New York State Department of Environmental Conservation

FOCUSED FEASIBILITY STUDY

Crown Dykman (Site No.130054), City of Glen Cove, New York

November 2019

Daniel J. Loewenstein, P.E., Senior Vice President

FOCUSED FEASIBILITY STUDY

Crown Dykman (Site No.130054), City of Glen Cove, New York

Prepared for:
New York State Department of Environmental Conservation
Division of Environmental Remediation
625 Broadway, 11th Floor
Albany, NY 12233-7012

Prepared by:

Arcadis CE, Inc.
855 Route 146
Suite 210
Clifton Park
New York 12065
Tel. 518-250-7300
Fax 518-250-7301

Our Ref.:
30001356

Date:
November 25, 2019

CONTENTS

TABLES

FIGURES

APPENDICES

EXECUTIVE SUMMARY

This Focused Feasibility Study (FFS) Report has been developed to further evaluate remedial measure alternatives for the Crown Dykman Site (the "Site") located at 66 Herb Hill Road in the City of Glen Cove, Nassau County, New York (Site #130054).

Based on a Remedial Investigation/ Feasibility Study (RI/FS) completed for the Site in 2009 (Malcolm Pirnie, 2009a; 2009b), the New York State department of Environmental Conservation (NYSDEC) issued a Record of Decision (ROD) in March 2010 to address the remediation of the remaining Site contamination. The ROD required in situ chemical oxidation (ISCO) of the groundwater plume area with the highest concentrations of chlorinated volatile organic compounds (VOCs), primarily Tetrachloroethene (PCE) and its degradation products, which are present in the southwestern portion of the Site. The results of pre-design ISCO pilot programs and subsequent supplemental investigations performed at the Site during 2013 to 2017 (Arcadis/Malcolm Pirnie, 2012a; 2012b; Arcadis, 2014; 2018) concluded that introduction of sodium permanganate to the subsurface via purpose-built injection wells is an effective technology to implement the ISCO strategy presented in the ROD for the Crown Dykman Site. However, the presence of significant heterogeneity and preferential flow paths may reduce the overall effectiveness of the ISCO remedy, as some areas of the subsurface may prove recalcitrant to in situ chemical oxidation. In addition, the results of the second ISCO pilot and subsequent soil and groundwater sampling within the southwestern portion of the former Crown Dykman building (Site Building) showed that a continuing non-aqueous phase liquid (NAPL) chlorinated VOC source was present beneath this portion of the building. Results from these evaluations also concluded that the low groundwater gradient beneath this portion of the Site Building, and the continued presence of a potential NAPL source of PCE beneath the building floor slab (and vicinity), is contributing to the persistence of chlorinated VOCs in both soil and groundwater beneath the southwestern corner of the Site Building and on-site areas of the dissolved-phase plume downgradient of the source area.

Therefore, while the results of the pre-design ISCO pilot indicated that chemical oxidation is an effective remedial solution for the groundwater plume if implemented in full-scale, the presence of such a continuing source would undermine the effectiveness of the remedy and would likely lengthen the remedial timeframe if not addressed. Based on these findings, it was determined that the ROD should be amended to address the chlorinated VOC source area.

Arcadis has completed this FFS in support of further evaluation of potential remedies to address both the chlorinated VOC source area and remaining dissolved-phase groundwater plume present at the Site. The FFS specifically evaluates those remedial technologies applicable to meet the existing and additional Remedial Action Objectives (RAOs) for the Site, which include:

- Eliminate, to the extent practicable, exposures to volatile organic compounds in the indoor air originating from groundwater and soil contamination as a result of soil vapor intrusion;
- Reduce, to the extent practicable, on-Site soil concentrations to less than NYSDEC Restricted (Commercial) Soil Cleanup Objectives (Part 375-6.8(b));
- Reduce, to the extent practicable, on-Site groundwater Contaminants of Concern (COC) concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values; and,

- Reduce, to the extent practicable, the potential for off-Site migration of dissolved-phase COCs in groundwater at concentrations exceeding NYSDEC Class GA Ambient Water Quality Criteria or guidance values.

This FFS was completed in accordance with NYSDEC Division of Environmental Remediation (DER) Technical Guidance for Site Investigation and Remediation (DER-10), NYSDEC DER program policy for Presumptive/Proven Remedial Technologies (DER-15), and other appropriate NYSDEC guidance.

Based on the RAOs developed for the Site, and the established Standards Criteria, and Guidance (SCGs), a limited number of specific applicable remedial technologies were screened based partly on those carried forward during the original Feasibility Study (FS) completed for Crown Dykman in 2009 (Malcolm Pirnie, 2009b). Based on additional technology screening focused on the RAOs and in consideration of remedial timeframes, remedial alternatives (RAs) were developed for further evaluation to include:

- Implementation of an Electrical Resistivity Heating (ERH) remedial program in the dense NAPL (DNAPL) source area and a sodium permanganate ISCO program in the on-site dissolved-phase plume;
- Implementation of an ERH remedial program in the DNAPL source area, with implementation of a directed groundwater recirculation (DGR) remedial program to reduce COC concentrations in the residual on-site dissolved-phase plume;
- Excavation of the DNAPL source area to a depth of up to 15 feet below grade, with implementation of a sodium permanganate ISCO program in the on-site dissolved-phase plume; and,
- Excavation of the DNAPL source area to a depth of up to 15 feet below grade, with implementation of a DGR remedial program to reduce COC concentrations in the residual on-site dissolved-phase plume.
- Excavation of DNAPL source area to a depth of up to 15 feet below grade, with implementation of DGR and sodium permanganate ISCO remedial program to reduce COC concentrations in the residual on-site dissolved-phase plume.

These alternatives were considered the best options for meeting the RAOs within a reasonable timeframe. Consistent with National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and United States Environmental Protection Agency (USEPA) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) guidance documents, the “No Further Action” alternative was included as a baseline to which other remedial alternatives are compared. Some General Response Actions (GRAs), including application of Institutional Controls, Soil Vapor Extraction (SVE)/Sub-slab Depressurization (SSDS), and long term monitoring (LTM) were retained as common components of each RA.

These RAs were evaluated with respect to the criteria specified in Technical and Administrative Guidance Memorandum (TAGM) 4025, which incorporate the NCP by reference, and the USEPA guidance document titled *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988). These criteria encompass statutory requirements and include other gauges of overall feasibility and acceptability of remedial alternatives. The RAs were further evaluated against each other with respect to the criteria to comparatively assess them in support of final remedy selection.

1 INTRODUCTION

This Focused Feasibility Study (FFS) Report has been developed to further evaluate remedial measure alternatives for the Crown Dykman Site (Site #130054) located at 66 Herb Hill Road in the City of Glen Cove, Nassau County, New York (the ‘Site’, Figures 1 and 2). This FFS Report expands on earlier Site investigations and feasibility studies and describes the screening of potential remedial measures to address existing, and newly identified areas of concern at the Site, as summarized below.

This FFS was completed in accordance with New York State Department of Environmental Conservation (NYSDEC) Division of Environmental Remediation (DER) Technical Guidance for Site Investigation and Remediation (DER-10), NYSDEC DER program policy for Presumptive/Proven Remedial Technologies (DER-15), and other appropriate NYSDEC guidance.

1.1 Site History

During the period of 1987 to 2009, several investigations to determine the environmental conditions at the one-acre Class 2 Inactive Hazardous Waste Site were performed by the Nassau County Department of Health, the property owner, and the NYSDEC (EEA, 1991; 1996; 1997a; 1997b; Weston, 1997; EEA, 1999; 2000; Walden, 2006; Malcolm Pirnie, 2006; 2009a; 2009b). These investigations identified the presence of soil and groundwater contaminated with tetrachloroethylene (PCE) and associated degradation products, 1,1,1-trichloroethane (TCA), toluene and xylene, associated with historic activities at the Site or adjacent sites.

Underground storage tanks (USTs) formerly containing solvents and gasoline were removed from the Site in the early 1990s (Figure 3). In 2005 an Interim Remedial Measure (IRM) was undertaken to remove and dispose of approximately 2,200 tons of contaminated soil from beneath the southern portion of the on-Site Building’s floor slab (Walden Associates, 2006; see Figure 3). Post-removal soil samples taken from the southwestern corner of the excavation, near the building’s footing, indicated the presence of PCE at concentrations of 290 parts per million (ppm) (Walden Associates, 2006). A Post-IRM remedial investigation (RI) identified residual soil and groundwater contamination, including a plume that extends off-Site to the south and southwest (Malcolm Pirnie, 2009a).

A soil vapor extraction (SVE) sub-slab piping system was installed under the on-Site Building during additional IRM work in 2005 (Walden Associates, 2006; see Figure 4). Additional IRM work was completed in 2009, including the installation and operation of an SVE system at the Site, connected to the previous sub-slab SVE piping (Malcolm Pirnie, 2009a) to mitigate potential soil vapor intrusion issues associated with the remaining contamination.

Based on a Remedial Investigation/ Feasibility Study (RI/FS) completed for the Site in 2009 (Malcolm Pirnie, 2009a; 2009b), the NYSDEC issued a Record of Decision (ROD) in March 2010 to address the remediation of the remaining Site contamination. The ROD required in situ chemical oxidation (ISCO) of the groundwater plume area with the highest concentrations of chlorinated volatile organic compounds (VOCs), which are present in the southwestern portion of the Site. To accomplish this objective, the ROD includes a provision for “an in situ chemical oxidation pilot test to determine the necessary injection parameters” to be included in the Site’s remedial design. The ROD also includes a provision for continued operation of the existing SVE system to mitigate the potential for soil vapor intrusion within the Site Building.

In November 2010, the NYSDEC retained Arcadis/Malcolm Pirnie, Inc. (now Arcadis CE, Inc., or 'Arcadis') to develop the design for ISCO to address contamination in the dissolved-phase plume area, as well as the other remedial elements identified in the ROD. Arcadis evaluated the existing data obtained from various historical Site investigations (EEA, 1991; 1996; 1997a; 1997b; Weston, 1997; EEA, 1999; 2000; Walden, 2006; Malcolm Pirnie, 2006; 2009a; 2009b) and developed and implemented an initial ISCO pilot test study in support of the final remedial design for the Crown Dykman Site (Arcadis/Malcolm Pirnie, 2012a; 2012b).

The pilot program implemented in 2012 included injection of sodium permanganate into the subsurface at the Site using a proprietary injection technology developed by Badger Technologies, Inc. (Badger), which utilized an alternative slotted injection nozzle method (Arcadis/Malcolm Pirnie, 2012a; 2012b). As an alternate delivery technique, the ISCO pilot program also assessed application through injection into an existing monitoring well at the Site. The pilot program concluded that the stratigraphy and heterogeneity of subsurface materials limited the applicability of Badger injection technology at the Crown Dykman Site for full-scale implementation. The alternate delivery methods evaluated during the pilot test (slotted tip injection and well injection) were generally unsuccessful at introducing permanganate to the subsurface. Therefore, evaluation of additional techniques for ISCO implementation, including injection through purpose-built injection wells, was recommended.

During the summer and fall of 2013, a second ISCO pilot program was completed using sodium permanganate injection techniques via injection wells. The second ISCO pilot study included injection of approximately 5,170 gallons of sodium permanganate over a period of seven days into two purpose-built injection wells (shallow and deep). The work performed, and the results and conclusions are documented in the Crown Dykman Pre-Design Investigation Report (Arcadis, 2014). The results of the pilot study concluded that introduction of sodium permanganate to the subsurface via purpose-built injection wells is an effective technology to implement the ISCO strategy presented in the ROD for the Crown Dykman Site. However, the presence of significant heterogeneity and preferential flow paths may reduce the overall effectiveness of the ISCO remedy, as some areas of the subsurface may prove recalcitrant to in situ chemical oxidation. The ISCO pilot study results were consistent with the heterogeneity observed in the geologic units at the Site. High and low permeability units are interspersed throughout the Site, resulting in preferential flow paths that can affect the distribution of the permanganate once injected. Such effects were also observed during the first chemical oxidation pilot, where the injection technology used had difficulty distributing the sodium permanganate evenly throughout the subsurface (Arcadis, 2014).

The results of the second ISCO pilot also suggested that a continuing groundwater chlorinated VOC source was potentially present in the vicinity of the southwestern corner of the Site Building. Therefore, supplemental investigation work was performed during the summer of 2014, including assessment of this potential chlorinated VOC source area. Soil sampling results during the July 2014 supplemental investigation indicated that concentrations of PCE are present in the soil below the Site Building, within the area (areal extent, or footprint) of the 2005 IRM excavation (Walden Associates, 2006), but below the vertical extent of the excavation (Figures 5a, 5b and 5c). In addition to chlorinated VOCs, petroleum-related BTEX (Benzene, Toluene, Ethylbenzene, Xylene) compounds, including ethylbenzene and xylenes, were present in soil samples from all four boring locations within the building. The study concluded that the low groundwater gradient beneath this portion of the building, and the continued presence of a potential non-aqueous phase liquid (NAPL) source of PCE in the vicinity, is contributing to the continued presence of chlorinated VOCs in both soil and groundwater beneath the southwestern corner of the Site Building. This area acts as a continuing source for the groundwater plume that must be addressed.

During 2015, an additional injection pilot was completed beneath the building floor slab in the southwestern corner of the Site Building to assess the ability of ISCO injections to reduce chlorinated VOC contaminant mass within the chlorinated VOC source area. Arcadis installed two additional shallow injection wells within this area and injected an additional quantity of sodium permanganate to a depth of approximately 15 feet below the groundwater table, within the source zone (Arcadis, 2018). However, after analysis of several subsequent post-injection groundwater sampling events (as summarized on Figure 6), reduction of chlorinated VOC mass was not evident in the groundwater analytical results from the source area and Site areas downgradient of the injections (Arcadis, 2018). As shown on Figure 6 and Figures 7a, 7b, and 7c, later analytical data suggested rebound of contaminant concentrations to near baseline levels in wells where groundwater monitoring initially showed the presence of permanganate, or slight decreases in contaminant concentrations (Arcadis, 2018).

Therefore, while the results of the pre-design chemical oxidation pilot indicated that chemical oxidation is an effective remedial solution for the dissolved-phase groundwater plume if implemented in full-scale, the presence of a continuing source area would undermine the effectiveness of the remedy, and would likely lengthen the remedial timeframe if not addressed (Arcadis, 2014; 2018). Based on these findings, it was concluded that the ROD should be amended to address the soil chlorinated VOC source area.

1.2 Site Description and Physical Characteristics

Physical characteristics of the Crown Dykman Site are documented in previous reports, including the Remedial Investigation Report (Malcolm Pirnie, 2006; 2009a; 2009b) and subsequent pilot study reporting (Arcadis/Malcolm Pirnie, 2012a; 2012b; Arcadis, 2014; 2018), as mentioned in Section 2. A brief summary of the Site and environs is provided below.

1.2.1 Site Description

The Site (Figure 2) is an approximately one-acre commercial property occupied by a former laundry and dry-cleaning facility, which is now used as a commercial, water-based laundry. A former auto-repair shop previously operated on the southern portion of the building. The building consists of a single-story brick and block structure, which is constructed on a concrete slab, with no basement or crawl-space present beneath the building. The Site is bordered on the south by Herb Hill Road, with the former Li Tungsten Parcel A present to the south on the opposite side of the roadway. The former Li Tungsten Parcel B is adjacent on the west of the Site, opposite an Access Road along the western Site boundary that provided access to the former Konica-Minolta industrial facility. The former Konica-Minolta property is adjacent to the Site boundary to the north and east of the Site. Parcels A and B were formerly part of the Li Tungsten industrial facility, which are now properties under redevelopment, as is the former Konica-Minolta facility (Figure 2). The Access Road is now reportedly owned by the City of Glen Cove.

1.2.2 Surface Topography and Surface Water Features

The ground surface of the undeveloped portions of the Crown Dykman Site exhibit a gradual slope from north to south, with a retaining wall along the southern portion of the Site where the ground surface drops off approximately three to four feet near Herb Hill Road. The section of Herb Hill Road in the vicinity of the Site occupies a low-lying area that frequently floods after precipitation events.

Adjacent parcels to the Site had been largely redeveloped with multi-story condominiums, which has modified the topography and land use patterns in properties adjacent to the Site. Prior to redevelopment, a small wetland area was present at the southern end of the former Li Tungsten Parcel B, and a flooded drainage ditch was present along the northern side of Herb Hill Road at the southernmost edge of the Site. Until 2017, a small concrete structure was present at the eastern extent of the ditch, from which water flows throughout most of the year (Figure 2). However, during a Site evaluation in November 2017, the concrete structure was found to be buried, and was reportedly destroyed. A small depression where water flows from is also present in the Access Road just north of MW-21S/D, which ground-penetrating radar data (used for clearing monitoring well locations during this Study) suggests may be from a leaking water line buried beneath the Access Road. During the initial ISCO Pilot Investigation (Arcadis/Malcolm Pirnie, 2012b) in 2012, the water discharging from this depression in the access road was sampled for VOC/SVOC analyses. The analytical results indicated the presence of trichloroethylene (TCE), cis-1,2-dichloroethylene (DCE), and trans-1,2-DCE at estimated values of 0.91, 0.91, and 0.41 micrograms per liter (µg/l), respectively (Arcadis/Malcolm Pirnie, 2012b).

1.2.3 Regional and Site Geology

Surficial geology in the vicinity of the Site consist of deposits associated with the Harbor Hill ground moraine, which at the Site consist predominantly of zones of fine to medium sand, medium to coarse sand, and silty sand with silt lenses (Arcadis, 2014). The Harbor Hill ground moraine is typically five to 10 feet thick but can be up to 40 feet thick. Upper Pleistocene age deposits associated with the Ronkonkoma glaciation are deposited beneath the Harbor Hill ground moraine deposits. The Ronkonkoma layer consists of interlayered glacial till and outwash deposits, which are not observed at the Site. The glacial sediments associated with both layers range in thickness from less than 10 feet to over 200 feet in the northern part of Long Island (Kilburn and Krulikas, 1987).

At the Site, the saturated thickness of the moraine units generally decreases from north to south, with the upper sand and silty sand units generally extending to a depth of approximately 35 feet below ground surface (bgs) at the northern portion of the Site to approximately 15 feet bgs south of Herb Hill Road. However, in the vicinity of monitoring well cluster MW-1/1D (boring location SB-14), the saturated aquifer thickness increases where the moraine deposits extend to approximately 43 feet bgs into an apparent trough in the underlying clay unit. The moraine units at the Site are generally heterogeneous, with numerous fluvial channels (coarse gravel and sand) cutting through the medium to fine moraine sands. These gravel channels represent preferential groundwater flow paths where saturated. One such gravel layer is present along the western edge of the Site Building in the vicinity of MW-13, IW-1S, MW-26, MW-27, and MW-28 (Figure 5a and 5b), generally between 18 and 20 feet bgs. The gravel channel present in this area consists of medium to coarse gravels in a coarse sand matrix, contrasting significantly with surrounding material that consists primarily of medium to fine sands and occasional silty sand zones.

Beneath the moraine deposits is an extensive confining unit (Port Washington clay) comprised of clay, silt, and a few layers of sand that correlates to the Pleistocene and Holocene epochs (Kilburn, 1972). Boring data from wells intersecting the Port Washington clay unit (Malcolm Pirnie, 2006; 2009a) indicates the presence of a northeast to southwest oriented depression (trough) in the clay underlying the southern portion of the Site.

Underlining the moraine sediments and Port Washington clay in the vicinity of the Site are unconsolidated deposits associated with the Raritan Formation. The lower unit of the Raritan Formation is the Lloyd Sand Member, which is up to 125 feet thick in this portion of Long Island. The Lloyd Sand lies above the bedrock, which is encountered at depths of up to 400 to 500 feet below mean sea level (Smolensky et al., 1989).

1.2.4 Hydrogeology

Groundwater levels at the Site range from approximately five to 10 feet below grade in the vicinity of the building and at the southern Site boundary. As shown on Figure 8, Groundwater generally flows from upland areas to the north of the Site toward the southeast and southwest, with a slight groundwater divide near the middle of the Site. The groundwater gradient slightly decreases beneath the southwestern portion of the building and steepens slightly between the building and Herb Hill Road. Heads in the monitoring well clusters at the southern edge of the Site (MW-10S/D, MW-23S/D, MW-25S/D, and the MW-1D/1DD cluster) indicate a downward head gradient indicating downward groundwater flow into the clay trough. However, a well screened in the shallow portion of the southeasternmost portion of the property (MW-1) occasionally appears artesian, with groundwater flowing from the well casing. The artesian flow is caused by perched water in the shallow portion of the saturated zone coming near the surface along Herb Hill Road during periods of extended precipitation.

1.3 Nature and Extent of Contamination

The nature and extent of soil and groundwater at the Crown Dykman Site is documented in previous reports, including the Remedial Investigation Report (Malcolm Pirnie, 2006; 2009a; 2009b) and subsequent pilot study reporting (Arcadis/Malcolm Pirnie, 2012a; 2012b; Arcadis, 2014; 2018), as mentioned in Section 2. A brief summary of the current nature and extent of soil and groundwater contamination is summarized below.

1.3.1 Distribution of Contaminants in Soil

As presented in the ROD, the primary groundwater contaminants of concern (COCs) are PCE, TCE, 1,2-DCE, vinyl chloride, as well as benzene, toluene and xylene. The distribution of these COCs is summarized in the section below.

As shown on Figures 5a and 5b, concentrations of PCE indicative of NAPL are present in the soil below the southwestern portion of the Site Building, within the area of the 2005 IRM excavation (Walden Associates, 2006). In addition to chlorinated VOCs, BTEX compounds, including ethylbenzene and xylenes, were present in soil samples from all four boring locations within the southwestern corner of the building. Soil samples from the well MW-27 boring, which was installed in the vicinity of the southwestern corner of the 2005 IRM excavation, yielded the greatest concentrations of PCE and TCE in soil at concentrations indicative of free-phase PCE within the soil in this area.

Soil samples from the vicinity of the southwestern corner of the 2005 IRM excavation (where post-removal soil samples indicated PCE at 290 ppm in soil), yielded the greatest concentrations of PCE and TCE in soil, at 24,000 ppm and 300 ppm, respectively, from 11-12 feet bgs (Figures 5a and 5b). Concentrations of PCE in soil in the same area were 110 ppm at the sample interval above (6-7 feet bgs). Such concentrations of PCE in the soil indicate the presence of free-phase PCE within this area. Concentrations of PCE in soil decreased toward the north and west of those presented above (150 ppm at 8-9 feet bgs, and 180 ppm 10-11 feet bgs). However, these PCE concentrations exceed both the NYSDEC Unrestricted Use (1.3 ppm) and Commercial (150 ppm) Soil Clean-up Objectives (SCOs).

In addition to chlorinated VOCs, BTEX compounds, including ethylbenzene and xylenes, were present in soil samples from boring locations sampled within the building during the supplemental investigation (Arcadis, 2014). Both ethylbenzene and total xylene concentrations exceeded their respective Unrestricted Use SCOs (1 ppm and 0.26 ppm, respectively) in the soil sampled at the water table (7-8 feet bgs). Total xylene concentrations were also present in soil samples at levels exceeding the respective Unrestricted Use SCOs.

1.3.2 Distribution of Contaminants in Groundwater

Based on groundwater analytical data from previous investigations at the Site (Malcolm Pirnie, 2009a; Arcadis/Malcolm Pirnie, 2012b), the pre-pilot baseline sampling for the ISCO pilot program (Arcadis, 2014) and subsequent supplemental pilot study (Arcadis, 2018), the greatest concentrations of PCE and its degradation products in groundwater at the Site are present in samples downgradient from the southwestern corner of the Site Building extending off-Site to northern portions of the former Li Tungsten Parcel A, and on the eastern portion of the former Li Tungsten Parcel B. Concentrations of PCE and related chlorinated VOCs in groundwater extend to a depth of up to 35 feet bgs.

Concentrations of petroleum compounds in some monitoring wells in the southwestern area of the Site Building indicate a petroleum release at the Site (Figures 7a, 7b, and 7c). The presence of petroleum in groundwater at the Site may be contributing to conditions favorable to the natural attenuation of chlorinated VOCs present in groundwater, as data from previous investigations (Malcolm Pirnie, 2009a; Arcadis/Malcolm Pirnie, 2012b) show that degradation of chlorinated VOCs in the groundwater is occurring. Concentrations of PCE and TCE in groundwater have generally decreased over time, with Site conditions generally favoring cis-1,2-DCE, with some trans-1,2-DCE. However, Site conditions have generally limited the production of vinyl chloride.

The extent of chlorinated VOCs in groundwater has not been fully delineated to the south and west on former Li Tungsten Parcels A and B, respectively (Figures 9a, 9b, and 9c). It is likely that PCE and related chlorinated VOCs in groundwater are moving to the south and southwest, toward Glen Cove Creek. Since the early 2000s, changing peripheral conditions potentially have influenced groundwater flow and contaminant migration patterns locally.

1.3.3 LNAPL Distribution and Trends

LNAPL was present in monitoring wells MW-6R, MW-8, MW-16R, and MW-17R during the initial sampling rounds, beginning in 2008-2009. However, by July 2014 there were no measurable thicknesses of LNAPL present in the Site wells. LNAPL characterization of a sample in well MW-8 is consistent with gasoline. While presence of LNAPL at the Site was consistent with detections of BTEX and other petroleum-related compounds in groundwater, LNAPL trends in all of the wells appear to indicate that measurable levels of LNAPL are no longer present in wells at the Site. No NAPL was observed during the most recent site monitoring in Spring 2019.

