial Standards, with MNA	- An effective alternative. - The institutional and engineered components of the SMP have a long useful life with routine operations and maintenance. - Residual risk remains until groundwater concentrations site wide reach standards. - Excavation should shorten the timeframe to reach standards. - Excavation removes the mass from the source area eliminating the portion of mass that is in the planned excavation footprint. - Maintaining Institutional controls reduces potential exposure.	- An active treatment alternative. - Removal of soil and groundwater results in an immediate reduction in mass and will reduce the toxicity below the applicable soil cleanup objectives and will improve progress toward groundwater standards. - Removal of the soils and water eliminates the volume of the chemicals of concern sorbed to soils and dissolved in the removed groundwater. - There is some chance sheeting and shoring will mobilize DNAPL.	- Poses minimal risk to the public, and the environment. - Some risk to workers from the use of heavy equipment and hazards related to the size and depth of the open excavation. - Effective in the short-term for achieving soil standards or guidance values. - Minimal contaminant-related risk of fire, exposure to hazardous substances, and minimal threats associated with remediation.	- Excavation requires both administrative activities and construction. - Requires off-site treatment, storage, or disposal of soil and groundwater removed from the excavated area. - Requires shoring for deep excavation. - Immediate beneficial results. - No construction is necessary to implement the SMP. - SMP requires minimal administrative activities. Expected wastes include the excavated soil, water from the excavation, and purge water. - Shorter timeframe is expected for the reduction of contaminants.	- Uses large-scale fuel-powered construction equipment with high energy requirements and air emissions. - Excavation involves the generation of considerable amounts of waste materials and the use of materials and resources for construction and restoration. - Movement of soil requires truck transport of soil to the disposal site. - The effectiveness of the excavation reduces the expected length of the remedy eliminating long term energy use and water consumption. - SMP requires fuel consumption and waste generation throughout the length of the remedy.	$2,890,000

Notes:
TMV Toxicity, mobility and volume
DNAPL Dense Non-Aqueous Phase Liquid
SMP Site Management Plan
MNA Monitored Natural Attenuation
COPC Contaminant of potential concern

Table 13
Summary of Alternatives for Area of Concern 2 Building 7 Area

Former Philips Display Components Facility
Seneca Falls, New York

Alternative	Description	Balancing Criteria					
		Long - Term Effectiveness	Reduction in TMV of Wastes	Short - Term Effectiveness	Implementability	Sustainability	Cost
Area of Concern 2							
2A	No Action	Not an effective alternative.	Does not reduce the TMV of wastes.	Not an effective alternative.	Requires no implementation.	Sustainable, but includes no active remediation or monitoring.	No costs.
2B	Monitored Natural Attenuation	- An effective alternative; should not be affected by site conditions. - Institutional and engineered components of the SMP have a long useful life with routine operations and maintenance. - Residual risk remains until soil and groundwater COPC concentrations reach standards. - Maintaining Institutional controls reduces potential exposure to residual concentrations.	- A passive alternative. - Has no effect on COPC concentrations so reductions in toxicity and volume are attributed to naturally occurring processes. - No additional reduction in mobility can be attributed to Alternative 2B.	- Poses minimal risk to the public, workers, and the environment. - Not effective in the short-term for achieving standards or guidance values. - Minimal contaminant-related risk of fire and exposure to hazardous substances.	- No construction necessary. - SMP requires minimal administrative activities. - Does not require off-site treatment or storage. - Minimal disposal of purge water associated with annual sampling will be required. - Does not require special technologies.	- Requires the extended creation of waste during sampling and consumption of fuel for site visits over the long life span of the remedy. - Has a long useful life which extends the environmental burden of the remedy (i.e. materials, fuel, etc. are used for a long period of time).	$275,000

Notes:
TMV Toxicity, mobility and volume
COPC Contaminant of potential concern
SMP Site Management Plan

Table 14
Summary of Alternatives for Area of Concern 3 Building 11 Area

Former Philips Display Components Facility
Seneca Falls, New York

Alternative	Description	Balancing Criteria					
		Long - Term Effectiveness	Reduction in TMV of Wastes	Short - Term Effectiveness	Implementability	Sustainability	Cost
Area of Concern 3							
3A	No Action	Not an effective alternative.	Does not reduce the TMV of wastes.	Not an effective alternative.	Requires no implementation.	Sustainable, but includes no active remediation or monitoring.	No costs.
3B	DNAPL Physical Removal, with MNA	- An effective alternative; should not be affected by site conditions. - Institutional and engineered components of the Site Management Plan have a long useful life with routine operations and maintenance. - Residual risk remains until soil and groundwater COPC concentrations reach standards. - Maintaining Institutional controls reduces potential exposure.	- A passive alternative, recovery of DNAPL at recovery wells. - Has limited effect on groundwater concentrations so reductions in toxicity and volume are attributed to natural degradation. - Natural limitations on mobility exist because of the low hydraulic conductivity of the soil.	- Poses minimal risk to the public, workers, and the environment during implementation. - Not effective in the short-term for achieving standards or guidance values. - Minimal contaminant-related risk of fire and exposure to hazardous substances.	- Only well construction necessary. - SMP requires minimal administrative activities. - Does not require off-site treatment or storage. - Minimal disposal of purge water associated with annual sampling and DNAPL recovery will be required. - Does not require special technologies.	- Requires the extended creation of waste during sampling and DNAPL removal and consumption of fuel for site visits over the long life span of the remedy. - Has the longest useful life (compared to other alternatives) which extends the environmental burden of the remedy (i.e. materials, fuel, etc. are used for a long period of time).	$330,000
3C	Thermal remediation of DNAPL Areas, with MNA	- An effective alternative. - The institutional and engineered components of the SMP have a long useful life with routine operations and maintenance. - Residual risk remains until groundwater COPC concentrations reach standards. - Thermal remediation should shorten the timeframe to reach standards. - The source mass is destroyed or removed as part of thermal remediation. - Maintaining Institutional controls reduces the potential exposure to residual concentrations.	- An active treatment alternative. - Thermal remediation would result in removal of mass, reducing toxicity below the applicable soil cleanup objectives and improving progress toward groundwater standards. - Removal of mass in soils and groundwater eliminates the volume and mobility of the chemicals of concern sorbed to soils and dissolved in the groundwater, and removes residual DNAPL.	- Poses minimal risk to the public and the environment. - Some risk to workers from elevated temperatures and volatilized chemicals of concern in soil vapors. - Risk is minimized by personal protective equipment and engineered controls. - Effective in the short-term for reducing mass and achieving standards. - Minimal contaminant-related risk of fire and exposure to hazardous substances.	- Well and electrode installation and temporary system construction are necessary to implement the thermal treatment. - Requires off-site treatment, storage, or disposal of groundwater removed from the treatment area. - Immediate beneficial results. - No construction is necessary to implement the SMP. - SMP requires minimal administrative activities. Expected wastes include the soil from well installation, purge water during monitoring, and extracted groundwater. - Shorter timeframe is expected for the reduction of contaminants.	- High energy requirements. - Thermal remediation creates water consumption, air emissions, and waste to manage. - Installation of the system will require the operation of fuel-powered equipment. - The effectiveness of the thermal treatment reduces the expected length of the remedy eliminating long term energy use and water consumption. - SMP requires fuel consumption and waste generation throughout the length of the remedy.	$2,246,000
3D	Excavate DNAPL, with MNA	- An effective alternative. - The institutional and engineered components of the SMP have a long useful life with routine operations and maintenance. - Residual risk remains until groundwater concentrations site wide reach standards. - Excavation should shorten the timeframe to reach standards. - Excavation removes the mass from the source area eliminating the portion of mass that is in the planned excavation footprint. - Maintaining Institutional controls reduces potential exposure.	- An active treatment alternative. - Removal of soil and groundwater results in an immediate reduction in mass and will reduce the toxicity below the applicable soil cleanup objectives and will improve progress toward groundwater standards. - Removal of the soils and water eliminates the volume of the chemicals of concern sorbed to soils and dissolved in the removed groundwater. - There is some chance sheeting and shoring will mobilize DNAPL.	- Poses minimal risk to the public, and the environment. - Some risk is posed to the workers through the use of heavy equipment and the depth of excavation required to reach the volatile organic compound-containing soil. - Effective in the short-term for achieving soil standards or guidance values however groundwater concentrations will persist. - Minimal contaminant-related risk of fire and exposure to hazardous substances.	- Excavation requires both administrative activities and construction. - Requires off-site treatment, storage, or disposal of soil and groundwater removed from the excavated area. - Requires shoring for deep excavation. - Immediate beneficial results. - No construction is necessary to implement the SMP. - SMP requires minimal administrative activities. Expected wastes include the excavated soil, water from the excavation, and purge water. - Shorter timeframe is expected for the reduction of contaminants.	- Uses large-scale fuel-powered construction equipment with high energy requirements and air emissions. - Excavation involves the generation of considerable amounts of waste materials and the use of materials and resources for construction and restoration. - Movement of soil requires truck transport of soil to the disposal site. - The effectiveness of the excavation reduces the expected length of the remedy eliminating long term energy use and water consumption. - SMP requires fuel consumption and waste generation throughout the length of the remedy.	$2,915,000

Notes:

TMV	Toxicity, mobility and volume
SMP	Site Management Plan
DNAPL	Dense Non-Aqueous Phase Liquid
MNA	Monitored Natural Attenuation
COPC	Contaminant of potential concern

Table 15
Summary of Costs

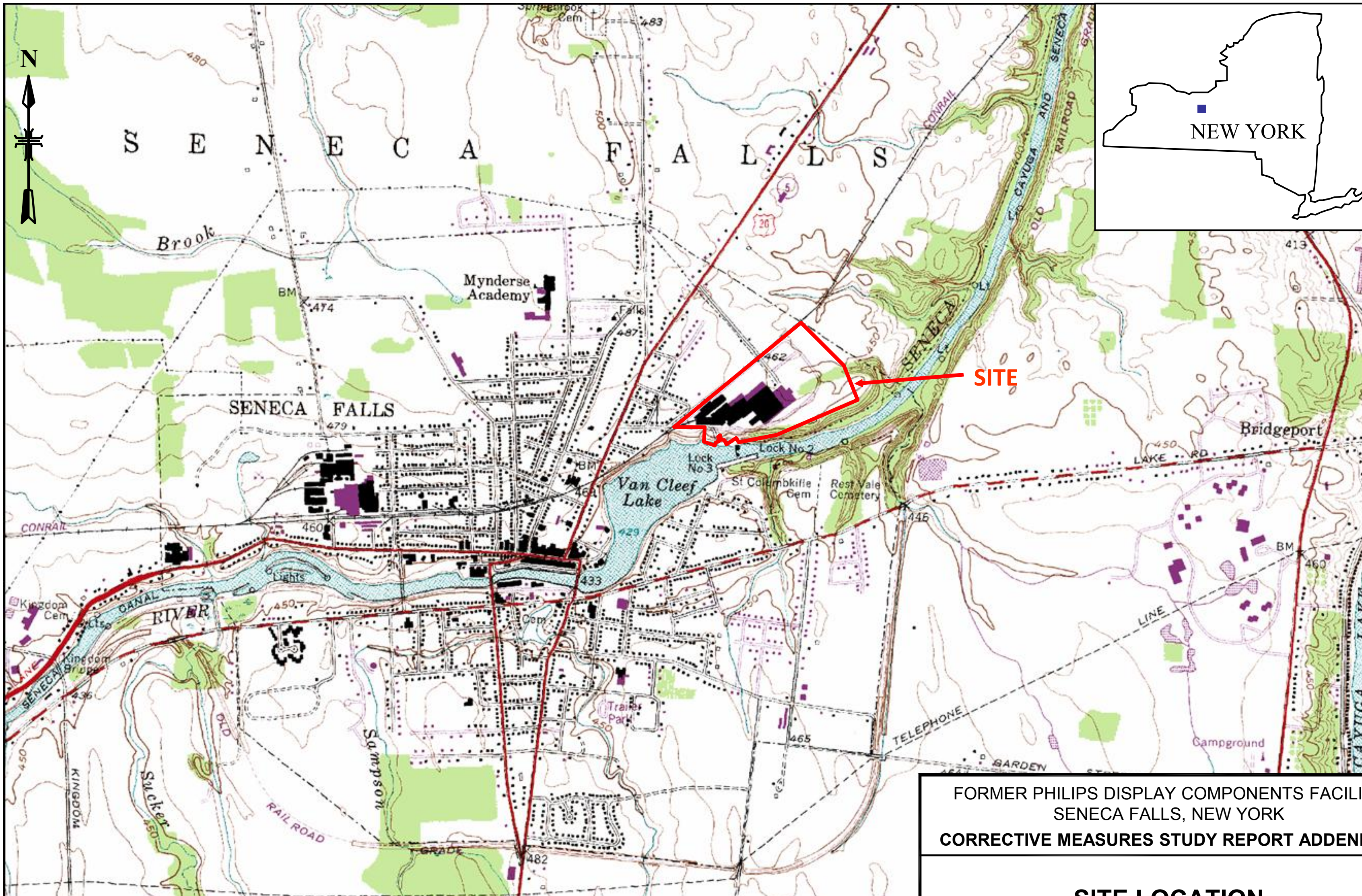
Former Philips Display Components Facility
Seneca Falls, NY

Remedial Alternative	Description	Capital Cost ($)	Annual O&M Cost ($)	Length of Remedy (Years)	Periodic Cost ($)	Total Cost ($)
AOC 1 Building 2 Area						
Alternative AOC 1A	No Action	$ -	$ -	-	$ -	$ -
Alternative AOC 1B	Physical Removal	$ 19,000	$ 6,100	5	$ 5,500	$ 330,000
	Site Management Plan	$ 20,000	$ 8,000	30	$ 15,000	
Alternative AOC 1C	Thermal Remediation	$ 2,397,000	$ -	1	$ -	$ 2,672,000
	Site Management Plan	$ 20,000	$ 8,000	30	$ 15,000	
Alternative AOC 1D	Excavation	$ 2,615,000	$ -	0.5	$ -	$ 2,890,000
	Site Management Plan	$ 20,000	$ 8,000	30	$ 15,000	
AOC 2 Building 7 Area						
Alternative AOC 2A	No Action	$ -	$ -	-	$ -	$ -
Alternative AOC 2B	Site Management Plan	$ 20,000	$ 8,000	30	$ 15,000	$ 275,000
AOC 3 Building 11 Area						
Alternative AOC 3A	No Action	$ -	$ -	-	$ -	$ -
Alternative AOC 3B	Physical Removal	$ 19,000	$ 6,100	5	$ 5,500	$ 330,000
	Site Management Plan	$ 20,000	$ 8,000	30	$ 15,000	
Alternative AOC 3C	Thermal Remediation	$ 1,971,000	$ -	1	$ -	$ 2,246,000
	Site Management Plan	$ 20,000	$ 8,000	30	$ 15,000	
Alternative AOC 3D	Excavation	$ 2,640,000	$ -	0.5	$ -	$ 2,915,000
	Site Management Plan	$ 20,000	$ 8,000	30	$ 15,000	

Total 1B, 2B & 3B	$ 935,000
Total 1C, 2B & 3C	$ 5,193,000
Total 1D, 2B & 3D	$ 6,080,000

Notes:
AOC = Area of Concern
O&M = Operation and Maintenance
USEPA = United States Environmental Protection Agency
Costs are rounded to the nearest $1000, except for values under $100,000 that are rounded to the nearest $100
Costs are based on an accuracy of +50/-30% (USEPA 2000)

FIGURES



MAP SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC SERIES, SENECA FALLS QUADRANGLE

APPROXIMATE SCALE IN MILES

0 0.25 0.5 1

FORMER PHILIPS DISPLAY COMPONENTS FACILITY
SENECA FALLS, NEW YORK

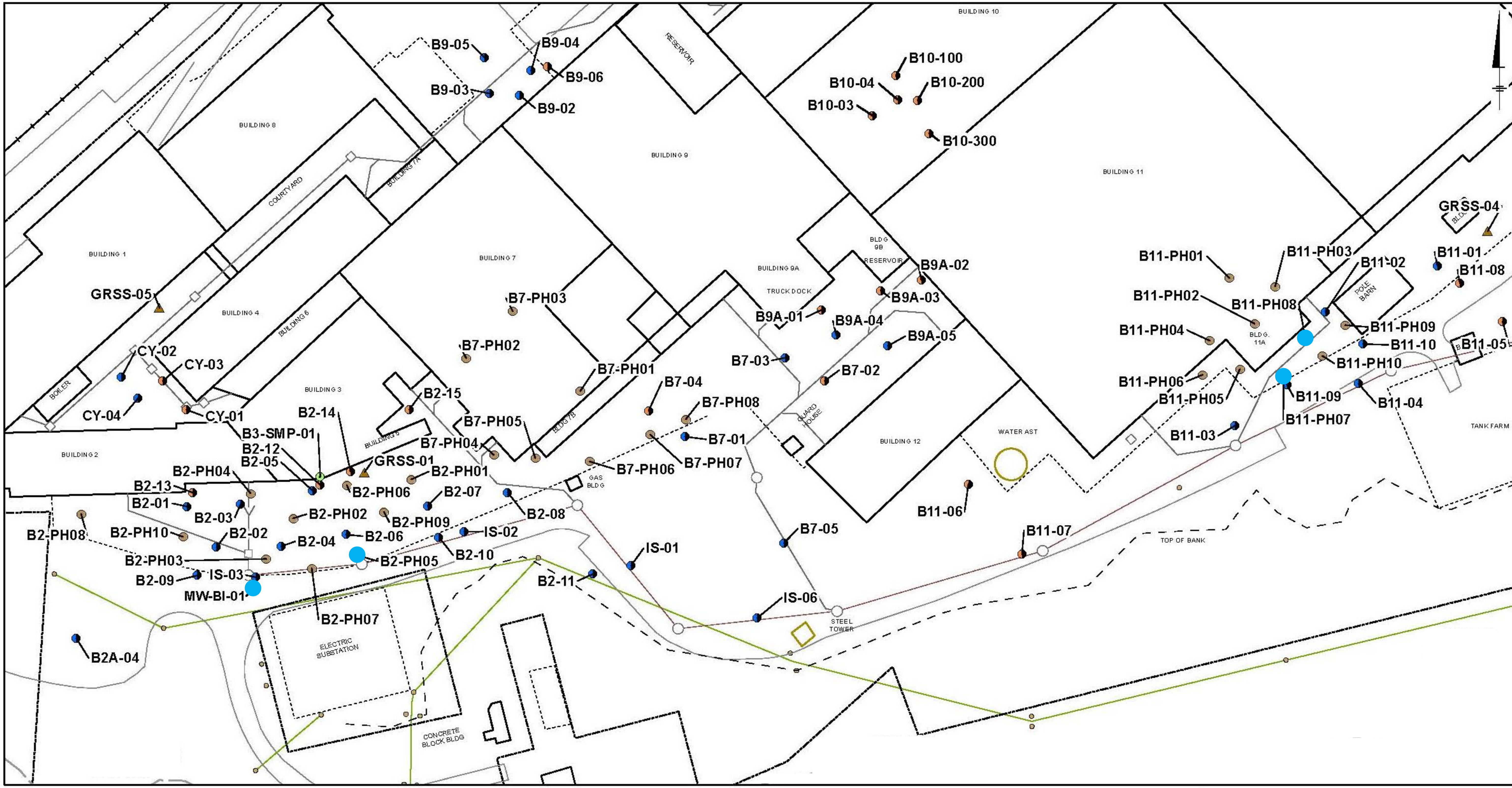
CORRECTIVE MEASURES STUDY REPORT ADDENDUM

SITE LOCATION

ARCADIS Design & Consultancy for natural and built assets

FIGURE

1



LEGEND

- Temporary Monitoring Well Soil Boring
- Surface Soil Sample Location
- Other Soil Boring Sample Location
- Sump Soil Sample Locaiton
- 2005 Geoprobe Boring
- Railroad Track
- Property Boundary
- Interceptor Pipe
- Fence
- Electric Overhead Line
- Location with historically observed dense non-aqueous phase liquid
- Storm Sewer Pipe
- Manhole/Catchbasin

0 100 200

SCALE IN FEET

PROJECTION: NAD_1983_StatePlane_New_York_Central_FIPS_3102_Feet
SOURCE:

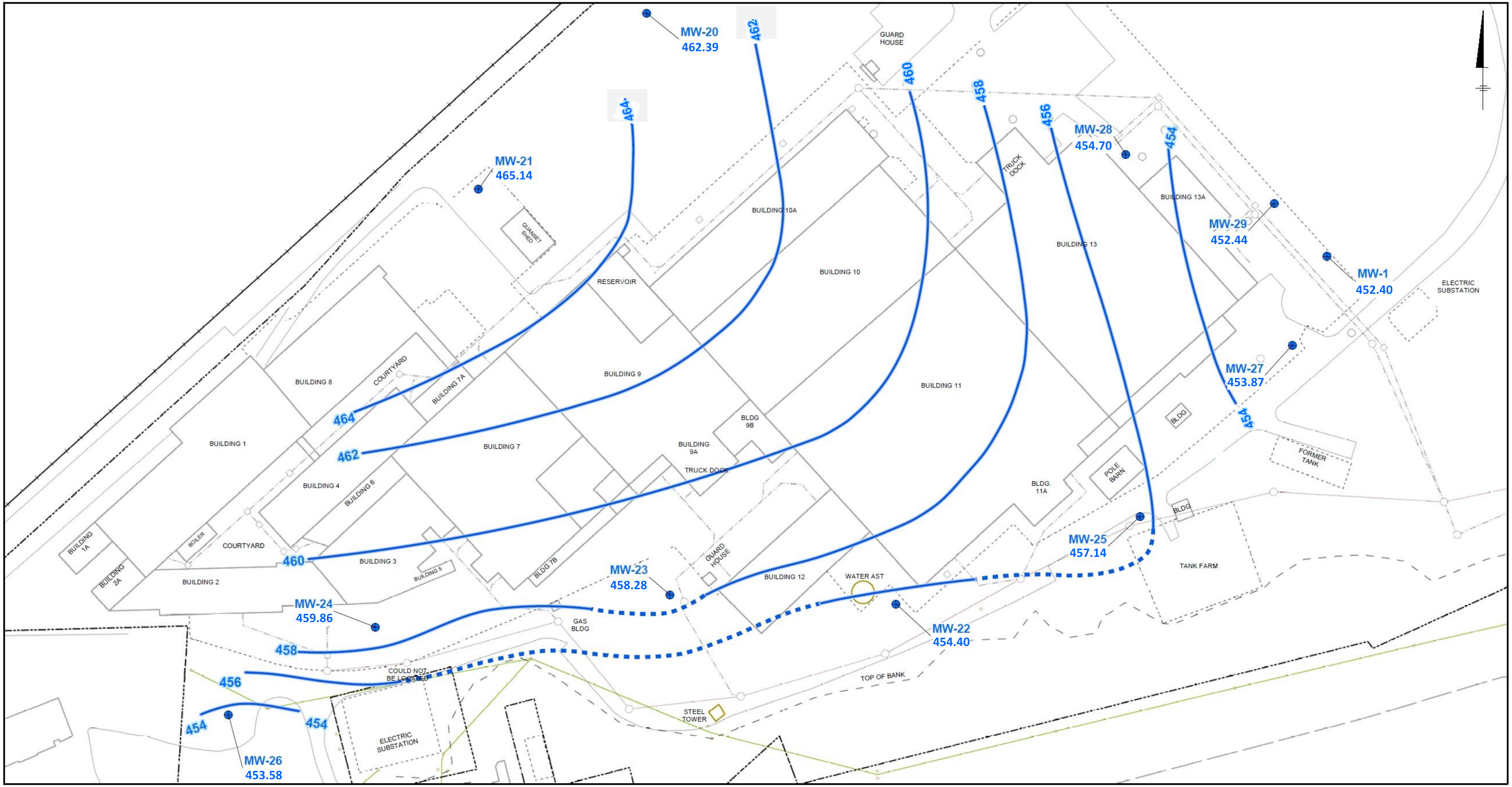
FORMER PHILIPS DISPLAY COMPONENTS FACILITY
SENECA FALLS, NEW YORK
CORRECTIVE MEASURES STUDY REPORT ADDENDUM