2 PURPOSE AND SCOPE OF FOCUSED FEASIBILITY STUDY

The overall purpose of the FFS is to develop and evaluate a range of alternatives that provide a comprehensive approach to remediation of chlorinated VOC contaminants in the soil and groundwater within the boundaries of the Site (remedial alternatives). The study area for the FFS (Figure 2) includes those portions of the Crown Dykman property impacted by chlorinated VOC and petroleum-related compounds in the southern and western portions of the Site. This includes the dissolved-phase constituents in groundwater, and the recently identified DNAPL source area.

The overall goal of a potential remedy is to reduce the current or potential threat to public health and the environment caused by contamination at the Site. The remedial alternatives developed for this FFS have been designed to provide a final remedy for:

- The chlorinated VOC soil source area beneath the southwestern corner of the Site Building;
- The dissolved-phase chlorinated VOC plume; and,
- Other petroleum-related contaminants in groundwater at the Site.

This FFS Report will identify, and screen proposed remedial technologies based on eight criteria, and will present and evaluate remedial alternatives based on those technologies that could be implemented to meet Remedial Action Objectives (RAOs) and provide Site-specific information on performance of the remedial technology.

As stated previously, this FFS has built on previous work to develop a comprehensive remedy for human health and environmental protection at the Crown Dykman Site. This work includes:

- Previous Site investigations by the NYSDEC, Nassau County Department of Health, and the property owner during the period 1987 to 2009 (EEA, 1991; 1996; 1997a; 1997b; Weston, 1997; EEA, 1999; 2000; Walden, 2006; Malcolm Pirnie, 2006; 2009a);
- The 2009 Feasibility Study (FS) for the Site (Malcolm Pirnie, 2009b), completed in support of the 2010 ROD and based on the 2008-2009 NYSDEC remedial investigation work (Malcolm Pirnie, 2009a); and,
- Pilot study programs (Arcadis/Malcolm Pirnie, 2012a; 2012b; Arcadis, 2014; 2018) completed in support of the preferred remedy specified in the 2010 Crown Dykman ROD.

The 2009 FS (Malcolm Pirnie, 2009b) screened treatment technologies for contaminants in groundwater (beyond a no further action (NFA) and LTM approach), including:

- **Biodegradation/ Enhanced Biodegradation** - including biostimulation through substrate injection, and bioaugmentation by adding microbial cultures.
- **In situ Chemical Oxidation (ISCO)** – including ISCO via Fenton's Reagent (hydrogen peroxide), sodium and potassium permanganate, sodium persulfate, and RegenOx (a proprietary mixture of oxidants).
- **Groundwater Extraction and Treatment** – including treatment through advanced oxidation, air stripping, and carbon adsorption.
- **Containment/ Barrier Technologies** – including zero-valent iron permeable reactive barriers (PRBs).
- **Zero-valent Iron Injections** – for abiotic reductive dehalogenation in situ through injection into the subsurface.
- **Air Sparging/ Soil Vapor Extraction (AS/SVE)** – including ex situ vapor-phase treatment using granular activated carbon (GAC).

The 2009 FS concluded that only three of the above technologies (ISCO with sodium permanganate, PRB using zero-valent iron, and zero-valent iron injections) would be effective for the groundwater contaminants at the Site.

Based on the RI completed in 2009 (Malcolm Pirnie, 2009a) and prior work performed at the Site, an evaluation of technologies or development of remedial alternatives for soil was not included in the 2009 FS. Based on the RI/FS completed in 2009, the NYSDEC issued a ROD in March 2010 identifying ISCO as the preferred Site remedy for the groundwater chlorinated VOC plume in the southwestern portion of the Site. The ROD also included a provision for continued operation of the existing SVE system to mitigate the potential for soil vapor intrusion within the Site Building, and provisions for LNAPL recovery, as discussed in Section 1.

However, as discussed in Section 1, the subsequent groundwater monitoring activities and pre-design study work completed in 2014 (Arcadis, 2014) lead to the discovery of the source area beneath the southwestern corner of the Site Building. As a result, it was decided to amend the 2010 ROD. In addition, subsequent quarterly monitoring of LNAPL at the Site and pre-design work has demonstrated the LNAPL is no longer present at the Site in significant quantity or thickness. Therefore, this FFS will amend the previous FS to include technologies and remedial alternatives for both groundwater and soil impacts, but remedial alternatives developed for the Site will no longer consider LNAPL recovery.

In November 2017 and March 2018, additional sampling for emerging contaminants including poly-fluoroalkyl substances (PFAS) and 1,4-dioxane was performed. Results from that sampling event identified concentrations of PFAS above New York State Health Advisory Levels at the Site. The FFS will also amend the previous FS to include technologies and remedial alternatives to address incidental PFAS encountered during implementation of remedial actions at the Site.

This FFS report, which includes an evaluation of technologies and remedial alternatives to address contaminants in both soil and groundwater, will support the ROD amendment for the Crown Dykman Site. This FFS includes additional technologies not evaluated in the original 2009 FS but may not re-evaluate those technologies previously screened out during the 2009 FS process.

Following finalization of this FFS Report, the forthcoming Crown Dykman ROD Amendment will update and add to previous plans described in the ROD for the Crown Dykman Site and in other related decision documents, as necessary.

3 IDENTIFICATION OF RAOS AND SCGS

This section outlines the RAOs proposed for the final Site-wide remedy, and the standards, criteria, and guidance (SCGs) to be considered in addressing the RAOs. General response actions (GRAs) are medium-specific actions that could be taken to address the RAOs. The RAOs presented herein are consistent with those presented in the 2009 Feasibility Study (Malcolm Pirnie, 2009b).

3.1 Remedial Action Objectives

RAOs are goals set for environmental media, such as soil, groundwater, sediment, surface water, soil vapor, and indoor air that are intended to provide protection for human health and the environment. RAOs form the basis for the FS by providing overall goals for Site remediation. The RAOs are considered during the identification of appropriate remedial technologies and formulation of alternatives for the Site, and later during the evaluation of remedial alternatives. RAOs are based on engineering judgment, risk-based information established in the risk assessment, and potentially applicable or relevant and appropriate SCGs. For the purposes of this feasibility study, and based on the results of previous Site investigations, the RAOs for the Site are:

- Eliminate, to the extent practicable, exposures to volatile organic compounds in the indoor air originating from groundwater and soil contamination as a result of soil vapor intrusion;
- Reduce, to the extent practicable, on-Site soil COC concentrations to less than NYSDEC Restricted (Commercial) Soil Cleanup Objectives (Part 375-6.8(b));
- Reduce, to the extent practicable, on-Site groundwater COC concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values; and,
- Reduce, to the extent practicable, the potential for off-Site migration of dissolved-phase COCs in groundwater at concentrations exceeding NYSDEC Class GA Ambient Water Quality Criteria or guidance values.

3.2 Applicable Standards, Criteria, and Guidance

6 NYCRR Part 375 requires that SCGs are identified and that remedial actions conform with SCGs unless “good cause exists why conformity should be dispensed with”. Standards and Criteria are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, or location. Guidance includes non-promulgated criteria and guidelines that are not legal requirements; however, the Site’s remedial program should be designed with

consideration given to guidance that, based on professional judgment, is determined to be applicable to the Site. The principle SCGs for the Site are listed below:

General:

- 6 NYCRR Part 375 – Environmental Remediation Programs, including the Inactive Hazardous Waste Disposal Site Remedial Program
- 6 NYCRR Part 371 – Identification and Listing of Hazardous Wastes

Soil:

- 6 NYCRR Part 375 – Soil Cleanup Objectives
- 6 NYCRR Part 376 – Land Disposal Restrictions
- NYSDEC Division of Solid and Hazardous Materials TAGM 3028 “Contained-in” Criteria for Environmental Media (8/97)

Water:

- 6 NYCRR Part 700-705, Water Quality Regulations for Surface Water and Groundwater
- NYSDEC Division of Water TOGS 1.1.1 – Ambient Water Quality Standards and Groundwater Effluent Limitations

Air:

- Air Guide 1 – Guidelines for Control of Toxic Ambient Air Contaminants
- NYSDOH October 2006 Final Guidance for Evaluating Soil Vapor Intrusion in the State of New York

There are three types of SCGs: chemical-, location-, and action-specific SCGs. Chemical-specific SCGs are health- or risk-based numerical values or methodologies which, when applied to Site-specific conditions, result in establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in or discharged to the ambient environment. Location-specific SCGs set restrictions on activities based on the characteristics of the Site or immediate environs. Action-specific SCGs set controls or restrictions on particular types of remedial actions once the remedial actions have been identified as part of a remedial alternative. The identification of potential SCGs is summarized in Table 1.

4 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section identifies remedial alternatives to achieve the RAOs described in Section 3. As an initial step, general response actions (GRAs) are identified to address impacted soil and groundwater. GRAs describe actions that will satisfy the RAOs, and may include various actions such as treatment, containment, institutional controls, excavation, or any combination of such actions. From the GRAs, potential remedial technology types and process options are identified and screened to determine those that are the most appropriate for the Site. Technologies/process options that are retained following the screening are used to develop remedial alternatives. Detailed evaluations of these remedial alternatives are presented in Section 5. A number of the technology types/ technology process options screened are potentially effective remedial methods for both soil and groundwater. Therefore, in lieu of a media-specific evaluation, the remedial technologies evaluated for this FFS are assessed separately for the DNAPL source area (to include both groundwater and soil remediation), and the dissolved-phase groundwater plume present at the Crown Dykman Site.

According to the USEPA's Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988a), the term "technology type" refers to general categories of technologies while "technology process options" refers to specific processes within each technology type. For each GRA identified, a series of technology types and associated process options has been assembled. In accordance with the USEPA guidance document, each technology type and associated processes are briefly described and evaluated against preliminary screening criteria. This approach was used to determine if the application of a particular technology type or process option is applicable given the Site-specific conditions for remediation of the impacted media.

Based on this screening, remedial technology types and process options were eliminated or retained and subsequently combined into potential remedial alternatives for further, more detailed evaluation. This approach is consistent with the screening and selection process provided in TAGM 4030, Selection of Remedial Actions at Inactive Hazardous Waste Sites (NYSDEC, 1990). In addition, those technologies that were screened out during the original 2009 FS completed for the Site (Malcolm Pirnie, 2009b) were preemptively screened out during the preliminary screening process, unless new data supported their re-evaluation as part of this FFS.

The NYSDEC Division of Environmental Remediation (DER) Presumptive/Proven Remedial Technologies (documented under "DER-15") allows for use of industry experience related to remedial actions to focus the evaluation of technologies to those that have been proven to be both feasible and cost-effective for specific Site types or constituents. The objective of DER-15 is to use experience gained at remediation sites and scientific and engineering evaluation of performance data to make remedy selection more efficient and consistent. In addition, known future uses of the Crown Dykman Site and adjacent areas were considered during the screening process.

4.1 General Response Actions

In accordance with DER-10, Section 4.2(a)(3), and based on the RAOs in Section 3, the following Site-specific GRAs were established for subsurface soil and groundwater at the Site:

- No Further Action
- Institutional Controls
- Long Term Monitoring
- In Situ Treatment
- Removal Measures
- Containment/ Barrier Measures

A No Further Action GRA has been included and retained throughout the screening evaluation as required by USEPA and NCP guidance.

4.1.1 No Further Action

A no action response required by DER-10 provides a baseline for comparison with other alternatives. Consistent with NCP and USEPA guidance documents, the No Further Action alternative must be developed and examined as a baseline to which other remedial alternatives are compared.

4.1.2 Institutional Controls

Remedial technologies associated with this GRA consist of nonintrusive administrative controls focused on minimizing contact with impacted subsurface soil and groundwater. Institutional controls are applied when active remedial measures do not achieve cleanup limits. Human exposure and potential health risks are reduced by limiting public access to Site contaminants. Institutional controls such as environmental easements can also apply through an extended remediation period, or to sites where cleanups are completed up to feasible levels but still leave residual contamination greater than background levels.

4.1.3 Long Term Monitoring (LTM)

LTM is used to evaluate the natural contaminant reduction processes, such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials, as part of overall Site remediation. These contaminant reduction processes are non-engineered remedial pathways.

4.1.4 In situ Treatment

Remedial technologies associated with this GRA involve treating impacted subsurface soil or groundwater without physical removal. In situ treatment for soil uses various technologies including thermal, biological, chemical, and reactive materials. In situ treatment is effective in treating source areas of contamination but can be prohibitively expensive for treatment of large areas of soil contamination.

4.1.5 Removal Measures

Technologies associated with this GRA involve removal of impacted subsurface soil or groundwater from the ground. Removal measures provide for the removal of contaminants or contaminated materials from their existing location for treatment (on-Site or off-Site) or disposal.

4.1.6 Containment/Barrier Measures

Technologies associated with this GRA involve measures that contain or isolate contaminants on-Site. Containment prevents migration of contaminants from the Site and attempts to prevent direct human and ecological exposure to contaminated media. Examples of containment technologies are grout slurry walls, sheet piling, and reactive barriers to prevent migration of contaminants from the soil source area, or in situ mixing with low-permeability mixtures to prevent dissolution and migration of contaminants to the surrounding soil or groundwater. Containment technologies are often combined with other treatment technologies to remove contamination.

4.2 Identification of Remedial Technologies

Remedial technologies potentially applicable for achieving the RAOs for the Site were identified through a variety of sources including vendor information, engineering experience and review of available literature, including the following documents:

- NYSDEC TAGM 4030, titled "Selection of Remedial Actions at Inactive Hazardous Waste Sites" (NYSDEC, 1990).
- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim Final) (USEPA, 1988a).
- Technology Screening Guide for Treatment of CERCLA Soils and Sludges (USEPA, 1988b).
- Crown Dykman Feasibility Study Report (Malcolm Pirnie, 2009b).

Those technologies that were screened out during the original 2009 FS completed for the Site (Malcolm Pirnie, 2009b) were preemptively screened out during the preliminary screening process, unless new data supported their re-evaluation as part of this FFS.

4.3 Preliminary Technology Screening

The preliminary screening focuses the number of potentially applicable technology types or measures on the basis of technical implementability and effectiveness (both long- and short-term). Technical implementability was evaluated using Site characterization information collected during the Site investigations, including the types and concentrations of impacts and subsurface conditions, to screen out technology types and process options that could not effectively be implemented at the Site. The general effectiveness of a technology is measured by its ability to meet the established RAOs.

To advance the alternatives development process, process options for subsurface soil and groundwater were subject to a preliminary screening. The objective of the screening process was to identify, when possible, one process option to represent each technology type and for comparison to the following screening criteria:

- Effectiveness - The effectiveness of each process option will be evaluated in terms of its ability to reduce the toxicity, mobility, and/or volume of chemical constituents in the impacted medium, limit the impacts to human health and the environment during the construction and implementation phase, and its reliability with respect to the nature and extent of impacts and conditions at the Site.
- Implementability - Implementability encompasses both the technical and administrative (e.g., the ability to obtain necessary permits for offsite actions, the availability of treatment, storage, and disposal services, etc.) feasibility of implementing a process option. This criterion also evaluates the ability to construct the process option, and availability of specific equipment and technical specialists to design, implement and operate and maintain the equipment as applicable.
- Relative Cost - The overall relative cost required to implement the remedial technology will be assessed qualitatively with respect to the other potential technologies. As a screening tool, assumptions of relative capital and operation, maintenance and monitoring (OM&M) costs are used rather than detailed cost estimates. For each technology process option, relative costs are

presented as low, moderate, or high, and made on the basis of engineering judgment and industry experience.

As discussed above, the remedial technologies evaluated for this FFS are assessed separately for the DNAPL source area (to include both groundwater and soil remediation), and the dissolved-phase groundwater plume present at the Crown Dykman Site. The results of the preliminary screening of technology types and process options are presented in the subsections below and are summarized in Table 2.

4.3.1 No Further Action

Consistent with NCP and USEPA guidance documents, the No Further Action alternative must be developed and examined as a baseline to which other remedial alternatives are compared. Although this technology does not include active remedial measures, natural attenuation processes would potentially reduce the toxicity, mobility, and volume of impacts to the environment over an extended period of time. However, monitoring of Site conditions would not be conducted to document the natural attenuation processes. No action is required to implement the technology, and there is no cost associated with it.

4.3.2 Institutional Controls

Institutional controls (e.g., governmental, proprietary, enforcement, or permit controls and/or informational devices such as signs, postings, etc.) were retained for further evaluation. Consistent with the 2010 NYSDEC ROD, imposition of an environmental easement that requires the remedial party or Site owner to periodically certify that institutional and engineering controls are in place, allows development of the property for commercial use only, and restricts the use of groundwater at the Site as a source of potable or process water without approved treatment methods.

Although this technology does not include active remedial measures, natural attenuation processes would potentially reduce the toxicity, mobility, and volume of impacts to the environment over an extended period of time. Institutional controls would not treat, contain, or remove impacted subsurface soil, but would support a reduced potential for contact with, inhalation or ingestion of, constituents of interest. Additionally, institutional controls could enhance the effectiveness and implementability of other technologies/ process options. This technology is readily implementable and has a low relative cost.

4.3.3 Long Term Monitoring

LTM is used to evaluate the natural contaminant reduction processes, such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials, as part of overall Site remediation. These contaminant reduction processes are non-engineered remedial pathways.

Consideration of this option usually requires evaluation of contaminant degradation rates and pathways and predicting contaminant concentrations at downgradient receptor points. The primary objective of this evaluation would be to demonstrate that the natural processes of contaminant degradation will reduce contaminant concentrations to less than regulatory standards or risk-based levels before potential exposure pathways are completed. In addition, LTM must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with the eventual attainment of RAOs.

Based on observed concentrations of chlorinated VOCs, the RAOs for the Site cannot be met by natural processes alone in a reasonable time period. LTM will not be considered further as a primary remedial alternative for the Site. If LTM alone is implemented, the dissolved-phase chlorinated VOC plume would not be remediated other than with natural processes (i.e. dilution, dispersion, natural attenuation, etc.). For this reason, LTM alone would not be in compliance with SCGs, would not be effective in the short- or long-term, and would not reduce the toxicity, mobility or volume of the dissolved-phase chlorinated VOC plume. However, LTM will be considered as a secondary or polishing remedial technology. No action is required to implement the technology, and there is no significant capital cost associated with it. Monitoring costs are relatively low compared with other potential remedial measures.

4.3.4 In Situ Treatment

Based on the GRAs for groundwater at the Site the following in situ treatment technologies have been evaluated during the FFS:

- Thermal Desorption/ Electrical Resistivity Heating (ERH);
- In Situ Chemical Oxidation (ISCO);
- Biodegradation/ Enhanced Reductive Dechlorination (ERD);
- Air Sparging/Soil Vapor Extraction (AS/SVE); and,
- Zero Valent Iron Injection

A summary and preliminary screening of these technologies is provided below. The results of the preliminary screening of these technologies are provided in Table 2.

As discussed in Section 4.3.5, below, soil vapor extraction within the building source area will be considered as a potential remedial component/ engineering control to be used in conjunction with in situ soil remedies in the DNAPL source area. This technology would include construction of an SSDS within a future building area, if constructed at a later date. Operation of the SSDS would be protective of human health and the environment.

4.3.4.1 Electrical Resistivity Heating

Electrical resistance heating uses an electrical current to heat less permeable soils such as clays and fine-grained sediments so that water and contaminants trapped in these relatively conductive regions are vaporized and ready for vacuum extraction. Electrodes are placed directly into the soil matrix and activated so that electrical current passes through the soil. The resistance to electrical flow that exists in the soil causes the formation of heat; resulting in an increase in temperature until the boiling point of water at depth is reached. After reaching this temperature, further energy input causes a phase change, forming steam and removing volatile contaminants (Beyke and Fleming, 2005; USEPA, 1995).

Volatilized contaminants are captured by a subsurface liquid and vapor recovery system and conveyed to the surface along with recovered liquid, air and steam. Similar to SVE, the air, steam and volatilized contaminants are then treated at the surface to separate water, air and the contaminants.

ERH is typically most effective on VOCs. Chlorinated VOCs, including PCE, TCE, and cis- or trans- 1,2-DCE are readily remediated through ERH/SVE. Less volatile contaminants like xylene or diesel can also be remediated with ERH but energy requirements increase as the volatility decreases. The design and cost of an ERH remediation system depends on a number of factors, primarily the volume of soil/groundwater to be treated, the type of contamination, and the treatment goals. Electrode spacing, and operating time can be adjusted to balance the overall remediation cost with the desired cleanup time. A typical remediation may consist of electrodes spaced 15 to 20 feet apart with operating times usually less than a year (Beyke and Fleming, 2005; USEPA, 1995). However, energy demands can be high, and the electrical energy usage required for heating the subsurface and volatilizing the contaminants can account for up to 40 percent of the overall remediation cost. ERH is typically more cost effective when used for treating contaminant source areas (Beyke and Fleming, 2005; USEPA, 1995).

ERH is retained as a potential remedial technology for application on the limited DNAPL source area beneath the building but is not considered an effective technology for treatment of the dissolved-phase groundwater plume, given the heterogeneity of the Site and extent of the plume.

4.3.4.2 In Situ Chemical Oxidation (ISCO)

ISCO has been used since the early 1990s to treat environmental contaminants in groundwater, soil, and sediment. Many of these projects have focused on the treatment of chlorinated solvents (e.g., TCE and PCE), although several projects have also used the process to treat petroleum compounds [(i.e., BTEX and methyl tertiary-butyl ether (MTBE)] and semi-volatile organic compounds such as polycyclic aromatic hydrocarbons (PAHs) and pesticides.

ISCO is defined as the delivery and distribution of oxidants and other amendments into the subsurface to transform contaminants of concern into innocuous end products such as carbon dioxide (CO_2), water, and inorganic compounds. Injection locations can be either permanently installed wells or temporary injection points installed using direct-push methods. When oxidants come in contact with contaminants they are broken down into non-toxic components. However, contact between the oxidant and contaminant required to facilitate the reaction is the most important technical limitation of this technology, as it can be difficult to accomplish.

Accordingly, this remedial approach generally includes several injections over time accompanied by groundwater sampling and analysis. Numerous injections are typically required to remediate the treatment area. Given this, and depending on the final contaminant concentration desired, the overall costs are typically medium to high relative to other technologies. Since the reaction with the contaminant and the chemical oxidant generally occurs over a relatively short period, treatment can be more rapid than other in situ technologies. This technology does not generate large volumes of residual waste material that must be treated and/or disposed.

ISCO can be used to treat highly localized source areas and dissolved-phase plumes since it is capable of treating high concentrations of contaminants by adding more oxidants. However, it has limited effectiveness for large source areas where NAPL may be present, or where significant heterogeneity and the presence of preferential flow pathways may limit its ability to contact contaminants. ISCO typically becomes prohibitively expensive for large areas requiring treatment to low concentration endpoints.

The most common oxidants utilized for ISCO are hydrogen peroxide (Fenton’s reagent), potassium and sodium permanganate, and sodium persulfate. During the 2009 FS completed for the Site (Malcolm Pirnie, 2009b), only sodium permanganate was considered for use as a potential ISCO alternative. As discussed in Section 1.2, subsequent pilot testing of this alternative at the Site demonstrated its implementability and indicated that it could be effective as a remedial technology for dissolved-phase groundwater contaminants. The relative costs of purchasing and delivering chemicals to supply the number of injection rounds potentially necessary to meet groundwater standards, the relative costs are moderate to high.

While ISCO has some drawbacks related to the difficulty of achieving contaminant contact in fine-grained sediments associated with heterogeneous aquifers, ISCO using sodium permanganate has demonstrated performance at the Site within the dissolved-phase plume. Therefore, ISCO using sodium permanganate is retained as a potential remedial option for the dissolved-phase plume.

Due to the presence of DNAPL and the potential technical difficulties and drawbacks associated with ISCO injections in a DNAPL source area, ISCO is not retained as a potential remedial option for the DNAPL source zone. However, ISCO could be used as a post-remedial polishing option for dissolved-phase contaminants in the source zone area.

4.3.4.3 Biodegradation/ Enhanced Reductive Dechlorination

Biodegradation, or bioremediation, is the controlled management of microbial processes in the subsurface. Enhanced bioremediation is accomplished through the addition of organic carbon source, nutrients (including phosphate, nitrate, and potassium), electron acceptors, and/or microbial cultures to stimulate degradation. This differs from monitoring of bioremediation processes through LTM as it is an active, designed, and managed process. Therefore, bioremediation can often be enhanced through biostimulation (substrates injected in situ to promote microbial activity) or bioaugmentation (increasing of bioremediation by adding microbial cultures). Biostimulation is used to set the proper conditions for increased microbial activity and may be all that is needed for satisfactory remediation. Biostimulation is often focused in areas where microbial populations are marginal and/or under conditions that are insufficient to support practical biodegradation rates.