HISTORICAL DENSE NON-AQUEOUS PHASE LIQUID LOCATIONS

ARCADIS Design & Consultancy for natural and built assets

FIGURE

2



LEGEND

- MONITORING WELL
- MANHOLE/CATCHBASIN
- Electrical Pole
- POTENTIOMETRIC CONTOUR (ft-anvd)
- RAILROAD TRACK
- PROPERTY BOUNDARY
- INTERCEPTOR PIPE
- FENCE
- ELECTRIC OVERHEAD LINE
- STORM SEWER PIPE
- INFERED POTENTIOMETRIC CONTOUR (ft-anvd)

0 150 300
SCALE IN FEET

PROJECTION: NAD_1983_StatePlane_New_York_Central_FIPS_3102_Feet

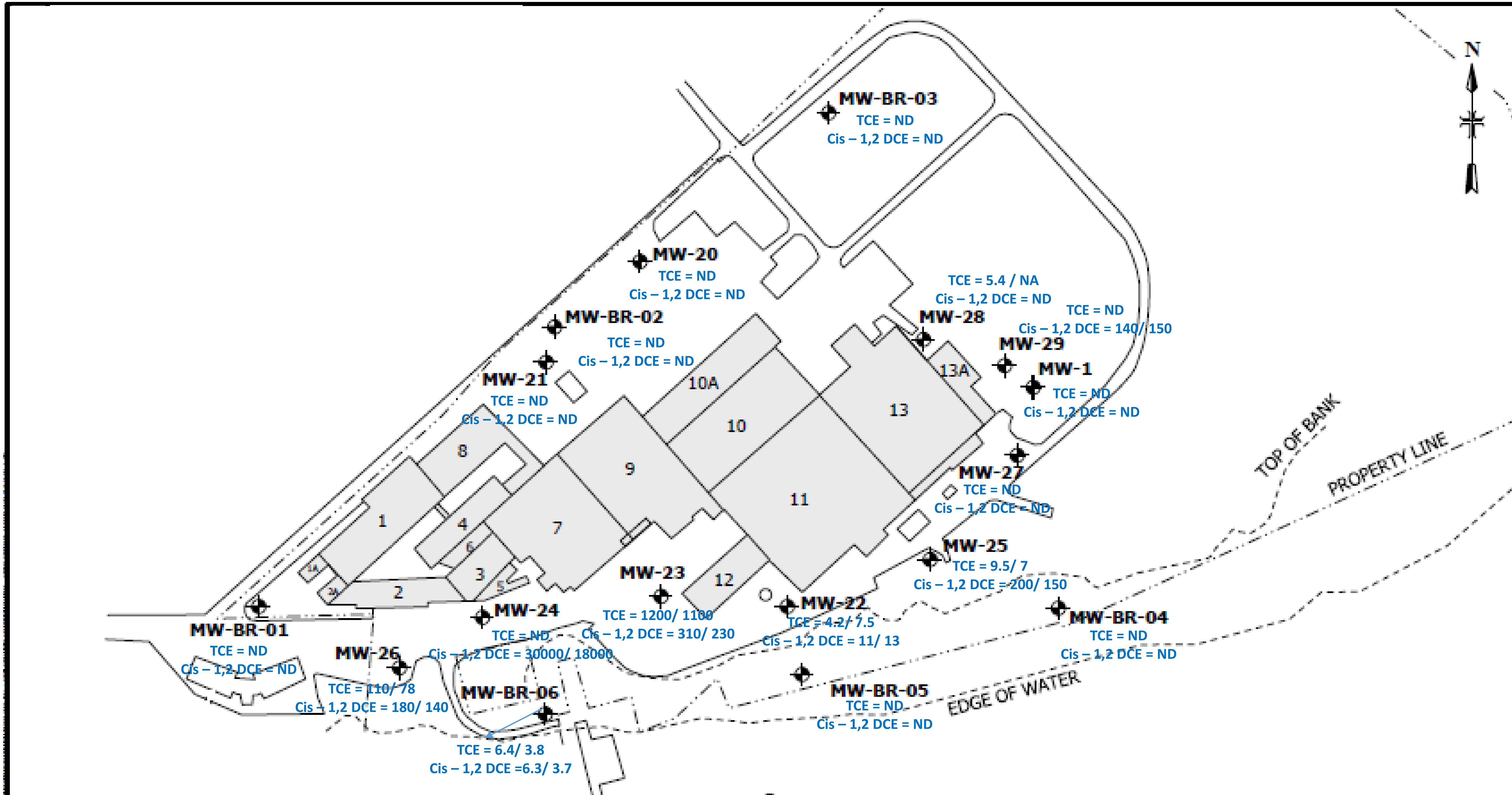
NOTES:
1. ft-anvd - Water Elevations presented in feet above National Vertical Datum.

FORMER PHILIPS DISPLAY COMPONENTS FACILITY
SENECA FALLS, NEW YORK
CORRECTIVE MEASURES STUDY REPORT ADDENDUM

POTENTIOMETRIC CONTOURS
SHALLOW GROUNDWATER
MARCH 29, 2016

ARCADIS Design & Consultancy for natural and built assets

FIGURE
3



LEGEND

MONITORING WELL

NOTES:

TCE – TRICHLOROETHENE
CIS-1,2-DCE – CIS-1,2-DICHLOROETHENE
ND – NOT DETECTED
1200/ 1100 = FALL 2015/SPRING 2016 CONCENTRATION IN MICROGRAMS PER LITER (µg/L)

APPROXIMATE SCALE IN FEET

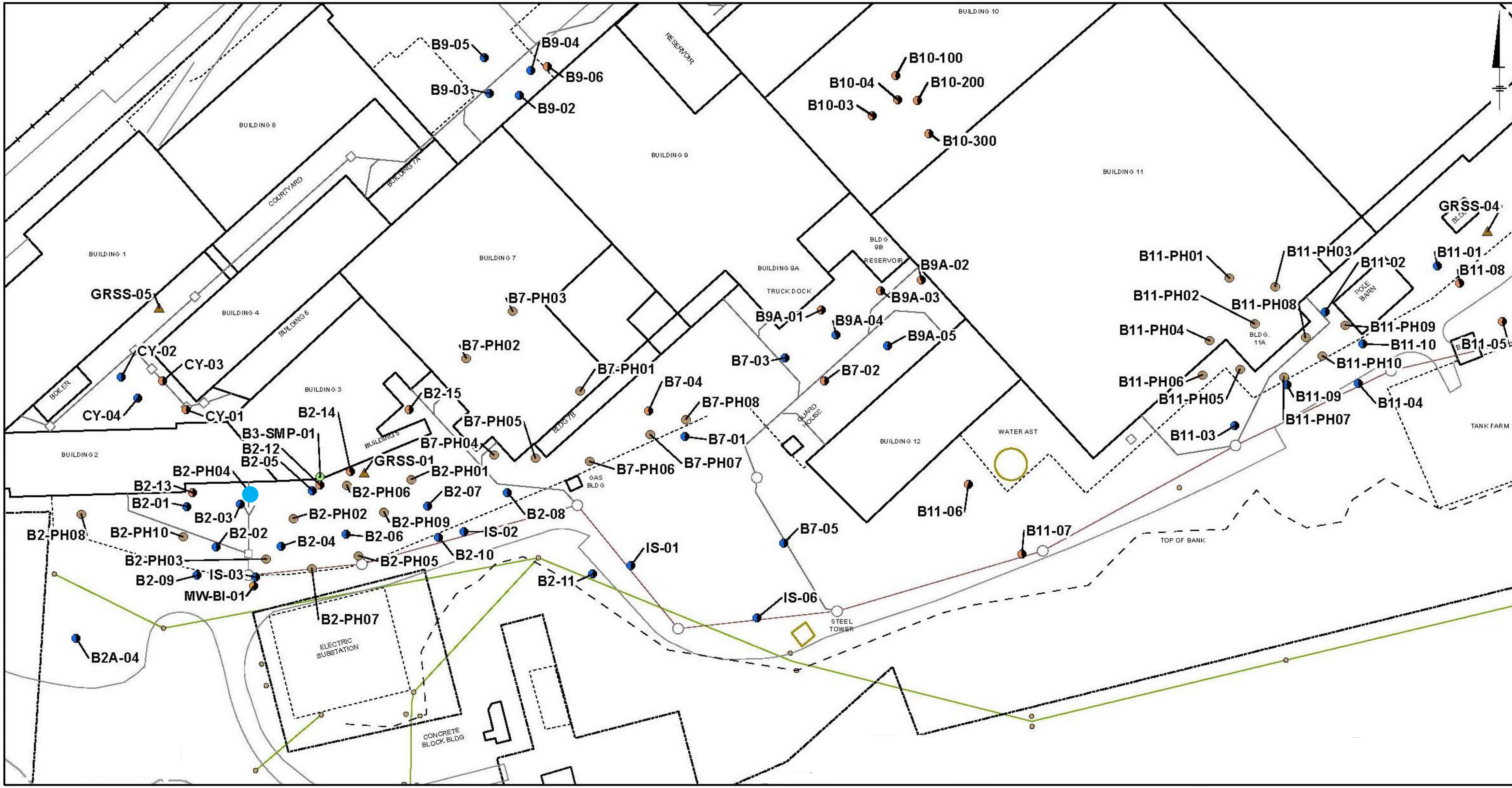
0 200 400 800

FORMER PHILIPS DISPLAY COMPONENTS FACILITY
SENECA FALLS, NEW YORK
CORRECTIVE MEASURES STUDY REPORT ADDENDUM

GROUNDWATER MONITORING RESULTS -
FALL 2015 / SPRING 2016

ARCADIS Design & Consultancy for natural and built assets

FIGURE
4



LEGEND

- Temporary Monitoring Well Soil Boring
- Surface Soil Sample Location
- Other Soil Boring Sample Location
- Sump Soil Sample Locaiton
- 2005 Geoprobe Boring
- Railroad Track
- Property Boundary
- Interceptor Pipe
- Fence
- Electric Overhead Line
- Storm Sewer Pipe
- Manhole/Catchbasin
- Location with a historical unsaturated soil trichloroethene concentration greater than the commercial soil cleanup objective (200 milligrams/kilogram)

0 100 200

SCALE IN FEET

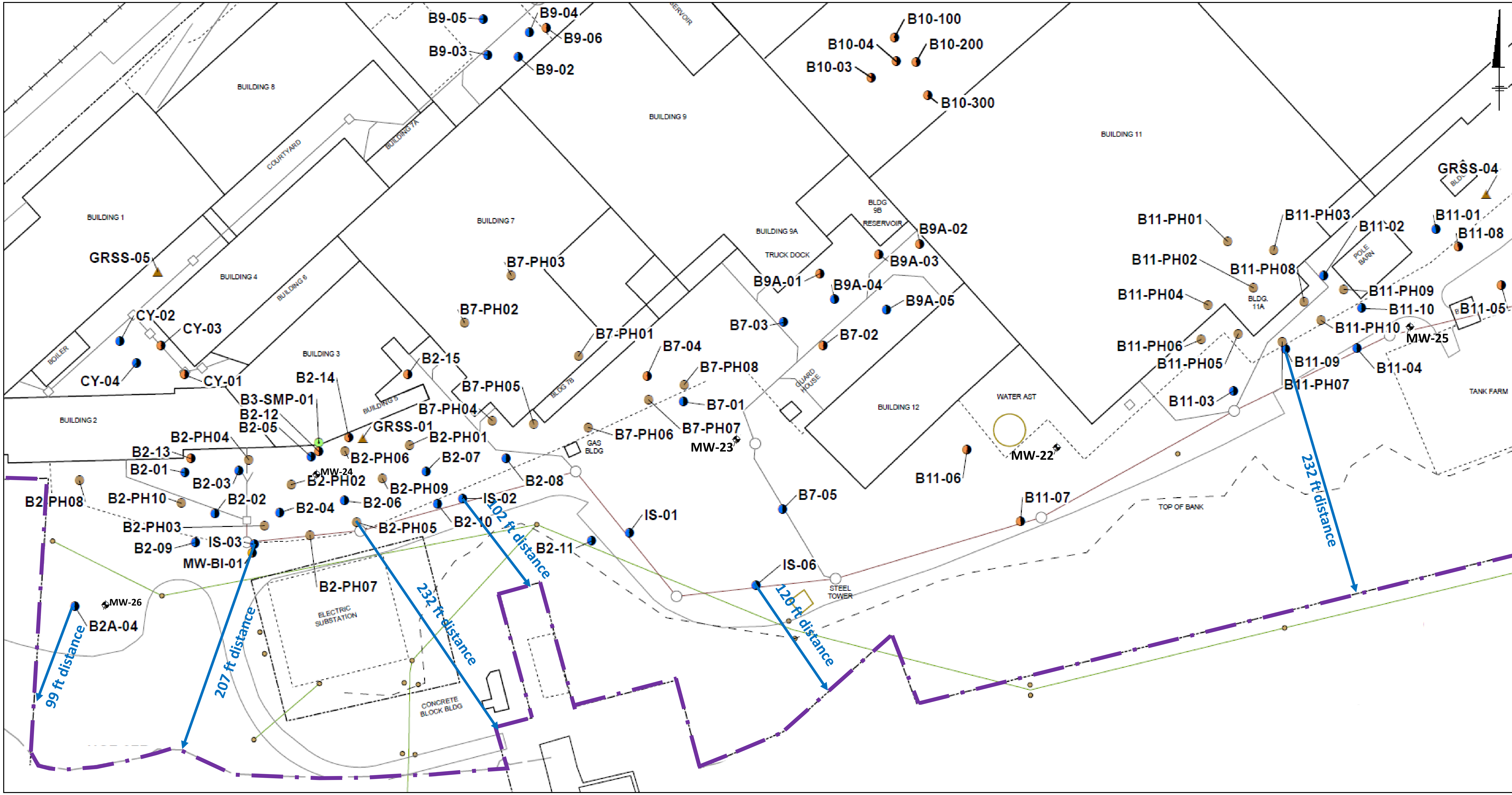
PROJECTION: NAD_1983_StatePlane_New_York_Central_FIPS_3102_Feet
SOURCE:

FORMER PHILIPS DISPLAY COMPONENTS FACILITY
SENECA FALLS, NEW YORK
CORRECTIVE MEASURES STUDY REPORT ADDENDUM

HISTORICAL LOCATIONS WITH UNSATURATED SOIL EXCEEDING COMMERICAL SOIL CLEANUP OBJECTIVES

ARCADIS Design & Consultancy for natural and built assets

FIGURE
5



LEGEND

- Temporary Monitoring Well Soil Boring
- Surface Soil Sample Location
- Other Soil Boring Sample Location
- Sump Soil Sample Locaiton
- 2005 Geoprobe Boring
- Railroad Track
- Interceptor Pipe
- Fence
- Electric Overhead Line
- Storm Sewer Pipe
- Manhole/Catchbasin
- Groundwater flow direction
- Boundary set for travel time calculations (property boundary)

0 100 200

SCALE IN FEET

PROJECTION: NAD_1983_StatePlane_New_York_Central_FIPS_3102_Feet

SOURCE:

FORMER PHILIPS DISPLAY COMPONENTS FACILITY
SENECA FALLS, NEW YORK
CORRECTIVE MEASURES STUDY REPORT ADDENDUM

GROUNDWATER TRAVEL DISTANCE TO PROPERTY BOUNDARY

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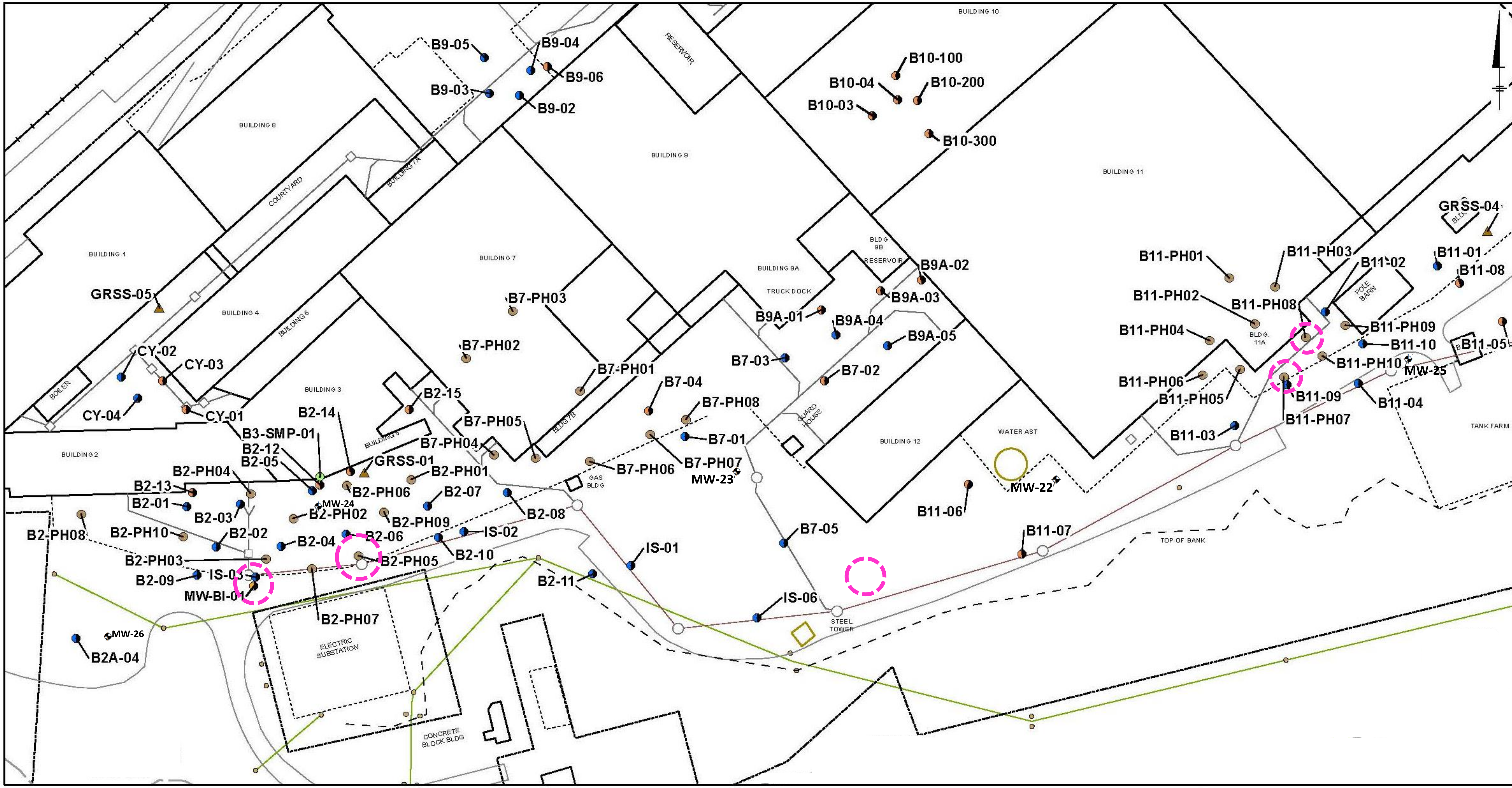
FIGURE

6



0 100 200
SCALE IN FEET

LEGEND

- Temporary Monitoring Well Soil Boring
- Surface Soil Sample Location
- Other Soil Boring Sample Location
- Sump Soil Sample Locaiton
- 2005 Geoprobe Boring
- Railroad Track
- Property Boundary
- Interceptor Pipe
- Fence
- Electric Overhead Line
- Storm Sewer Pipe
- Manhole/Catchbasin
- Proposed well location area

PROJECTION: NAD_1983_StatePlane_New_York_Central_FIPS_3102_Feet
SOURCE:

FORMER PHILIPS DISPLAY COMPONENTS FACILITY
SENECA FALLS, NEW YORK
CORRECTIVE MEASURES STUDY REPORT ADDENDUM

PROPOSED WELL LOCATIONS FOR ALTERNATIVES 1B, 2B, AND 3B

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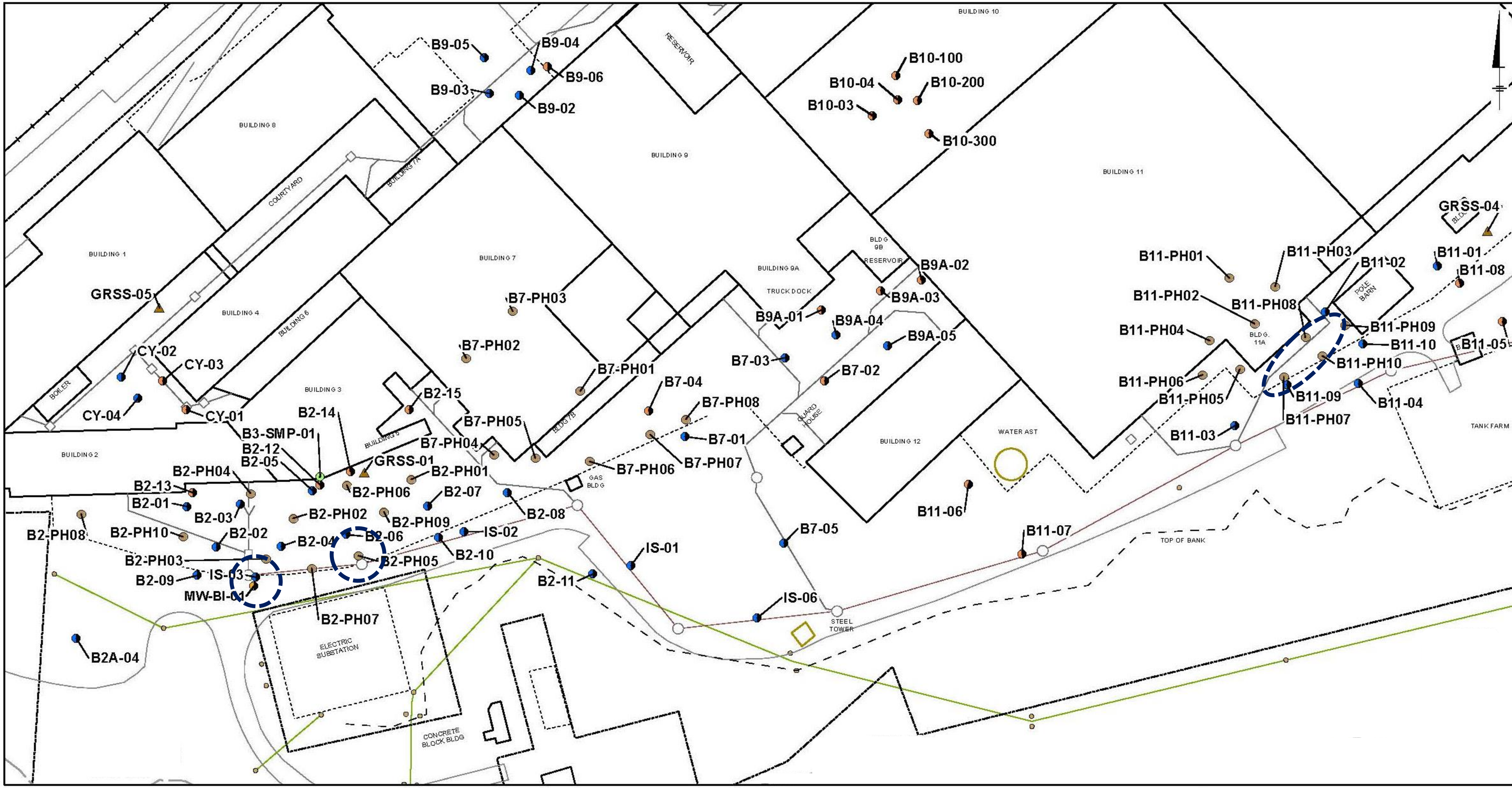
FIGURE
7