Biostimulation through enhanced reductive dechlorination (ERD) is implemented by stimulating biological degradation through the addition of Hydrogen Releasing Compound (HRC™), molasses, sodium lactate, vegetable oil, or a similar organic carbon source. Reductive dechlorination is accomplished through two biological processes. The first process is the biodegradation of lactic acid that is slowly released from the HRC. This process generates hydrogen that supports the second reaction, reductive dechlorination. Different types of bacteria catalyze the two processes and both types must be present for reductive dechlorination to occur. Lactic acid fermenting bacteria are extremely common and would never be expected to limit the reaction. However, reductive dechlorinating bacteria (also known as halo-respirers) may not be as widespread. They may be less robust in their ability to compete with other microbial populations in the subsurface. Dehalococcoides ethanogenes is one species known to dechlorinate chlorinated ethenes.

While ERD has been successfully applied for in situ treatment of dissolved chlorinated solvents, in situ treatment of DNAPL is more challenging due to contaminant toxicity, low pH, and challenges in effectively delivering electron donors. Under ideal conditions PCE and TCE may be reduced all the way to nontoxic end-products (ethene and ethane). However, in the presence of DNAPL, substantial amounts of dichloroethene (DCE) and vinyl chloride (VC) are often produced. Conversion of PCE and TCE to DCE can still accelerate source zone remediation by reducing contaminant concentrations in the aqueous phase near the NAPL-water interface, increasing the dissolution rate. DCE and VC produced by dechlorination can partition back into the DNAPL. However, since DCE and VC are more soluble than the parent compounds, the effective solubility of the resulting multicomponent DNAPL can be considerably higher than the original DNAPL, accelerating cleanup.

For efficient DNAPL removal, the contaminant degradation rate must be high relative to contact time with the DNAPL. However, contaminant degradation rates can be limited by contaminant toxicity, low pH, and challenges in effectively delivering electron donors to the NAPL. When using soluble electron donors, ERD treatment efficiency can be limited by poor delivery of the donor to the NAPL interface. A disadvantage of a biodegradation is the possible increase of 1,2-DCE and VC within and downgradient of the treatment area. This is due to the TCE byproducts' (DCE and VC) slower anaerobic reduction rates. Additional byproducts of bioremediation may include increased methane and increased concentration of dissolved iron and manganese and occasionally other metals if the local pH is significantly lowered through biological activity

Because naturally occurring bacteria are the primary degradation mechanism, enhanced bioremediation can be less expensive than chemical or physical treatment technologies.

Enhanced bioremediation through ERD could be appropriate for the Crown Dykman Site, as data indicate that natural biotic degradation of the contaminants is occurring, and populations of Dehalococcoides have been identified (Malcolm Pirnie, 2009a). Anaerobic conditions are generally required for heavily chlorinated compounds including PCE, TCE, 1,1,1-TCA, and 1,2-DCE; such conditions have been observed in the areas impacted by the presence of petroleum compounds (Malcolm Pirnie, 2009a).

Remedial timeframes could be extensive when compared to an ISCO approach and given the uncertainty associated with maintaining an effective distribution of microbes throughout the Site, the effectiveness of ERD to support dissolved-phase reduction in a reasonable timeframe is also uncertain. Therefore, ERD is not retained as a remedial option for the Site.

4.3.4.4 Air Sparging/Soil Vapor Extraction

Air sparging is an in situ remedial technology that reduces concentrations of volatile constituents in petroleum products that are adsorbed to soils and dissolved in groundwater. This technology involves the injection of contaminant-free air into the subsurface saturated zone, enabling a phase transfer of hydrocarbons from a dissolved state to a vapor phase. The air is then vented through the unsaturated zone. Air sparging is most often used together with SVE, but it can also be used with other remedial technologies. When air sparging is combined with SVE, the SVE system creates a negative pressure in the unsaturated zone through a series of extraction wells to control the vapor plume migration.

The system would be designed so that the area of influence of the systems overlap, although this may not be feasible if sufficient thickness of uncontaminated aquifer material is not available beneath the contaminated zone. Pilot tests are often performed to evaluate the most effective distance between injection wells. An injection pump and vacuum extractor would be located above ground. The extracted soil vapor may be treated on-Site prior to release to the atmosphere.

Air sparging and soil vapor extraction will not be considered further for the source area or dissolved-phase groundwater plume present at the Site because of the heterogeneous nature of the aquifer and difficulties associated with extraction of soil vapor, designing an effective vapor control, and implementation next to and under the Site Building. Heterogeneities and stratified soils at the Site would cause air to not flow uniformly through the subsurface causing some zones to be less treated. In addition, portions of the contaminated aquifer in both the DNAPL source area and the dissolved-phase plume are semi-confined, and the use of air sparging in these areas would not be feasible.

4.3.4.5 Zero-Valent Iron Injection

ZVI can be injected into the subsurface to degrade chlorinated VOCs via abiotic reductive dehalogenation. The degradation processes are the same as during the treatment of contaminated groundwater with a zero-valent iron PRB. Zero-valent iron can be injected into the subsurface using a gas- or liquid-based delivery system. The path of the zero-valent iron in the subsurface can be monitored to ensure fracture coalescence or overlap using resistivity sensors. In low permeability or heterogeneous formations, pneumatic or hydraulic fracturing can be used prior to injection of the zero-valent iron to increase the permeability of the formation and radius of influence. Zero-valent iron is often combined with controlled-release carbon or other substances to more fully degrade contaminants in groundwater.

Zero-valent iron would be used to treat the area of highest groundwater chlorinated VOC concentration, in the vicinity of the DNAPL Source Area and in areas immediately downgradient of the source area on the Site. It is anticipated that injecting a 2-4 micron zero-valent iron colloidal suspension will reduce the time required to create dechlorinating conditions and may also reduce the time needed to completely dechlorinate chlorinated VOCs. In the presence of zero-valent iron, oxidation of the dissolved phased chlorinated VOCs will occur while initiating the production of hydrogen for microbial mineralization processes. Zero-valent iron would be used to treat dissolved-phased chlorinated VOCs while acting in synergy with anaerobic degradation processes.

Experience with this technology since completion of the original 2009 FS (Malcolm Pirnie, 2009b) has shown that it is difficult to inject sufficient mass, and to provide sufficient contaminant contact, in heterogeneous aquifers similar to that at the Crown Dykman Site. It is unlikely that sufficient ZVI mass could be delivered effectively within the DNAPL source area and would be cost prohibitive and ineffective in the dissolved-phase plume. Therefore, ZVI injection is not carried forward as a potential remedial alternative for the Site.

4.3.5 Removal

Removal technology process options applicable to the Site (for both the DNAPL source area and dissolved-phase plume) include the following:

- Soil Excavation with Off-Site Disposal;
- Groundwater Extraction and Ex Situ Treatment;
- Directed Groundwater Recirculation; and,
- Soil Vapor Extraction.

These technology processes are summarized and evaluated below. A summary of the evaluation is included in Table 2.

4.3.5.1 Excavation with Off-Site Disposal

Excavation of the DNAPL source area would require dewatering and excavating at depths up to 20 feet below grade below the southwest corner of the Site Building area. As dewatering would include pumping of contaminated groundwater at relatively high concentrations, on-Site treatment of the pumped water would be required and may include GAC, air stripping, and/or advanced oxidation process as a component of the remedy. Final treatment design will be determined during the remedial design.

Excavation of subsurface soil was retained for further evaluation as a remedial option for the DNAPL source area. While technically challenging and having a relatively high cost, this technology type and process option is a proven process for removing impacted material with a high degree of certainty. Excavation of soil is considered implementable. Equipment and labor capable of soil excavation is readily available, and while it has a high capital cost, OM&M costs are low during post-remediation.

In addition, dewatering operations in support of excavation would, in effect, act as additional treatment of dissolved-phase contaminants while the DNAPL source is being removed, enhancing the remedial effectiveness. Such dewatering could also be implemented post-excavation in the form of polishing groundwater recirculation.

Excavation is not applicable to the dissolved-phase plume and is only considered a source area remedial option. Off-Site disposal was retained as a process component for excavation due to the ease of implementability and effectiveness. In addition, multiple offsite treatment technologies could be utilized to treat or dispose of media with different concentrations of impacts.

4.3.5.2 Groundwater Extraction with Ex Situ Treatment

Groundwater extraction and treatment, also referred to as “pump and treat”, would involve the removal of contaminant-containing groundwater through the use of pumping wells. The extracted water would be treated and returned to the subsurface, a surface water body, or sewer system. Groundwater pumping systems can also be used to minimize the potential for dissolved-phase plume migration.

While groundwater extraction has the potential to limit dissolved-phase plume migration, there are numerous potential drawbacks related to installation, operation, and maintenance that may limit the applicability and effectiveness of groundwater pumping as a remedial process:

- Due to aquifer heterogeneity, the time necessary to achieve the remediation goal may be extensive;
- Heterogeneity of the aquifer may also limit the ability of the extraction system to mobilize/ remove the DNAPL source;
- Contaminants tend to be sorbed in the soil matrix, especially in fine-grained units. Groundwater pumping is generally not applicable as a remedial technology for contaminants with high residual saturation, contaminants with high sorption capabilities, and aquifers with hydraulic conductivity less than 10^{-5} centimeters per second (cm/sec);
- The cost of procuring and operating treatment systems can be high in the long term. Additional cost may also be attributed to the disposal of spent carbon and the handling of other treatment residuals and wastes; and

- Bio-fouling of the extraction wells, and associated treatment stream, is a common problem which can severely affect system performance.

Groundwater extraction alone will not be considered further because it is not cost effective compared to other technologies and implementation of the groundwater extraction would require significant operation and maintenance effort over an extended time period.

This technology was not carried forward in the 2009 FS, and there has not been a significant change in Site conditions or the distribution of contaminants that would make groundwater extraction an effective remedial option considering only extraction with treatment. However, this technology would be a required component of a combined injection/extraction directed groundwater recirculation (DGR) system, or as implemented for excavation dewatering.

4.3.5.3 Directed Groundwater Recirculation

DGR, a technology similar in application to groundwater extraction, would be applied at the Site to both provide treatment of the source area and to provide further polishing of the dissolved-phase plume. The technology involves on-site pumping at or near the Site boundary, coupled with re-injection of treated groundwater mixed with sodium permanganate in a 4 percent solution within the source area. The extracted groundwater is treated ex situ prior to re-injection using similar potential treatment technologies to groundwater extraction. Design of a DGR system for the Site would include completion of a limited design study, development of a simplistic groundwater model for the Site to assist in designing the full-scale remedy. The design study would include completion of a recirculation test and tracer test, using the existing source area injection well, and pumping in one or more Site wells, to evaluate aquifer hydraulic parameters and assess extraction well placement and suitable pumping rates.

If utilized with an amendment to the injected water, DGR can result in a two-fold reduction of constituent mass, through both oxidation and removal with ex situ treatment using carbon or another applicable technology. Pumping and injection rates can be modified over time, as necessary, to direct additional recirculation through potentially recalcitrant areas within the treatment area.

DGR is not recommended as a stand-alone remedial measure for the Site, for similar reasons to groundwater extraction with ex situ treatment. Considering the presence of the source area, and the observed heterogeneity at the Site, DGR may have limited effectiveness decreasing contaminant mass within reasonable timeframes. However, as DGR can be implemented in phases as a polishing step in support of other technologies (such as ERH or as an initial dewatering component for source excavation), DGR is retained as a potential component alternative.

4.3.5.4 Soil Vapor Extraction

SVE is a treatment process for in situ remediation of volatile contaminants in vadose zone (unsaturated) soils. The removal of soil vapor, and its relationship to mass removal relies on the mass transfer of contaminants from the liquid (aqueous or non-aqueous) phases into the vapor phase, with subsequent collection of the vapor phase contamination at extraction wells. Extracted contaminant mass in the vapor phase, and any condensed fluid is treated in an above-ground SVE system.

An SVE/ Sub-slab system is currently in operation in the DNAPL source area at the Site (see section 1.2). Based on the monitored performance of the existing SVE system at the Site, SVE alone is not a viable option for mass removal or remediation at the Site for either the DNAPL source area or the dissolved-phase plume. However, while not effective at removing contaminant mass, SVE is a viable remedial component to mitigate exposure risk and to limit impacts to human health. However, SVE will not be retained as a stand-alone remedial option for the source area, as SVE would likely not be sufficient to decrease source area concentrations in a reasonable timeframe. Given the extent of dissolved-phase concentrations at the Site, SVE would not be practical for treatment of dissolved-phase chlorinated VOCs.

However, soil vapor extraction within the source area will be considered as a potential remedial component/ engineering control to be used in conjunction with in situ soil remedies in the DNAPL source area, in the event that future site use and site conditions require consideration of soil vapor mitigation. Operation of an SSDS would continue to be protective of human health and the environment.

4.3.6 Containment/ Barrier Technologies

Containment/ barrier technology processes applicable for the Crown Dykman Site include the following:

- Low-permeability barrier; and,
- ZVI Permeable Reactive Barrier (PRB).

These technology processes are summarized and evaluated below. A summary of the evaluation is included in Table 2.

4.3.6.1 Low-permeability Barrier

Hydraulic containment features are installed to contain and control the lateral flow of contaminated groundwater, divert uncontaminated groundwater flow, and/or provide a barrier for a groundwater treatment system. Hydraulic containment features include physical walls, such as grout curtains, slurry walls, or sheet pile retaining walls. A physical wall will contain contaminants within a specific area. However, further remediation is often necessary because, unlike a PRB, a physical wall does not treat or destroy the contaminants. As such, physical/ hydraulic control barriers have been screened out as potential remedial option, consistent with the 2009 FS evaluation (Malcolm Pirnie, 2009b).

4.3.6.2 Permeable Reactive Barrier

PRBs are installed in or downgradient of a dissolved phase plume by excavating a trench across the path of a migrating dissolved phase plume and filling it with the appropriate reactive material (such as a mixture of sand and iron particles), or by injecting the reactive material into the ground as a mobile slurry using direct push technology or injection wells. Groundwater flowing passively under a hydraulic gradient through the PRB is treated as the contaminants in the dissolved phase plume are broken down into byproducts or immobilized by precipitation or sorption after reacting with the substrate inside the PRB. Although PRBs are a remedial technology that requires no pumping, the rate of groundwater treatment can be accelerated by groundwater withdrawal or injection in the vicinity of the PRB. Groundwater monitoring systems are typically installed to monitor the effectiveness of a PRB (or other remedial technology) over the long term.

The most common PRB technology utilizes zero-valent iron particles, typically in granular (macro-scale) form, to completely degrade chlorinated VOCs via abiotic reductive dehalogenation. As the iron is oxidized, a chlorine atom is removed from the compound using electrons supplied by the oxidation of iron. As the groundwater containing chlorinated VOCs flows through the reactive material, a number of reactions occur that indirectly or directly lead to the reduction of the chlorinated solvents. One mechanism is the reaction of iron filings with oxygen and water, which produces hydroxyl radicals. The hydroxyl radicals in turn oxidize the contaminants. During this process, the chloride in the compound is replaced by hydrogen, resulting in the complete transformation of chlorinated VOCs to byproducts (ethene, ethane, and chloride ions). Since degradation rates using the process are several orders of magnitude greater than under natural conditions, any intermediate degradation byproducts formed during treatment (e.g., VC) are also reduced to byproducts in a properly designed treatment zone. The use of zero-valent iron to treat chlorinated VOCs has been well documented, and is covered under several patents, depending on the installation method.

A ZVI PRB is a potential option for hydraulic control and treatment of dissolved-phase contaminants migrating downgradient of the immediate DNAPL source area. However, the zero-valent iron PRB is a passive method of treatment, likely requiring long-term OM&M costs to support continued degradation of source concentrations. While a ZVI barrier would significantly reduce continued migration of the plume from the DNAPL source area if installed immediately downgradient, the remedial timeframes could be unreasonably long without additional source treatment or removal. Therefore, application of a ZVI PRB is not retained as a potential source zone remedial alternative.

The ZVI PRB will also not be further considered for remediation of the dissolved-phase groundwater plume. While the plume could be intercepted at the downgradient boundary of the Site through emplacement of a PRB along Herb Hill Road, emplacement of a PRB using conventional trenching methods can be complicated by underground utilities present in this area, and by planned road re-construction activities in the area. Once emplaced the PRB is expensive to adjust, re-locate or remove, and changes in groundwater direction or velocity, though unlikely, can reduce the PRB effectiveness.

4.4 Development of Remedial Alternatives

This section uses the screened technologies presented in Section 4.3 to develop remedial alternatives (RAs) for the Crown Dykman Site. As summarized below and on Table 3, five remedial alternatives (RA1 through RA6) have been identified to address the RAOs for subsurface soil and groundwater within both the DNAPL source area, the dissolved-phase groundwater plume present at the Site (Figures 9a, 9b, and 9c). In keeping with NCP and USEPA requirements, Alternative RA1, No Further Action, is provided as a basis for comparison for the other alternatives.

As a number of the technologies screened are potentially effective remedial methods for both soil and groundwater, the remedial alternatives for this FFS have been developed into individual, comprehensive alternatives for both the DNAPL source area (to include both groundwater and soil remediation), and the dissolved-phase groundwater plume at the Site, in lieu of a media-specific analysis.

4.4.1 Common Components of Remedial Alternatives

The elements common to each of the RAs being evaluated for the Site (with the exception of RA1) are discussed below and summarized in the description of each remedial alternative in Section 4.4.2.

4.4.1.1 Site Management Plan (all RAs)

A Site Management Plan would guide future activities at the Site by addressing property and groundwater use restriction and by developing requirements for periodic Site management reviews. The periodic Site management reviews would focus on evaluating the Site with regard to the continuing protection of human health and the environment as provided by information such as indoor air and groundwater monitoring results and documentation of field inspections. The Site management plan could mandate the monitoring of indoor air quality and/or the operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. In addition, a Site management plan could preclude excavation and construction activities that would expose workers without proper protective equipment to affected groundwater.

4.4.1.2 Environmental Easement (All RAs)

Building/property use restrictions and groundwater use restrictions would be placed on the Site property through an environmental easement that would require compliance with the approved Site management plan. Costs for an environmental easement were not included in the remedial alternative cost estimates.

4.4.1.3 Soil Vapor Intrusion Mitigation (All RAs)

A sub-slab depressurization system (SSDS) would be considered as the basis of a soil vapor extraction (SVE) system under a future site redevelopment scenario where site conditions indicated the need for soil vapor mitigation in a building or structure. If implemented, a soil vapor intrusion mitigation plan would be developed to assess the effectiveness of the SSDS. This SSDS would be operated continuously until approval is given to discontinue operation. Periodic SSDS inspections would be conducted to confirm that it is functioning as intended and designed.

4.4.1.4 Long Term Monitoring (All RAs)

LTM would be implemented as part of each active remedial alternative in areas outside of the treatment zone. LTM would involve periodic sampling and analysis of Site groundwater. To further delineate the extent of groundwater contamination, 6 additional monitoring wells would be installed. Groundwater from approximately 14 wells in the Site monitoring well network would be sampled annually and analyzed for VOCs, field parameters, and natural attenuation (NA) parameters. Field parameters will include oxidation/reduction potential (ORP), DO, pH, temperature, and specific conductance. Evaluated parameters will include chloride, nitrite, nitrate, sulfate, ferrous iron, ferric iron, alkalinity, dissolved sulfide, dissolved organic carbon, methane, ethane, ethene, and carbon dioxide.

No active groundwater remediation is included in LTM. LTM requires minimal effort to implement and would have significantly lower capital and OM&M costs than technologies that include active treatment of the dissolved-phase chlorinated VOC plume. LTM would be implemented for a period of five years as a secondary component of the selected groundwater treatment remedial alternative.

4.4.2 Summary of Remedial Alternatives

The RAs and their Site-specific components are briefly summarized below and summarized in Table 3. A summary technical description of the Site-specific components of each remedial alternative is provided in the detailed analysis in Section 5.

4.4.2.1 Alternative RA1 – No Further Action

Consistent with NCP and USEPA guidance documents, the No Further Action alternative was developed as a baseline to which other remedial alternatives are compared. This alternative assumes that no additional remedial actions or Site monitoring would continue, and that active SSDS would cease to operate. No action is required to implement this alternative, and there is no cost associated with it.

While no active remediation would be implemented or continued at the Site, natural attenuation processes would potentially reduce the toxicity, mobility, and volume of impacts to the environment over an extended period of time. However, monitoring of Site conditions would not be conducted to document the natural attenuation processes.

4.4.2.2 Alternative RA2 – DNAPL Source Area ERH with ISCO

RA2 would consist of implementation of an ERH remedial program in the DNAPL source area and a sodium permanganate ISCO program in the dissolved-phase groundwater plume at the Site (Figures 11a and 11b). This RA would include the common components discussed in Section 4.4.1, above, with additional soil vapor mitigation being applied as part of the ERH program in the DNAPL source area.

The ERH program would include additional design and treatability testing, drilling and system installation activities, and OM&M activities. The ISCO program would include additional injection well installations in the treatment area, additional rounds of chemical injections, and implementation of a monitoring and sampling program, as discussed in Section 5.

4.4.2.3 Alternative RA3 – DNAPL Source Area ERH with DGR

Alternative RA3 would consist of implementation of an ERH remedial program in the DNAPL source area, with implementation of a DGR remedial program in the down-gradient dissolved-phase plume (Figures 12a and 12b). This RA would include the common components discussed in Section 4.4.1, above, with additional soil vapor mitigation being applied as part of the ERH program in the DNAPL source area.

The ERH program would include additional design and treatability testing, drilling and system installation activities, and OM&M activities, as discussed in Section 5. The DGR program would include additional hydraulic design testing, drilling and system installation activities, and OM&M activities, also discussed in Section 5.

4.4.2.4 Alternative RA4 – DNAPL Source Area Excavation with ISCO

RA4 would consist of excavation of the DNAPL source area to a depth of up to 15 feet below grade, with direct application of ISCO occur during backfilling, and subsequent installation and use of an injection system at the source area and onsite downgradient plume area (Figures 13a and 13b). This RA would include the common components discussed in Section 4.4.1, above.

Excavation activities would include construction dewatering and associated treatment, along with engineering and shoring associated with the excavation activities. The ISCO program would include additional injection well installations in the treatment area, additional rounds of chemical injections, and implementation of a monitoring and sampling program, as discussed in Section 5.

4.4.2.5 Alternative RA5 – DNAPL Source Area Excavation with DGR

Alternative RA5 would consist of excavation of the DNAPL source area to a depth of up to 15 feet below grade, with implementation of a DGR remedial program in the dissolved-phase groundwater plume at the Site (Figures 134a and 14b). This RA would include the common components discussed in Section 4.4.1, above.

Excavation activities would include construction dewatering and associated treatment, along with engineering, and shoring associated with excavation activities. The DGR program would include additional hydraulic design testing, drilling and system installation activities, and OM&M activities, as discussed in Section 5.

4.4.2.6 Alternative RA6 – DNAPL Source Area Excavation with DGR and ISCO Polishing

Alternative RA6 would consist of excavation of the DNAPL source area to a depth of up to 15 feet below grade, with implementation of a DGR remedial program in the dissolved-phase groundwater plume at the Site (Figures 15a and 15b) that would also provide a component of the excavation dewatering program. This RA would include the common components discussed in Section 4.4.1, above with the addition of ISCO treatment after excavation within the source area to treat residual COCs and enhance DGR treatment performance.

Excavation activities would include construction dewatering and associated treatment, along with engineering, and shoring associated with excavation activities. The DGR program would include additional hydraulic design testing in support of excavation dewatering and DGR treatment, drilling and system installation activities, and OM&M activities, as discussed in Section 5. The ISCO program would involve injections and installation of injection piping within the excavation footprint.

5 EVALUATION OF REMEDIAL ALTERNATIVES

This section further evaluates the remedial alternatives identified in Section 4. These remedial alternatives were evaluated with respect to the criteria specified in TAGM 4025, which incorporate the NCP by reference, and the USEPA guidance document titled, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988). The evaluation criteria are arranged in the order specified in TAGM 4030. These criteria encompass statutory requirements and include other gauges of overall feasibility and acceptability of remedial alternatives.

Medium-specific Remedial Action Alternatives (RAAs) for the protection of public health and the environment were developed based on a comparison of the results of the RI to SCGs. Potential RAAs for the Site were identified by:

- Developing RAOs that specify the contaminants and media of interest, potential exposure pathways, and remediation goals. The objectives developed were based on contaminant-specific cleanup criteria and SCGs;
- Developing general response actions for each medium of interest that may be taken to satisfy the RAOs for the Site;
- Identifying volumes or areas of media to which general response actions might be applied, considering the requirements for protectiveness as identified in the RAOs and the chemical and geological characterization of the Site;
- Identifying and screening the technologies applicable to each medium of interest to eliminate those technologies that cannot be implemented technically at the Site; and,
- Assembling the selected representative technologies into appropriate alternatives.

The remedial alternatives were evaluated based on the following criteria, as outlined DER-10 Section 4.1(e):

- Overall protectiveness of the public health and the environment;
- Compliance with SCGs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume;
- Short-term effectiveness;
- Implementability; and,
- Cost.