LEGEND

- Temporary Monitoring Well Soil Boring
- Surface Soil Sample Location
- Other Soil Boring Sample Location
- Sump Soil Sample Locaiton
- 2005 Geoprobe Boring
- Railroad Track
- Property Boundary
- Interceptor Pipe
- Fence
- Electric Overhead Line
- Storm Sewer Pipe
- Manhole/Catchbasin
- Proposed area for thermal remediation

0 100 200
SCALE IN FEET

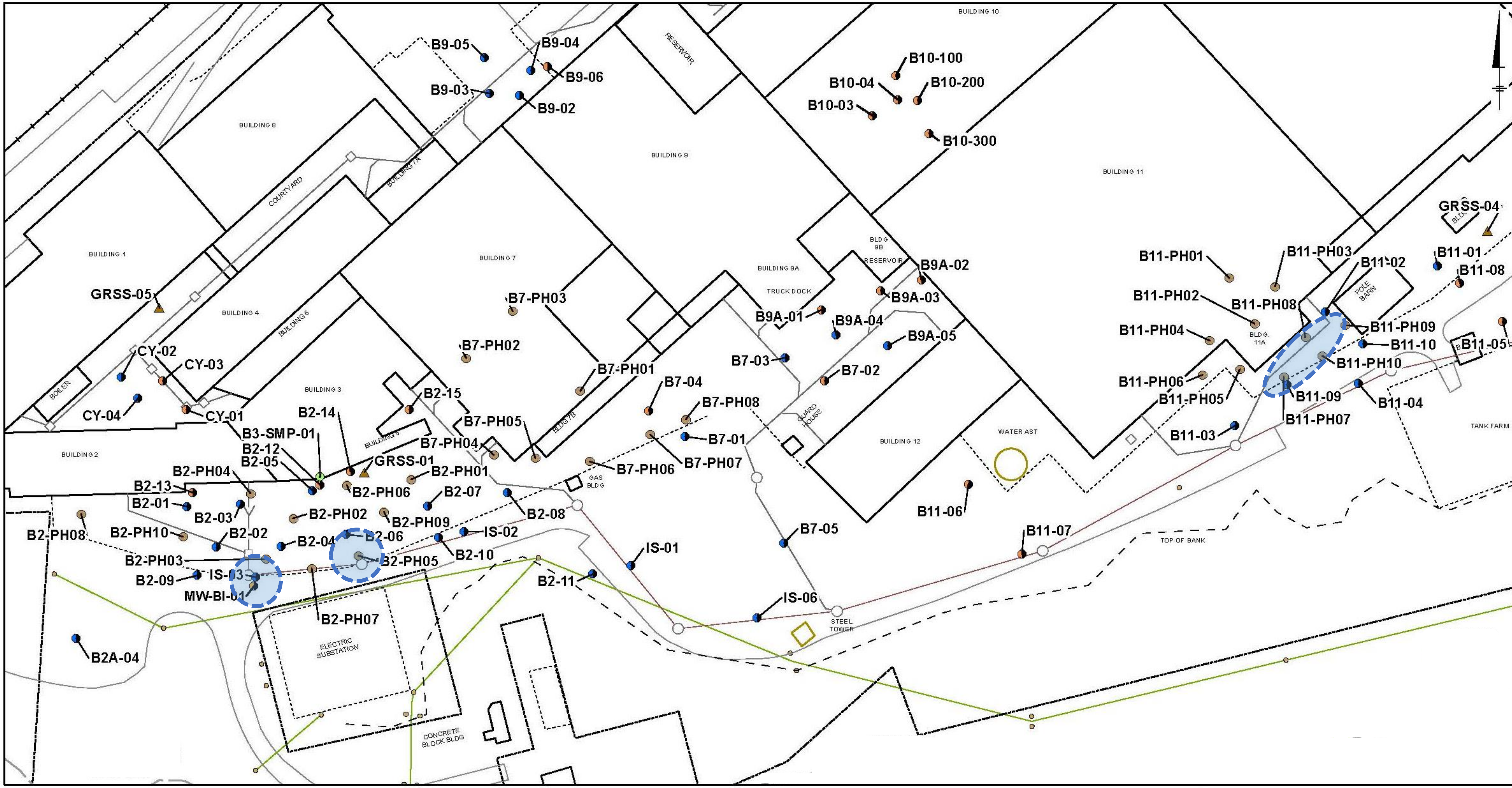
PROJECTION: NAD_1983_StatePlane_New_York_Central_FIPS_3102_Feet
SOURCE:

FORMER PHILIPS DISPLAY COMPONENTS FACILITY
SENECA FALLS, NEW YORK
CORRECTIVE MEASURES STUDY REPORT ADDENDUM

ALTERNATIVES 1C and 3C

ARCADIS Design & Consultancy for natural and built assets

FIGURE
8



LEGEND

- Temporary Monitoring Well Soil Boring
- Surface Soil Sample Location
- Other Soil Boring Sample Location
- Sump Soil Sample Locaiton
- 2005 Geoprobe Boring
- Railroad Track
- Property Boundary
- Interceptor Pipe
- Fence
- Electric Overhead Line
- Storm Sewer Pipe
- Manhole/Catchbasin
- Proposed area for dense non-aqueous phase liquid excavation

0 100 200

SCALE IN FEET

PROJECTION: NAD_1983_StatePlane_New_York_Central_FIPS_3102_Feet
SOURCE:

FORMER PHILIPS DISPLAY COMPONENTS FACILITY
SENECA FALLS, NEW YORK
CORRECTIVE MEASURES STUDY REPORT ADDENDUM

ALTERNATIVES 1D and 3D

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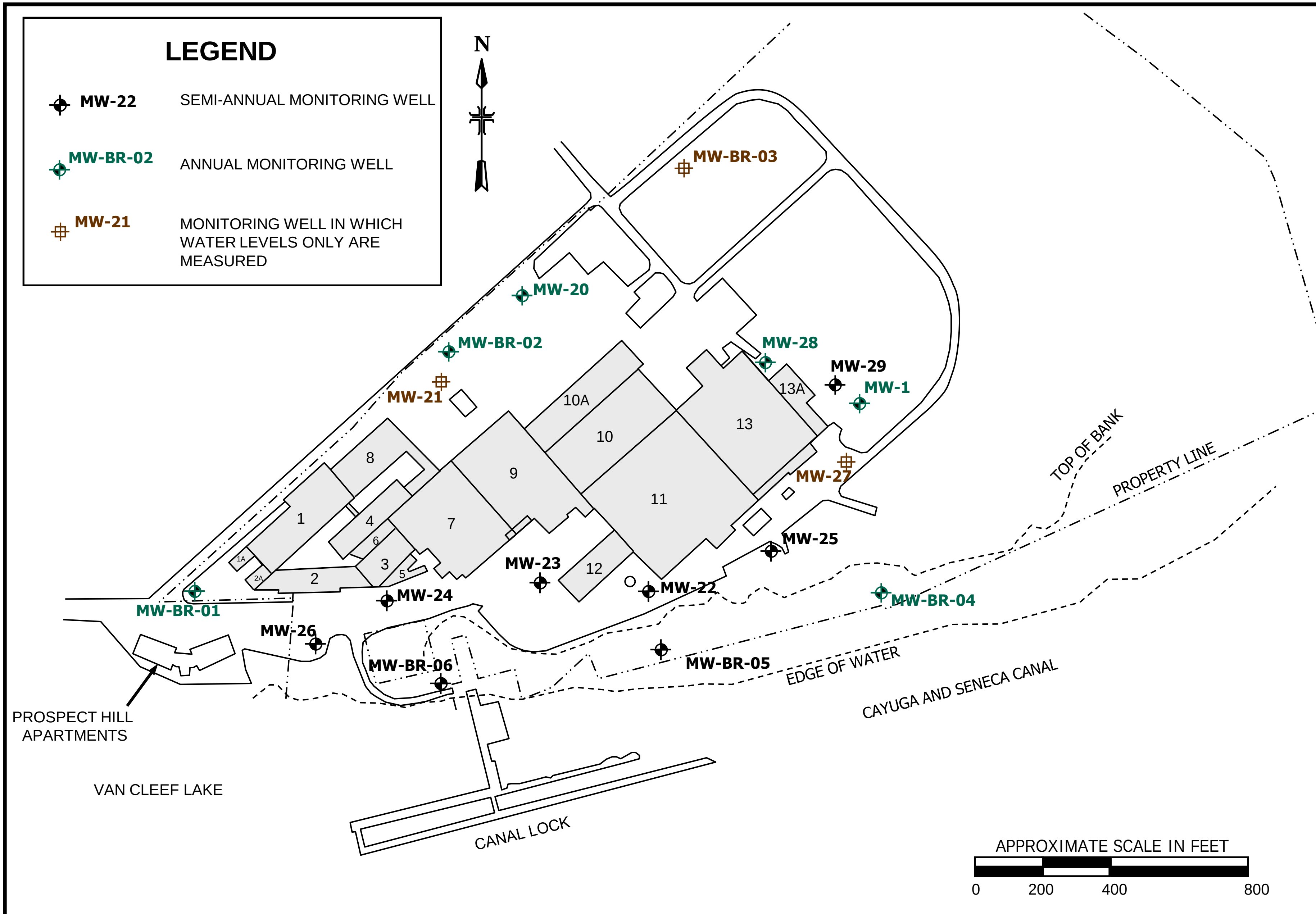
FIGURE
9

APPENDIX A

Groundwater Concentration Graphs



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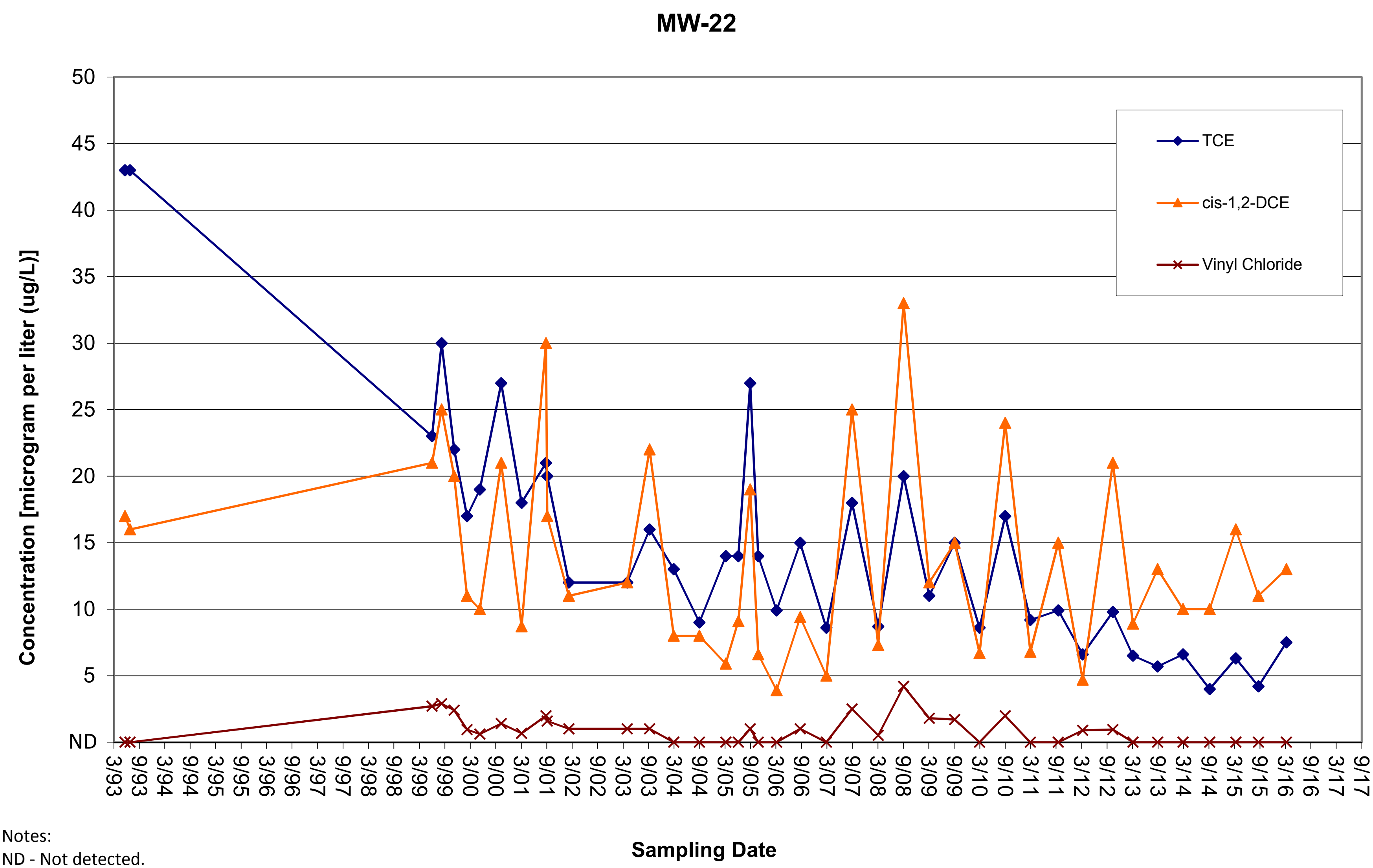
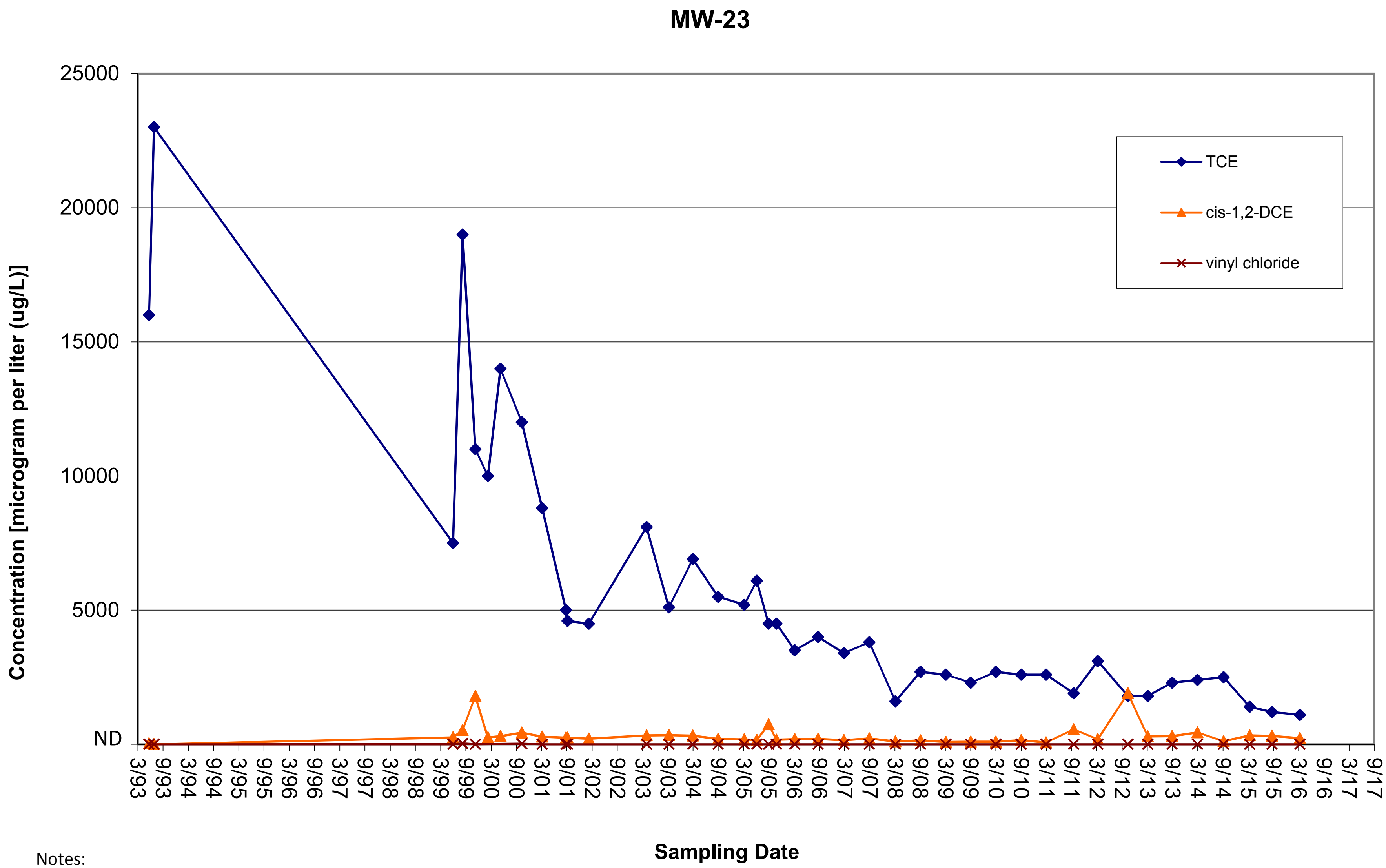
FORMER PHILIPS DISPLAY COMPONENTS FACILITY
SENECA FALLS, NEW YORK