As indicated in 6 NYCRR Part 375-1.8(f), other criteria to be considered when evaluating potential remedial alternatives are land use and community acceptance. Land use may be considered in the FFS provided there is reasonable certainty associated with such land use. The community acceptance assessment will be completed after community comments on the PRAP are received. The results of the evaluation are typically considered when a preferred remedial alternative is selected and are typically presented in a Responsiveness Summary. The Responsiveness Summary is part of the ROD amendment process and responds to all comments and questions raised during a public meeting associated with the PRAP, as well as comments received during the associated public comment period.

In addition to assessing each potential remedial alternative against the seven criteria presented above, the detailed analysis of the remedial alternatives presented in this section also includes a detailed technical description of each remedial alternative. In addition, unique engineering aspects (if any) of the physical components of the remedial alternative are discussed.

5.1 Description of Evaluation Criteria

5.1.1 Overall Protectiveness of the Public Health and the Environment

This criterion assesses whether each alternative is protective of human health and the environment. The overall assessment of protection is based on a composite of factors assessed under other evaluation criteria; especially long-term effectiveness and performance, short-term effectiveness, and compliance with SCGs. This evaluation focuses on how a specific alternative achieves protection over time and how Site risks are reduced. The analysis includes how each source of contamination is to be eliminated, reduced, or controlled for each alternative.

5.1.2 Compliance with SCGs

This evaluation criterion assesses how each alternative complies with applicable or relevant and appropriate SCGs, as discussed and identified in Section 3. If an SCG is not met, the basis for one of the four waivers allowed under 6 NYCRR Part 375-1.10(c)(1) is discussed. If an alternative does not meet the SCGs and a waiver is not appropriate or justifiable, it should not be considered further.

5.1.3 Long-term Effectiveness and Permanence

This evaluation criterion addresses the results of a remedial action in terms of its permanence and quantity/nature of waste or residual remaining at the Site after RAOs have been met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the waste or residual compounds remaining in environmental media at the Site and operating systems necessary for the remedy to remain effective. The factors being evaluated include the permanence of the remedial alternative, magnitude of the remaining risk, adequacy of controls used to manage residual waste, and reliability of controls used to manage residual waste.

5.1.4 Reduction of Toxicity, Mobility, or Volume

This evaluation criterion assesses the remedial alternative’s use of the technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous wastes as their principal element. Preference is given to alternatives that eliminate any significant threats at the Site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in the contaminant’s mobility, or reduction of the total volume of contaminated media. This evaluation includes: the amount of the hazardous materials that would be destroyed or treated, the degree of expected reduction in toxicity, mobility, or volume measured as a percentage, the degree in which the treatment would be irreversible, and the type and quantity of treatment residuals that would remain following treatment.

5.1.5 Short-term Effectiveness

This evaluation criterion assesses the effects of the alternative during the construction and implementation phase. Alternatives are evaluated with respect to the effects on human health and the environment during implementation of the remedial action. The aspects evaluated include: protection of the community during remedial actions, environmental impacts as a result of remedial actions, time until the remedial response objectives are achieved, and protection of workers during the remedial action.

5.1.6 Implementability

This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. The evaluation includes: feasibility of construction and operation; the reliability of the technology; the ease of undertaking additional remedial action; monitoring considerations; activities needed to coordinate with other offices or agencies; availability of adequate off-Site treatment, storage, and disposal services; availability of equipment; and the availability of services and materials.

5.1.7 Cost

Cost estimates were prepared and evaluated for each alternative, as presented in Appendix A, and summarized on Table 4. The cost estimates include capital, OM&M, and future capital costs. A cost analysis is performed which includes the following factors: the effective life of the remedial action, the OM&M costs, the duration of the cleanup, the volume of contaminated material, other design parameters, and the discount rate. Building demolition is not included. Cost estimates developed at the detailed analysis of alternatives phase of a feasibility study generally have an expected accuracy range of –30 to +50 percent (USEPA, 2000).

5.1.8 Community Acceptance

This evaluation criterion addresses the public participation program that was followed for the project. The public's comments, concerns and overall perception of the proposed remedial alternative are evaluated in a format that responds to all questions that are raised. For the purposes of this FFS, community acceptance of a proposed remedy for the Crown Dykman Site will be evaluated after the public comments have been received.

5.2 Detailed Evaluation of Alternatives

5.2.1 Alternative RA1; No Further Action

Under the no further action alternative, no additional work will be completed at the Site. This alternative will serve as a baseline for comparison for all other remedial alternatives considered for the Site. This alternative is considered to be ineffective because groundwater contamination would not be remediated.

5.2.1.1 Overall Protectiveness of the Public Health and the Environment

The NFA alternative would be ineffective at remediating or controlling the Site contaminants, and therefore, unprotective of public health or the environment.

5.2.1.2 Compliance with SCGs

SCGs would not be met through the implementation of the NFA alternative. This alternative does not meet the RAOs for the Site.

5.2.1.3 Long-term Effectiveness and Permanence

The NFA alternative would provide minimal long-term protection of sensitive receptors, as it does not remediate the contaminants in groundwater.

5.2.1.4 Reduction of Toxicity, Mobility, or Volume

The NFA does not directly influence the toxicity, mobility, or volume of contaminants within groundwater at the Site. However, over time the concentrations of contaminants may decrease due to natural attenuation.

5.2.1.5 Short-term Effectiveness

There would be no short term impacts due to the implementation of this alternative. This alternative does not actively address groundwater contamination at the Site and would not be effective in the short-term.

5.2.1.6 Implementability

This alternative requires no effort to implement.

5.2.1.7 Cost

There are no costs associated with this alternative.

5.2.2 Alternative RA2; DNAPL Source Area ERH with ISCO

Alternative RA2 includes implementation of thermal source area treatment, followed by ISCO polishing using sodium permanganate in the on-Site, dissolved-phase plume (Figures 11a and 11b). Ex situ treatment of groundwater using air stripping and GAC would be implemented to treat both the dewatering and groundwater extraction for the thermal source area treatment. Soil vapor extraction would be implemented and maintained during source treatment and subsequent ISCO polishing, using an upgraded SSDS with GAC treatment on the system exhaust.

Thermal treatment would consist of one thermal cell implemented beneath the southwestern corner of the Site Building. The ERH thermal system would be implemented around the source area (Figure 11a), which would include thermal probes with temperature sensors surrounding a central dual-phase extraction well to extract heated groundwater and evolved gasses. Extracted groundwater would be treated through the on-Site ex situ treatment system and discharged to the storm sewer. Soil gasses/vapors would be extracted through a soil vapor extraction system installed above the thermal cell and treated with a GAC system before release to the atmosphere. Implementation of the ERH technology would require additional bench-scale and Site testing and analysis to support remedial design.

During ERH activities, groundwater extraction would be used to treat groundwater containing mobilized contaminants within the footprint of the source treatment area. The extraction wells would be piped to an ex situ treatment system for removal of VOCs and other Site constituents using an oil/water separator, air stripper, and GAC system. Treated water would be discharged to the on-Site storm sewer, which may require upgrade as part of the remedy to handle the require flows. Groundwater treatment would be discontinued after ERH treatment was complete, and prior to ISCO implementation in the dissolved-phase plume.

Construction of the on-site downgradient ISCO injection well system would be implemented during source area treatment, but the injection program would not be implemented until source area VOC concentrations were significantly reduced or met Site SCGs. ISCO polishing would utilize a 4-percent sodium permanganate injectate to provide polishing of down-gradient chlorinated VOCs after completion of thermal source treatment. The ISCO program would include installation of injection wells assuming a 10-foot radius of influence (ROI) for each point, which assumes up to 12 permanent injection wells. An injection trailer/system would be installed at the Site, to include mixing tanks, injection manifolds, piping, and mixing equipment.

The oxidant would be injected into the subsurface within the treatment zone, which is shown on Figure 11b, and is bounded by Crown Dykman building, Herb Hill Road, the access road, and the parking area at the east of the property. Groundwater monitoring upgradient, downgradient at the property boundary, and within the treatment area would be required to evaluate the effectiveness of the ISCO injections at reducing contaminant concentrations and protecting downgradient areas from further dissolved-phase plume migration, requiring the installation of additional process monitoring and property boundary monitoring wells.

Since ISCO relies on direct contact between the oxidant solution and the contaminant, the success of the ISCO treatment would be highly dependent on the ability to effectively distribute the oxidant through the treatment area. If such distribution can be achieved, it is anticipated that the ISCO treatment is capable of meeting the RAOs for the Site. Multiple injections are required to sustain the oxidants in the subsurface, commonly 3 to 6 months apart.

As discussed in Section 4.4, an environmental easement, an LTM program, and development and implementation of Site management and soil vapor intrusion mitigation plans would be included in this alterative. Building/property use restrictions and groundwater use restrictions would be placed on the Site property that would require compliance with the approved Site management plan. The Site management plan could mandate the ongoing monitoring, operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. LTM would be implemented as a secondary component of this alternative and would involve periodic sampling and analysis of Site groundwater.

5.2.2.1 Overall Protectiveness of the Public Health and the Environment

RA2 is anticipated to be protective of public health and the environment during the source area treatment phase by reducing contaminant mass and reducing the potential for groundwater contaminant migration off Site. Reduction of additional off-Site contaminant migration would reduce or limit potential exposure of off-Site workers who may come into contact with groundwater during construction activities. In addition, vapor-phase capture during source area treatment would limit exposure of Site workers to soil vapor exposure, if any.

Post-source treatment of dissolved-phase and residual source area groundwater contaminants using ISCO would ultimately limit exposure to potential Site receptors by reducing contaminant levels to below SCGs. Such treatment would also reduce the potential for future contaminant loading into adjacent surface water bodies but limiting or eliminating the flux of contaminant mass off-site, thus reducing the chances of contact with potential environmental receptors in the long term.

5.2.2.2 Compliance with SCGs

Based on an initial assessment of the thermal technology, it is anticipated that RA2 would be capable of reducing source area COC concentrations beneath the southwestern corner of the Site Building. Thermal technology is capable of mobilizing and reducing NAPL and dissolved-phase VOCs in the subsurface in the narrow volume of the source area. However, In the dissolved-phase plume areas, thermal would be less likely to reduce concentrations below SCGs, as there are higher hydraulic gradients and greater heterogeneity in those areas, resulting in greater inefficiency for thermal heating and mobilization of VOCs. Therefore, a subsequent polishing technology (which, in the case of this RA, would be ISCO) may be necessary to reduce residual concentrations of dissolved-phase contaminants in areas adjacent to the source area to below the SCGs, and further mobilize contaminants in recalcitrant areas.

ISCO pilot studies at the Site have demonstrated that injections of sodium permanganate alone within the source area are unlikely to reduce source area concentrations to below SCGs, due to the potential presence of NAPL, and difficulty of adequate contact between the ISCO and COCs. However, Site data suggest that in the absence of a continuing source, sodium permanganate ISCO injections applied as a post-source removal polishing technology could meet SCGs for the Site for chlorinated VOCs.

This alternative is also anticipated to reduce, to the extent practicable, on-Site soil COC concentrations to less than NYSDEC Restricted (Commercial) Soil Cleanup Objectives and on-Site groundwater COC concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values. The application of ISCO in the dissolved-phase plume may initially allow migration of groundwater contaminants off-Site at levels greater than SCGs prior to fully establishing contaminant mass reduction via oxidation over time. However, long-term trends in groundwater leaving the Site would ultimately meet SCG criteria in the absence of a continuing source.

5.2.2.3 Long-term Effectiveness and Permanence

Source area treatment via ERH is anticipated to result in permanent degradation of the chlorinated VOC source area, and removal of mass. However, certain recalcitrant areas could be present in areas with lower permeability or less mobile porosity, resulting in residual mass contribution to dissolved phase concentrations downgradient of the source area. Reduction of residual source and dissolved-phase contaminants in groundwater using ISCO injections may result in some concentration rebound if there is insufficient contact in recalcitrant areas, or if preferential flow paths limit contact between the oxidant and the contaminants. However, long-term treatment with ISCO is anticipated to result in a permanent decrease in chlorinated VOC concentrations to levels below SCGs.

5.2.2.4 Reduction of Toxicity, Mobility, or Volume

Application of ERH within the chlorinated VOC source area is anticipated to significantly reduce the mobility and volume of contaminants in soil and groundwater. Application of extraction wells during source area treatment will capture mobilized dissolved-phase COCs. The toxicity of source area and dissolved-phase contaminants will not be reduced significantly during ERH source area remedial activities. The hazards posed to human health for occupants of the Site will be limited through the source area soil vapor extraction, which will also further reduce contaminant mass. Subsequent polishing with ISCO will reduce the toxicity and volume of contaminants but will be less effective at reducing the mobility of contaminants in groundwater, as oxidant treatment of groundwater contaminants is a function of time and contact.

5.2.2.5 Short-term Effectiveness

Once implemented, this RA would immediately begin removal of contaminants at the Site. Source area treatment via in situ ERH would likely result in effective reduction of source concentrations and removal of contaminant mass during system operation. In addition, this remedy would require substantial pre-design studies, engineering, and local infrastructure enhancements that could delay implementation.

5.2.2.6 Implementability

Implementation of RA2 is anticipated to be moderately difficult. Overall, there would be significant lead-time for permitting and site preparation prior to beginning remedy construction. This RA would require additional bench-scale testing and hydraulic studies to implement. Specific modifications or enhancements to local electrical transmission infrastructure could be necessary to support the thermal system, which would require additional coordination with local utilities and routing of additional utility infrastructure to the Site from the local area. Installation of the ERH equipment and ISCO injection system would require significant modification to current Site features.

5.2.2.7 Cost

The Capital Cost (Year 1) for RA2 is estimated to be approximately $4.1 million (M), with a low-high estimate range of approximately $2.8M to $6.1M (Table A-1, Appendix A). Based on an anticipated operational timeframe of up to four years (Years 2 through 5) for RA2 to meet RAOs for the Site, OM&M costs are estimated to total approximately $4.0M, for a total estimated present net worth (PNW) of approximately $7.6M (Table A-1, Appendix A).

As shown on Table A-1 in Appendix A, Capital Costs (Year 1) for RA2 include costs associated with Site preparation, installation of ex situ groundwater treatment systems, and local routing of a dedicated utility line to the Site for ERH support. Capital costs also include replacement and additional installation of performance monitoring wells. OM&M costs for RA2 include system operation and treatment for COCs and ancillary constituents present in groundwater at the Site, routine maintenance and analytical monitoring of groundwater treatment and overall system performance. OM&M cost estimates assume up to 19 months of source area treatment, with up to eight subsequent post-source treatment ISCO injection rounds; each followed up with up to 6 months of performance monitoring and analysis between injection.

5.2.3 Alternative RA3; DNAPL Source Area ERH with DGR

Alternative RA3 includes implementation of thermal source area treatment, with subsequent implementation of DRG to provide further reduce concentrations of the remaining chlorinated VOCs at the Site (Figures 12a and 12b). Ex situ treatment of groundwater using air stripping and GAC would be implemented to treat the groundwater extraction for the thermal source area treatment. Soil vapor extraction would be implemented during source treatment in support of removal of mobilized soil vapors generated during the ERH remedy.

Groundwater extraction would be implemented on Site to provide reduce on site dissolved COCs. The extraction wells would be piped to an ex situ treatment system that treated to remove VOCs and other Site constituents using an oil/water separator, air stripper, and GAC system. Treated water would be discharged to the on-Site storm sewer, which may require upgrade as part of the remedy to handle the require flows. The dewatering system would be implemented as the dewatering component of the ERH source treatment, then would be expanded as part of the subsequent DGR system, with operation of additional injection and extraction wells after the completion of thermal source treatment. For continued polishing of dissolved-phase COCs.

Thermal treatment would consist of one thermal cell implemented beneath the southwestern corner of the Site Building. The ERH thermal system would be implemented around the source area (Figure 12a), which would include thermal probes with temperature sensors surrounding a central dual-phase extraction well to extract heated groundwater and evolved gasses. Extracted groundwater would be treated through the on-Site ex situ treatment system and discharged to the storm sewer. Soil gases/vapors would be extracted through an expanded sub-slab soil vapor extraction system installed above the thermal cell and treated with a GAC system before release to the atmosphere. Implementation of the ERH technology would require additional bench-scale and Site testing and analysis to support remedial design.

Construction of the DGR system would be concurrent with the ERH system, but the DGR operation would not be fully implemented until source area concentrations were significantly reduced or met Site SCGs. The DGR system would recirculate groundwater from upgradient of the former source area to the dewatering wells near the Site boundary (Figure 12b). The DGR program would include installation of additional upgradient injection wells, the design and location of which would be based on pumping and hydraulic data obtained during pre-design studies and source treatment.

Groundwater monitoring upgradient, downgradient at the property boundary, and within the treatment area would be required to evaluate the effectiveness of the DGR at reducing COC concentrations at the Site, which would require the installation of additional Site boundary monitoring wells.

As discussed in Section 4.4, an environmental easement, an LTM program, and development and implementation of Site management and soil vapor intrusion mitigation plans would be included in this alterative. Building/property use restrictions and groundwater use restrictions would be placed on the Site property that would require compliance with the approved Site management plan. The Site management plan could mandate the ongoing monitoring, operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. LTM would be implemented as a secondary component of this alternative and would involve periodic sampling and analysis of Site groundwater.

5.2.3.1 Overall Protectiveness of the Public Health and the Environment

RA3 is anticipated to be protective of public health and the environment during the source area treatment phase and subsequent down-gradient treatment phase by reducing contaminant mass and reducing the potential for groundwater contaminant migration off Site. Reduction of additional off-Site contaminant migration would reduce or limit potential exposure of off-Site workers who may come into contact with groundwater during construction activities. In addition, vapor-phase capture during source area treatment would limit exposure of Site workers to soil vapor exposure. Limiting downgradient migration of groundwater contaminants would also reduce the potential for future contaminant loading into adjacent surface water bodies, thus reducing the chances of contact with potential environmental receptors.

5.2.3.2 Compliance with SCGs

Based on an initial assessment of the thermal technology, it is anticipated that RA3 would be capable of reducing source area COC concentrations beneath the southwestern corner of the Site Building. Thermal technology is capable of mobilizing and reducing NAPL and dissolved-phase VOCs in the subsurface in the narrow volume of the source area. However, In the dissolved-phase plume areas, thermal would be less likely to reduce concentrations below SCGs, as there are higher hydraulic gradients and greater heterogeneity in those areas, resulting in greater inefficiency for thermal heating and mobilization of VOCs. Therefore, a subsequent polishing technology (which, in the case of this RA, would be DGR) may be necessary to reduce residual concentrations of dissolved-phase contaminants in areas adjacent to the source area to below the SCGs, and further mobilize contaminants in recalcitrant areas.

Once contaminant mass within the source area has been significantly reduced or eliminated, DGR could effectively reduce dissolved-phase contaminant mass over time to levels below SCGs, in addition to providing limited hydraulic control of the remaining plume.

This alternative is anticipated to reduce, to the extent practicable, on-Site soil concentrations to less than NYSDEC Restricted (Commercial) Soil Cleanup Objectives and on-Site groundwater concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values. This alternative is also anticipated to limit the potential for off-Site migration of groundwater COC concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria during both source treatment and subsequent polishing by DGR.

5.2.3.3 Long-term Effectiveness and Permanence

Source area treatment via ERH is anticipated to result in permanent degradation of the chlorinated VOC source area, and removal of mass. Additional permanent mass removal would be expected during DGR. However, certain recalcitrant areas could be established in subsurface zones with lower permeability or less mobile porosity, resulting in residual mass contribution to dissolved phase concentrations at the Site downgradient of the source area. Reduction of residual source and dissolved-phase contaminants in groundwater using some pump-and-treat technologies may result in some concentration rebound if there is insufficient access and connection to preferential flow paths, resulting in back diffusion from stagnant flow areas. Such recalcitrance can occur with DGR as well. However, the flexibility of DGR allows changes in recirculation direction and volume, with the desired effect of limiting stagnant flow and changing flow regime to access recalcitrant areas. This flexibility provides for greater long-term performance and less recalcitrance than with standard groundwater extraction and ex situ treatment technologies.

5.2.3.4 Reduction of Toxicity, Mobility, or Volume

Application of ERH within the chlorinated VOC source area is anticipated to significantly reduce the mobility and volume of contaminants in soil and groundwater. Application of extraction wells during source area treatment will capture mobilized dissolved-phase COCs. The toxicity of source area and dissolved-phase contaminants will not be reduced significantly during ERH source area remedial activities. The hazards posed to human health to future occupants of the Site will be limited through the source area soil vapor extraction, which will also further reduce contaminant mass. Subsequent polishing using DGR will reduce the mobility and volume of dissolved-phase groundwater at the Site.

5.2.3.5 Short-term Effectiveness

Once implemented, this RA would immediately begin removal of contaminants at the Site. Source area treatment via in situ ERH would likely result in effective reduction of source chlorinated VOC concentrations and removal of contaminant mass during system operation. During source treatment, dewatering activities would likely result in a reduction of downgradient migration of COCs. However, this remedy would require extensive pre-design studies, engineering, and local infrastructure enhancements that could delay implementation.

5.2.3.6 Implementability

Implementation of RA3 is anticipated to be moderately difficult. Overall, there would be significant lead-time for permitting and site preparation prior to beginning remedy construction. The RA would require additional bench-scale testing and hydraulic studies to implement. Specific modifications or enhancements to local electrical transmission infrastructure could be necessary to support the thermal system, which would require additional coordination with local utilities and routing of additional utility infrastructure to the Site from the local area. Installation of the ERH equipment and DGR system would require substantial modification to the Site.

5.2.3.7 Cost

The Capital Cost for RA3 (Year 1) is estimated to be approximately $3.5M, with a low-high estimate range of approximately $2.5M to $5.3M (Table A-2, Appendix A). Based on an anticipated operational timeframe of up to six years for RA3 to meet RAOs for the Site (Years 2 through 7), OM&M costs are estimated to total approximately $4.3M, for a total estimated present net worth (PNW) of approximately $6.6M (Table A-2, Appendix A).

As shown on Table A-2 in Appendix A, Capital Costs for RA3 include costs associated with Site preparation, installation of ex situ groundwater treatment systems, and local routing of a dedicated utility line to the Site for ERH support. OM&M costs for RA3 include system operation and treatment for COCs and ancillary constituents present in groundwater at the Site, routine maintenance and analytical monitoring of groundwater treatment and overall system performance. OM&M cost estimates assume up to 19 months of source area treatment, with up to six years of DGR operation and monitoring.

5.2.4 Alternative RA4; DNAPL Source Area Excavation with ISCO

Alternative RA4 includes excavation of the source area, with direct application of ISCO occur during backfilling, followed by ISCO polishing using sodium permanganate within the on-Site, dissolved-phase plume in areas of the Site downgradient of the source area (Figures 13a and 13b). Implementation of the source area excavation would include implementation of excavation dewatering, requiring ex situ treatment of groundwater using air stripping and GAC to treat water the pumped water.

The excavation would include removal of existing Site utilities in preparation for excavation activities. The source area excavation would include the area shown on Figure 13a. The excavation would be shored using suitable temporary shoring techniques. Excavation of the source area up to 15 feet below grade would be monitored with air monitoring equipment and evaluated using confirmatory analytical sampling. Excavated soil would be stockpiled in a protected area for off-Site transportation and disposal at a licensed facility. After excavation was completed, as approved by the NYSDEC, the area would be appropriately backfilled, and the surface would be completed with the application of 12-inch gravel surfacing and demarcation geotextile.

During excavation dewatering, pumping wells would be piped to an ex situ treatment system that treated to remove chlorinated VOCs and other Site constituents using an oil/water separator, air stripper, and liquid- and vapor-phase GAC systems. Treated water would be discharged to the on-Site storm sewer system after applicable analytical testing.

Construction of the on-site ISCO system would be implemented during source area excavation, but the injection program would not be implemented until source area excavation was complete. ISCO polishing would utilize a 4-percent sodium permanganate injectate to provide polishing of downgradient chlorinated VOCs after completion of source area excavation. The ISCO program would include installation of injection wells assuming a 10-foot radius of influence (ROI) for each point, which assumes up to 12 permanent injection wells. An injection trailer/system would be temporarily installed at the Site during each injection round to support ISCO injections, which would include mixing tanks, injection manifolds, piping, and mixing equipment.

The oxidant would be injected into the subsurface within the treatment zone, which is shown on Figure 13b. Groundwater monitoring upgradient, downgradient at the property boundary, and within the treatment area would be required to evaluate the effectiveness of the ISCO injections at reducing contaminant concentrations, which would require the installation of additional process monitoring and site boundary monitoring wells.

Since ISCO relies on direct contact between the oxidant solution and the contaminant, the success of the ISCO treatment would be highly dependent on the ability to effectively distribute the oxidant through the treatment area. If such distribution can be achieved, it is anticipated that the ISCO treatment is capable of meeting the RAOs for the Site. Multiple injections could be required to sustain the oxidants in the subsurface, commonly 3 to 6 months apart.

As discussed in Section 4.4, an environmental easement, an LTM program, and development and implementation of Site management and soil vapor intrusion mitigation plans would be included in this alterative. Building/property use restrictions and groundwater use restrictions would be placed on the Site property that would require compliance with the approved Site management plan. The Site management plan could mandate the ongoing monitoring, operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. LTM would be implemented as a secondary component of this alternative and would involve periodic sampling and analysis of Site groundwater.