MONITORING WELL LOCATIONS

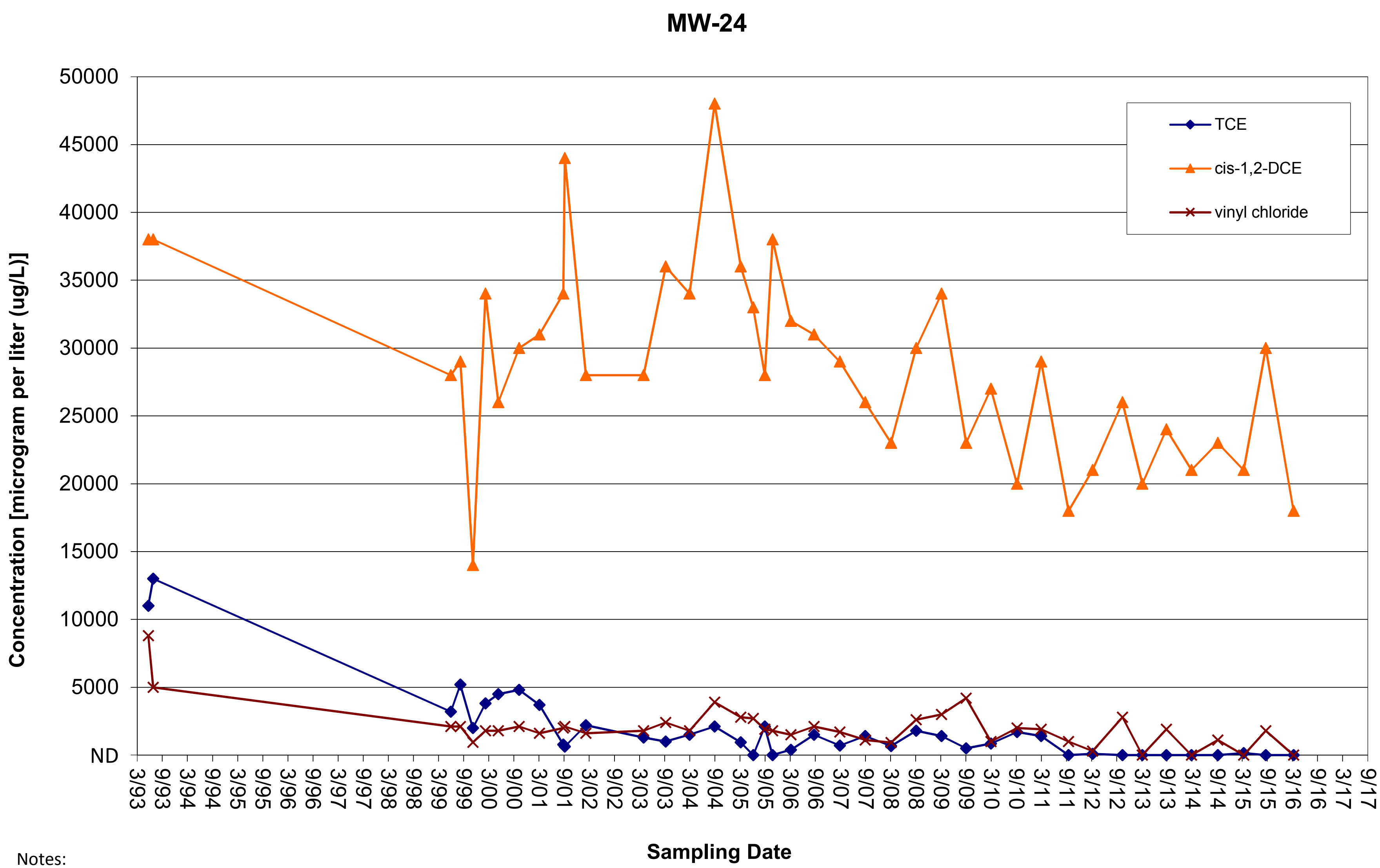
FIGURE 1



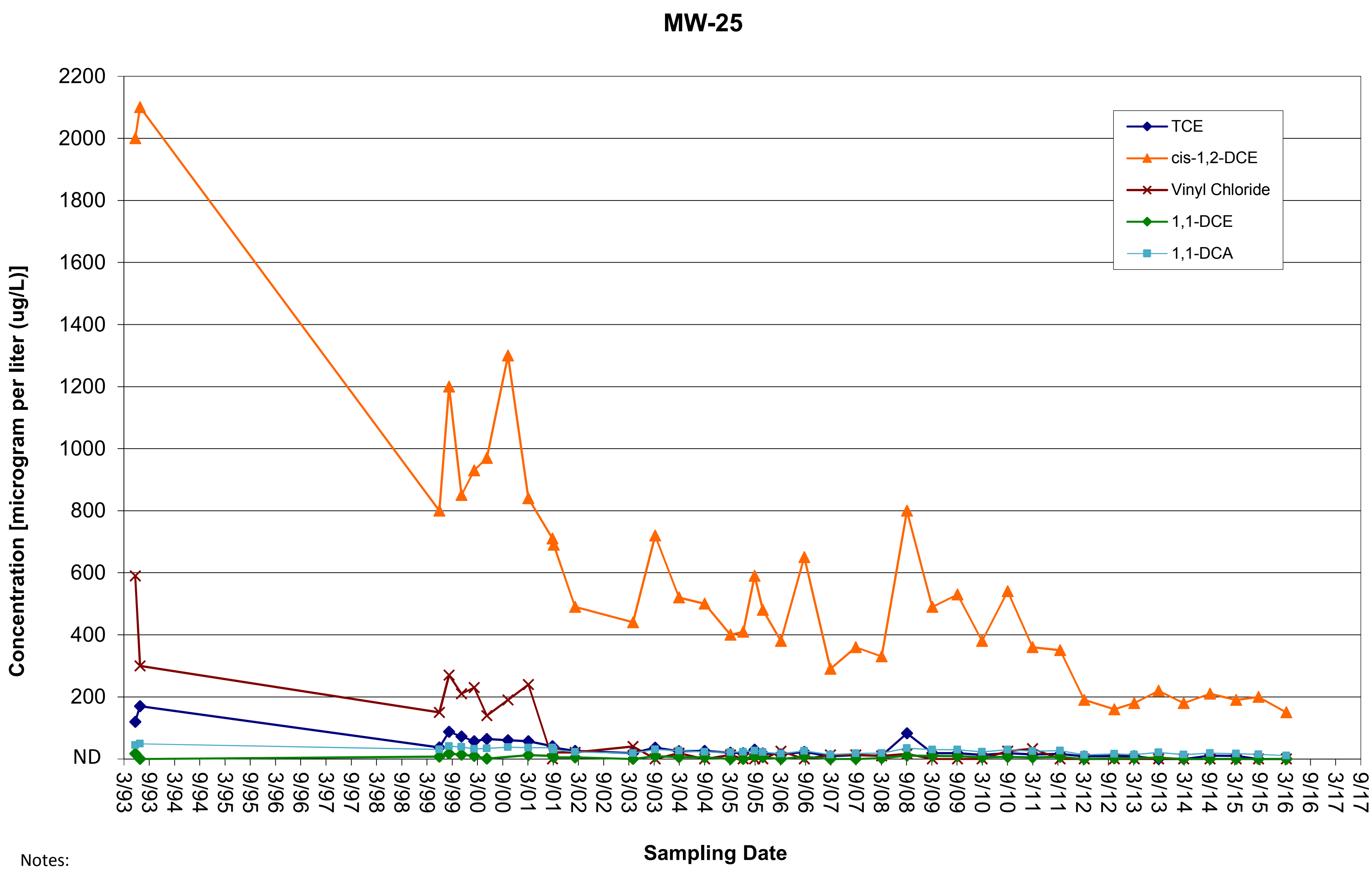
Notes:
ND - Not detected.
Reporting limit is 5 ug/L.
Results less than the reporting limit are estimated.
Volatile organic comopunds not shown were analyzed but not reported by the laboratory.



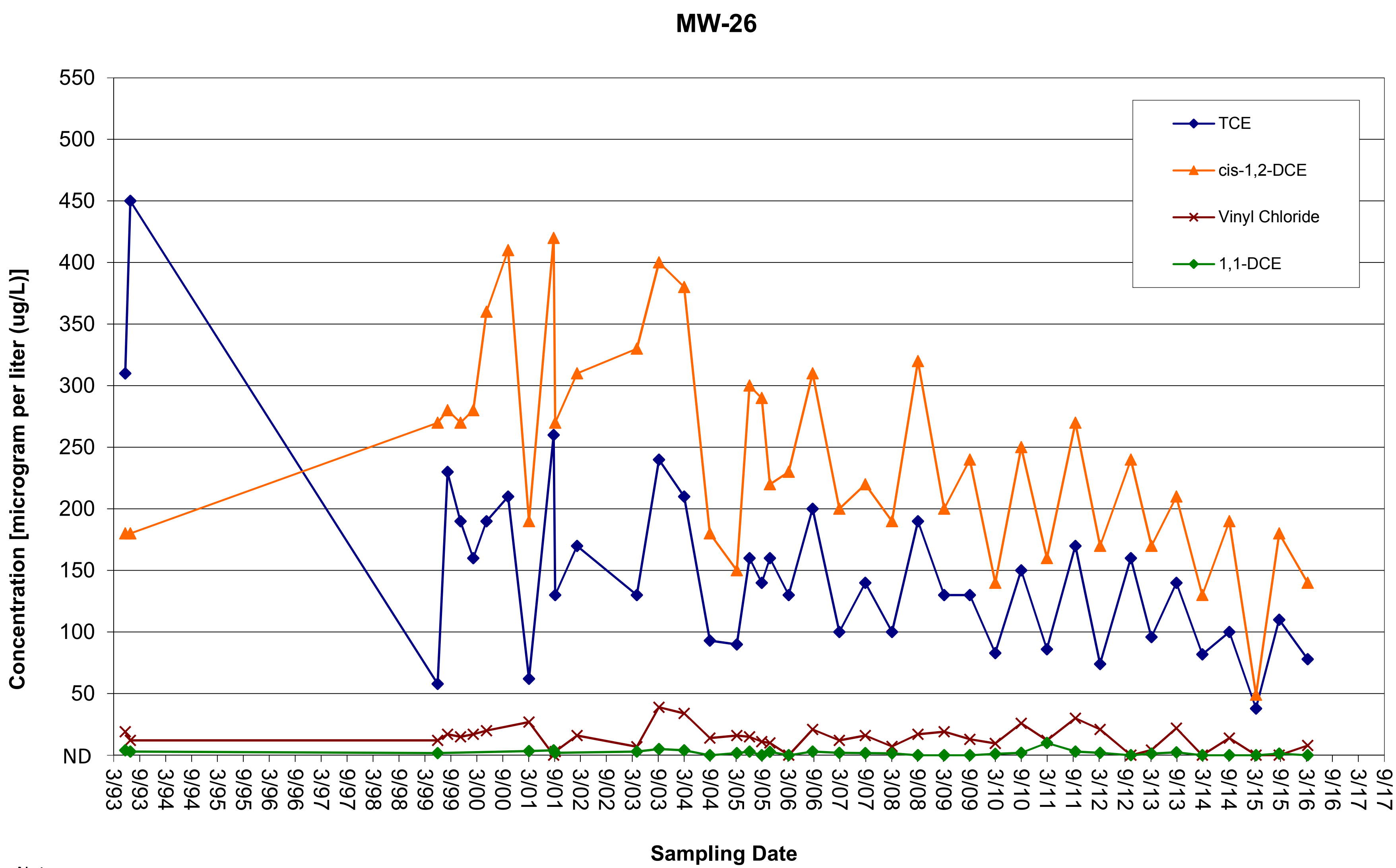
Notes:
ND - Not detected.
Reporting limit is variable.
Volatile organic comopunds not shown were analyzed but not reported by the laboratory.



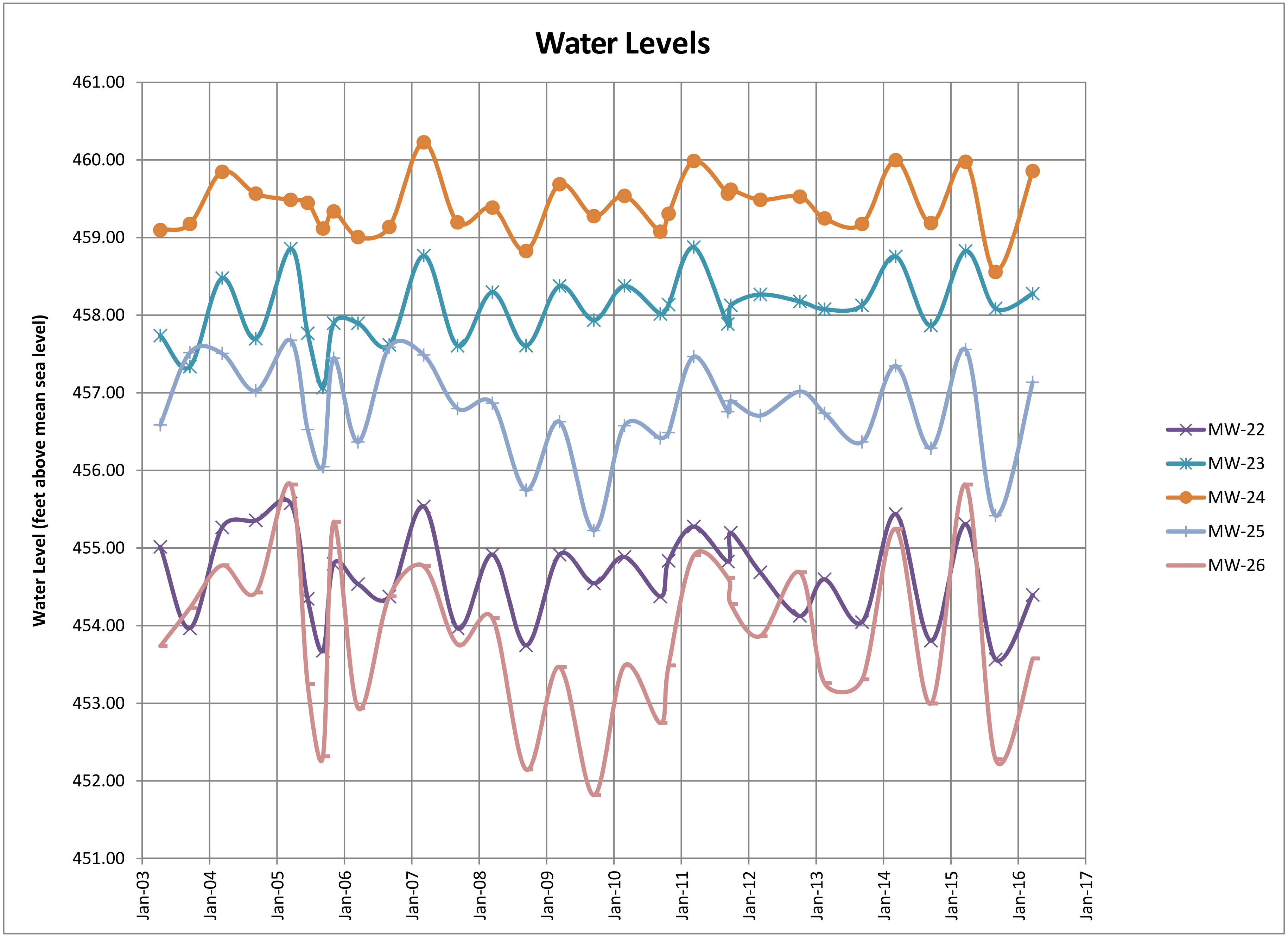
Notes:
ND - Not detected.
Reporting limit is variable.
Volatile organic comopunds not shown were analyzed but not reported by the laboratory.



Notes:
ND - Not detected.
Reporting limit is variable.
Volatile organic comopunds not shown were analyzed but not reported by the laboratory.



Notes:
ND - Not detected.
Reporting limit is variable.
Volatile organic comopunds not shown were analyzed but not reported by the laboratory.



Water Levels
Water Level (feet above mean sea level)
461.00
460.00
459.00
458.00
457.00
456.00
455.00
454.00
453.00
452.00
451.00
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
MW-22
MW-23
MW-24
MW-25
MW-26

APPENDIX B

Natural Attenuation Evaluation

Corrective Measures Report Addendum Appendix B

Technical Memorandum 1

REVISED MONITORED NATURAL ATTENUATION ASSESSMENT

AOCs 1, 2 and 3 Former Philips Display Components Facility Seneca Falls, New York

Facility EPA ID # NYD002246015

NYSDEC ID # 850003

October 2016

INTRODUCTION

The objective of this Technical Memorandum is to update to the evaluation of groundwater concentration trends and natural attenuation rates for chemicals of potential concern (COPC) within Areas of Concern (AOC) 1 (Building 2 Area), AOC 2 (Building 7 area) and AOC 3 (Building 11 area) at the Former Philips Display Components Facility in Seneca Falls, New York (site) that was performed as part of the CMS Report (Arcadis 2013). The information provided herein was used to update the conceptual site model (CSM) and groundwater corrective measures screening in the *Corrective Measures Study (CMS) Report Addendum*.

Monitored natural attenuation (MNA) was assessed as described in this memorandum using groundwater samples collected from the five groundwater monitoring wells in AOCs 1, 2, and 3. Groundwater monitoring at these wells has been conducted for more than 20 years. The data collected at monitoring wells MW-22 and MW-25 in AOC 3 (Building 11 Area), MW-23 in AOC 2 (Building 7 Area) and, MW-24 and MW-26 in AOC 1 (Building 2 Area) were used to update the CSM and the potential for applying natural attenuation. MNA, as defined by the USEPA in Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17P (USEPA 1999) (MNA Directive), refers to the reliance on natural attenuation processes (biodegradation, dispersion, dilution, sorption, volatilization, chemical or biological stabilization, transformation, or destruction of contaminants) to reduce the mass, toxicity, mobility, volume, or concentration of contaminants to achieve site-specific corrective action objectives (CAOs). The use of site-specific data eliminates the need for theoretical assumptions because the changes in concentration reflect processes that are occurring at the site.

CONCENTRATION TREND ANALYSIS

A trend analysis was conducted for COPC at the site with concentrations greater than the groundwater standards and guidance values (SGVs) to estimate, with an acceptable level of confidence, the rate of COPC attenuation. Trichloroethene (TCE) is the most prevalent dissolved COPC in groundwater within AOCs 1, 2, and 3. Concentrations of daughter products resulting from reductive dehalogenation of TCE (cis-1,2-dichlorothene [DCE] and vinyl chloride), are also greater than SGVs and are included as COPC.

The trend analysis was conducted by calculating first-order degradation rate constants from groundwater concentration data. Site-specific data allow the calculation of first-order degradation rates that lump several transport and attenuation processes into a single rate constant (e.g., advection, dispersion, adsorption, biodegradation, transformation, partitioning from unsaturated soils, and diffusion from potential dense non-aqueous phase liquid sources). The first-order degradation rate calculation methods outlined in EPA Ground Water Issue Paper: *Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies* (USEPA 2002) (EPA White Paper) were used for this evaluation. Where sufficient site-specific data were available, COPC first-order degradation rates were calculated for each of the five wells. The first-order degradation rates were then used to calculate COPC attenuation half-lives.

The MNA assessment performed in 2013 as part of the *CMS Report* (Arcadis 2013) indicated statistically significant decreasing concentration trends at two of the five monitoring wells within AOCs 1, 2, and 3 (MW-23 and MW-25). One of the main limitations encountered in the 2013 MNA assessment when correlating data points to linear regression lines with statistical confidence was seasonal fluctuations in groundwater concentration between the spring and fall sampling events. Water table elevations fluctuate by as much as 3 feet between the spring and fall semiannual sampling events, with seasonal low concentrations observed in the spring that are likely caused by dilution from elevated water levels. This updated MNA assessment limits the evaluated data to groundwater concentrations from the fall sampling events, representing seasonal high groundwater COPC concentrations. By removing the seasonal variability, changes in concentrations over time more accurately represent site-specific natural attenuation processes, and concentration variability caused water level changes is reduced.

Additionally, the *CMS Report Addendum* identifies dense non-aqueous phase liquid (DNAPL) as a potential COPC source within AOCs 1 and 3. The mass within these potential source areas contribute to the dissolved groundwater concentrations observed at the site.

Peak COPC concentrations at each monitoring well were identified and used as starting points for calculating representative first-order degradation rates. The peak TCE concentrations coincide with the point in time when reductions from natural attenuation processes began to exceed the mass flux from residual sources, such as potential DNAPL. For the daughter products cis-1,2-DCE and vinyl chloride, peak concentrations coincide with the point in time when reductions from natural attenuation processes began to exceed rates of production by reductive dehalogenation of the parent compound (TCE and cis-1,2-DCE, respectively).

Revised Data Set Assessment

The revised data sets were used to assess MNA. A summary of the statistical analyses and calculated attenuation half-lives is provided in Table B-1.

COPC-specific linear regression trends were evaluated using natural log-normalized concentration data to estimate trend direction and first-order degradation rates in accordance with guidance from the USEPA (USEPA 2002). The linear regression calculations calculate first-order degradation rates that can be used for extrapolating future concentrations. The calculations also assess the fit of data against a first-order degradation rate model.

Trend directions were defined as decreasing if the slope of the best fit line indicated that concentrations decreased with time (negative slope), and as increasing if the slope of the best fit line indicated that concentrations increased with time (positive slope). To perform the analysis, data sets must include at least three data points (reported concentrations), with at least 75% of the data having known concentrations. The assessment of vinyl chloride was limited to AOC 1 monitoring wells because concentrations were not reported in more than half of the groundwater samples collected during the last several years from monitoring wells in AOCs 2 and 3. Statistically significant trends could not be established for vinyl chloride concentrations in MW-24 or MW-26; however, concentrations appear to be decreasing.

The R^2 value is a statistical measure of how close the site data are to the fitted linear regression line. The tolerance for the closeness of fit (distance between data points and regression line) is higher for regression lines with larger slopes than for smaller slopes. The size of the data set also affects the R^2 values; unusual data points in large data sets have less influence on R^2 than in small data sets.

R^2 values close to zero indicate weak model fits, while R^2 values close to one indicate strong model fits. R^2 values less than 0.5, indicating variability in the data, were defined as not statistically significant in the *CMS Report* (Arcadis 2013). Based on the guidance provided in the 2011 USEPA *Approach for Evaluation the Progress of Natural Attenuation in Groundwater,* R^2 values less than 0.1 indicate a weak fit of the linear model to groundwater concentration data. For regression lines with R^2 values greater than 0.1, the decision criteria for the appropriate fit of a regression line has changed from the correlation factor (R^2) to the confidence level (p-value, described below). The R^2 values for linear regressions used to calculate attenuation half-lives ranged between 0.8 and 0.4 (Table B-1).

The p-value of the correlation is a measure of the level of significance of the statistical test. Correlations were accepted as statistically significant for p-values less than or equal to 0.1 (i.e., 90% confidence level). All of the data sets analyzed, except for cis-1,2-DCE at MW-23 and vinyl chloride at MW-24 and MW-26, had decreasing trends with p-values of 0.02 or less (confidence levels of at least 98%).

First-Order Rate Constant Calculations

Linear regression trend analyses were completed to estimate COPC degradation half-lives at wells with decreasing COPC concentration trends. For the analyses, degradation half-lives are determined for data with decreasing trends that are statistically significant at the 90 percent confidence level. Where concentrations were below laboratory reporting limits (LRL) or qualified concentrations were used in computations, the concentrations were set equal to the LRL or reported value. Using the LRL for concentrations lower than the LRLs provides a conservative estimate for evaluating concentration trends through time.

The applicable first-order rate equation being is:

$$C = C_0 e^{-kt} \qquad (1)$$

Where

C = the concentration at time (t)

C_0 = the initial constituent concentration

k = the first-order rate constant

Taking the natural log of both sides of the equation (as below) allows a simple linear solution for the rate constant (k), the statistical significance of which can be evaluated using linear regression:

$$\ln(C) = -kt + \ln(C_0) \qquad (2)$$

When ln (C) versus time (t) is plotted, the slope of the best fit line is equivalent to –k, and the y-intercept is equivalent to C_o. Equation 3 relates the attenuation half-life to the first order degradation rate determined in Equation 2.

$$\lambda = \frac{0.693}{k} \qquad (3)$$

Where

k = the first-order rate constant (years)

λ = attenuation half-life (years)

Table B-1 summarizes the calculated attenuation half-lives for each of the data sets analyzed. Attenuation half-life calculations are presented in Figures B-1 through B-5 for TCE, Figures B-6 through B-10 for cis-1,2-DCE, and Figures B-11 through B-13 for vinyl chloride.

The attenuation half-lives for TCE are similar for wells MW-23, MW-24 and MW-25. The TCE attenuation half-life calculated at MW-22 is slightly longer, but the SGV has already been achieved. Although TCE concentrations are clearly decreasing at MW-26, the attenuation half-life calculated for TCE in MW-26 is an outlier. Since the attenuation half-life intrinsically incorporates mass entering the well from upgradient and attenuation occurring within the well it is assumed that the attenuation half-life is impacted by mass migrating into the area.

The attenuation half-lives for cis-1,2-DCE (Table B-1) are similar for AOC 3 (MW-22 and MW-25). Because of the limited data for MW-23 (the well in AOC 2), the p-value determined that the trend was not statistically significant and an attenuation half-life was not calculated. Although an attenuation half-life was not calculated, a clear downward trend exists. The attenuation half-lives calculated for AOC 1 (MW-24 and MW-26) are three to six times higher than the attenuation half-lives calculated for AOC 3.

The formation of cis-1.2-DCE (from reductive dehalogenation of TCE) and concurrent attenuation of cis-1,2-DCE (direct metabolism or reductive dehalogenation to vinyl chloride) play a large role in the apparent attenuation half-life. TCE is present and degrading to cis-1,2-DCE at both MW-24 and MW-26. The clear decreasing trend in TCE concentrations suggest that the formation of cis-1,2-DCE from TCE degradation will decrease over time. Additionally, decreasing cis-1,2-DCE concentrations at MW-24 and MW-26 indicate that cis-1,2-DCE is attenuating faster than it is being formed. With the depletion of TCE, the formation of cis-1,2-DCE is expected to decrease and the attenuation half-life will improve with time.

Attenuation half-life calculations for vinyl chloride at MW-24 and MW-26 are provided in Figures B-12 and B-13, respectively. Attenuation half-lives could not be calculated for vinyl chloride at MW-24 and MW-26 because concentration trends were not statistically significant (confidence levels less than 80%); however, concentrations appear to be decreasing.

A key assumption of the first-order rate equation is that the COPC decay rate depends on the COPC concentration. This model does not assume a linear concentration trend, but rather represents a solvable form of the first-order rate model. The first-order rate model is commonly used and well supported for many environmental processes, including the assessment of natural attenuation processes, as outlined in the USEPA guidance document *An Approach for Evaluating the Progress of Natural Attenuation in Groundwater* (USEPA 2011).