5.2.4.1 Overall Protectiveness of the Public Health and the Environment

RA4 is anticipated to be protective of public health and the environment during the source area treatment phase by permanently removing contaminant mass while reducing the potential for groundwater contaminant migration off Site. Reduction of additional off-Site contaminant migration would reduce or limit potential exposure of off-Site workers who may come into contact with groundwater during construction activities. Limiting downgradient migration of groundwater contaminants would also reduce the potential for future contaminant loading into adjacent surface water bodies, thus reducing the chances of contact with potential environmental receptors. Post-source treatment of dissolved-phase and residual source area groundwater contaminants using ISCO would limit exposure to potential Site receptors by reducing contaminant levels to below SCGs.

5.2.4.2 Compliance with SCGs

It is anticipated that RA4 would be capable of substantially removing source area COC concentrations within the source area, providing that the source area is removed to the extent practicable, and subsequent implementation of ISCO is able to contact and mitigate any residual concentrations in the source area. If full removal of the source area is achieved, subsequent polishing with ISCO may not be necessary within the source area itself to attain SCGs within that area but would be necessary to achieve SCGs for the residual dissolved-phase concentrations in groundwater at the Site.

ISCO pilot studies at the Site have demonstrated that injections of sodium permanganate alone within the source area are unlikely to reduce source area concentrations to below SCGs, due to the potential presence of NAPL, and difficulty of adequate contact. However, Site data suggest that in the absence of a continuing source, sodium permanganate ISCO injections applied as a post-source removal polishing technology in dissolved-phase groundwater plume areas at the Site could meet SCGs for chlorinated VOCs.

Alternative RA4 is anticipated to reduce, to the extent practicable, on-Site soil COC concentrations to less than NYSDEC Restricted (Commercial) Soil Cleanup Objectives and on-Site groundwater COC concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values. This alternative is anticipated to limit the potential for off-Site migration of groundwater COC concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values during source removal through dewatering. However, the application of ISCO in the dissolved-phase plume following source removal may initially allow migration of groundwater contaminants off-Site prior to fully establishing contaminant mass reduction and removal via oxidation over time.

5.2.4.3 Long-term Effectiveness and Permanence

Source area removal via excavation is anticipated to result in permanent removal of the remaining chlorinated VOC source area. Additional permanent mass removal would be expected during excavation dewatering. Reduction of residual source and dissolved-phase contaminants in groundwater using ISCO injections may result in some concentration rebound if there is insufficient contact in recalcitrant areas, or if preferential flow paths limit contact between the oxidant and the contaminants. However, long-term treatment with ISCO is anticipated to result in a permanent decrease in contaminant concentrations to levels below SCGs.

5.2.4.4 Reduction of Toxicity, Mobility, or Volume

Excavation and removal of the source area, coupled with the associated excavation dewatering, is anticipated to significantly reduce the mobility and volume of contaminants in soil and groundwater in the dissolved-phase plume. The toxicity of source area and dissolved-phase contaminants would be reduced significantly on-Site after completion of the source removal. Subsequent polishing with ISCO will reduce the toxicity and volume of contaminants but will be less effective at reducing the mobility of contaminants in groundwater, as oxidant treatment of groundwater contaminants is a function of time and contact.

5.2.4.5 Short-term Effectiveness

Once implemented, this RA would provide immediate removal of some contaminants in soil and groundwater at the Site. Source area excavation and removal, coupled with excavation dewatering, would likely result in immediate reduction of contaminant mass in the source area. However, subsequent polishing of dissolved-phase COCs in groundwater would take additional time to reach SCGs, resulting in less short-term effectiveness in mitigating the residual dissolved-phase plume.

5.2.4.6 Implementability

Implementation of RA4 is anticipated to be relatively easy. In the absence of the Site building, the source area will be readily accessible, and there would be sufficient area to support excavation activities. However, the presence of a shallow water table in the source area will make excavation more difficult and will require additional limited hydraulic studies to develop an effective excavation dewatering program. Implementation of the excavation and associated dewatering system and ISCO injection system would require significant modification to Site features. However, once the injection infrastructure is installed, subsequent ISCO introductions would be relatively simple.

5.2.4.7 Cost

The Capital Cost (Year 1) for RA4 is estimated to be approximately $2.7M, with a low-high estimate range of approximately $1.9M to $4.0M (Table A-3, Appendix A). Based on an anticipated operational and monitoring timeframe of up to four years (Years 2 through 5) for RA4 to meet RAOs for the Site, OM&M costs are estimated to total approximately $2.2M, for a total estimated present net worth (PNW) of approximately $4.7M (Table A-3, Appendix A).

As shown on Table A-3 in Appendix A, Capital Costs (Year 1) for RA4 include costs associated with Site preparation, installation of ex situ groundwater treatment systems, and site reconstruction post-excavation. Excavation costs assume an additional 30% volume of excavated soils as a cost contingency factor, due to the uncertainty in the excavation volume necessary to attain standards. Capital costs also include replacement and additional installation of performance monitoring wells. OM&M costs for R4 include dewatering system operation and treatment for COCs and ancillary constituents present in groundwater at the Site during excavation, routine maintenance and analytical monitoring of groundwater treatment and overall system performance. OM&M cost estimates assume that excavation is completed during Year 1, with up to four subsequent post-source treatment ISCO injection rounds; each followed up with up to 6 months of performance monitoring and analysis between injection; ISCO program will be followed by up to two years of additional Site monitoring.

5.2.5 Alternative RA5; DNAPL Source Area Excavation with DGR

Alternative RA5 includes excavation of the chlorinated VOC source area, with subsequent implementation of DRG to provide a polishing treatment of the remaining dissolved-phase groundwater plume (Figures 14a and 14b). Implementation of the source area excavation would include implementation of excavation dewatering, requiring ex situ treatment of groundwater using air stripping and GAC to treat water the pumped water. Some of the dewatering wells would later become components of the DGR system. Ex situ treatment of groundwater during dewatering would subsequently be used to provide treatment for the DGR system.

The excavation would include removal of existing Site utilities in preparation for excavation activities. The source area excavation would include the area shown on Figure 14a. The excavation would be shored using suitable temporary shoring techniques. Excavation of the source area up to 15 feet below grade would be monitored with air monitoring equipment and evaluated using confirmatory analytical sampling. Excavated soil would be stockpiled in a protected area for off-Site transportation and disposal at a licensed facility. After excavation was completed, as approved by the NYSDEC, the area would be appropriately backfilled, and the surface would be completed with the application of 12-inch gravel surfacing and demarcation geotextile.

During excavation dewatering, pumping wells would be piped to an ex situ treatment system that treated to remove chlorinated VOCs and other Site constituents using an oil/water separator, air stripper, and liquid- and vapor-phase GAC systems. Treated water would be discharged to the on-Site storm sewer system after applicable analytical testing. Some of the excavation dewatering wells would subsequently become components of the DGR system.

After excavation of the source area, a, injection header and injection wells would be installed in the former source area, with some of the dewatering wells maintained as the extraction component of the DGR system. The DGR system would recirculate groundwater from the upgradient edge of the former source area to the dewatering wells near the Site boundary (Figure 14b). The design and location of the final DRG components would be based on pumping and hydraulic data obtained during pre-design testing and excavation dewatering pumping.

Groundwater monitoring upgradient, downgradient at the property boundary, and within the treatment area would be required to evaluate the effectiveness of the DGR at reducing residual contaminant concentrations, requiring installation of additional monitoring wells.

As discussed in Section 4.4, an environmental easement, an LTM program, and development and implementation of Site management and soil vapor intrusion mitigation plans would be included in this alterative. Property use restrictions and groundwater use restrictions would be placed on the Site property that would require compliance with the approved Site management plan. The Site management plan could mandate the ongoing monitoring, operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. LTM would be implemented as a secondary component of this alternative and would involve periodic sampling and analysis of Site groundwater.

5.2.5.1 Overall Protectiveness of the Public Health and the Environment

RA5 is anticipated to be protective of public health and the environment during the source area treatment phase by permanently removing contaminant mass while reducing the potential for groundwater contaminant migration off Site during excavation dewatering. Reduction of additional off-Site contaminant migration would reduce or limit potential exposure of off-Site workers who may come into contact with groundwater during construction activities. Limiting downgradient migration of groundwater contaminants would also reduce the potential for future contaminant loading into adjacent surface water bodies, thus reducing the chances of contact with potential environmental receptors. Post-source treatment of dissolved-phase and residual source area groundwater contaminants using DGR would limit exposure to potential Site receptors by reducing contaminant levels to below SCGs, and through hydraulic control of plume migration.

5.2.5.2 Compliance with SCGs

It is anticipated that RA5 would be capable of substantially removing source area COC concentrations beneath the southwestern corner of the Site Building, providing that the source area is removed to the extent practicable, and subsequent implementation of DGR is able to mitigate any residual concentrations in the source area. Once contaminant mass within the source area has been significantly reduced or eliminated, DGR could effectively reduce dissolved-phase COC contaminant mass at the Site over time to levels below SCGs.

Alternative RA5 is anticipated to reduce, to the extent practicable, on-Site soil concentrations to less than NYSDEC Restricted (Commercial) Soil Cleanup Objectives and on-Site groundwater concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values. This alternative is anticipated to limit the potential for off-Site migration of groundwater COC concentrations and other constituents to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values during source removal during excavation dewatering and subsequent polishing of residual COC concentrations through implementation of DGR.

5.2.5.3 Long-term Effectiveness and Permanence

Source area removal via excavation is anticipated to result in permanent removal of the remaining chlorinated VOC source area. Additional permanent mass removal would be expected during excavation dewatering and the subsequent polishing with DGR. Reduction of residual source and dissolved-phase contaminants in groundwater using some pump-and-treat technologies may result in some concentration rebound if there is insufficient access and connection to preferential flow paths, resulting in back diffusion from stagnant flow areas. Such recalcitrance can occur with DGR as well. However, the flexibility of DGR allows changes in recirculation direction and volume, with the desired effect of limiting stagnant flow and changing flow regime to access recalcitrant areas. This flexibility provides for greater long-term performance and less recalcitrance than with standard groundwater extraction and ex situ treatment technologies.

5.2.5.4 Reduction of Toxicity, Mobility, or Volume

Excavation and removal of the source area, coupled with associated excavation dewatering, is anticipated to significantly reduce the mobility and volume of contaminants in soil and groundwater in the dissolved-phase plume. The toxicity of source area and dissolved-phase contaminants would be reduced significantly on the Site after completion of the source removal. Subsequent polishing using DGR with ex situ treatment will reduce the toxicity and volume of contaminants and reduce the potential mobility of contaminants in groundwater.

5.2.5.5 Short-term Effectiveness

Once implemented, RA5 would immediately remove contaminants in soil and groundwater at the Site. Source area excavation and removal, coupled with excavation dewatering, would result in immediate reduction of contaminant mass in the source area. Subsequent implementation of DGR would provide short-term hydraulic control of the plume, along with short-term mass reduction of dissolved-phase contaminants. However, the heterogeneity of the aquifer could cause substantial recalcitrance, limiting the short-term effectiveness of the DGR system and requiring longer-term operation.

5.2.5.6 Implementability

Implementation of RA5 is anticipated to be relatively easy. In the absence of the Site building, the source area will be readily accessible, and there would be sufficient area to support excavation activities. However, the presence of a shallow water table in the source area will make excavation more difficult and will require additional limited hydraulic studies to develop an effective excavation dewatering program. Implementation of the excavation and associated dewatering system, and subsequent DGR system would require significant modification to Site features. However, once the DGR infrastructure is installed, operation of DGR would be relatively simple, although somewhat disruptive to the Site.

5.2.5.7 Cost

The Capital Cost (Year 1) for RA5 is estimated to be approximately $2.8M, with a low-high estimate range of approximately $2.0 M to $4.2M (Table A-4, Appendix A). Based on an anticipated operational and monitoring timeframe of up to six years (Years 2 through 7) for RA5 to meet RAOs for the Site, OM&M costs are estimated to total approximately $2.3M, for a total estimated present net worth (PNW) of approximately $4.6M (Table A-4, Appendix A).

As shown on Table A-4 in Appendix A, Capital Costs (Year 1) for RA5 include costs associated with Site preparation, installation of ex situ groundwater treatment systems, and site reconstruction post-excavation. Excavation costs assume an additional 30% volume of excavated soils as a cost contingency factor, due to the uncertainty in the excavation volume necessary to attain standards. Capital costs also include replacement and additional installation of performance monitoring wells. OM&M costs for RA5 include dewatering system operation and treatment for COCs and ancillary constituents present in groundwater at the Site, routine maintenance and analytical monitoring of groundwater treatment and overall system performance. OM&M cost estimates assume excavation completed during Year 1, with up to six years of DGR operation followed by up to two years of additional Site monitoring.

5.2.6 Alternative RA6; DNAPL Source Area Excavation with DGR and ISCO Polishing

Alternative RA6 includes excavation of the chlorinated VOC source area, with subsequent implementation of DRG to provide a polishing treatment of the remaining dissolved-phase groundwater plume (Figures 15a and 15b). Implementation of the source area excavation would include implementation of excavation dewatering, requiring ex situ treatment of groundwater using air stripping and GAC to treat water the pumped water. Some of the dewatering wells would later become components of the DGR system. Ex situ treatment of groundwater during dewatering would subsequently be used to provide treatment for the DGR system.

The excavation would include removal of existing Site utilities in preparation for excavation activities. The source area excavation would include the area shown on Figure 15a. The excavation would be shored using suitable temporary shoring techniques. Excavation of the source area up to 15 feet below grade would be monitored with air monitoring equipment and evaluated using confirmatory analytical sampling. Excavated soil would be stockpiled in a protected area for off-Site transportation and disposal at a licensed facility. After excavation was completed, as approved by the NYSDEC, the area would be appropriately backfilled, and the surface would be completed with the application of 12-inch gravel surfacing and demarcation geotextile.

During excavation dewatering, pumping wells would be piped to an ex situ treatment system that treated to remove chlorinated VOCs and other Site constituents using an oil/water separator, air stripper, and liquid- and vapor-phase GAC systems. Treated water would be discharged to the on-Site storm sewer system after applicable analytical testing. Some of the excavation dewatering wells would subsequently become components of the DGR system.

After excavation of the source area, a, injection header and injection wells would be installed in the former source area, with some of the dewatering wells maintained as the extraction component of the DGR system. The DGR system would recirculate groundwater from the upgradient edge of the former source area to the dewatering wells near the Site boundary (Figure 14b). The design and location of the final DRG components would be based on pumping and hydraulic data obtained during pre-design testing and excavation dewatering pumping.

A provision for adding an ISCO injection amendment would be included as a component of the DGR injection header within the former source area. The DGR system would provide increased distribution of ISCO within the plume area, and allow for focus on potential recalcitrant areas within the aquifer. An ISCO amendment used in conjunction with DGR would include injections of a 4-percent sodium permanganate solution into the source area injection header system to provide polishing of downgradient chlorinated VOCs. A permanent injection trailer/system would be installed at the Site as part of the overall DGR control and treatment system to support ISCO amendment to the recirculation system. The Injection system would include mixing tanks, injection manifolds, piping, and mixing equipment.

Groundwater monitoring upgradient, downgradient at the property boundary, and within the treatment area would be required to evaluate the effectiveness of the DGR at reducing residual contaminant concentrations, requiring installation of additional monitoring wells.

As discussed in Section 4.4, an environmental easement, an LTM program, and development and implementation of Site management and soil vapor intrusion mitigation plans would be included in this alterative. Property use restrictions and groundwater use restrictions would be placed on the Site property that would require compliance with the approved Site management plan. The Site management plan could mandate the ongoing monitoring, operation and maintenance of engineered mitigation systems, as well as prohibit the use of groundwater. LTM would be implemented as a secondary component of this alternative and would involve periodic sampling and analysis of Site groundwater.

5.2.6.1 Overall Protectiveness of the Public Health and the Environment

RA6 is anticipated to be protective of public health and the environment during the source area treatment phase by permanently removing contaminant mass while reducing the potential for groundwater contaminant migration off Site during excavation dewatering. Reduction of additional off-Site contaminant migration would reduce or limit potential exposure of off-Site workers who may come into contact with groundwater during construction activities. Limiting downgradient migration of groundwater contaminants would also reduce the potential for future contaminant loading into adjacent surface water bodies, thus reducing the chances of contact with potential environmental receptors. Post-source treatment of dissolved-phase and residual source area groundwater contaminants using DGR would limit exposure to potential Site receptors by reducing contaminant levels to below SCGs, and through hydraulic control of plume migration. The use of ISCO amendments coupled with DGR allows for further polishing within the source area if residual source material remains after excavation.

5.2.6.2 Compliance with SCGs

It is anticipated that RA6 would be capable of substantially removing source area COC concentrations within the source area, providing that the source area is removed to the extent practicable, and subsequent implementation of DGR with an ISCO amendment is able to mitigate any residual concentrations in the source area. Subsequent ISCO applications within source area would complement DGR polishing. Previous Site investigations have suggested that, once contaminant mass within the source area has been significantly reduced or eliminated, ISCO could effectively reduce dissolved-phase COC contaminant mass at the Site over time to levels below SCGs. When coupled with DGR, the resultant improved contact between the oxidant and the COCs may further reduce overall remedial timeframes.

This alternative is also anticipated to reduce, to the extent practicable, on-Site soil COC concentrations to less than NYSDEC Restricted (Commercial) Soil Cleanup Objectives and on-Site groundwater COC concentrations to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values. This alternative is anticipated to limit the potential for off-Site migration of groundwater COC concentrations and other constituents to less than NYSDEC Class GA Ambient Water Quality Criteria or guidance values during source removal through use of excavation dewatering and subsequent implementation of ISCO and DGR.

5.2.6.3 Long-term Effectiveness and Permanence

Source area excavation is anticipated to result in permanent removal of the remaining chlorinated VOC source area. Additional permanent mass removal would be expected during excavation dewatering and subsequent DGR operation with ISCO amendment. Reduction of residual source and dissolved-phase contaminants in groundwater using DGR may result in some concentration rebound if there is insufficient access and connection to preferential flow paths, resulting in back diffusion from stagnant flow areas. However, the flexibility of DGR allows changes in recirculation direction and volume, with the desired effect of limiting stagnant flow and changing flow regime to access recalcitrant areas. In addition, the strategic application of ISCO may also enhance oxidant application and contact in recalcitrant areas, further limiting rebounding effects.

5.2.6.4 Reduction of Toxicity, Mobility, or Volume

Excavation and removal of the source area, coupled with the associated excavation dewatering, is anticipated to significantly reduce the mobility and volume of contaminants in soil and groundwater in the dissolved-phase groundwater plume. The toxicity of source area and dissolved-phase contaminants would be reduced significantly on the Site after completion of the source removal. Subsequent polishing using DGR and ISCO will reduce the toxicity and volume of contaminants and reduce the mobility of contaminants in groundwater.

5.2.6.5 Short-term Effectiveness

Once implemented, this RA would immediately remove some contaminants at the Site. Source area excavation and removal, coupled with excavation dewatering, would result in immediate reduction of contaminant mass in the source area. Based on past ISCO pilot observations, application of ISCO within the source area would likely see substantial short-term reductions of COCs in the dissolved-phase plume. Coupled with DGR, the ISCO amendment application could be controlled and directed to enhance short-term reductions.

5.2.6.6 Implementability

Implementation of RA6 is anticipated to be moderately difficult. In the absence of the Site building, the source area will be readily accessible, and there would be sufficient area to support excavation activities. However, the presence of a shallow water table in the source area will make excavation more difficult, and will require additional limited hydraulic studies to develop an effective excavation dewatering program. Implementation of the excavation and associated dewatering system, and subsequent DGR system would require significant modification to Site features and disruption to the site. However, once the injection infrastructure is installed, operation of DGR and subsequent ISCO introductions would be relatively simple.

5.2.6.7 Cost

The Capital Cost (Year 1) for RA6 is estimated to be approximately $2.9M, with a low-high estimate range of approximately $2.0M to $4.3M (Table A-5, Appendix A). Based on an anticipated operational and monitoring timeframe of up to four years (Years 2 through 5) for RA6 to meet RAOs for the Site, OM&M costs are estimated to total approximately $2.0M, for a total estimated present net worth (PNW) of approximately $4.8M (Table A-5, Appendix A).

As shown on Table A-5 in Appendix A, Capital Costs (Year 1) for RA6 include costs associated with Site preparation, installation of ex situ groundwater treatment systems, and site reconstruction post-excavation. Excavation costs assume an additional 30% volume of excavated soils as a cost contingency factor, due to the uncertainty in the excavation volume necessary to attain standards. Capital costs also include replacement and additional installation of performance monitoring wells. OM&M costs for RA6 include dewatering system operation and treatment for COCs and ancillary constituents present in groundwater at the Site , four injection events over 2 years at two injection wells within the source area, routine maintenance and analytical monitoring of groundwater treatment and overall system performance. OM&M cost estimates assume excavation completed during Year 1, with up to four years of DGR operation followed by up to two years of additional Site monitoring.

6 COMPARISON OF ALTERNATIVES

Five of the six remedial alternatives summarized in Section 4.4.2 and evaluated in Section 5.2 are “active remedial alternatives” (RA2, RA3, RA4, RA5, and RA6) and are evaluated below relative to each other and the criteria summarized in Section 5.1. While RA1 was retained for evaluation to facilitate the comparison of the other remedial alternatives, it involves no monitoring, institutional controls, or remediation. RA1 requires no costs or effort to implement and would not be protective of human health and the environment, would not be in compliance with SCGs, would not be effective in the short- or long-term, and would not reduce the toxicity, mobility or volume of the dissolved-phase chlorinated VOC plume. Therefore, as RA1 would not treat the dissolved-phase VOC plume, this alternative is not evaluated further in this section under each separate criterion but serves as a baseline alternative.

6.1 Overall Protection of Human Health and the Environment

All five of the active remedial alternatives (RA2, RA3, RA3, RA5, and RA6) are anticipated to be protective of human health and the environment with respect to chlorinated VOC contact with potential human receptors on-Site and off-Site at adjacent properties (primarily construction workers performing construction tasks on adjacent sites), and to potential environmental receptors in adjacent water bodies receiving groundwater. The three RAs that include dewatering during source treatment and active water recirculation as polishing of the dissolved-phase contaminant plume may be harder to implement compared to. RA2 and RA4 which include pilot-study proven ISCO as a post-source treatment/removal component.

The source area excavation proposed in RA4, RA5 and RA6 would potentially result in a more complete removal of the chlorinated VOC source than thermal treatment (RA2 and RA3), resulting in less residual contaminant mass contributing to potential soil vapor issues, and less dissolved-phase mass. Therefore, source removal through excavation would likely be more protective of human health and potential environmental receptors. Based on this, it is anticipated that RA4, which includes source removal through excavation combined with on-site polishing by ISCO, or RA6 which consists of RA5 with additional post-excavation source zone treatment through ISCO and DGR would likely be the most protective of human health and the environment, due to faster and more complete source removal, coupled with continued reduction of the dissolved-phase groundwater plume at the Site, with less anticipated concentration rebound.

6.2 Compliance with SCGs

All five of the active remedial alternatives (RA2, RA3, RA4, RA5, and RA6) are anticipated to meet SCGs for the Site, as they include source treatment or removal coupled with treatment and polishing of dissolved-phase contaminants in groundwater to attain SCGs. Without considering remedial timeframe, which is evaluated in over long-term and short-term timeframes in Sections 6.3 and 6.5, respectively, all active remedies would be equally expected to meet SCGs.

6.3 Long-Term Effectiveness and Permanence

Active remedial alternatives using source removal (e.g.,RA4, RA5, and RA6) would be more effective in the long term that those using ERH (RA2 and RA3), as there is more certainty associated with source removal versus in situ treatment, and source removal would likely result in less remaining residual source. Limiting the amount of residual source or residual dissolved-phase contaminants remaining within the source area would result in greater long-term performance and treatment permanence, as there would be less chance for rebound of contaminant concentrations post-treatment. Source excavation is a more permanent remedy, as removal is more certain, and there is less expected residual contamination left in the subsurface.

Dissolved-phase groundwater plume treatment via DGR (RA3, RA5, and RA6) is anticipated to have similar long-term effectiveness and permanence, as both DGR and ISCO are focused on zones with greater mobile porosity and preferential flow. However, purely ex situ treatment options (RA3 and RA5) can result in longer remedial timeframes and less permanence, as there is greater potential that contaminant mass will remain in recalcitrant areas of the aquifer, or will remain sorbed to aquifer matric materials, resulting in back diffusion and contaminant rebound post-treatment. In situ application of ISCO as a primary treatment (RA4) or as an amendment coupled with recirculation (RA6) can be more effective in reaching recalcitrant areas and destroying sorbed contaminant mass in situ, potentially resulting in less contaminant rebound post-treatment.

Therefore, while all active alternatives are considered to have acceptable long-term effectiveness and permanence, RA6 would likely have the greatest comparative long-term effectiveness and permanence that the other active alternatives, as it allows for flexibility in future polishing of residual chlorinated VOCs in the source area through ISCO application and DGR. RA4 would likely be the next most effective alternative in those respects.

6.4 Reduction of Toxicity, Mobility, or Volume

All remedial alternatives (RA2, RA3, RA4, RA5, and RA6) are anticipated to be effective at reducing toxicity, mobility, and volume of groundwater contaminants within the source area and areas of the Site immediately downgradient of the source area. However, source area removal (RA4, RA5 and RA6) would likely be more effective at reducing or eliminating overall contaminant mass, as excavation coupled with dewatering and ex situ treatment would provide removal of both contaminant source and dissolved-phase mass. Excavation dewatering in conjunction with subsequent DGR (RA5 and RA6) would further reduce the overall mobility of contaminants in groundwater off-Site and outside of the source area via hydraulic control. Treatment by ISCO has been shown to be effective in reducing the volume and toxicity of contaminants at the Site through numerous field pilot studies. However, ISCO alone will not immediately reduce the mobility of contaminants that have not come into contact with it in the subsurface.

Thermal treatment through ERH (RA2 and RA3) would, by design, increase contaminant mobility and allow greater removal of contaminant mass from the source area during treatment. Active liquid- and vapor-phase removal and treatment during thermal treatment would, however, limit contaminant mass migration from the source treatment area. However, ERH would likely be less effective at reducing the overall volume of contaminants in the source area, as in situ treatment may result in more remaining residual contaminants within the source area than physical removal via excavation.

The changes in hydraulic gradient induced though DGR (RA3, RA5, and RA6) may result in greater removal of contaminants mass during the short term but may be limited in long-term performance once easily-accessible and mobile mass has been removed from the aquifer. However, the strategic application of ISCO within the excavation footprint (RA2, RA4 and RA6) could result in better long-term reduction in residual chlorinated VOC mass from recalcitrant areas within the aquifer if it can diffuse into lower permeability zones and make sufficient contract with mass in those areas.

6.5 Short-Term Effectiveness

Remedial alternatives that include excavation (RA4, RA5, and RA6) would be most effective in the short term, once implemented compared to in situ source treatment via ERH (RA2 and RA3). Excavation dewatering would likely result in immediate reduction and removal of contaminant mass in the source area in the short-term. Implementation of ERH (RA2 and RA3) would result in reduction of source area dissolved-phase contaminants via liquid-phase extraction. However, excavation of the source area would result in faster removal of the contributing source, and therefore would be more effective in the short term for both source area treatment and subsequent dissolved-phase treatment. Physical removal takes less time and is more certain that in situ source treatment.

Once the source area is removed, polishing and treatment of residual dissolved-phase contaminants would likely show the greatest short-term decreases through a combination of flushing enhanced with ISCO (RA6). The use of DGR, either alone (RA5) or coupled with ISCO (RA6) in the former source area and adjacent plume areas would provide both hydraulic control of the plume and both removal of mass and in situ destruction of residual mass. Previous site studies have shown that ISCO alone, in the absence of a source (RA4), would also be effective in creating short-term mass reduction in the aquifer.

Therefore, RA6 would likely be the most effective alternative to advance remedial goals for the site in the short-term, but RA4 and RA5 would also have substantial short-term effectiveness. Excavation of the source area coupled with source area ISCO and/or DGR to treat remaining dissolved-phase contaminants in groundwater would likely demonstrate the greatest short-term reduction in contaminants after implementation.

6.6 Implementability

Alternatives involving the use of in situ thermal source treatment (RA2 and RA3) would be moderately difficult to implement at the Site. Installation of the necessary groundwater and vapor-phase treatment systems would take up significant space at the Site and would require significant modification electrical distribution to the Site. There would also be significant bench-scale and field studies required to complete the design of an ERH system. Implementation of ERH would be marginally less disruptive to Site activities than excavation-based alternatives, however.

In the absence of the Site building, excavation of the source area (RA4, RA5, and RA6) would be relatively easy to implement at the Site. There is sufficient area to move and stage equipment, stage and stockpile soils for disposal, and control the excavation area. However, the presence of a shallow water table in the source area adds some difficulty, and will require excavation dewatering and accompanying treatment. During excavation and subsequent remedial construction, much of the site will be unavailable and inaccessible.

Implementation of post-removal technologies involving DGR (RA3, RA5 and RA6) would be more difficult, and would have a larger site footprint than those involving ISCO application. In addition to wells, DGR would require complex buried conveyance structures, control systems, treatment systems, and injections permanently installed at the Site for the duration of treatment. In the case of DGR only options, the longer remedial timeframes mean that such infrastructure will limit the full use of the property for longer. Options involving only ISCO polishing post-removal (RA2 and RA4) would likely consist only of injection wells, with a temporary, trailerable injection system capable of being maintained off-site. Given the long duration between injection events, this would result in the site having more accessibility and less limitations to use.

6.7 Cost

Based on the estimated conceptual-level costs provided in Appendix A, which are also summarized on Table 4, remedial alternatives that include ERH are the most expensive (PNW of $7.6M and $6.6M for RA2 and RA3, respectively).   RA5 would likely be the least expensive alternatives (PNW of approximately $4.6M). RA4 and RA6 costs are slightly higher than RA5. Capital costs for all five active remedial alternatives were generally similar, ranging from approximately $2.6M (RA4) to $4.0M (RA2).

7 REFERENCES

Arcadis, 2018. “Supplemental Pre-Design Summary Report (DRAFT).” Crown Dykman Site, Glen Cove, New York; Arcadis CE, Inc., for: New York State Department of Environmental Conservation, Division of Environmental Remediation, March 2018.

Arcadis/Malcolm Pirnie, 2014. “Pre-Design Investigation Report (DRAFT).” Crown Dykman Site, Glen Cove, New York; Arcadis/Malcolm Pirnie, Inc., for: New York State Department of Environmental Conservation, Division of Environmental Remediation, October 2014.

Arcadis/Malcolm Pirnie, 2012a. “In-situ Chemical Oxidation Pilot Test Work Plan.” Crown Dykman Site, Glen Cove, New York; Arcadis/Malcolm Pirnie, Inc., for: New York State Department of Environmental Conservation, Division of Environmental Remediation, January 2012.

Arcadis/Malcolm Pirnie, 2012b. “Chemical Oxidation Pilot Study Summary (DRAFT).” Crown Dykman Site, Glen Cove, New York; Arcadis/Malcolm Pirnie, Inc., for: New York State Department of Environmental Conservation, Division of Environmental Remediation, August 2012.

Beyke, G., and Fleming, D. 2005. *In Situ Thermal Remediation of DNAPL and LNAPL Using Electrical Resistance Heating*. In: Remediation, Summer 2005. Pages 5-22.

EEA, Inc., 1991. “Revised Work Plan for Site Investigation and Remediation at 60 Herb Hill Road, Glen Cove, New York.” Energy and Environmental Analysts, Inc., 1991.

EEA, 1996. “Remedial Investigation/ Feasibility Study (RI/FS).” (Crown Dykman Site, Glen Cove, New York); Energy and Environmental Analysts, Inc., 1996.

EEA, 1997a, “Site Investigation Prior to Performing Interim Remediation at the Crown Dykman Site, Glen Cove, New York.” (Crown Dykman Site, Glen Cove, New York); Energy and Environmental Analysts, Inc., 1997.

EEA, 1997b, “Results of the Remedial Investigation at the Crown Dykman Site, Glen Cove, New York.” (Crown Dykman Site, Glen Cove, New York); Energy and Environmental Analysts, Inc., 1997.

EEA, 1999, “Remedial Investigation/ Feasibility Study (RI/FS).” (Crown Dykman Site, Glen Cove, New York); Energy and Environmental Analysts, Inc., 1999.

EEA, 2000, “Results of the Interim Remediation at the Crown Dykman Site.” (Crown Dykman Site, Glen Cove, New York); Energy and Environmental Analysts, Inc., 2000.

Kilburn, C., 1979. “Hydrogeology of the Town of North Hempstead, Nassau County, Long Island, New York”: Long Island Water Resources Bulletin 12, 87 p., scale approx.1:107,000.

Kilburn, C., and Krulikas, R.K., 1987. “Hydrogeology and groundwater quality of the northern part of the Town of Oyster Bay, Nassau County, Long Island, in 1980”: U.S. Geological Survey Water-Resources Investigations Report 85–4051, 61pp.

Malcolm Pirnie, 2006. “Pre-project Management Work Plan Investigation Results” – Crown Dykman Site (Site #1-30-054), Glen Cove, New York. Malcolm Pirnie, Inc., September 2006.

Malcolm Pirnie, 2009a. Remedial Investigation Report – Crown Dykman Site (Site #1-30-054), Glen Cove, New York. Malcolm Pirnie, Inc., December 2009.

Malcolm Pirnie, 2009b. Feasibility Study – Crown Dykman Site (Site #1-30-054), Glen Cove, New York. Malcolm Pirnie, Inc., December 2009.

NYSDEC 1990. *Selection of Remedial Actions at Inactive Hazardous Waste Sites*. NYSDEC Division of Hazardous Waste Remediation (HWR), Technical and Administrative Guidance Memorandum (TAGM) (TAGM HWR-4030). May 15, 1990.

NYSDEC, 2002. "Draft DER-10 Technical Guidance for Site Investigation and Remediation." New York State Department of Environmental Conservation, Division of Environmental Remediation. December 2002.

NYSDEC, 2007. "DER-15 NYSDEC Program Policy: Presumptive/Proven Remedial Technologies." New York State Department of Environmental Conservation, Division of Environmental Remediation. February 27, 2007.

Smolensky, D.A., Buxton, H.T., and Shernoff, K., 1989. "Hydrologic framework of Long Island, New York." U.S. Geol. Surv. hydrologic investigation atlas, 1989.

USEPA, 1988a. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (Interim Final), EPA/540/G-89/004; October 1988.

USEPA. 1988b. *Technology Screening Guide for Treatment of CERCLA Soils and Sludges*, EPA OSWER, Washington, DC; EPA/540/2-88/004; September 1988.

USEPA, 1995. *Soil Vapor Extraction (SVE) Enhancement Technology Resource Guide*, EPA OSWER, Washington, DC; EPA/542/K-95/003; October 1995.

USEPA, 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*. USEPA OSWER Guidance Document 540-R-00-002; July 2000.

Walden, 2006. "On-Site Source Area Removal Interim Remedial Measure (IRM) Report." (Crown Dykman Site, Glen Cove, New York); Walden Environmental Engineering, PLLC. June 2006.

Weston, 1997. "Final Site Inspection Report." (Crown Dykman Site, Glen Cove, New York); Roy F. Weston, Inc., 1997.

TABLES

Table 1.

EVALUATION OF POTENTIAL SCGs

Crown Dykman Site

(NYSDEC Site No.130054)

Glen Cove, New York

Medium/Location/Action	Citation	Requirements	Comments	Potential SCG
Potential chemical-specific SCGs				
Ground water	6 NYCRR 703 - Class GA ground water quality standards	Promulgated state regulation that requires that fresh groundwaters of the state must attain Class GA standards	Potentially applicable to site groundwater.	Yes
Indoor Air	NYSDOH - Guidance for Evaluating Soil Vapor Intrusion	Guidance that provides action levels for mitigation of indoor air influences	Potentially applicable to all occupied structures affected soil vapor intrusion as a result of the CVOC Source and dissolve-phase CVOC plume.	Yes
Soil	NYSDEC 6 NYCRR Part 375-2 Inactive Hazardous Waste Disposal Site Remedial Program	Regulation that provides guidance for soil cleanup objectives for various property uses.	Potentially applicable to site soil.	Yes
Potential location-specific SCGs				
Wetlands	6 NYCRR 633 - Freshwater wetland permit requirements	Actions occurring in a designated freshwater wetland (within 100 ft) must be approved by NYSDEC of its designee. Activities occurring adjacent to freshwater wetlands must: be compatible with preservation, protection, and conservation of wetlands and benefits; result in no more than insubstantial degradation to or loss of any part of the wetland; and be compatible with public health and welfare.	Not applicable or relevant and appropriate. No wetlands within 100 feet of the Site.	No
	Executive Order 11990 - Protection of Wetlands	Activities occurring in wetlands must avoid, to the extent possible, the long- and short-term adverse impacts associated with the destruction or modification of wetlands. The procedures also require USEPA to avoid direct or indirect support of new construction in wetlands wherever there are practicable alternatives or minimal potential harm to wetlands when there are no practicable alternatives.	Not applicable or relevant and appropriate. No wetlands within 100 feet of the Site.	No
100-year flood plain	6 NYCRR 373-2.2 - Location standards for hazardous waste treatment, storage, and disposal facilities - 100-yr floodplain	Hazardous waste treatment, storage, or disposal facilities located in a 100-yr floodplain must be designed, constructed, operated and maintained to prevent washout of hazardous waste during a 100-yr flood.	Not applicable or relevant and appropriate. Site is not located in the 100-year floodplain.	No
	Executive Order 11988 - Floodplain Management	EPA is required to conduct activities to avoid, to the extent possible, the long- and short- term adverse impacts associated with the occupation or modification of floodplain. The procedures also require EPA to avoid direct or indirect support of floodplain development wherever there are practicable alternatives and minimize potential harm to floodplains when there are no practicable alternatives..	Not applicable or relevant and appropriate. Site is not located in the 100-year floodplain.	No
Within 61 meters (200 ft) of a fault displaced in Holocene time	40 CFR Part 264.18	New treatment, storage, or disposal of hazardous waste is not allowed.	Not applicable or relevant and appropriate. Site is not located within 200 ft of a fault displaced in Holocene time, as listed in 40 CFR 264 Appendix VI.	No
River or stream	16 USC 661 - Fish and Wildlife Coordination Act	Required protection of fish and wildlife in a stream when performing activities that modify a stream or river.	Not applicable or relevant and appropriate. No modification to river or stream .	No
Habitat of an endangered or threatened species	6 NYCRR 182	Provides requirements to minimize damage to habitat of an endangered species.	Not applicable or relevant and appropriate. No habitat of endangered species identified at the Site.	No

Table 1.

EVALUATION OF POTENTIAL SCGs

Crown Dykman Site

(NYSDEC Site No.130054)

Glen Cove, New York

Medium/Location/Action	Citation	Requirements	Comments	Potential SCG
Habitat of an endangered or threatened species	Endangered Species Act	Provides a means for conserving various species of fish, wildlife, and plants that are threatened with extinction.	Not applicable or relevant and appropriate. No endangered species identified at the Site.	No
Historical property or district	National Historic Preservation Act	Remedial actions are required to account for the effects of remedial activities on any historic properties included on or eligible for inclusion on the National Register of Historic Places.	Not applicable or relevant and appropriate. Site not identified as a historic property.	No
Potential action-specific SCGs				
Treatment actions	6 NYCRR 373- Hazardous waste management facilities	Provides requirements for managing hazardous wastes.	Not applicable. No hazardous waste anticipated to be produced.	No
Construction	29 CFR Part 1910 - Occupational Safety and Health Standards - Hazardous Waste Operations and Emergency Response	Remedial activities must be in accordance with applicable OSHA requirements.	Applicable for construction and monitoring phase of remediation.	Yes
	29 CFR Part 1926 - Safety and Health Regulations for Construction	Remedial construction activities must be in accordance with applicable OSHA requirements.	Applicable for construction and monitoring phase of remediation.	Yes
Transportation	6 NYCRR 364 - Waste Transporter Permits	Hazardous waste transport must be conducted by a hauler permitted under 6 NYCRR 364.	Potentially applicable for treatment residuals.	Yes
	6 NYCRR Part 372- Hazardous Waste Manifest System and Related Standards for Generators, Transporters, and Facilities	Substantive hazardous waste generator and transportation requirements must be met when hazardous waste is generated for disposal. Generator requirements include obtaining an EPA Identification Number and manifesting hazardous waste for disposal.	Potentially applicable for treatment residuals.	Yes
	49 CFR 172-174 and 177-179 - Department of Transportation Regulations	Hazardous waste transport to offsite disposal facilities must be conducted in accordance with applicable DOT requirements.	Potentially applicable for treatment residuals.	Yes
Generation of air emissions	NYS Air Guide 1	Provides annual guideline concentrations (AGCs) and short-term guideline concentrations (SGCs) for specific chemicals. These are property boundary limitations that would result in no adverse health effects.	Potentially applicable for treatment residuals.	Yes
	NYS TAGM 4031- Dust Suppressing and Particle Monitoring at Inactive Hazardous Waste Disposal Sites	Provides limitations on dust emissions.	Potentially applicable. Dust emissions may be anticipated depending on remedy selected.	Yes
Construction storm water management	NYSDEC General permit for storm water discharges associated with construction activities. Pursuant to Article 17 Titles 7 and 8 and Article 70 of the Environmental Conservation Law.	The regulation prohibits discharge of materials other than storm water and all discharges that contain hazardous substance in excess of reportable quantities established by 40 CFR 117.3 or 40 CFR 302.4, unless a separate NPDES permit has been issued to regulate those discharges. A permit must be acquired if activities involve the disturbance of 5 acres or more. If the project is covered under the general permit, the following are required: development and implementation of a monitoring program; all records must be retained for a period of at least 3 years after construction is complete.	Potentially applicable for discharge of extracted groundwater after treatment.	Yes
Underground Injection	40 CFR 144 and 146 USEPA Underground Injection Control Regulations	This regulation sets forth minimum requirements for the UIC program promulgated under Part C of the Safe Drinking Water Act and describes the technical standards to follow when implementing the UIC program.	Applicable for the installation of injection wells.	Yes

SCG - site cleanup goal

Table 2. Summary of Preliminary Technology Screening
DRAFT Focused Feasibility Study Report - Crown Dykman (Site # 130054); City of Glen Cove, New York

GRA/ Technology	Technology Process Option	Preliminary Screening Criteria						Retained for Remedy Development?		Summary
		Effectiveness		Implementability		Relative Cost				
		DNAPL Source Area	Dissolved-phase Plume	DNAPL Source Area	Dissolved-phase Plume	DNAPL Source Area	Dissolved-phase Plume	DNAPL Source Area	Dissolved-phase Plume	
No Further Action	---	LOW	LOW	EASY	EASY	LOW	LOW	YES	YES	Consistent with NCP and USEPA guidance documents, the No Further Action alternative must be developed and examined as a baseline to which other remedial alternatives are compared.
Institutional Controls	Environmental Easments	LOW TO MODERATE	LOW TO MODERATE	EASY	EASY	LOW	LOW	YES (component)	YES (component)	Institutional controls would not treat, contain, or remove impacted subsurface soil, but would support a reduced potential for contact with, inhalation or ingestion of, constituents of interest. Institutional Controls will not be considered further as a primary remedial alternative for the site. Institutional controls could enhance the effectiveness and implementability of other technologies/ process options. Institutional Controls will be further considered as a component of the selected remedy.
Long Term Monitoring	---	LOW	MODERATE	EASY	EASY	LOW	LOW	YES (component)	YES (component)	Based on observed concentrations of CVOCs, the RAOs for the site cannot be met by LTM alone in a reasonable time period. Evaluation of natural attenuation processes by LTM will not be considered further as a primary remedial alternative for the site. Evaluation of natural attenuation by LTM will be considered as a secondary or polishing remedial technology component for the DNAPL source area and dissolved-phase plume in the selected remedy.
In Situ Treatment	Thermal Desorption/ERH	HIGH	HIGH	EASY	EASY	MODERATE TO HIGH	MODERATE TO HIGH	YES	NO	ERH may be effective at mobilization and removal of dissolved-phase constituents in the fine-grained sediments present at the Site. ERH will also enhance dissolution and mobilization of DNAPL in the source zone. Therefore ERH is carried forward for further consideration as a remedial option.
	ISCO (Sodium Permanganate)	LOW	HIGH	EASY	EASY	MODERATE TO HIGH	MODERATE TO HIGH	NO	YES	While ISCO has some drawbacks related to the difficulty of achieving contaminant contact in fine-grained sediments associated with heterogeneous aquifers, ISCO using sodium permanganate has demonstrated performance at the Site. Therefore, ISCO using sodium permanganate is retained as a potential remedial option for the dissolved-phase plume. Due to the presence of DNAPL and the potential technical difficulties and drawbacks associated with ISCO injections in a DNAPL source area, ISCO is not retained as a potential remedial option for the DNAPL source zone. However, ISCO could be used as a post-remedial polishing option for dissolved-phase contaminants in this area.
	Biostimulation/ERD	MODERATE	LOW	EASY	EASY	MODERATE TO HIGH	MODERATE	NO	NO	While ERD has been successfully applied for in situ treatment of dissolved chlorinated solvents, in situ treatment of DNAPL is more challenging due to contaminant toxicity, low pH, and challenges in effectively delivering electron donor. Therefore, ERD will not be considered as a remedial option for the DNAPL source zone. For the dissolved-phase plume, anaerobic conditions required for heavily chlorinated compounds have been observed in the areas impacted by the presence of petroleum compounds (Malcolm Pirnie, 2009a). However, these conditions are not prevalent throughout the site, and recent ISCO applications have turned conditions aerobic in pilot program areas. Given the uncertainty associated with maintaining an effective distribution of microbes throughout the site, the effectiveness of ERD to support dissolved-phase reduction in a reasonable timeframe is also uncertain. Therefore, ERD is not retained as a remedial option for the Site.
	AS/SVE	LOW	LOW	SOMEWHAT DIFFICULT	SOMEWHAT DIFFICULT	MODERATE TO HIGH	HIGH	NO	NO	Air sparging and soil vapor extraction will not be considered further because of the heterogeneous nature of the aquifer. Portions of the contaminated aquifer are semi-confined, making this technology ineffective.
	ZVI Injection	LOW	LOW	SOMEWHAT DIFFICULT	VERY DIFFICULT	HIGH	VERY HIGH	NO	NO	Experience with this technology since completion of the original 2009 FS has shown that it is difficult to inject sufficient mass, and to provide sufficient contaminant contact, in heterogeneous aquifers similar to that at the Crown Dykman Site. It is unlikely that sufficient ZVI mass could be delivered effectively within the DNAPL source area, and would likely be cost prohibitive and ineffective in the dissolved-phase plume. Therefore ZVI injection is not carried forward as a potential remedial alternative for the Site.

Table 2. Summary of Preliminary Technology Screening
DRAFT Focused Feasibility Study Report - Crown Dykman (Site # 130054); City of Glen Cove, New York

GRA/ Technology	Technology Process Option	Preliminary Screening Criteria						Retained for Remedy Development?		Summary
		Effectiveness		Implementability		Relative Cost				
		DNAPL Source Area	Dissolved-phase Plume	DNAPL Source Area	Dissolved-phase Plume	DNAPL Source Area	Dissolved-phase Plume	DNAPL Source Area	Dissolved-phase Plume	
Removal Measures	Excavation	HIGH	N/A	SOMEWHAT DIFFICULT	N/A	VERY HIGH	N/A	YES	N/A	Excavation of subsurface soil was retained for further evaluation as a remedial option for the DNAPL source area. While technically challenging and having a relatively high cost, this technology type and process option is a proven process for removing impacted material with a high degree of certainty. In addition, dewatering operations would in effect act as additional treatment of dissolved-phase contaminants while the DNAPL source is being removed, enhancing the remedial effectiveness. Excavation is not applicable to the dissolved-phase plume, and is only considered a source area remedial option.
	Groundwater Extraction	LOW	MODERATE	SOMEWHAT DIFFICULT	SOMEWHAT DIFFICULT	MODERATE TO HIGH	HIGH	NO	YES (component)	Groundwater extraction is not carried forward as a viable stand-alone remedial option for the Site, because it is not cost effective compared to other technologies and implementation of the groundwater extraction would require significant operation and maintenance effort over an extended time period. This technology was not carried forward in the 2009 FS, and there has not been a significant change in site conditions or the distribution of contaminants that would make groundwater extraction an effective remedial option. Groundwater extraction is retained as a component of a directed groundwater recirculation (DGR) and as a dewatering component during excavation, which would utilize groundwater extraction with ex-situ treatment to provide dewatering during excavation , and partial or full up-gradient re-injection after source-area remediation to provide flushing of contaminants to increase mobilization and removal of contaminant mass.
	Soil Vapor Extraction	MODERATE	LOW	EASY	SOMEWHAT DIFFICULT	LOW	HIGH	YES (component)	NO	Based on the monitored performance of the existing SVE system at the Site, SVE alone is not a viable option for mass removal or remediation at the site for either the DNAPL source area or the dissolved-phase plume. However, while not effective at removing contaminant mass, SVE is a viable remedial component to mitigate exposure risk and to limit impacts to human health. While near-term site usage will be limited to a parking area, future development on site is possible and soil vapor extraction in a future building footprint will be considered as a potential remedial component/ engineering control to be used in conjunction with in situ soil remedies in the DNAPL source area.
Containment/ Barrier Measures	Low-permeability Hydraulic Barrier	MODERATE	MODERATE	SOMEWHAT DIFFICULT	DIFFICULT	MODERATE	MODERATE TO HIGH	NO	NO	A physical wall will contain contaminants within a specific area. However, further remediation is often necessary because, unlike a PRB, a physical wall does not treat or destroy the contaminants. As such, physical/ hydraulic control barriers have been screened out as potential remedial option, consistent with the 2009 FS evaluation (Malcolm Pirnie, 2009b).
	ZVI PRB	LOW	HIGH	SOMEWHAT DIFFICULT	DIFFICULT	MODERATE	MODERATE TO HIGH	NO	NO	A ZVI PRB will not be further considered for remediation of the DNAPL source or downgradient dissolved-phase plume. Emplacement of a PRB using conventional trenching methods can be complicated by underground utilities present on the Site, and by planned road re-construction activities in the area. Once emplaced the PRB is expensive to adjust, re-locate or remove, and changes in groundwater direction or velocity, though unlikely, can reduce the PRB effectiveness.