Molar Comparison

Total molar COPC concentrations over time were assessed as part of the *CMS Report* (Arcadis 2013), and showed decreasing total molar COPC trends at AOC 1, 2, and 3 groundwater monitoring wells. After the completing the natural attenuation assessment in the *CMS Report* (Arcadis 2013), additional groundwater samples have been collected as part of the semi-annual groundwater sampling program. Graphs showing TCE concentrations from groundwater samples collected since submittal of the *CMS Report* (Arcadis 2013) are provided in the *March 2016 Semi-Annual Groundwater Sampling Event Report* (Arcadis 2016). Total molar COPC concentration graphs have been updated with data collected since the *CMS Report* (Arcadis 2013) in Figures B-14 through B-18 for monitoring wells MW-22 through

MW-26, respectively. The total molar data for MW-22 through MW-26 are shown in Tables B-2 through B-6, respectively.

The updated figures show that total molar COPC concentrations in groundwater have continued to decrease at monitoring wells in AOCs 1, 2, and 3. The decreasing total molar concentration trends demonstrate complete degradation of COPC at the site.

CONCLUSIONS

The *CMS Report* (Arcadis 2013) Appendix B MNA assessment determined that natural attenuation via reductive dechlorination was occurring, as evidenced by mass reductions in TCE, cis-1,2-DCE, and vinyl chloride. Exponential regression analysis of individual COPC concentrations indicated only two of the five groundwater monitoring wells in AOCs 1, 2, and 3 (MW-23 and MW-25) had decreasing concentration trends with a statistically significant linear regression correlation.

Groundwater COPC data were reevaluated, including additional COPC concentration data collected after the *CMS Report* (Arcadis 2013), using only the seasonal high COPC concentrations to reduce concentration variability. The revised assessment resulted in better statistical evidence for decreasing COPC concentration trends and greater confidence in the calculated COPC attenuation half-lives in AOCs 1, 2, and 3.

The calculated half-lives for TCE are similar in AOCs 1, 2, and 3, ranging between 1,960 and 2,796 days at monitoring wells MW-22 through MW-25. Although TCE concentrations are clearly decreasing at MW-26, the calculated attenuation half-life (4,592 days) is an outlier.

The calculated half-lives for cis-1,2-DCE are similar at MW-22 and MW-25 in AOC 3, between 1,181 and 1,898 days. The attenuation half-lives calculated for MW-24 and MW-26 in AOC 1, between 6,054 and 6,692 days, are three to six times higher than the attenuation half-lives calculated for AOC 3. With the further depletion of TCE concentrations in AOC 1, the formation of cis-1,2-DCE is expected to decrease and the attenuation half-life will improve with time. A half-life for cis-1,2-DCE was not calculated at MW-23 because of the limited number of reported concentrations, but a clear decreasing concentration trend exists.

The calculated half-life for vinyl chloride in MW-22 is 651 days. Attenuation half-lives could not be calculated for vinyl chloride in MW-24 and MW-26 because concentration trends were not statistically significant; however, concentrations appear to be decreasing.

REFERENCES

Arcadis. 2013. *Corrective Measures Study Report*. Former Philips Display Components Facility, Seneca Falls, New York. June, 2013.

Arcadis. 2016. *March 2016 Semi-Annual Groundwater Sampling Event Report*. Former Philips Display Components Facility, Seneca Falls, New York. May 26, 2016.

USEPA. 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites, April, 1999

USEPA. 2002. Ground Water Issue: Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies, 2002

USEPA. 2011. An Approach for Evaluating the Progress of Natural Attenuation in Groundwater. EPA 600/R-11/204, National Risk Management Research Laboratory, Office of Research and Development, Ada, OK. December.

TABLES

Table B-1
Summary of Statistical Analysis of Groundwater Analytical Data
Former Philips Display Components Facility
Seneca Falls, New York

Constituent	Well	Cleanup Goal/Screening Level/Remediation goal (µg/L)[1]	Data Range						Linear Regression Analysis				
			Minimum Concentration (µg/L)	Maximum Concentration (µg/L)	Concentration Measured Most Recently (µg/L)	% of Data Above Laboratory Reporting Limit	Start Date	End Date	Coefficient of Determination, R-squared	p-value of Correlation (Significance of Slope)	Attenuation Half-life (days)	Trend Direction	Significance of Trend[3]
TCE	MW-22	5	4	30	4	100	9/1/1999	9/10/2015	0.7	<0.01	2,796	Decreasing	Significant
TCE	MW-23	5	1,200	19,000	1,200	100	9/1/1999	9/10/2015	0.8	<0.01	1,960	Decreasing	Significant
TCE	MW-24	5	500	13,000	1,700	95	6/16/1993	9/27/2010	0.5	<0.01	1,978	Decreasing	Significant
TCE	MW-25	5	10	88	10	100	9/1/1999	9/10/2015	0.7	<0.01	2,158	Decreasing	Significant
TCE	MW-26	5	100	200	110	100	9/14/2006	9/10/2015	0.56	0.02	4,592	Decreasing	Significant
cis-1,2-DCE	MW-22	5	10	33	11	100	9/24/2008	9/10/2015	0.6	0.02	1,898	Decreasing	Significant
cis-1,2-DCE	MW-23	5	120	1,900	310	100	11/1/2012	9/10/2015	0.5	0.30	NA	Decreasing	NS
cis-1,2-DCE	MW-24	5	18,000	48,000	30,000	100	9/21/2004	9/10/2015	0.4	0.02	6,054	Decreasing	Significant
cis-1,2-DCE	MW-25	5	160	800	200	100	9/24/2008	9/10/2015	0.8	<0.01	1,181	Decreasing	Significant
cis-1,2-DCE	MW-26	5	180	420	180	100	9/18/2001	9/10/2015	0.4	0.01	6,692	Decreasing	Significant
Vinyl Chloride [2]	MW-22	2	1	4	1	60	9/24/2008	11/1/2012	0.8	0.02	651	Decreasing	Significant
Vinyl Chloride	MW-24	2	1,000	4,200	1,800	100	9/23/2009	9/10/2015	0.2	0.28	NA	Decreasing	NS
Vinyl Chloride	MW-26	2	2	39	2	86	9/29/2003	9/10/2015	0.2	0.12	NA	Decreasing	NS

Notes, Abbreviations and Assumptions:
µg/L = micrograms per liter
NS = not significant
NA = not applicable due to increasing trend or non-significant trend
[1] Screening levels are NYSDEC Class GA Standards.
[2] - Vinyl chloride at MW-22 is a data sets with less than 75% known values and so the half-life was not used for site calculations.
[3] Statistically significant trend defined as having p-value ≤ 0.10.

Table B-2

WELL ID:	**MW-22**
Initial Date:	**6/15/1993**

							165.83	131.29	96.94	96.94	62.50	
Days	**Date**	**PCE (ug/L)**	**TCE (ug/L)**	**cis-DCE (ug/L)**	**1,1-DCE (ug/L)**	**VC (ug/L)**	**PCE (umol/L)**	**TCE (umol/L)**	**Cis-DCE (umol/L)**	**1,1-DCE (umol/L)**	**VC (umol/L)**	**Total M (umol/L)**
1	6/16/1993	10	43	17	10	0	0.06	0.33	0.18	0.10	0.00	0.67
36	7/21/1993	10	43	16	10	0	0.06	0.33	0.17	0.10	0.00	0.66
2200	6/24/1999	0.5	23	21	0.19	2.70	0.00	0.18	0.22	0.00	0.04	0.44
2269	9/1/1999		30	25		2.90		0.23	0.26		0.05	0.53
2360	12/1/1999		22	20		2.40		0.17	0.21		0.04	0.41
2451	3/1/2000		17	11		0.95		0.13	0.11		0.02	0.26
2543	6/1/2000		19	10		0.61		0.14	0.10		0.01	0.26
2696	11/1/2000		27	21		1.40		0.21	0.22		0.02	0.44
2843	3/28/2001	0.5	18	8.7	0.13	0.67	0.00	0.14	0.09	0.00	0.01	0.24
3017	9/18/2001	5	21	30	5	2	0.03	0.16	0.31	0.05	0.03	0.58
3027	9/28/2001	0.5	20	17	0.16	1.60	0.00	0.15	0.18	0.00	0.03	0.36
3181	3/1/2002		12	11		1		0.09	0.11		0.02	0.22
3600	4/24/2003	5	12	12	5	1	0.03	0.09	0.12	0.05	0.02	0.31
3760	10/1/2003	5	16	22	5	1	0.03	0.12	0.23	0.05	0.02	0.45
3933	3/22/2004	0.40	13	8	0.8	0	0.00	0.10	0.08	0.01	0.00	0.19
4116	9/21/2004	5	9	8	5	0	0.03	0.07	0.08	0.05	0.00	0.23
4305	3/29/2005	0.5	14	5.9	0.7	0	0.00	0.11	0.06	0.01	0.00	0.18
4396	6/28/2005	5	14	9.1	5	0	0.03	0.11	0.09	0.05	0.00	0.28
4481	9/21/2005	5	27	19	5	1	0.03	0.21	0.20	0.05	0.02	0.50
4538	11/17/2005	5	14	6.6	5	0	0.03	0.11	0.07	0.05	0.00	0.26
4670	3/29/2006	5	9.9	3.9	5	0	0.03	0.08	0.04	0.05	0.00	0.20
4839	9/14/2006	0.93	15	9.4	5	1	0.01	0.11	0.10	0.05	0.02	0.28
5027	3/21/2007	5.0	**8.6**	**5.0**	5.0	0.0	0.03	0.07	0.05	0.05	0.00	0.20
5210	9/20/2007	5.0	**18**	**25**	5.0	**2.5**	0.03	0.14	0.26	0.05	0.04	0.52
5398	3/26/2008	5.0	**8.7**	**7.3**	5.0	**0.51**	0.03	0.07	0.08	0.05	0.01	0.23
5580	9/24/2008	5.0	**20**	**33**	5.0	**4.20**	0.03	0.15	0.34	0.05	0.07	0.64
5764	3/27/2009	5.0	**11**	**12**	5.0	1.8	0.03	0.08	0.12	0.05	0.03	0.32
5945	9/24/2009	5.0	**15**	**15**	5.0	**1.70**	0.03	0.11	0.15	0.05	0.03	0.38
6124	3/22/2010	5.0	**8.6**	**6.7**	5.0	0.0	0.03	0.07	0.07	0.05	0.00	0.22
6308	9/22/2010	5.0	**17**	**24**	5.0	**2.00**	0.03	0.13	0.25	0.05	0.03	0.49
6488	3/21/2011	5.0	**9.2**	**6.8**	5.0	0.00	0.03	0.07	0.07	0.05	0.00	0.22
6688	10/7/2011	5.0	9.9	15.0	5.0	0.0	0.03	0.08	0.15	0.05	0.00	0.31
6862	3/29/2012	0.36	6.6	4.7	0.29	0.9	0.00	0.05	0.05	0.00	0.01	0.12
7079	11/1/2012	0	9.8	21.0	0.0	0.96		0.07	0.22	0.00	0.02	0.31
7224	3/26/2013	0	6.5	8.9	0.0	0		0.05	0.09	0.00	0.00	0.14
7399	9/17/2013	0	5.7	13	0.0	0		0.04	0.13	0.00	0.00	0.18
7582	3/19/2014	0	6.6	10	0	0		0.05	0.10			0.15
7772	9/25/2014	0	4.0	10.0	0.0	0.0		0.03	0.10	0.00	0.00	0.13
7960	4/1/2015	0	6.3	16.0	0.0	0.0		0.05	0.17	0.00	0.00	0.21
8122	9/10/2015	0	4.2	11.0	0	0		0.03	0.11			0.15
8323	3/29/2016	0	7.5	**13**	0	0	0.00	0.06	0.13	0.00		0.19
8492	9/14/2016	0	4.6	17.0	0	0.91	0.00	0.04	0.18	0.00	0.01	0.22

Table B-3

WELL ID:	**MW-23**
Initial Date:	**6/15/1993**

Days	Date	PCE (ug/L)	TCE (ug/L)	cis-DCE (ug/L)	1,1-DCE (ug/L)	VC (ug/L)	PCE (umol/L)	TCE (umol/L)	cis- DCE (umol/L)	1,1-DCE (umol/L)	VC (umol/L)	Total M (umol/L)
							165.83	131.29	96.94	96.94	62.50	
	6/16/1993	10	16000	31	10	0	0.06	121.87	0.32	0.10	0.00	122.35
36	7/21/1993	1000	23000	0	1000	0	6.03	175.18	0.00	10.32	0.00	191.53
2200	6/24/1999	0.5	7500	260	1.3	5.3	0.00	57.13	2.68	0.01	0.08	59.91
2269	9/1/1999		19000	530		32		144.72	5.47		0.51	150.70
2360	12/1/1999		11000	1800		7.5		83.78	18.57		0.12	102.47
2451	3/1/2000		10000	260				76.17	2.68			78.85
2543	6/1/2000		14000	300				106.63	3.09			109.73
2696	11/1/2000		12000	430		18		91.40	4.44		0.29	96.12
2843	3/28/2001	25	8800	280	25	0	0.15	67.03	2.89	0.26	0.00	70.32
3017	9/18/2001	250	5000	250	250	0	1.51	38.08	2.58	2.58	0.00	44.75
3027	9/28/2001	25	4600	250	25	0	0.15	35.04	2.58	0.26	0.00	38.02
3181	3/1/2002		4500	210				34.28	2.17			36.44
3600	4/24/2003	250	8100	330	250	0	1.51	61.70	3.40	2.58	0.00	69.19
3760	10/1/2003	250	5100	340	250	0	1.51	38.85	3.51	2.58	0.00	46.44
3934	3/23/2004	20	6900	320	40	0	0.12	52.56	3.30	0.41	0.00	56.39
4116	9/21/2004	250	5500	200	250	0	1.51	41.89	2.06	2.58	0.00	48.04
4306	3/30/2005	50	5200	180	70	0	0.30	39.61	1.86	0.72	0.00	42.49
4396	6/28/2005	500	6100	160	500	0	3.02	46.46	1.65	5.16	0.00	56.29
4481	9/21/2005	500	4500	740	500	0	3.02	34.28	7.63	5.16	0.00	50.08
4538	11/17/2005	250	4500	170	250	0	1.51	34.28	1.75	2.58	0.00	40.12
4670	3/29/2006	250	3500	190	250	0	1.51	26.66	1.96	2.58	0.00	32.71
4839	9/14/2006	250	4000	200	250	0	1.51	30.47	2.06	2.58	0.00	36.62
5027	3/21/2007	250	**3400**	**150**	250	0	1.51	25.90	1.55	2.58	0.00	31.53
5210	9/20/2007	200	**3800**	**220**	200	0	1.21	28.94	2.27	2.06	0.00	34.48
5398	3/26/2008	50	**1600**	**110**	50	0	0.30	12.19	1.13	0.52	0.00	14.14
5580	9/24/2008	200	**2700**	**140**	200	0	1.21	20.57	1.44	2.06	0.00	25.28
5764	3/27/2009	250	**2600**	**87**	250	0	1.51	19.80	0.90	2.58	0.00	24.79
5944	9/23/2009	120	**2300**	**100**	120	0	0.72	17.52	1.03	1.24	0.00	20.51
6124	3/22/2010	120	**2700**	**93**	120	0	0.72	20.57	0.96	1.24	0.00	23.49
6308	9/22/2010	120	**2600**	**150**	120	0	0.72	19.80	1.55	1.24	0.00	23.31
6488	3/21/2011	120	**2600**	**71**	120	0	0.72	19.80	0.73	1.24	0.00	22.50
6688	10/7/2011	50	1900.0	560.0	50	0	0.30	14.47	5.78	0.52	0.00	21.07
6862	3/29/2012	0.36	3100	190	1	0	0.00	23.61	1.96	0.01	0.00	25.58
7079	11/1/2012	0	1800.0	1900.0	0.0	0.0	0.00	13.71	19.60	0.00	0.00	33.31
7224	3/26/2013	0	**1800**	**290**	0.0	0.0	0.00	13.71	2.99	0.00	0.00	16.70
7399	9/17/2013	0	**2300**	**300**	0.0	0.0	0.00	17.52	3.09	0.00	0.00	20.61
7582	3/19/2014	0	**2400**	**440**	0	0	0.00	18.28	4.54	0.00	0.00	22.82
7772	9/25/2014	0.0	2500.0	120.0	0.0	0.0	0.00	19.04	1.24	0.00	0.00	20.28
7960	4/1/2015	0.0	1400.0	330.0	0.0	0.0	0.00	10.66	3.40	0.00	0.00	14.07
8122	9/10/2015	0.0	**1200**	**310**	0.0	0.0	0.00	9.14	3.20	0.00	0.00	12.34
8323	3/29/2016	0	**1100**	**230**	0	0	0.00	8.38	2.37	0.00	0.00	10.75
8492	9/14/2016	0	**1400**	**280**	0	0	0.00	10.66	2.89	0.00	0.00	13.55

Table B-4

WELL ID:	MW-24
Initial Date:	6/15/1993

							165.83	131.29	96.94	96.94	62.50	
Days	**Date**	**PCE (ug/L)**	**TCE (ug/L)**	**cis-DCE (ug/L)**	**1,1-DCE (ug/L)**	**VC (ug/L)**	**PCE (umol/L)**	**TCE (umol/L)**	**cis-DCE (umol/L)**	**1,1-DCE (umol/L)**	**VC (umol/L)**	**Total M (umol/L)**
1	6/16/1993	10	11000	38000	100	8800	0.06	83.78	392.00	1.03	140.80	617.67
36	7/21/1993	2000	13000	38000	2000	5000	12.06	99.02	392.00	20.63	80.00	603.70
2200	6/24/1999	0.129999995	3200	28000	66	2100	0.00	24.37	288.84	0.68	33.60	347.49
2269	9/1/1999		5200	29000	68	2100		39.61	299.15	0.70	33.60	373.06
2360	12/1/1999		2000	14000	65	940		15.23	144.42	0.67	15.04	175.36
2451	3/1/2000		3800	34000	65	1800		28.94	350.73	0.67	28.80	409.15
2543	6/1/2000		4500	26000		1800		34.28	268.21		28.80	331.28
2696	11/1/2000		4800	30000		2100		36.56	309.47		33.60	379.63
2843	3/28/2001	50	3700	31000	62	1600	0.30	28.18	319.79	0.64	25.60	374.51
3017	9/18/2001	1200	770	34000	1200	2000	7.24	5.86	350.73	12.38	32.00	408.21
3027	9/28/2001	100	630	44000	71	2100	0.60	4.80	453.89	0.73	33.60	493.62
3181	3/1/2002		2200	28000		1600		16.76	288.84		25.60	331.20
3600	4/24/2003	1200	1300	28000	1200	1800	7.24	9.90	288.84	12.38	28.80	347.16
3760	10/1/2003	1200	1000	36000	1200	2400	7.24	7.62	371.36	12.38	38.40	437.00
3934	3/23/2004	100	1500	34000	200	1800	0.60	11.43	350.73	2.06	28.80	393.62
4116	9/21/2004	1500	2100	48000	1500	3900	9.05	16.00	495.15	15.47	62.40	598.07
4306	3/30/2005	250	940	36000	350	2800	1.51	7.16	371.36	3.61	44.80	428.44
4396	6/28/2005	2500	0	33000	2500	2700	15.08	0.00	340.42	25.79	43.20	424.48
4481	9/21/2005	2500	2100	28000	2500	1900	15.08	16.00	288.84	25.79	30.40	376.10
4538	11/17/2005	2500	0	38000	2500	1800	15.08	0.00	392.00	25.79	28.80	461.66
4670	3/29/2006	2500	380	32000	2500	1500	15.08	2.89	330.10	25.79	24.00	397.86
4839	9/14/2006	2500	1500	31000	2500	2100	15.08	11.43	319.79	25.79	33.60	405.68
5027	3/21/2007	2500	**700**	**29000**	2500	**1700**	15.08	5.33	299.15	25.79	27.20	372.55
5210	9/20/2007	1000	**1400**	**26000**	1000	**1100**	6.03	10.66	268.21	10.32	17.60	312.82
5398	3/26/2008	1000	**670**	**23000**	1000	**920**	6.03	5.10	237.26	10.32	14.72	273.43
5580	9/24/2008	2500	**1800**	**30000**	2500	**2600**	15.08	13.71	309.47	25.79	41.60	405.64
5764	3/27/2009	2500	**1400**	**34000**	2500	**3000**	15.08	10.66	350.73	25.79	48.00	450.26
5944	9/23/2009	2000	**500**	**23000**	2000	**4200**	12.06	3.81	237.26	20.63	67.20	340.96
6124	3/22/2010	1200	**850**	**27000**	1200	**1000**	7.24	6.47	278.52	12.38	16.00	320.61
6313	9/27/2010	2000	**1700**	**20000**	2000	**2000**	12.06	12.95	206.31	20.63	32.00	283.95
6488	3/21/2011	2000	**1400**	**29000**	2000	**1900**	12.06	10.66	299.15	20.63	30.40	372.91
6688	10/7/2011	1000	**0**	**18000**	1000	**1000**	6.03	0.00	185.68	10.32	16.00	218.03
6862	3/29/2012	72	100	21000	58	290	0.43	0.76	216.63	0.60	4.64	223.06
7079	11/1/2012	0	0.0	26000.0	0.0	2800.0	0.00	0.00	268.21	0.00	44.80	313.01
7224	3/26/2013	0.0	0.0	**20000**	0.0	0.0	0.00	0.00	206.31	0.00	0.00	206.31
7399	9/17/2013	0.0	0.0	**24000**	0.0	1900.0	0.00	0.00	247.58	0.00	30.40	277.98
7582	3/19/2014	0.0	0.0	**21000**	0.0	0.0	0.00	0.00	216.63	0.00	0.00	216.63
7772	9/25/2014	0.0	0.0	23000	0.0	1100.0	0.00	0.00	237.26	0.00	17.60	254.86
7960	4/1/2015	0.0	140	21000	0.0	0.0	0.00	1.07	216.63	0.00	0.00	217.70
8122	9/10/2015	0.0	0.0	**30000**	0.0	**1800**	0.00	0.00	309.47	0.00	28.80	338.27
8323	3/29/2016	0.0	0.0	**18000**	0.0	**0**	0.00	0.00	185.68	0.00	0.00	185.68
8492	9/14/2016	0.0	0.0	**23000**	0.0	**2300**	0.00	0.00	237.26	0.00	36.80	274.06