Notes:

N/A - Not Applicable
ZVI - zero valent iron
PRB - permeable reactive barrier
ISCO - in-situ chemical oxication
GRA - General Response Actions
NCP - National Oil and Hazardous Substances Pollution Contingency Plan
USEPA -United States Environmental Protection Agency
DNAPL - dense non-aqueous phase liquid
LTM - long term monitoring
ERD - enhanced reductive dechlorination
RAO - Remedial Action Objectives
CVOCs - Chlorinated volatile organic compounds
SVE - Soil vapor extraction

Table 3.

Comparative Summary of Remedial Alternative Components

Crown Dykman (Site #130054), City of Glen Cove, New York

ALTERNATIVE	SUMMARY	Applicable Remedial Technologies					
		Institutional Controls	LTM	Thermal Desorption/ ERH	Removal (Excavation)	ISCO (sodium permanganate)	DGR
RA2	Thermal source area treatment followed by ISCO polishing using sodium permanganate in on-site, dissolved-phase plume. Dewatering during source treatment.	X	X	X		X	
RA3	Thermal source area treatment followed by directed groundwater recirculation (DGR) polishing of the residual dissolved-phase plume. Dewatering during source treatment, remaining as component of DGR post-source treatment.	X	X	X			X
RA4	Source area excavation/ removal followed by ISCO polishing using sodium permanganate in on-site, dissolved-phase plume and former source area. Dewatering during source removal.	X	X		X	X	
RA5	Source area excavation/ removal followed by directed groundwater recirculation (DGR) polishing of residual dissolved-phase plume. Dewatering during source removal, remaining as component of DGR post-source treatment.	X	X		X		X
RA6	Source area excavation/ removal followed by ISCO application within excavation footprint and directed groundwater recirculation (DGR) polishing of residual dissolved-phase plume. Dewatering during source removal, remaining as component of DGR post-source treatment.	X	X		X	X (within source zone)	X

NOTES:

RA - remedial alternative

ERH - electrical resistivity heating

LTM - long term monitoring

ISCO - in-situ chemical oxidation

DGR - directed groundwater recirculation

Table 4.

Comparative Summary of Remedial Alternative Costs

Crown Dykman (Site #130054), City of Glen Cove, New York

ALTERNATIVE	SUMMARY	ESTIMATED REMEDIAL COSTS[1]			PRESENT VALUE[2]
		POINT ESTIMATE	*LOW (-30%)*	*HIGH (+50%)*	
RA2	Thermal source area treatment followed by ISCO polishing using sodium permanganate in on-site, dissolved-phase plume. Dewatering during source treatment.	$8,109,000	*$5,676,300*	*$12,164,000*	$7,617,000
RA3	Thermal source area treatment followed by directed groundwater recirculation (DGR) polishing of the residual dissolved-phase plume. Dewatering during source treatment, remaining as component of DGR post-source treatment.	$7,254,000	*$5,077,800*	*$10,881,000*	$6,588,000
RA4	Source area excavation/ removal followed by ISCO polishing using sodium permanganate in on-site, dissolved-phase plume and former source area. Dewatering during source removal.	$4,889,000	*$3,422,300*	*$7,333,500*	$4,705,000
RA5	Source area excavation/ removal followed by directed groundwater recirculation (DGR) polishing of residual dissolved-phase plume. Dewatering during source removal, remaining as component of DGR post-source treatment.	$5,088,000	*$3,561,600*	*$7,632,000*	$4,636,000
RA6	Source area excavation/ removal followed by ISCO application within excavation footprint and directed groundwater recirculation (DGR) polishing of residual dissolved-phase plume. Dewatering during source removal, remaining as component of DGR post-source treatment.	$4,915,000	*$3,440,500*	*$7,372,500*	$4,756,093

NOTES:

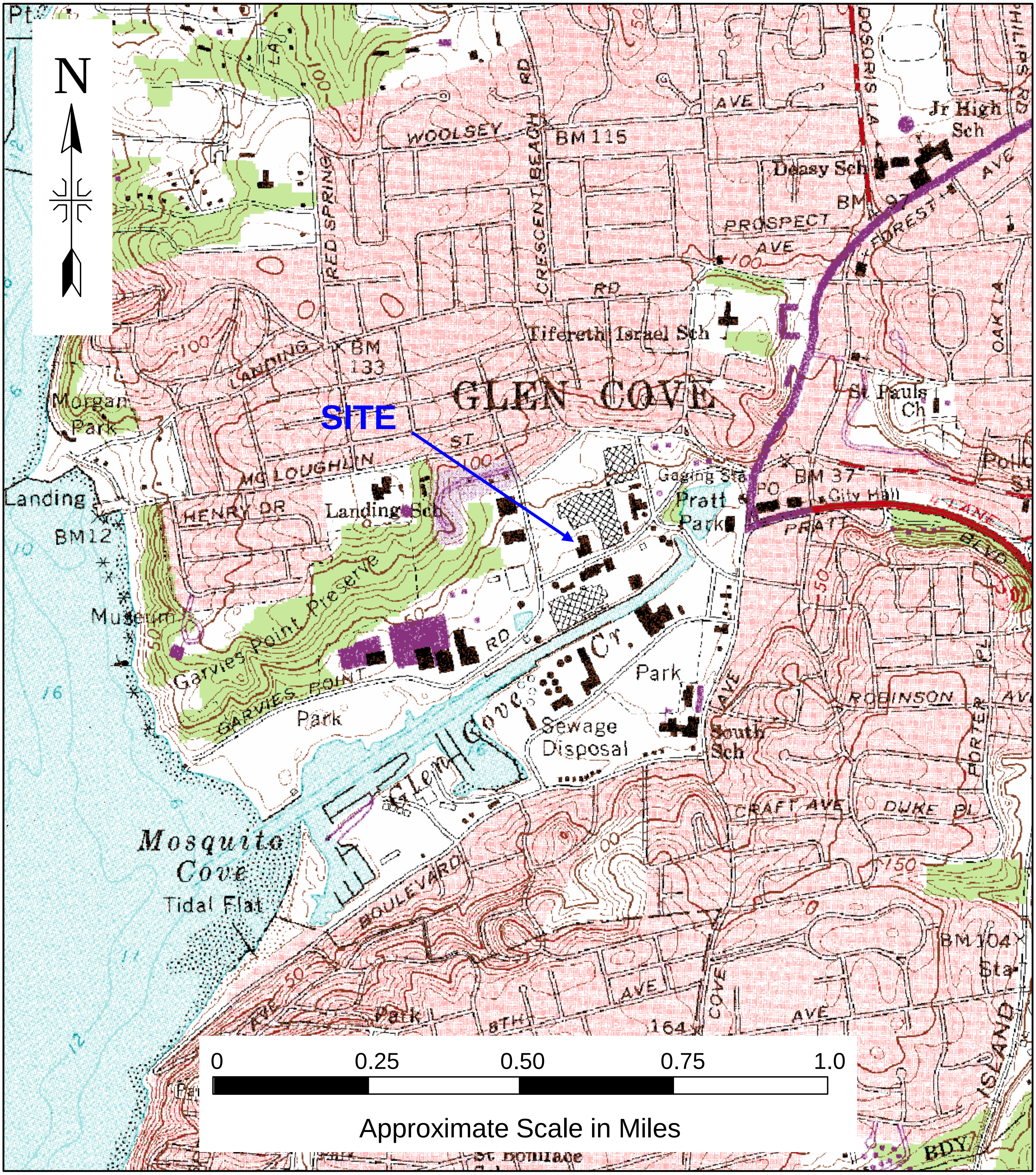
[1] Costs estimated using recent costs and/or cost quotes for similar work, and construction costs estimated from project experience and/or RS Means data.

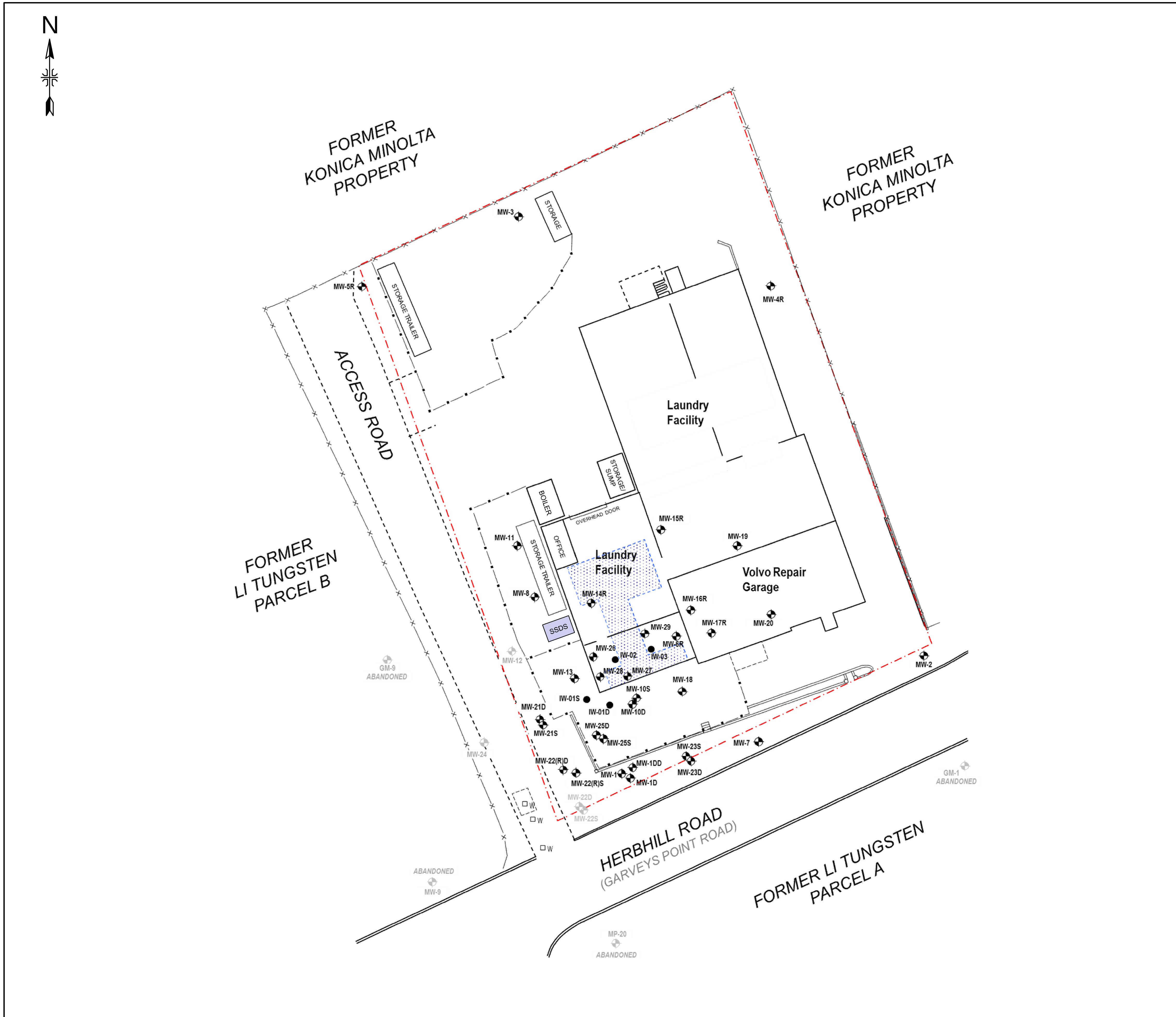
[2] Present Value - Present Net Worth based on 5% discount value using point estimate.

FIGURES

Figure 1
Site Location

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York





LEGEND

CHAIN-LINK FENCE

WOOD-PICKET FENCE

PROPERTY BOUNDARY (SURVEY)

MW-9 GROUNDWATER MONITORING WELL

MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL

2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING

0 30 60

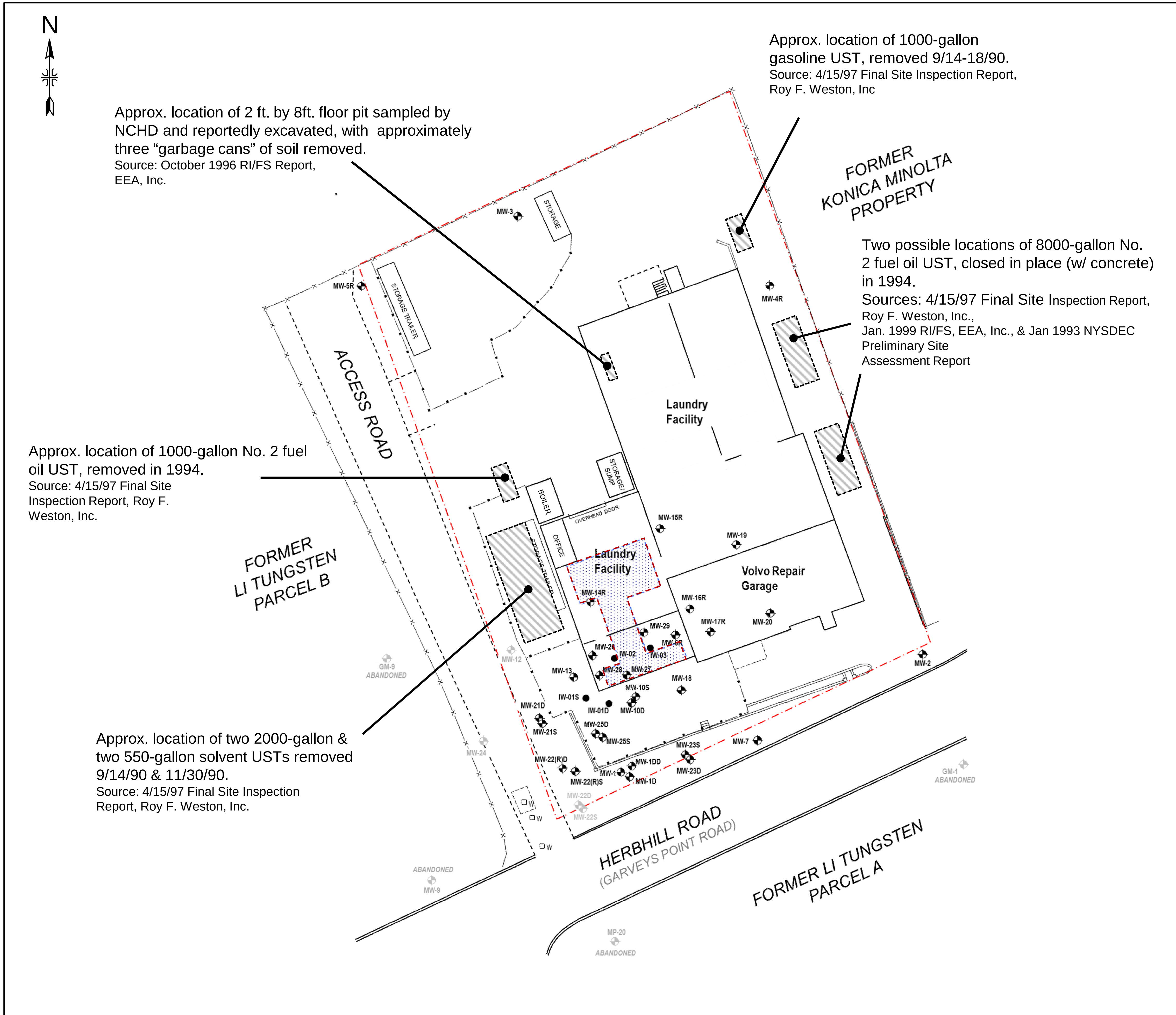
Approximate Scale in Feet

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Site Plan

ARCADIS Design & Consultancy for natural and built assets

FIGURE 2



LEGEND

- CHAIN-LINK FENCE
- WOOD-PICKET FENCE
- PROPERTY BOUNDARY (SURVEY)
- MW-9 GROUNDWATER MONITORING WELL
- MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL
- 2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING
- APPROXIMATE LOCATION OF FORMER UST

Notes:

IRM Information Source: June 2006 On-site Source Area Removal IRM Report, Walden Associates.

0 30 60

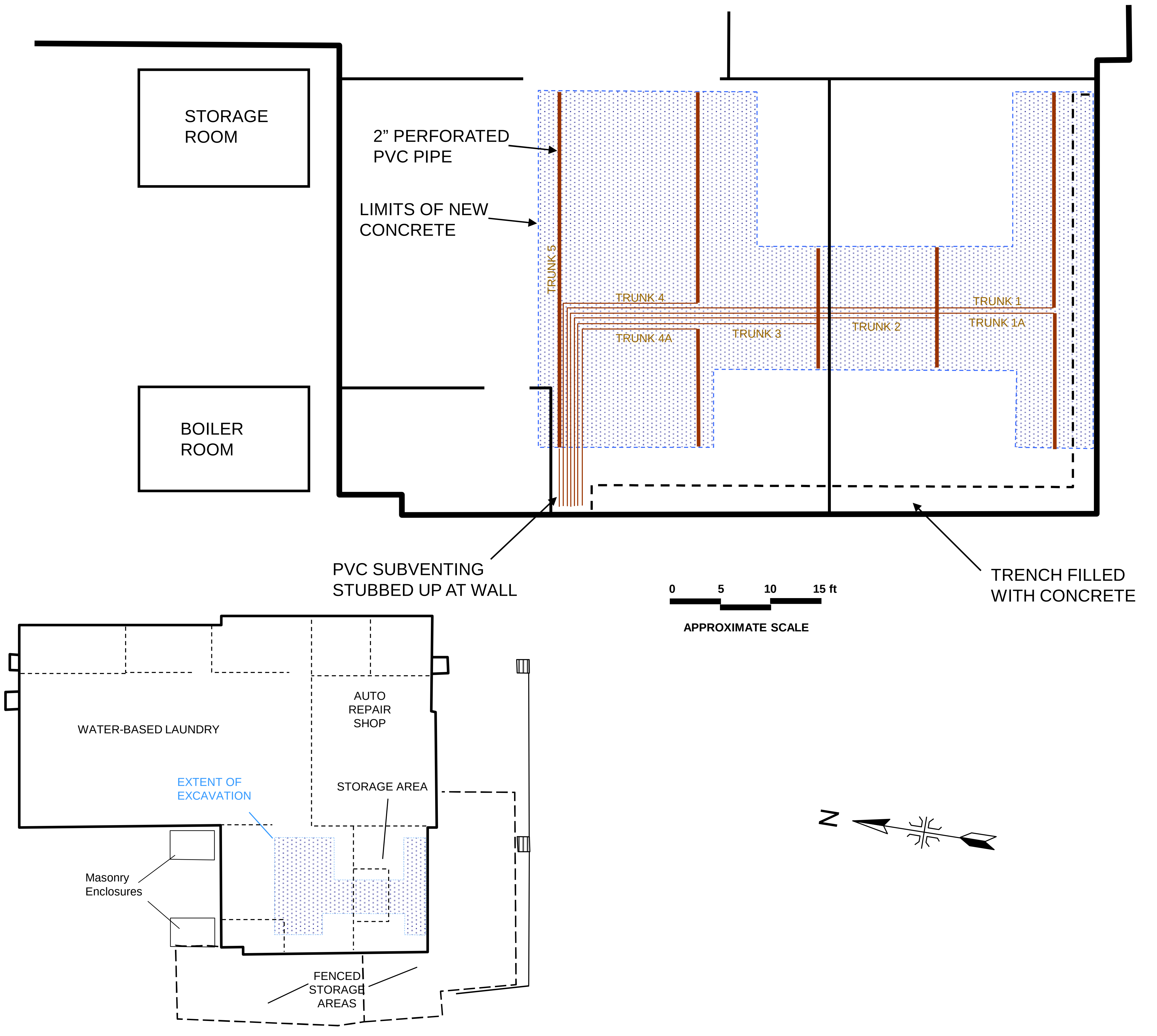
Approximate Scale in Feet

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Approximate Locations of Former Underground Storage Tanks and 2005 Interim Remedial Measure Excavation Area

ARCADIS Design & Consultancy for natural and built assets

FIGURE 3



LEGEND

AREA OF EXCAVATION WITH NEW CONCRETE FLOOR

2” PVC PIPING - SOILD

2” PVC PIPING - PERFORATED

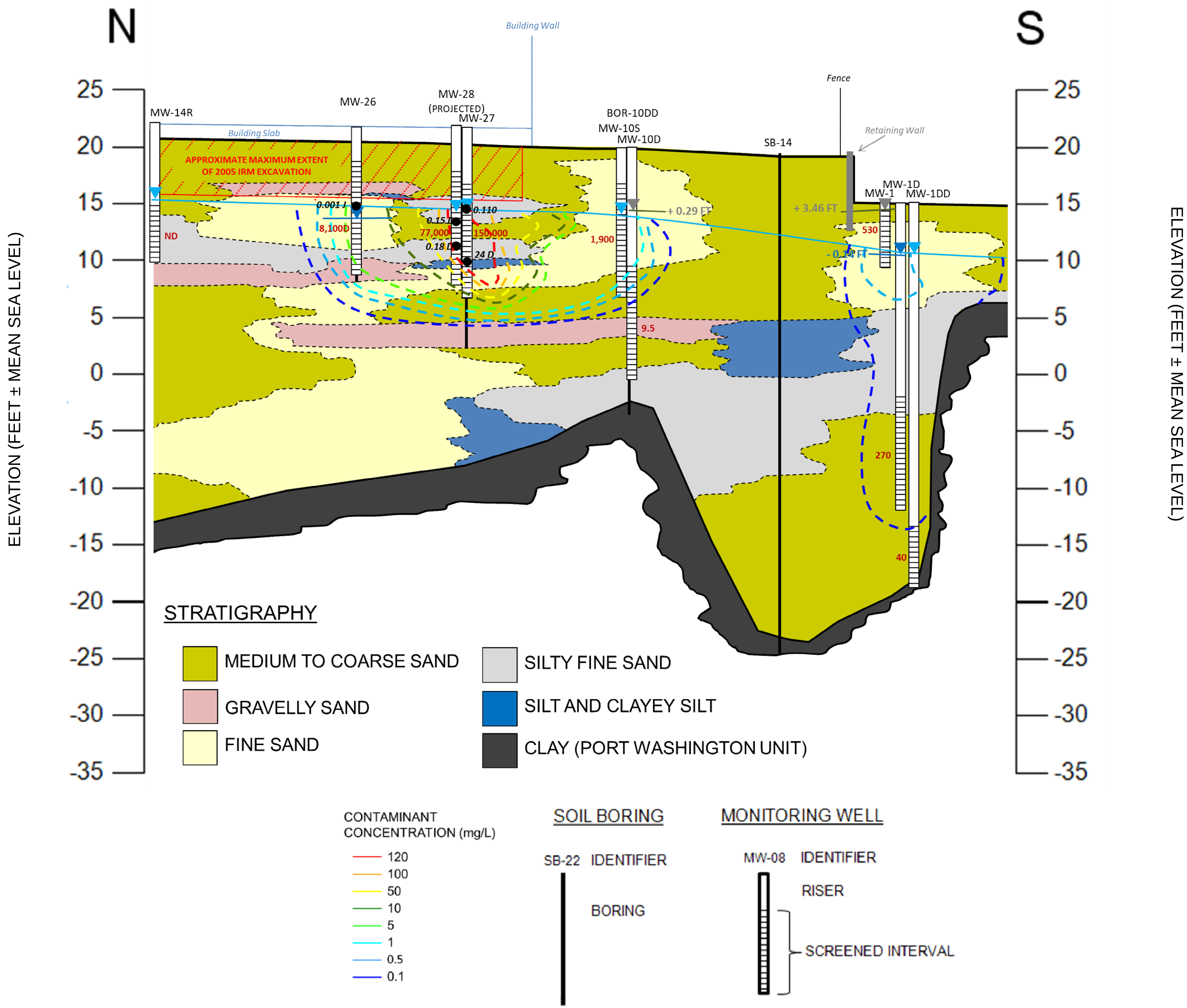
Source: June 2006 On-site Source Area Removal IRM Report, Walden Associates

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Existing Sub-slab Depressurization/ Soil Vapor Extraction System Layout

ARCADIS Design & Consultancy for natural and built assets

4
FIGURE



LEGEND

GROUNDWATER TABLE (DASHED WHERE INFERRED)

WELL WATER LEVEL OBSERVATION

● 0.11 SOIL SAMPLE INTERVAL (SOIL CONCENTRATION IN mg/Kg)

0.53 PCE CONCENTRATION – JULY 2014 (GROUNDWATER CONCENTRATION IN ug/L)

GROUNDWATER CONTAMINANT CONCENTRATION ISOCONTOUR

NOTES

0* - Indicates assumed non-detect due to presence of permanganate in well.

J – Indicates value is estimated.

D – Indicates value is based on sample dilution.

ND – Indicates compound not detected above reporting limit.