Table B-5

WELL ID:	MW-25
Initial Date:	6/15/1993

Days	Date	PCE (ug/L)	TCE (ug/L)	cis-DCE (ug/L)	1,1-DCE (ug/L)	VC (ug/L)	PCE (umol/L)	TCE (umol/L)	Cis-DCE (umol/L)	1,1-DCE (umol/L)	VC (umol/L)	Total M (umol/L)
							165.83	131.29	96.94	96.94	62.50	
1	6/16/1993	4.00	120.00	2000.00	17.00	590.00	0.02	0.91	20.63	0.18	9.44	31.18
36	7/21/1993	10.00	170.00	2100.00	0.00	300.00	0.06	1.29	21.66	0.00	4.80	27.82
2200	6/24/1999	1.10	37.00	800.00	7.20	150.00	0.01	0.28	8.25	0.07	2.40	11.02
2269	9/1/1999		88.00	1200.00	17.00	270.00		0.67	12.38	0.18	4.32	17.54
2360	12/1/1999		72.00	850.00	14.00	210.00		0.55	8.77	0.14	3.36	12.82
2451	3/1/2000		57.00	930.00	10.00	230.00		0.43	9.59	0.10	3.68	13.81
2543	6/1/2000		64.00	970.00	1.00	140.00		0.49	10.01	0.01	2.24	12.74
2696	11/1/2000		60.00	1300.00		190.00		0.46	13.41		3.04	16.91
2843	3/28/2001	25.00	57.00	840.00	12.00	240.00	0.15	0.43	8.67	0.12	3.84	13.21
3017	9/18/2001	2.00	41.00	710.00	10.00	0.00	0.01	0.31	7.32	0.10	0.00	7.75
3027	9/28/2001	12.00	36.00	690.00	4.80	21.00	0.07	0.27	7.12	0.05	0.34	7.85
3181	3/1/2002		26.00	490.00	5.00	21.00		0.20	5.05	0.05	0.34	5.64
3600	4/24/2003	25.00	19.00	440.00	0.00	40.00	0.15	0.14	4.54	0.00	0.64	5.47
3760	10/1/2003	25.00	36.00	720.00	9.00	0.00	0.15	0.27	7.43	0.09	0.00	7.95
3933	3/22/2004	2.00	25.00	520.00	6.00	19.00	0.01	0.19	5.36	0.06	0.30	5.93
4117	9/22/2004	25.00	26.00	500.00	5.00	0.00	0.15	0.20	5.16	0.05	0.00	5.56
4305	3/29/2005	5.00	20.00	400.00	0.00	13.00	0.03	0.15	4.13	0.00	0.21	4.52
4396	6/28/2005	50.00	19.00	410.00	0.00	0.00	0.30	0.14	4.23	0.00	0.00	4.68
4479	9/19/2005	50.00	30.00	590.00	8.20	0.00	0.30	0.23	6.09	0.08	0.00	6.70
4538	11/17/2005	25.00	18.00	480.00	6.10	0.00	0.15	0.14	4.95	0.06	0.00	5.30
4670	3/29/2006	25.00	15.00	380.00	0.00	25.00	0.15	0.11	3.92	0.00	0.40	4.58
4839	9/14/2006	50.00	23.00	650.00	7.50	0.00	0.30	0.18	6.71	0.08	0.00	7.26
5027	3/21/2007	50.00	**8.80**	**290.00**	0.00	**13.00**	0.30	0.07	2.99	0.00	0.21	3.57
5210	9/20/2007	10.00	**12.00**	**360.00**	0.00	**13.00**	0.06	0.09	3.71	0.00	0.21	4.07
5398	3/26/2008	10.00	**11.00**	**330.00**	3.00	**10.00**	0.06	0.08	3.40	0.03	0.16	3.74
5580	9/24/2008	50.00	**83.00**	**800.00**	11.00	**16.00**	0.30	0.63	8.25	0.11	0.26	9.56
5764	3/27/2009	50.00	**19.00**	**490.00**	10.00	0.00	0.30	0.14	5.05	0.10	0.00	5.60
5945	9/24/2009	50.00	**19.00**	**530.00**	8.80	0.00	0.30	0.14	5.47	0.09	0.00	6.00
6124	3/22/2010	20.00	**13.00**	**380.00**	**5.30**	0.00	0.12	0.10	3.92	0.05	0.00	4.19
6308	9/22/2010	25.00	**19.00**	**540.00**	**6.50**	**25.00**	0.15	0.14	5.57	0.07	0.40	6.33
6488	3/21/2011	25.00	**15.00**	**360.00**	**5.00**	**33.00**	0.15	0.11	3.71	0.05	0.53	4.56
6688	10/7/2011	10.00	16.00	350.00	6.50	0.00	0.06	0.12	3.61	0.07	0.00	3.86
6862	3/29/2012	1.80	7.90	190.00	0.00	0.00	0.01	0.06	1.96	0.00	0.00	2.03
7079	11/1/2012	0.00	10.00	160.00	2.00	0.00	0.00	0.08	1.65	0.02	0.00	1.75
7224	3/26/2013	0.00	8.80	180.00	2.40	0.00	0.00	0.07	1.86	0.02	0.00	1.95
7399	9/17/2013	0.00	**11**	220.00	4.10	0.00	0.00	0.08	2.27	0.04	0.00	2.40
7582	3/19/2014	0.00	**8.7**	180.00	0.00	0.00	0.00	0.07	1.86	0.00	0.00	1.92
7772	9/25/2014	0.00	11.00	210.00	0.00	0.00	0.00	0.08	2.17	0.00	0.00	2.25
7960	4/1/2015	0.00	9.90	190.00	0.00	0.00	0.00	0.08	1.96	0.00	0.00	2.04
8122	9/10/2015	0.00	**9.5**	**200.00**	0.00	0.00	0.00	0.07	2.06	0.00	0.00	2.14
8323	3/29/2016	0.00	**7**	**150.00**	0.00	0.00	0.00	0.05	1.55	0.00	0.00	1.60
8492	9/14/2016	0.00	**10**	**220.00**	0.00	0.00	0.00	0.08	2.27	0.00	0.00	2.35

Table B-6

WELL ID:	MW-26
Initial Date:	6/15/1993

Days	Date	PCE (ug/L)	TCE (ug/L)	cis-DCE (ug/L)	1,1-DCE (ug/L)	VC (ug/L)	PCE (umol/L)	TCE (umol/L)	Cis-DCE (umol/L)	1,1-DCE (umol/L)	VC (umol/L)	Total M (umol/L)
							165.83	131.29	96.94	96.94	62.50	
1	6/16/1993	10	310	180	4	19	0.06	2.36	1.86	0.04	0.30	4.62
36	7/21/1993	10	450	180	3	12	0.06	3.43	1.86	0.03	0.19	5.57
2200	6/24/1999	5	58	270	1.8	12	0.03	0.44	2.79	0.02	0.19	3.47
2269	9/1/1999		230	280		17		1.75	2.89		0.27	4.91
2360	12/1/1999		190	270		15		1.45	2.79		0.24	4.47
2451	3/1/2000		160	280		17		1.22	2.89		0.27	4.38
2543	6/1/2000		190	360		20		1.45	3.71		0.32	5.48
2696	11/1/2000		210	410				1.60	4.23			5.83
2843	3/28/2001	0.5	62	190	3.3	27	0.00	0.47	1.96	0.03	0.43	2.90
3017	9/18/2001	20	260	420	4	0	0.12	1.98	4.33	0.04	0.00	6.47
3027	9/28/2001	0.5	130	270	2	2.90	0.00	0.99	2.79	0.02	0.05	3.85
3181	3/1/2002		170	310		16		1.29	3.20		0.26	4.75
3601	4/25/2003	10	130	330	3	7	0.06	0.99	3.40	0.03	0.11	4.60
3758	9/29/2003	20	240	400	5	39	0.12	1.83	4.13	0.05	0.62	6.75
3934	3/23/2004	0.80	210	380	4	34	0.00	1.60	3.92	0.04	0.54	6.11
4116	9/21/2004	10	93	180	0	14	0.06	0.71	1.86	0.00	0.22	2.85
4305	3/29/2005	1	90	150	1.8	16	0.01	0.69	1.55	0.02	0.26	2.51
4395	6/27/2005	20	160	300	2.9	15	0.12	1.22	3.09	0.03	0.24	4.70
4481	9/21/2005	20	140	290	0	11	0.12	1.07	2.99	0.00	0.18	4.35
4538	11/17/2005	20	160	220	2.8	10	0.12	1.22	2.27	0.03	0.16	3.80
4670	3/29/2006	20	130	230	0	0	0.12	0.99	2.37	0.00	0.00	3.48
4839	9/14/2006	20	200	310	2.9	21	0.12	1.52	3.20	0.03	0.34	5.21
5027	3/21/2007	10	**100**	**200**	**2.0**	**12**	0.06	0.76	2.06	0.02	0.19	3.10
5210	9/20/2007	10	**140**	**220**	**1.8**	**16**	0.06	1.07	2.27	0.02	0.26	3.67
5398	3/26/2008	5	**100**	**190**	**1.5**	**7.2**	0.03	0.76	1.96	0.02	0.12	2.88
5580	9/24/2008	20	190	320	**0.0**	17	0.12	1.45	3.30	0.00	0.27	5.14
5764	3/27/2009	10	130	200	**0.0**	19	0.06	0.99	2.06	0.00	0.30	3.42
5946	9/25/2009	20	**130**	**240**	**0.0**	**13**	0.12	0.99	2.48	0.00	0.21	3.79
6124	3/22/2010	5	**83**	**140**	**1.2**	**9.5**	0.03	0.63	1.44	0.01	0.15	2.27
6308	9/22/2010	10	**150**	**250**	**2**	**26**	0.06	1.14	2.58	0.02	0.42	4.22
6488	3/21/2011	10	**86**	**160**	10	**12**	0.06	0.66	1.65	0.10	0.19	2.66
6688	10/7/2011	10	170.0	270.0	2.9	30.0	0.06	1.29	2.79	0.03	0.48	4.65
6862	3/29/2012	0.36	74	170	1.9	21	0.00	0.56	1.75	0.02	0.34	2.68
7079	11/1/2012	0	160.0	240.0	0.0	0.0	0.00	1.22	2.48	0.00	0.00	3.69
7224	3/26/2013	0	96	170	1.3	4.2	0.00	0.73	1.75	0.01	0.07	2.57
7399	9/17/2013	0	140	210	**2.3**	22	0.00	1.07	2.17	0.02	0.35	3.61
7582	3/19/2014	0	82	130	**0.0**	0	0.00	0.62	1.34	0.00	0.00	1.97
7772	9/25/2014	0.0	100.0	190.0	0.0	14.0	0.00	0.76	1.96	0.00	0.22	2.95
7960	4/1/2015	0.0	38.0	49.0	0.0	0.0	0.00	0.29	0.51	0.00	0.00	0.79
8122	9/10/2015	0.0	110	180	1.4	0.0	0.00	0.84	1.86	0.01	0.00	2.71
8323	3/29/2016	0.0	78	140	0.0	7.9	0.00	0.59	1.44	0.00	0.13	2.16
8492	9/14/2016	0.0	2.8	0.0	0.0	0.0	0.00	0.02	0.00	0.00	0.00	0.02

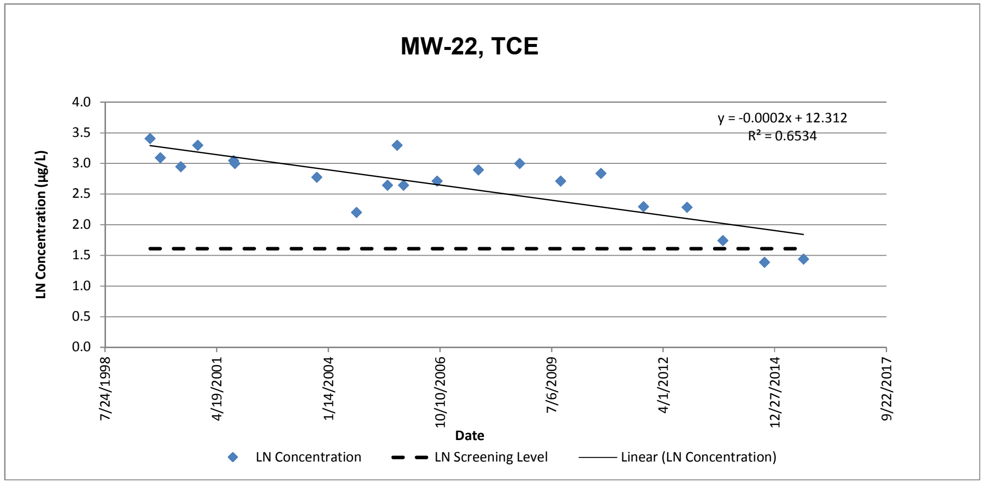
FIGURES

Figure B-1

Sample Information
Sample Location **MW-22**
Constituent TCE

Data

Sample Date	Concentration (µg/L)	LN Concentration
9/1/1999	30	3.40
12/1/1999	22	3.09
6/1/2000	19	2.94
11/1/2000	27	3.30
9/18/2001	21	3.04
9/28/2001	20	3.00
10/1/2003	16	2.77
9/21/2004	9	2.20
6/28/2005	14	2.64
9/21/2005	27	3.30
11/17/2005	14	2.64
9/14/2006	15	2.71
9/20/2007	**18**	2.89
9/24/2008	**20**	3.00
9/24/2009	**15**	2.71
9/22/2010	**17**	2.83
10/7/2011	9.9	2.29
11/1/2012	9.8	2.28
9/17/2013	5.7	1.74
9/25/2014	4.0	1.39
9/10/2015	4.2	1.44



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis
Qualified data converted to reported value

Data quality	
Total # of data points used in regression	21
# of results with conc. below RL	0
% of samples with reported conc.	100

Results		
Coefficient of Determination (R^2) =	0.6534	
p-Value =	9.27E-06	
Attenuation Rate in Groundwater (K) =	0.0002	$days^{-1}$
Attenuation Rate in Groundwater at 95% confidence (K) =	0.0002	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	2.80E+03	days

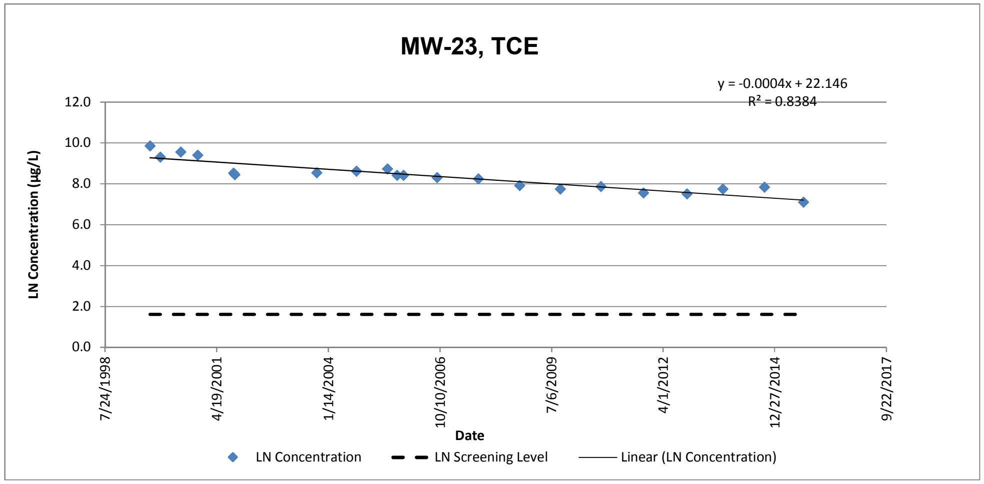
Abbreviations and Notes
ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

Figure B-2

Sample Information
Sample Location **MW-23**
Constituent TCE

Data

Sample Date	Concentration (µg/L)	LN Concentration
9/1/1999	19000	9.85
12/1/1999	11000	9.31
6/1/2000	14000	9.55
11/1/2000	12000	9.39
9/18/2001	5000	8.52
9/28/2001	4600	8.43
10/1/2003	5100	8.54
9/21/2004	5500	8.61
6/28/2005	6100	8.72
9/21/2005	4500	8.41
11/17/2005	4500	8.41
9/14/2006	4000	8.29
9/20/2007	**3800**	8.24
9/24/2008	**2700**	7.90
9/23/2009	**2300**	7.74
9/22/2010	**2600**	7.86
10/7/2011	1900	7.55
11/1/2012	1800	7.50
9/17/2013	2300	7.74
9/25/2014	2500	7.82
9/10/2015	1200	7.09



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis
Qualified data converted to reported value

Data quality	
Total # of data points used in regression	21
# of results with conc. below RL	0
% of samples with reported conc.	100

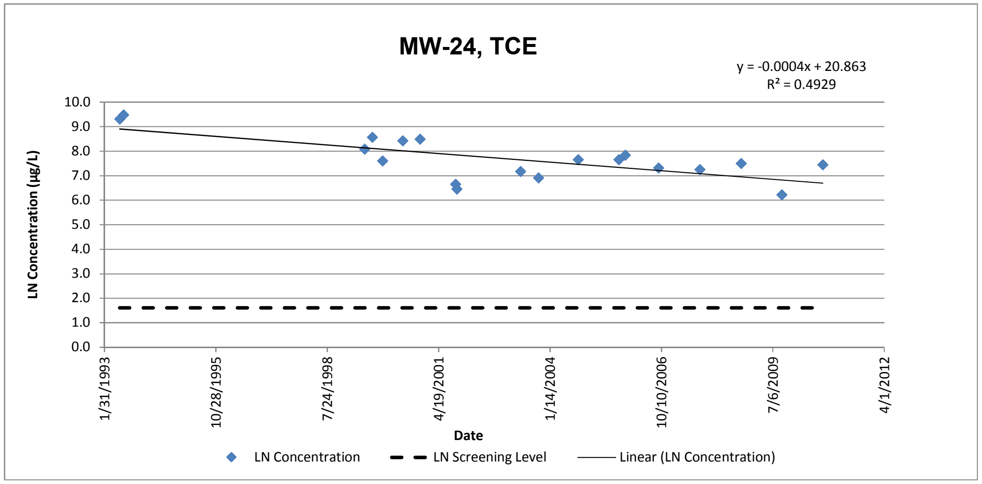
Results		
Coefficient of Determination (R^2) =	0.8384	
p-Value =	5.90E-09	
Attenuation Rate in Groundwater (K) =	0.0004	$days^{-1}$
Attenuation Rate in Groundwater at 95% confidence (K) =	0.0003	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	1.96E+03	days

Abbreviations and Notes
ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

Figure B-3

Sample Information
Sample Location **MW-24**
Constituent TCE

Data		
Sample Date	Concentration (µg/L)	LN Concentration
6/16/1993	11000	9.31
7/21/1993	13000	9.47
6/24/1999	3200	8.07
9/1/1999	5200	8.56
12/1/1999	2000	7.60
6/1/2000	4500	8.41
11/1/2000	4800	8.48
9/18/2001	770	6.65
9/28/2001	630	6.45
4/24/2003	1300	7.17
10/1/2003	1000	6.91
9/21/2004	2100	7.65
9/21/2005	**2100**	7.65
11/17/2005	2500	7.82
9/14/2006	**1500**	7.31
9/20/2007	1400	7.24
9/24/2008	1800	7.50
9/23/2009	500	6.21
9/27/2010	1700	7.44



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis
Qualified data converted to reported value

Data quality	
Total # of data points used in regression	19
# of results with conc. below RL	1
% of samples with reported conc.	95

Results		
Coefficient of Determination (R^2) =	0.4929	
p-Value =	8.05E-04	
Attenuation Rate in Groundwater (K) =	0.0004	$days^{-1}$
Attenuation Rate in Groundwater at 95% confidence (K) =	0.0002	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	1.98E+03	days

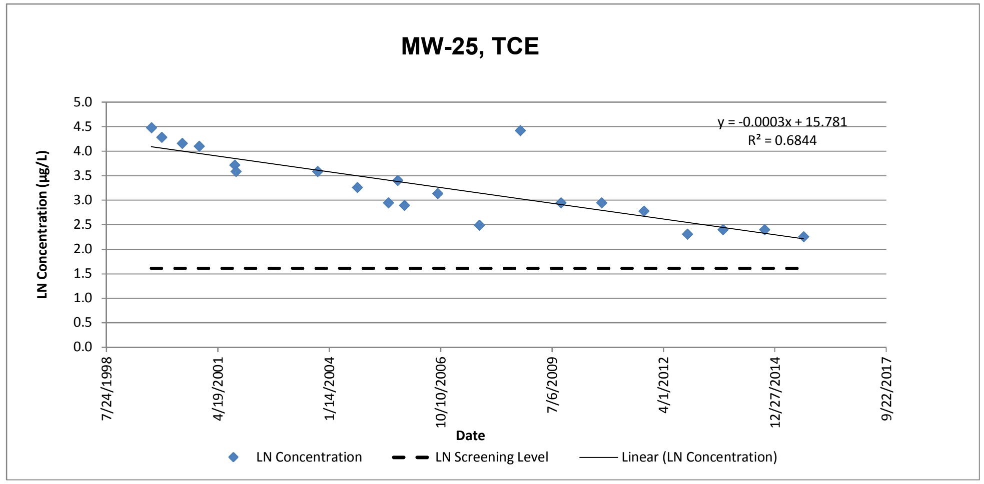
Abbreviations and Notes
ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

Figure B-4

Sample Information
Sample Location **MW-25**
Constituent TCE

Data

Sample Date	Concentration (µg/L)	LN Concentration
9/1/1999	88	4.48
12/1/1999	72	4.28
6/1/2000	64	4.16
11/1/2000	60	4.09
9/18/2001	41	3.71
9/28/2001	36	3.58
10/1/2003	36	3.58
9/22/2004	26	3.26
6/28/2005	19	2.94
9/19/2005	30	3.40
11/17/2005	18	2.89
9/14/2006	23	3.14
9/20/2007	**12**	2.48
9/24/2008	**83**	4.42
9/24/2009	19	2.94
9/22/2010	19	2.94
10/7/2011	16	2.77
11/1/2012	10	2.30
9/17/2013	11	2.40
9/25/2014	11	2.40
9/10/2015	9.5	2.25



Notes:
Sample results less than the RL were set at the RL for the purposes of this analysis
Qualified data converted to reported value

Data quality	
Total # of data points used in regression	21
# of results with conc. below RL	0
% of samples with reported conc.	100

Results		
Coefficient of Determination (R^2) =	0.6844	
p-Value =	3.74E-06	
Attenuation Rate in Groundwater (K) =	0.0003	$days^{-1}$
Attenuation Rate in Groundwater at 95% confidence (K) =	0.0002	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	2.16E+03	days

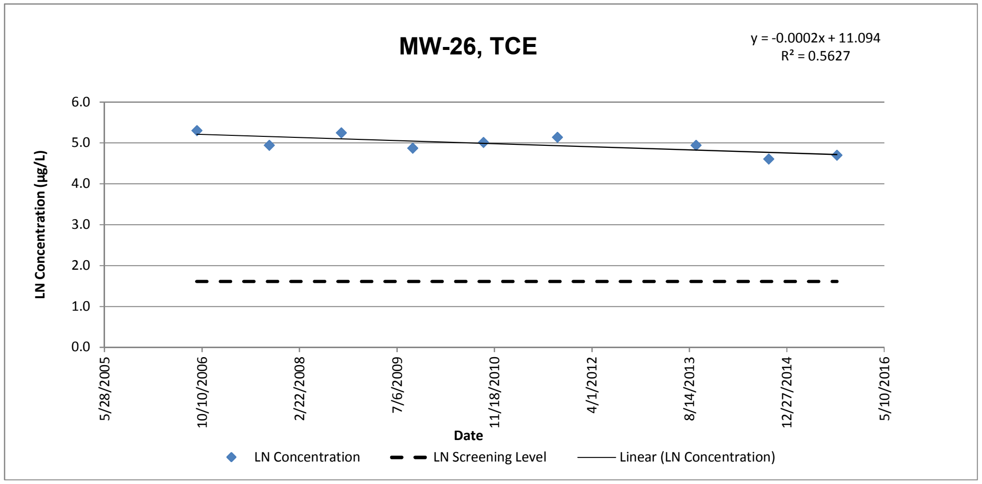
Abbreviations and Notes
ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

Figure B-5

Sample Information
Sample Location **MW-26**
Constituent TCE

Data

Sample Date	Concentration (µg/L)	LN Concentration
9/14/2006	200	5.30
9/20/2007	140	4.94
9/24/2008	190	5.25
9/25/2009	130	4.87
9/22/2010	150	5.01
10/7/2011	170	5.14
9/17/2013	140	4.94
9/25/2014	**100**	4.61
9/10/2015	**110**	4.70



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis
Qualified data converted to reported value

Data quality	
Total # of data points used in regression	9
# of results with conc. below RL	0
% of samples with reported conc.	100

Results		
Coefficient of Determination (R^2) =	0.5627	
p-Value =	1.99E-02	
Attenuation Rate in Groundwater (K) =	0.0002	$days^{-1}$
Attenuation Rate in Groundwater at 95% confidence (K) =	0.0001	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	4.59E+03	days

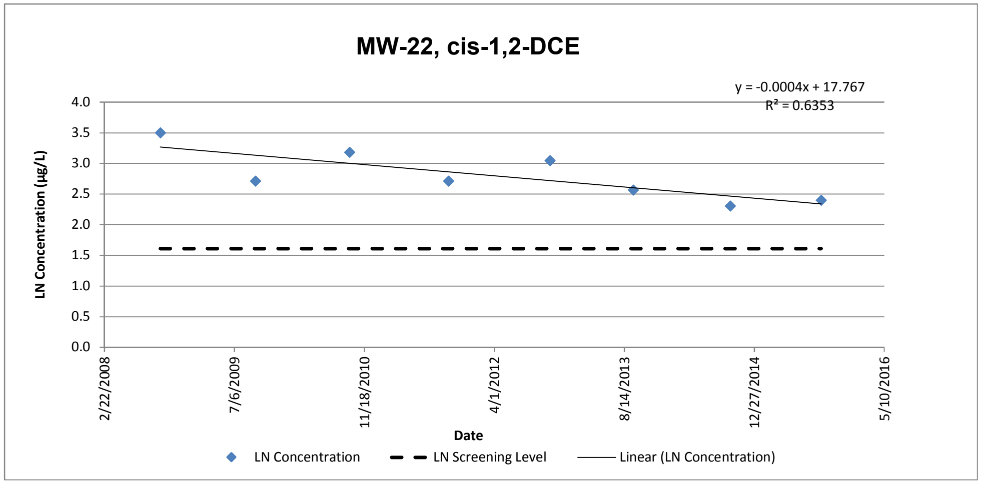
Abbreviations and Notes
ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

Figure B-6

Sample Information
Sample Location **MW-22**
Constituent cis-1,2-DCE

Data

Sample Date	Concentration (µg/L)	LN Concentration
9/24/2008	**33**	3.50
9/24/2009	**15**	2.71
9/22/2010	**24**	3.18
10/7/2011	15	2.71
11/1/2012	21	3.04
9/17/2013	13	2.56
9/25/2014	10	2.30
9/10/2015	11	2.40



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis
Qualified data converted to reported value

Data quality	
Total # of data points used in regression	8
# of results with conc. below RL	0
% of samples with reported conc.	100

Results		
Coefficient of Determination (R^2) =	0.6353	
p-Value =	1.78E-02	
Attenuation Rate in Groundwater (K) =	0.0004	$days^{-1}$
Attenuation Rate in Groundwater at 95% confidence (K) =	0.0001	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	1.90E+03	days

Abbreviations and Notes
ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

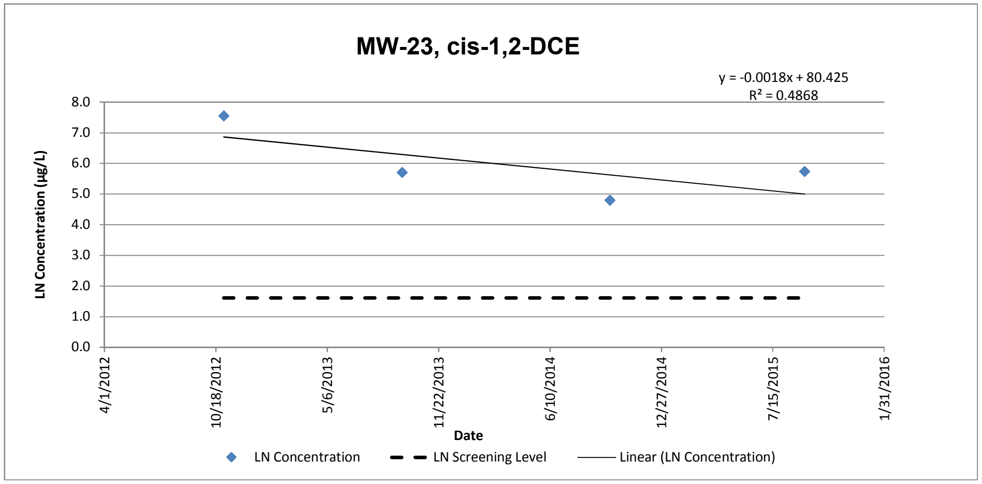
Figure B-7

Sample Information

Sample Location	**MW-23**
Constituent	cis-1,2-DCE

Data

Sample Date	Concentration (µg/L)	LN Concentration
11/1/2012	**1900**	7.55
9/17/2013	**300**	5.70
9/25/2014	**120**	4.79
9/10/2015	310	5.74



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis

Qualified data converted to reported value

Data quality	
Total # of data points used in regression	4
# of results with conc. below RL	0
% of samples with reported conc.	100

Results		
Coefficient of Determination (R^2) =	0.4868	
p-Value =	3.02E-01	
Attenuation Rate in Groundwater (K) =	0.0018	$days^{-1}$
Attenuation Rate in Groundwater at 90% confidence (K) =	-0.0007	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	NA	days

Abbreviations and Notes

ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

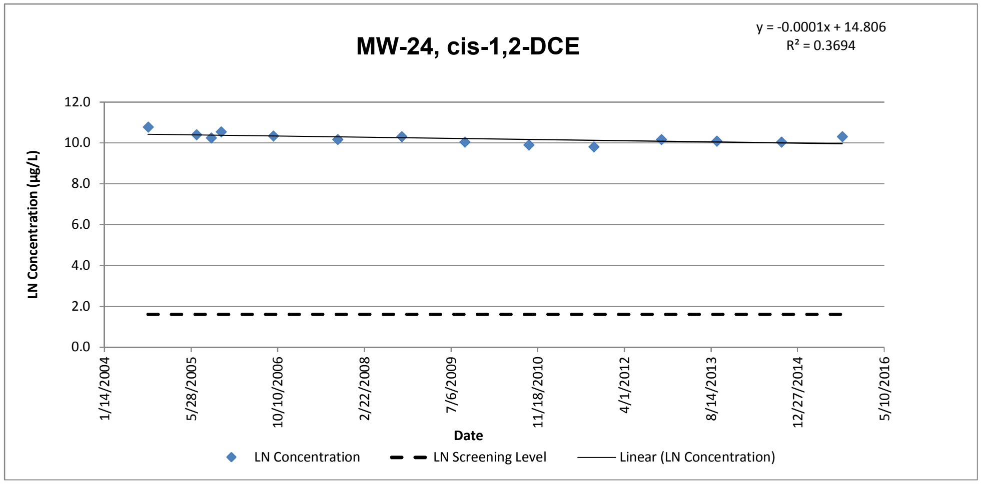
Figure B-8

Sample Information

Sample Location	**MW-24**
Constituent	cis-1,2-DCE

Data

Sample Date	Concentration (µg/L)	LN Concentration
9/21/2004	**48000**	10.78
6/28/2005	**33000**	10.40
9/21/2005	**28000**	10.24
11/17/2005	38000	10.55
9/14/2006	31000	10.34
9/20/2007	26000	10.17
9/24/2008	30000	10.31
9/23/2009	23000	10.04
9/27/2010	**20000**	9.90
10/7/2011	**18000**	9.80
11/1/2012	**26000**	10.17
9/17/2013	**24000**	10.09
9/25/2014	23000	10.04
9/10/2015	30000	10.31



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis

Qualified data converted to reported value

Data quality	
Total # of data points used in regression	14
# of results with conc. below RL	0
% of samples with reported conc.	100

Results		
Coefficient of Determination (R^2) =	0.3694	
p-Value =	2.11E-02	
Attenuation Rate in Groundwater (K) =	0.0001	$days^{-1}$
Attenuation Rate in Groundwater at 90% confidence (K) =	0.0001	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	6.05E+03	days

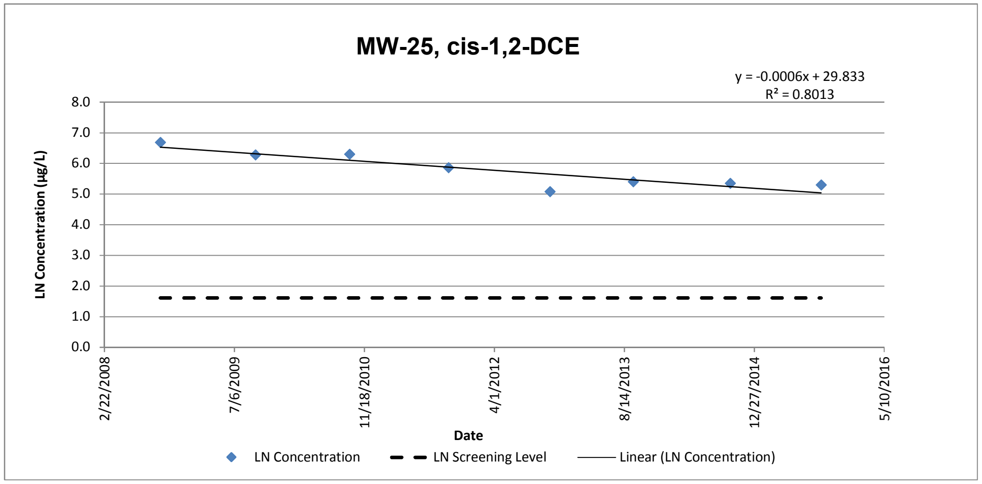
Abbreviations and Notes

ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

Figure B-9

Sample Information
Sample Location **MW-25**
Constituent cis-1,2-DCE

Data		
Sample Date	Concentration (µg/L)	LN Concentration
9/24/2008	**800**	6.68
9/24/2009	**530**	6.27
9/22/2010	**540**	6.29
10/7/2011	350	5.86
11/1/2012	160	5.08
9/17/2013	220	5.39
9/25/2014	210	5.35
9/10/2015	200	5.30



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis
Qualified data converted to reported value

Data quality	
Total # of data points used in regression	8
# of results with conc. below RL	0
% of samples with reported conc.	100

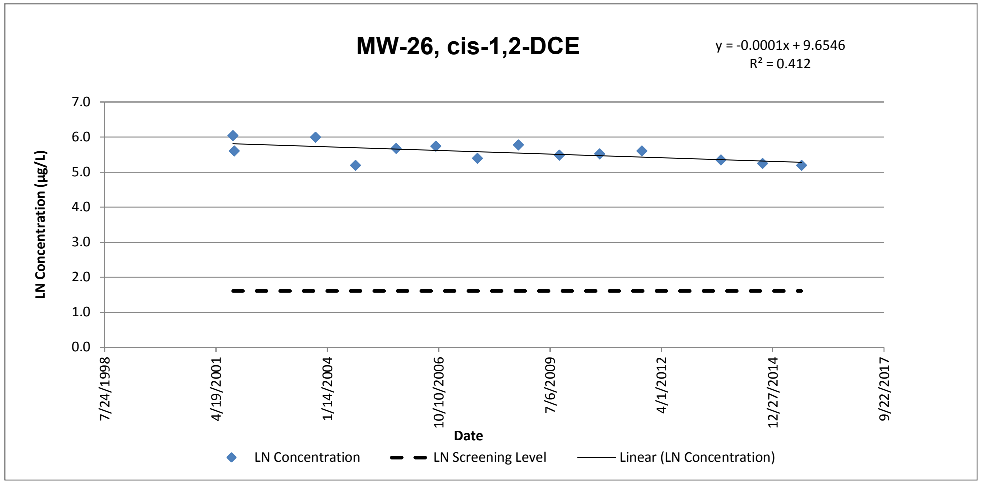
Results		
Coefficient of Determination (R^2) =	0.8013	
p-Value =	2.66E-03	
Attenuation Rate in Groundwater (K) =	0.0006	days^{-1}
Attenuation Rate in Groundwater at 90% confidence (K) =	0.0004	days^{-1}
Chemical Half Life in Groundwater ($t_{1/2}$) =	1.18E+03	days

Abbreviations and Notes
ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

Figure B-10

Sample Information
Sample Location **MW-26**
Constituent cis-1,2-DCE

Data		
Sample Date	Concentration (µg/L)	LN Concentration
9/18/2001	**420**	6.04
9/28/2001	**270**	5.60
9/29/2003	**400**	5.99
9/21/2004	180	5.19
9/21/2005	290	5.67
9/14/2006	310	5.74
9/20/2007	220	5.39
9/24/2008	320	5.77
9/25/2009	**240**	5.48
9/22/2010	**250**	5.52
10/7/2011	**270**	5.60
9/17/2013	**210**	5.35
9/25/2014	190	5.25
9/10/2015	180	5.19



Notes:
Sample results less than the RL were set at the RL for the purposes of this analysis
Qualified data converted to reported value

Data quality	
Total # of data points used in regression	14
# of results with conc. below RL	0
% of samples with reported conc.	100

Results		
Coefficient of Determination (R^2) =	0.4120	
p-Value =	1.33E-02	
Attenuation Rate in Groundwater (K) =	0.0001	$days^{-1}$
Attenuation Rate in Groundwater at 90% confidence (K) =	0.0001	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	6.69E+03	days

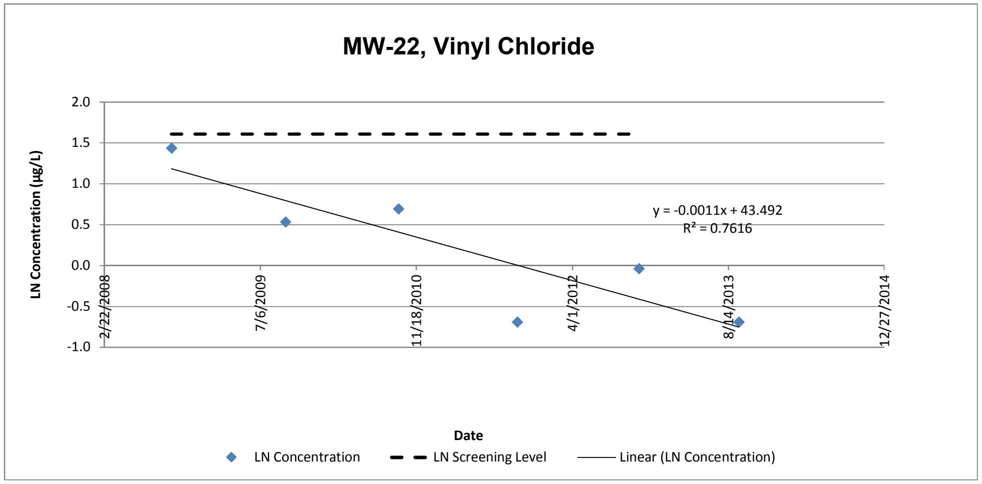
Abbreviations and Notes
ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

Figuer B-11

Sample Information
Sample Location **MW-22**
Constituent Vinyl Chloride

Data

Sample Date	Concentration (µg/L)	LN Concentration
9/24/2008	**4.2**	1.44
9/24/2009	**1.7**	0.53
9/22/2010	**2**	0.69
10/7/2011	.5	-0.69
11/1/2012	0.96	-0.04
9/17/2013	0.5	-0.69



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis
Qualified data converted to reported value

Data quality	
Total # of data points used in regression	5
# of results with conc. below RL	2
% of samples with reported conc.	60

Less than 75% data above reporting limits.

Results		
Coefficient of Determination (R^2) =	0.7616	
p-Value =	2.33E-02	
Attenuation Rate in Groundwater (K) =	0.0011	$days^{-1}$
Attenuation Rate in Groundwater at 90% confidence (K) =	0.0006	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	6.51E+02	days

Abbreviations and Notes
ug/l = micrograms per liter
LN = Natural Logarithm
RL = Reporting Limit
conc. = concentration

Figuer B-12

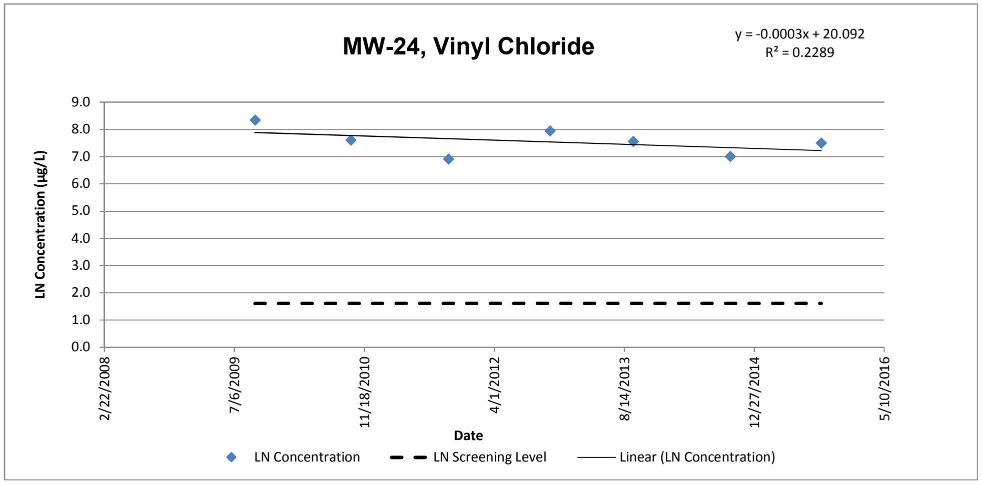
Sample Information

Sample Location **MW-24**

Constituent Vinyl Chloride

Data

Sample Date	Concentration (µg/L)	LN Concentration
9/23/2009	**4200**	8.34
9/27/2010	**2000**	7.60
10/7/2011	**1000**	6.91
11/1/2012	2800.0	7.94
9/17/2013	1900.0	7.55
9/25/2014	1100.0	7.00
9/10/2015	**1800**	7.50



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis

Qualified data converted to reported value

Data quality	
Total # of data points used in regression	7
# of results with conc. below RL	0
% of samples with reported conc.	100

Results		
Coefficient of Determination (R^2) =	0.2289	
p-Value =	2.77E-01	
Attenuation Rate in Groundwater (K) =	0.0003	$days^{-1}$
Attenuation Rate in Groundwater at 90% confidence (K) =	-0.0001	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	NA	days

Abbreviations and Notes

ug/l = micrograms per liter

LN = Natural Logarithm

RL = Reporting Limit

conc. = concentration

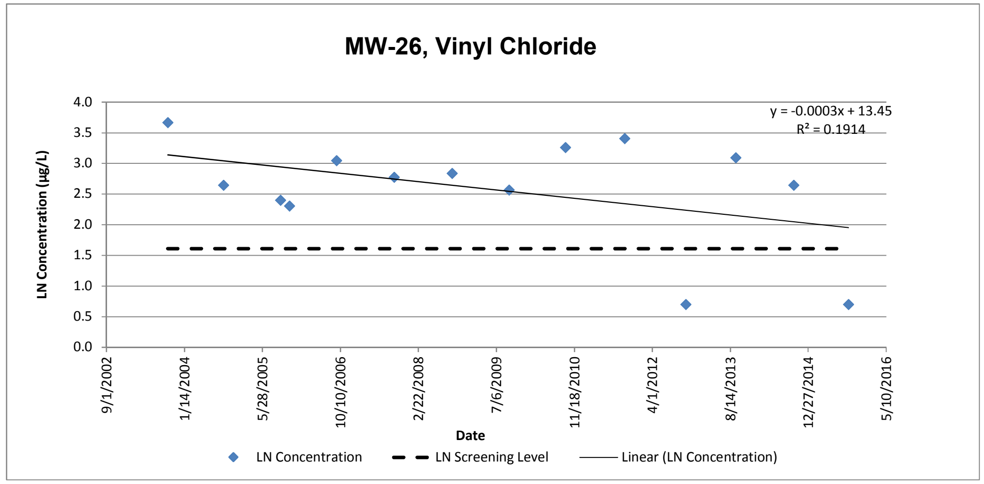
Figure B-13

Sample Information

Sample Location	**MW-26**
Constituent	Vinyl Chloride

Data

Sample Date	Concentration (µg/L)	LN Concentration
9/29/2003	39	3.66
9/21/2004	14	2.64
9/21/2005	11	2.40
11/17/2005	10	2.30
9/14/2006	21	3.04
9/20/2007	**16**	2.77
9/24/2008	17	2.83
9/25/2009	**13**	2.56
9/22/2010	**26**	3.26
10/7/2011	30.0	3.40
11/1/2012	2	0.69
9/17/2013	22	3.09
9/25/2014	14.0	2.64
9/10/2015	2	0.69



Notes:

Sample results less than the RL were set at the RL for the purposes of this analysis

Qualified data converted to reported value

Data quality	
Total # of data points used in regression	14
# of results with conc. below RL	2
% of samples with reported conc.	86

Results		
Coefficient of Determination (R^2) =	0.1914	
p-Value =	1.18E-01	
Attenuation Rate in Groundwater (K) =	0.0003	$days^{-1}$
Attenuation Rate in Groundwater at 90% confidence (K) =	0.0001	$days^{-1}$
Chemical Half Life in Groundwater ($t_{1/2}$) =	NA	days

Abbreviations and Notes

ug/l = micrograms per liter

LN = Natural Logarithm

RL = Reporting Limit

conc. = concentration

Figure B-14: MW-22 Performance Monitoring Results

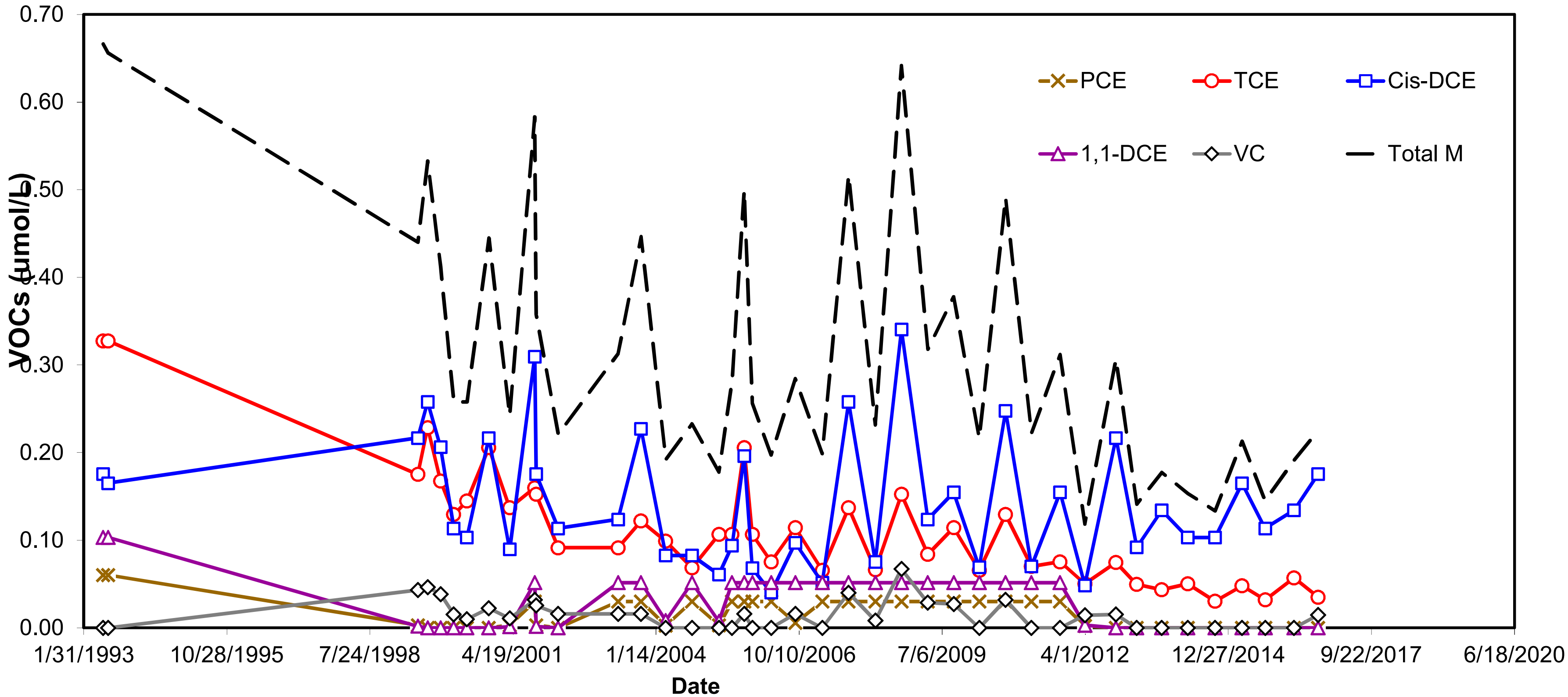


Figure B-15: MW-23 Performance Monitoring Results

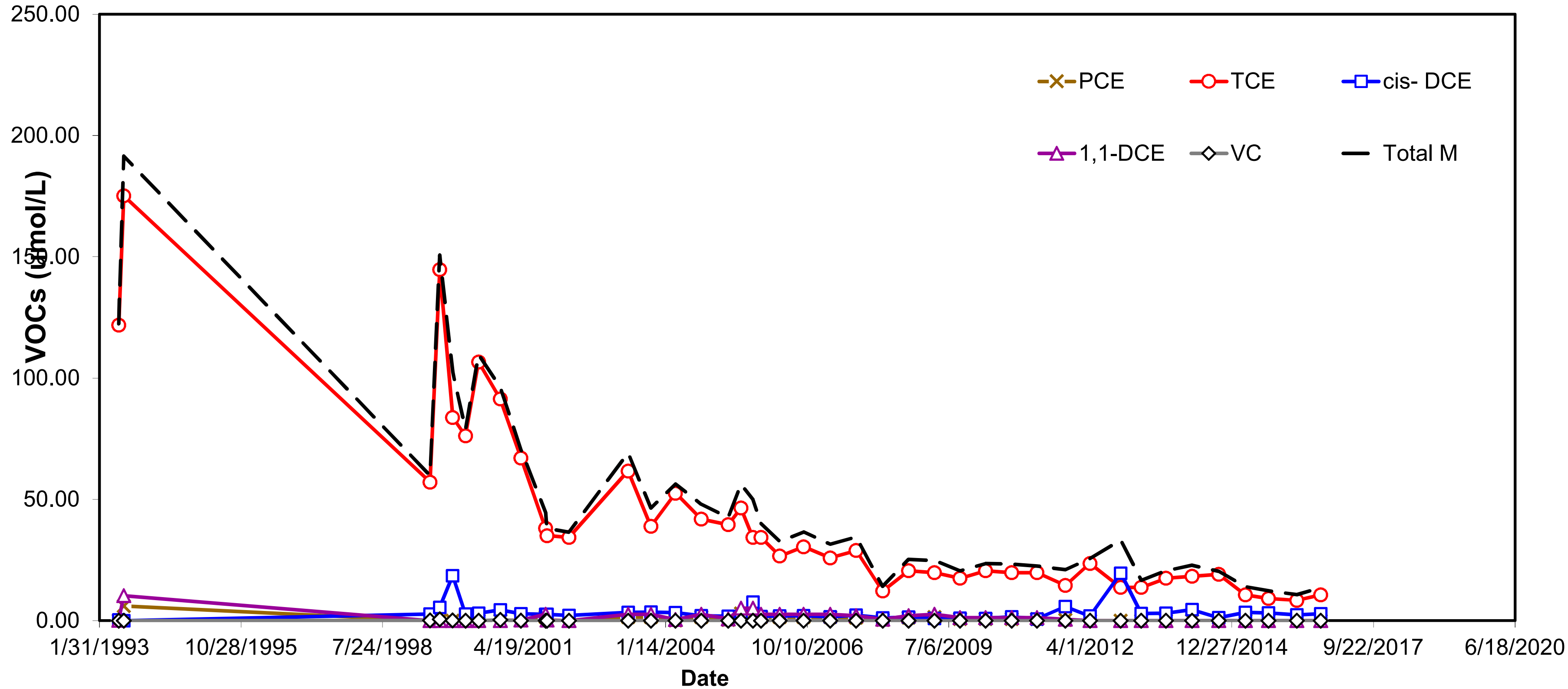


Figure B-16: MW-24 Performance Monitoring Results

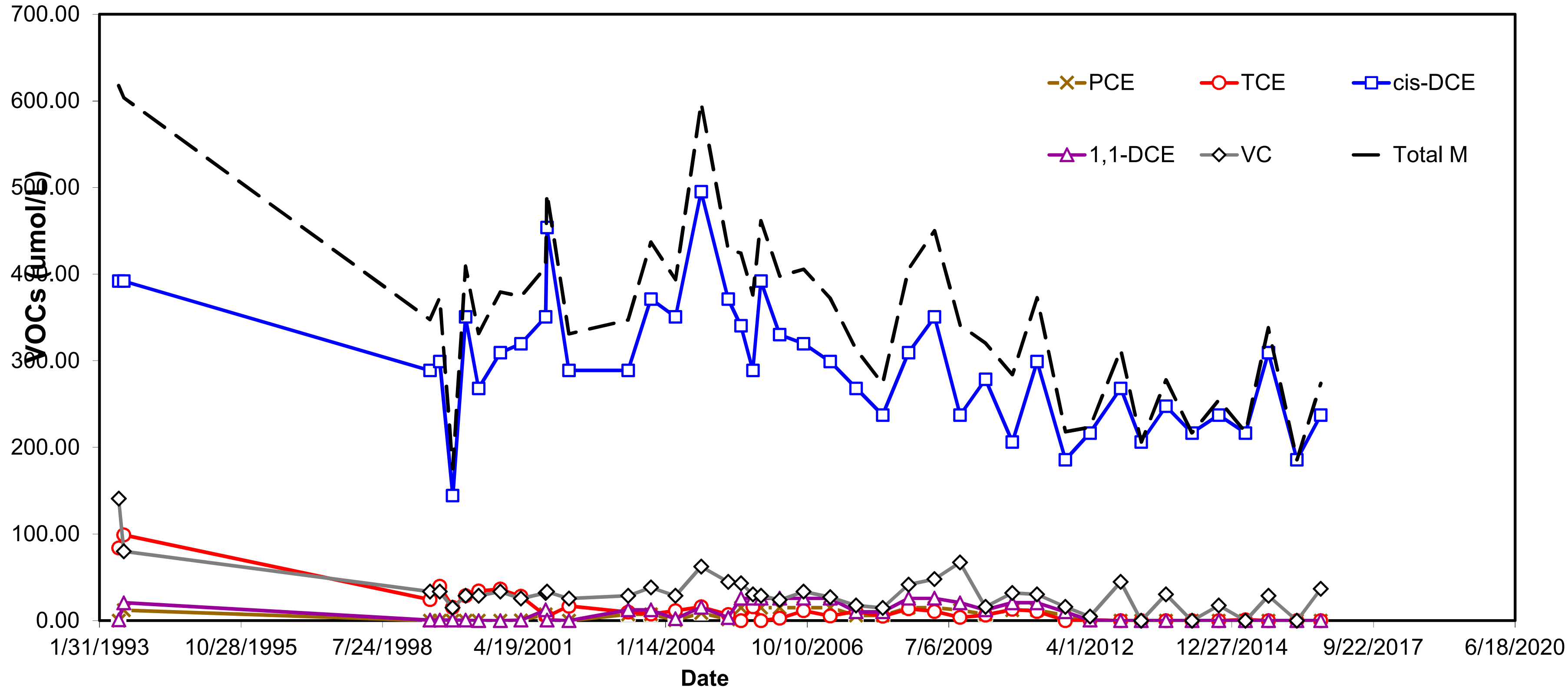


Figure B-17: MW-25 Performance Monitoring Results

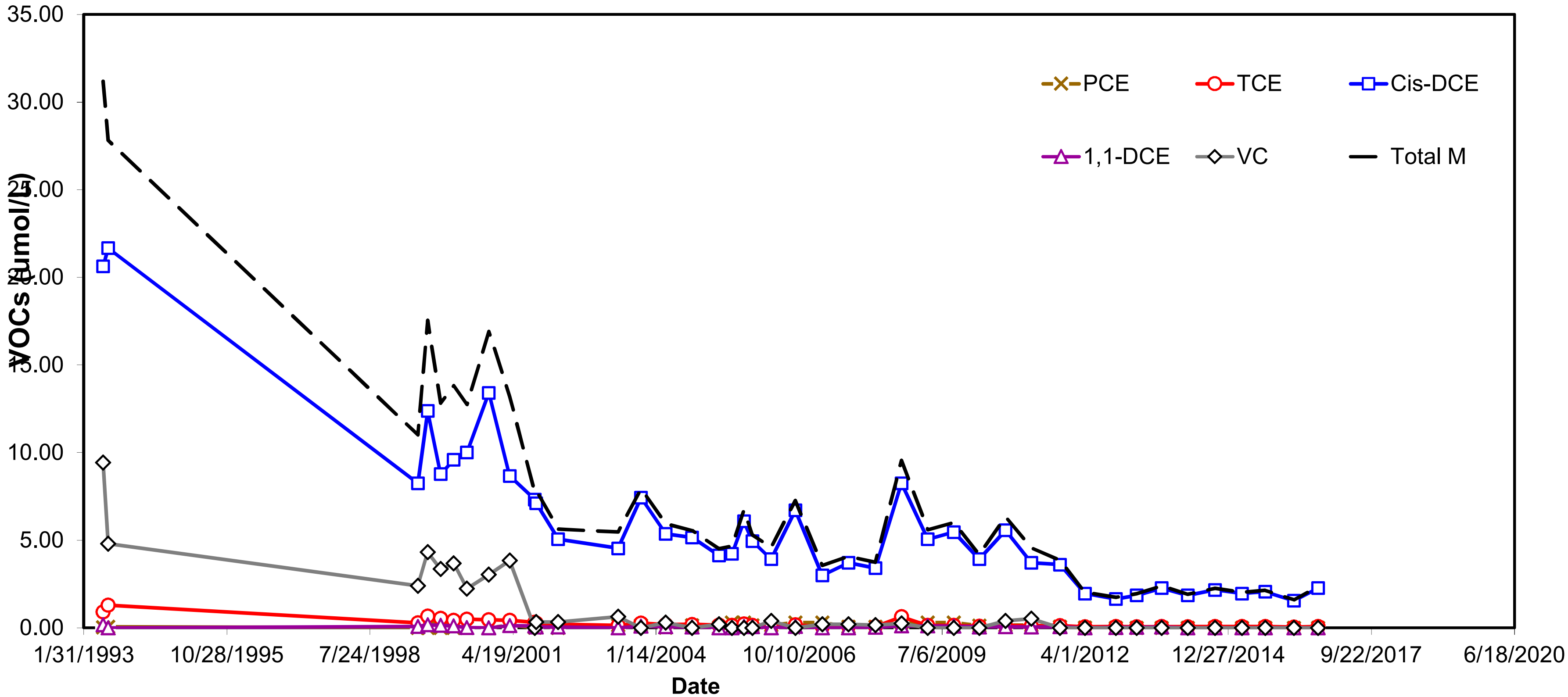
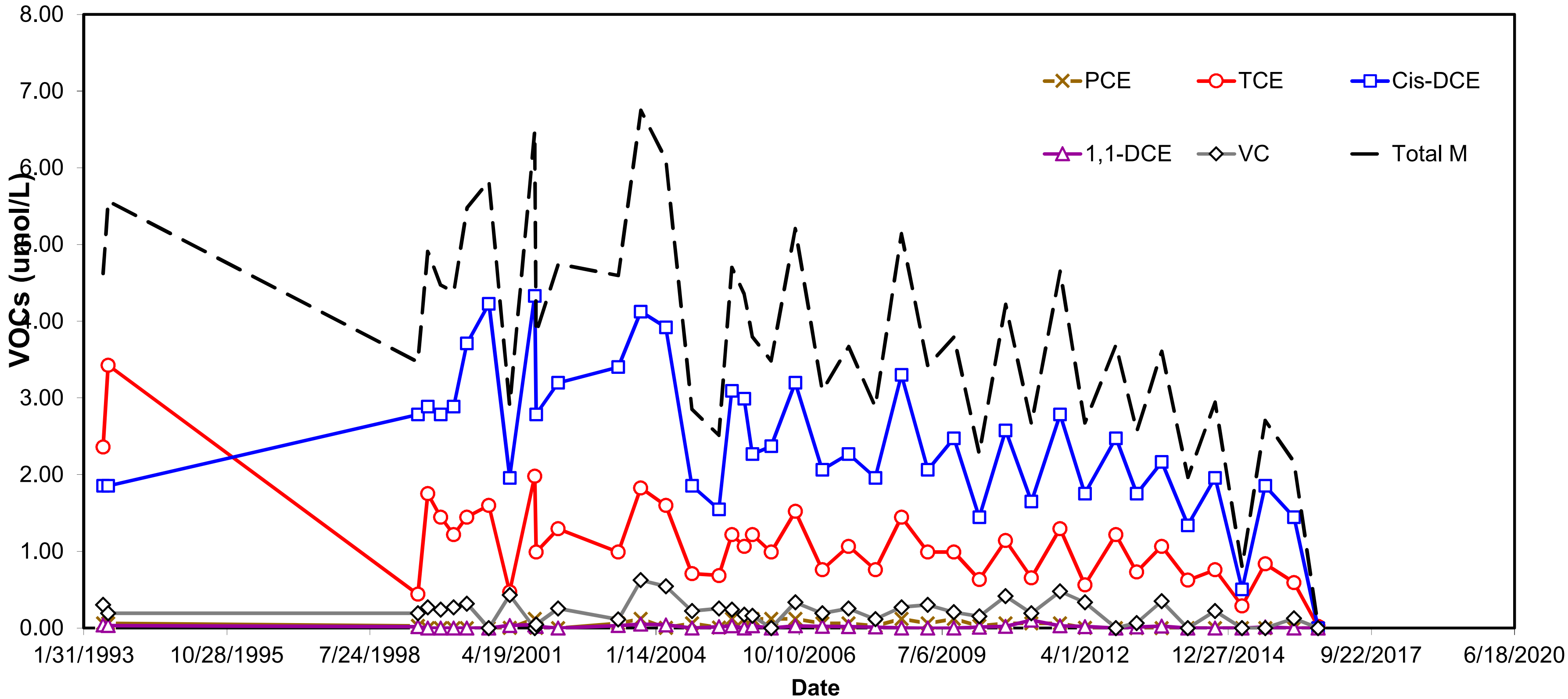


Figure B-18: MW-26 Performance Monitoring Results



APPENDIX C

Corrective Measures Costing Summary Sheets

Appendix C. Corrective Measures Costing Summary Sheets
Former Philips Display Components Facility, Seneca Falls, New York
Table of Contents

		Page No
Site Management Plan	AOC 1, 2, & 3	2
Physical Removal of non-aqueous phase liquid	AOC 1, 2, & 3	3
Thermal Remediation	AOC 1 & 3	4
Excavation	AOC 1 & 3	5

Physical Removal of non-aqueous phase liquid

Number of Additional Monitoring Wells to install	0	
Number of Wells Monitored	15	
Frequency of Groundwater sampling	2	events per year
Frequency of Institutional Controls Inspections	4	events per year

Capital Costs

SMP Implementation	$100,000	Oversight, design, permitting
Indoor Air Protection Establishment	$120,000	Quarterly VOC analysis of Indoor air to establish SMP
Total Capital Costs	$220,000	
Captial for AOC 4 & 5 from CMS Report	$160,000	SMP Implementation & Indoor Air Analysis
Capital per AOC (1-3)	$20,000	SMP Implementation

Periodic Costs

Site Abandonment and Restoration	$40,000	Mob costs, labor, equipment
Site Closure Negotiation and Reporting	$35,000	Reporting
Total Periodic Costs	$75,000	
Periodic for AOC 4 & 5 from CMS Report	$30,000	
Periodic per AOC (1-3)	$15,000	

O&M Costs - Annual

Direct Annual Sampling Operating Costs	$10,800	Mob costs, labor, equipment
Annual Analytical Costs	$3,800	VOC analytical
Direct Annual Inspections Operating Costs	$5,100	20% of direct costs
Annual Reporting and Operating Costs	$8,000	Quarterly updates, administrative charges, MNA evaluation and annual reports
Total O&M Costs	$28,000	Annual
O&M Cost for AOC 4 & 5 from CMS Report	$4,280	Controls Inspections
O&M Cost per AOC (1-3)	$8,000	Groundwater Monitoring and Controls Inspections

Cost assumes that area is clear and accessible
SMP cost were divided between AOC 1, AOC 2, AOC 3, AOC 4 and AOC 5 according to activities related to each AOC.
Costs are rounded to the nearest $1000, except for values under $100,000 that are rounded to the nearest $100
Costs are based on an accuracy of +50/-30% (USEPA, 2000)

Physical Removal of non-aqueous phase liquid

Number of Additional Monitoring Wells to install	4	
Number of Wells Monitored	4	
Frequency of NAPL Gauging	12	events per year
Frequency of NAPL Removal	4	events per year

Capital Costs

Well Installation	$38,000	Well installation, Design & Permitting
Total Capital Costs	$38,000	
Capital per AOC (1 & 3)	$19,000	

Periodic Costs

Well Abandonment	$8,000	Mob costs, labor, equipment
Well Abandonment Report	$3,000	Reporting
Total Periodic Costs	$11,000	
Periodic per AOC (1 & 3)	$5,500	

O&M Costs - Annual

Direct Annual Sampling Operating Costs	$10,200	Mob costs, labor, equipment
Annual Disposal Costs	$4,400	Purge water disposal
Annual Reporting and Operating Costs	$3,700	Quarterly updates, administrative charges, and annual reports
Total O&M Costs	$19,000	Annual
O&M Cost per AOC (1-3)	$6,100	Groundwater Monitoring and Controls Inspections

Cost assumes that area is clear and accessible
Cost were divided between AOC 1 & 3
Costs are rounded to the nearest $1000, except for values under $100,000 that are rounded to the nearest $100
Costs are based on an accuracy of +50/-30% (USEPA 2000)

Appendix C. Corrective Measures Costing Summary Sheets
Thermal Remediation
Former Philips Display Components Facility, Seneca Falls, New York

AOC 1 Building 2 Area

Thermal Remediation Area	*3,825*	*ft^2*
Treatment Duration	*6*	*months*

Capital Costs

Installation Costs	$1,440,000	Electrical profiling, modeling, system installation and testing
Operation and System Maintenance	$445,000	Subcontractor cost
Site Restoration	$55,000	Subcontractor cost
Electricity Costs	$236,500	Electricity, etc
Indirect Costs	$194,700	Includes design, bidding, permitting, project management
As Built Report	$25,000	Summary report of thermal activities
Total Capital Costs	$2,397,000	

AOC 3 Building 11 Area

Thermal Remediation Area	*3,200*	*ft^2*
Treatment Duration	*6*	*months*

Capital Costs

Installation Costs	$1,177,000	Electrical profiling, modeling, system installation and testing
Operation and System Maintenance	$365,000	Subcontractor cost
Site Restoration	$45,000	Subcontractor cost
Electricity Costs	$194,000	Electricity, etc
Indirect Costs	$159,300	Includes design, bidding, permitting, project management
As Built Report	$30,000	Summary report of thermal activities
Total Capital Costs	$1,971,000	

Notes
Cost assumes that area is clear and accessible
Costs are rounded to the nearest $1000, except for values under $100,000 that are rounded to the nearest $100
Costs are based on an accuracy of +50/-30% (USEPA 2000)
Assumes that system installation will be completed at the same time for both areas resulting in cost savings

AOC 1 Building 2 Area

Excavation Area	*3,825*	*ft^2*
Excavation Depth	*33*	*ft*

Capital Costs

Site Preparation	$25,000	Erosion control, well abandonment
Excavation Activities	$1,278,700	Excavation, mob/demob, air monitoring
T & D	$1,189,300	Waste characterization and disposal including transport
Restoration Activities	$10,000	Restore to grade with stabilization, no asphalt replacement
Indirect Costs	$85,000	Includes design, bidding, permitting, project management
As-Built Reort	$27,000	Summary report of excavation activities
Total Capital Costs	$2,615,000	

AOC 3 Building 11 Area

Excavation Area	*3,200*	*ft^2*
Excavation Depth	*30*	*ft*

Capital Costs

Site Preperation	$55,000	Erosion control, well abandonment
Excavation Activities	$1,309,300	Cason excavation with backfill assuming 20% overlap
T & D	$1,190,000	Waste characterization and disposal including transport
Indirect Costs	$55,000	Includes design, treatment plan, bidding, permitting, project mana
As-Built Report	$30,000	Summary report of excavation activities
Total Capital Costs	$2,640,000	

Notes

Cost assumes that area is clear and accessible

Costs are rounded to the nearest $1000, except for values under $100,000 that are rounded to the nearest $100

Costs are based on an accuracy of +50/-30% (USEPA 2000)

Areas assume that 60% of excavated material will be disposed as hazardous waste and the remaining 40% will be disposed as non-hazardous waste

Assumes site preperation will be completed at the same time for both areas resulting in cost savings