0 6 12 18

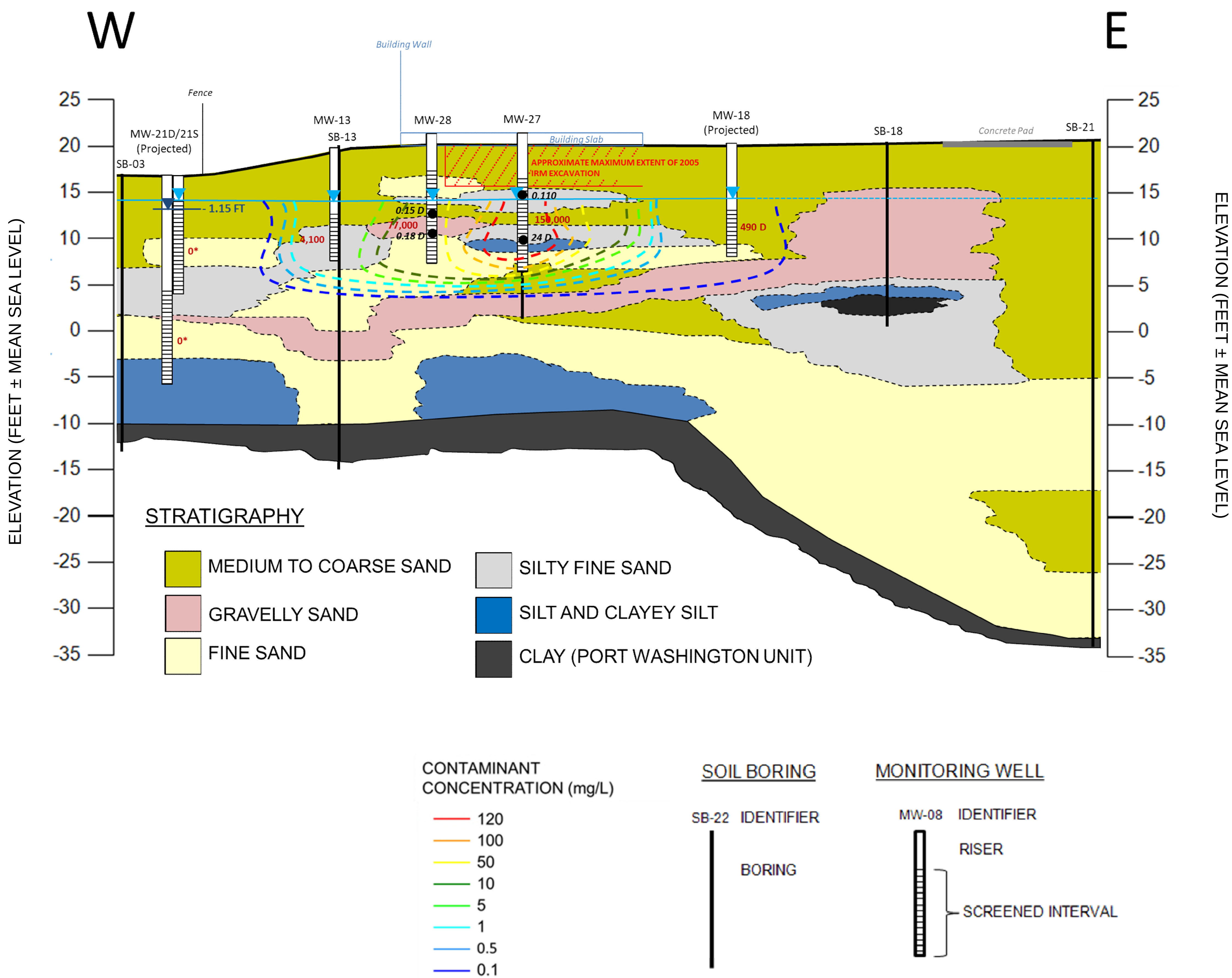
APPROXIMATE SCALE IN FEET
No Vertical Exaggeration

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Vertical Extent of Chlorinated VOCs in Soil and Groundwater (July 2014); North-South Cross-section

ARCADIS Design & Consultancy for natural and built assets

5a
FIGURE



LEGEND

GROUNDWATER TABLE (DASHED WHERE INFERRED)

WELL WATER LEVEL OBSERVATION

0.11 SOIL SAMPLE INTERVAL - JULY 2014 (SOIL CONCENTRATION IN mg/Kg)

0.53 PCE CONCENTRATION – JULY 2014 (GROUNDWATER CONCENTRATION IN ug/L)

GROUNDWATER CONTAMINANT CONCENTRATION ISOCONTOUR

NOTES

0* - Indicates assumed non-detect due to presence of permanganate in well.

J – Indicates value is estimated.

D – Indicates value is based on sample dilution.

ND – Indicates compound not detected above reporting limit.

0 8 16 24

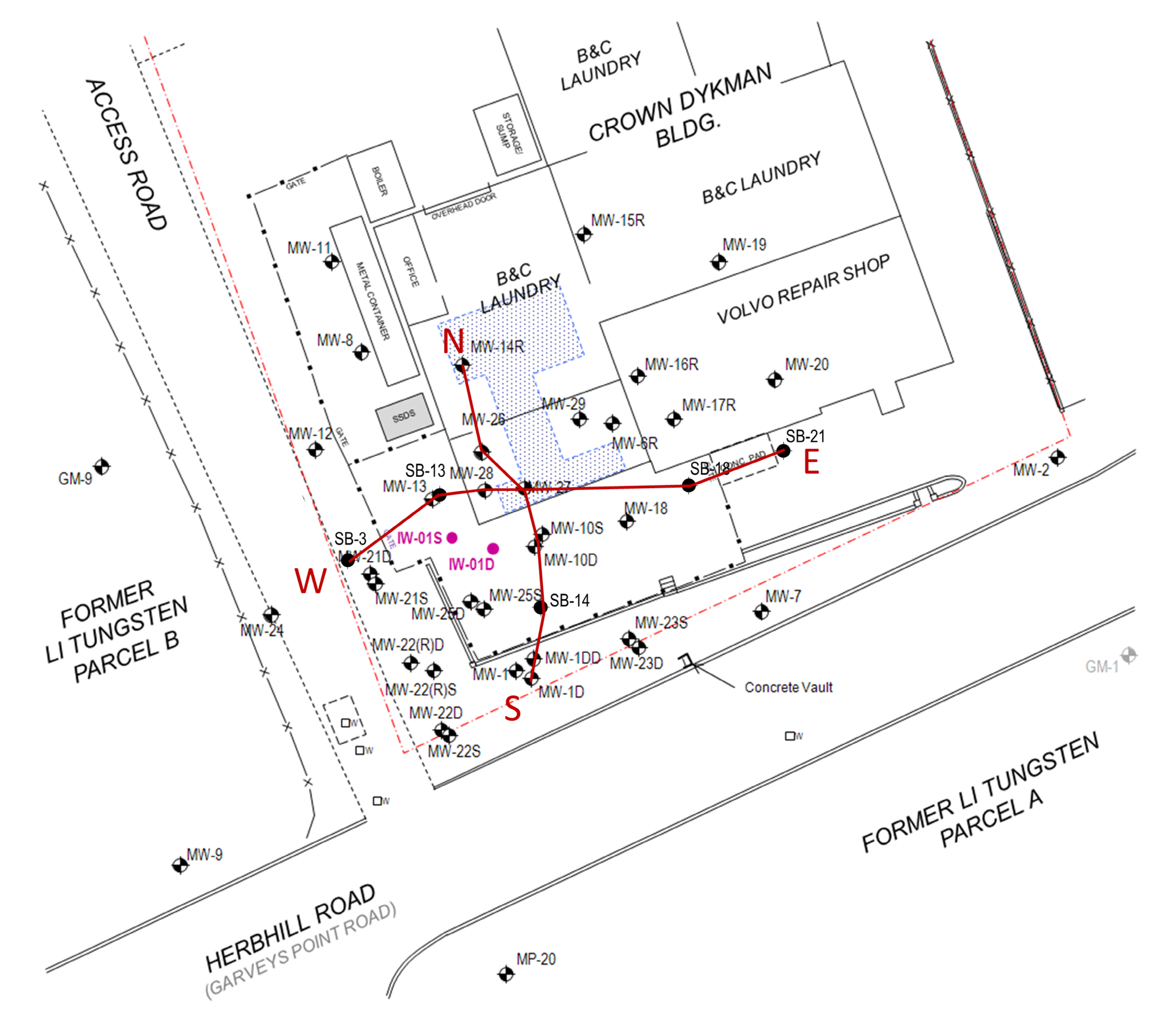
APPROXIMATE SCALE IN FEET
No Vertical Exaggeration

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Vertical Extent of Chlorinated VOCs in Soil and Groundwater (July 2014); East-West Cross-section

ARCADIS Design & Consultancy for natural and built assets

5b
FIGURE



LEGEND

- CHAIN-LINK FENCE
- WOOD-PICKET FENCE
- PROPERTY BOUNDARY (SURVEY)
- MW-9 GROUNDWATER MONITORING WELL
- GM-1 DAMAGED/MISSING WELL LOCATION
- SB-3 CROSS-SECTION SOIL BORING
- APPROXIMATE 2005 IRM EXCAVATION AREA/ SVE PIPING
- IW-01D SODIUM PERMANGANATE INJECTION WELL

N

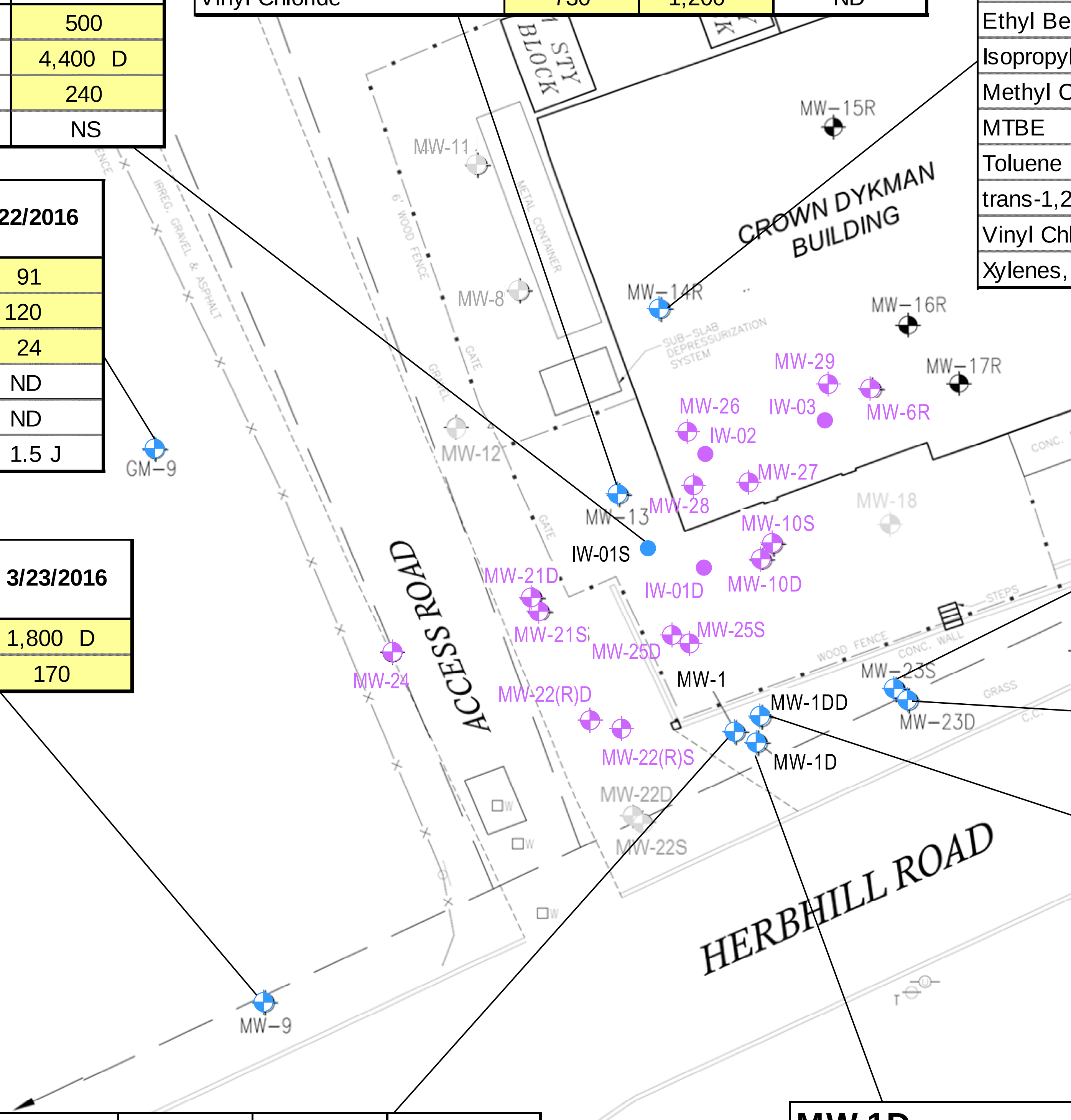
0 37.5 75

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Vertical Extent of Chlorinated VOCs in Soil and Groundwater (July 2014); Cross Section Locations

ARCADIS Design & Consultancy for natural and built assets

5c
FIGURE



MW-13 Compound	11/12/2015	1/28/2016	3/22/2016
cis-1,2-Dichloroethene	28,000	44,000	15,000
Tetrachloroethene	630	4,100	3,500
Trichloroethene	410	2,800	1,800
Vinyl Chloride	730	1,200	ND

MW-14R Compound	11/11/2015	1/28/2016	3/23/2016
1,2-Dibromo-3-Chloropropane	ND	NS	2.3
Acetone	ND	NS	6.7 J
Benzene	ND	NS	1.8 J
cis-1,2-Dichloroethylene	260	NS	1,500 D
Ethyl Benzene	34	NS	29
Isopropylbenzene	17	NS	14
Methyl Cyclohexane	1.2	NS	1.4 J
MTBE	1.3	NS	1.7 J
Toluene	11	NS	25
trans-1,2-Dichloroethene	ND	NS	8.3
Vinyl Chloride	480	NS	1,100 D
Xylenes, Total	190	NS	200

IW-01S Compound	11/12/2015	1/28/2016	3/22/2016
cis-1,2-Dichloroethylene	800	Mn^{-4}	500
Tetrachloroethylene	35	Mn^{-4}	4,400 D
Trichloroethylene	27	Mn^{-4}	240
Vinyl Chloride	33	Mn^{-4}	NS

GM-9 Compound	11/11/2015	1/28/2016	3/22/2016
cis-1,2-Dichloroethene	390	89	91
Tetrachloroethene	440	120	120
Trichloroethene	110	26	24
Vinyl Chloride	14	2.4	ND
1,2-Dichloroethane	ND	0.42 J	ND
MTBE	1.9 J	1.6 J	1.5 J

MW-23S Compound	11/11/2015	1/27/2016	3/22/2016
cis-1,2-Dichloroethene	750	270	3,000 D F1
Tetrachloroethene	780	210	2,000 D F1
Trichloroethene	270	88	680
trans-1,2-Dichloroethene	ND	ND	15
Vinyl Chloride	11	ND	ND

MW-9 Compound	11/11/2015	1/28/2016	3/23/2016
cis-1,2-Dichloroethylene	700	NS	1,800 D
Vinyl Chloride	340	NS	170

MW-23D Compound	11/11/2015	1/27/2016	3/22/2016
cis-1,2-Dichloroethene	ND	500	1,200 D F1
Tetrachloroethene	ND	560	820 D F1
Trichloroethene	ND	220	300 F1
Vinyl Chloride	140	ND	ND
MTBE	12	ND	ND

LEGEND

- WOODEN-SLAT FENCE
- CHAIN-LINK FENCE
- GM-9 MONITORING WELL
- MW-18 DAMAGED/MISSING WELL
- PILOT INJECTION WELLS

MW-1DD Compound	11/10/2015	1/28/2016	3/22/2016
1,1-Dichloroethane	0.67	ND	ND
1,1-Dichloroethene	ND	ND	1.4
Benzene	ND	ND	0.49 J
cis-1,2-Dichloroethene	43	65	560 D
Tetrachloroethene	28	46	290 D
Trichloroethene	11	18	150 D
trans-1,2-Dichloroethene	ND	ND	2.6
Vinyl Chloride	13	ND	31
MTBE	ND	0.39 J	9.9

MW-1 Compound	11/10/2015	1/28/2016	3/22/2016
cis-1,2-Dichloroethene	1,700	1,200	1,300
Tetrachloroethene	260	330	350
Trichloroethene	170	180	130

MW-1D Compound	11/11/2015	1/28/2016	3/22/2016
cis-1,2-Dichloroethene	960	1,900	1,900
Tetrachloroethene	1,900	1,700	3,500 D
Trichloroethene	530	810	1,000
Vinyl Chloride	32	46	31

MP-20 Compound	11/11/2015	1/28/2016	3/23/2016
cis-1,2-Dichloroethylene	3.0	NS	4.1
Tetrachloroethylene	0.69	NS	0.51 J
Trichloroethylene	0.91	NS	0.98 J
Vinyl Chloride	ND	NS	1.9

NOTE:

- BLUE indicates that well was checked visually, and no permanganate was observed. Well was sampled for laboratory analysis.
- PURPLE indicates that permanganate was observed in the well when purged. Well was not sampled.
- Sodium Permanganate injected in wells IW-02 and IW-03 in building.

Data Qualifiers:

a) D – Based on dilution of original sample.
b) J – Result is estimated value, as result is below reporting limit for respective compound.
c) F1 – MS and/or MSD Recovery is outside acceptance limits.
d) Mn-4 - Permanganate present in well.
e) ND – Not Detected
f) NS – Not sampled
g) Indicates that compound exceeds the respective NYSDEC Class GA standard or guidance value.

N

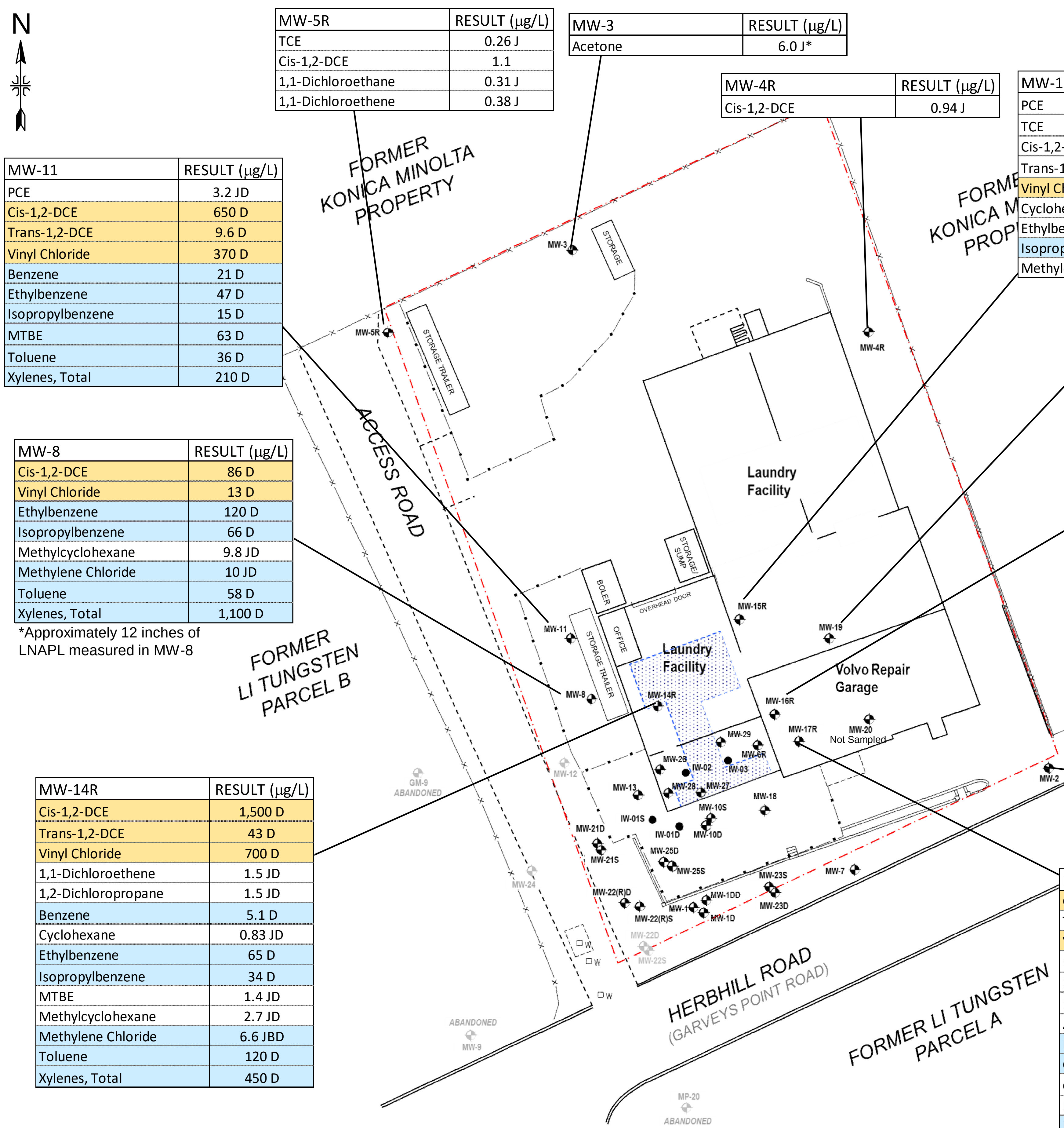
0 20 40
APPROXIMATE SCALE IN FEET

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Source Area ISCO Pilot Injection Baseline and Post-Injection Analytical Sampling Summary; March 2016

ARCADIS Design & Consultancy for natural and built assets

6
FIGURE



MW-5R	RESULT (µg/L)
TCE	0.26 J
Cis-1,2-DCE	1.1
1,1-Dichloroethane	0.31 J
1,1-Dichloroethene	0.38 J

MW-3	RESULT (µg/L)
Acetone	6.0 J*

MW-4R	RESULT (µg/L)
Cis-1,2-DCE	0.94 J

MW-15R	RESULT (µg/L)
PCE	0.38 J
TCE	0.2 J
Cis-1,2-DCE	3.7
Trans-1,2-DCE	0.34 J
Vinyl Chloride	5.3
Cyclohexane	0.66 J
Ethylbenzene	4.6
Isopropylbenzene	12
Methylcyclohexane	4.4 J

MW-11	RESULT (µg/L)
PCE	3.2 JD
Cis-1,2-DCE	650 D
Trans-1,2-DCE	9.6 D
Vinyl Chloride	370 D
Benzene	21 D
Ethylbenzene	47 D
Isopropylbenzene	15 D
MTBE	63 D
Toluene	36 D
Xylenes, Total	210 D

MW-19	RESULT (µg/L)
PCE	1.2
TCE	0.94 J
Cis-1,2-DCE	11
Trans-1,2-DCE	0.53 J
Vinyl Chloride	0.39 J

MW-8	RESULT (µg/L)
Cis-1,2-DCE	86 D
Vinyl Chloride	13 D
Ethylbenzene	120 D
Isopropylbenzene	66 D
Methylcyclohexane	9.8 JD
Methylene Chloride	10 JD
Toluene	58 D
Xylenes, Total	1,100 D

*Approximately 12 inches of LNAPL measured in MW-8

MW-16R	RESULT (µg/L)
TCE	0.43 J
Cis-1,2-DCE	2.4
Trans-1,2-DCE	0.6 J
Vinyl Chloride	0.47 J
1,4-Dichlorobenzene	0.21 J
Acetone	5.2 J
Cyclohexane	0.20 J
Ethylbenzene	11
Isopropylbenzene	11
Methylcyclohexane	0.59 J

MW-2	RESULT (µg/L)
PCE	17
TCE	3.5
Cis-1,2-DCE	1.1

MW-14R	RESULT (µg/L)
Cis-1,2-DCE	1,500 D
Trans-1,2-DCE	43 D
Vinyl Chloride	700 D
1,1-Dichloroethene	1.5 JD
1,2-Dichloropropane	1.5 JD
Benzene	5.1 D
Cyclohexane	0.83 JD
Ethylbenzene	65 D
Isopropylbenzene	34 D
MTBE	1.4 JD
Methylcyclohexane	2.7 JD
Methylene Chloride	6.6 JBD
Toluene	120 D
Xylenes, Total	450 D

MW-17R	RESULT (µg/L)
Cis-1,2-DCE	58
Trans-1,2-DCE	1.8
Vinyl Chloride	73
1,2-Dichlorobenzene	0.22 J
1,2-Dichloropropane	1.3
1,4-Dichlorobenzene	0.76 J
Acetone	6.3 J
Benzene	3.8
Chloroethane	14
Cyclohexane	0.71 J
Ethylbenzene	3.6
Isopropylbenzene	27
MTBE	12
Methylcyclohexane	2.4 J
Toluene	0.18 J

LEGEND

CHAIN-LINK FENCE

WOOD-PICKET FENCE

PROPERTY BOUNDARY (SURVEY)

MW-9 GROUNDWATER MONITORING WELL

MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL

2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING

Notes:

J – Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

B – Compound was found in laboratory blank and sample (indicates potential laboratory contaminant)

D – Result is based on dilution of the sample.

ug/L – Micrograms per liter.

Primary Contaminant/CVOC exceeding respective NYS Class GA Standard or Guidance Value

Other detected VOC exceeding respective NYS Class GA Standard or Guidance Value

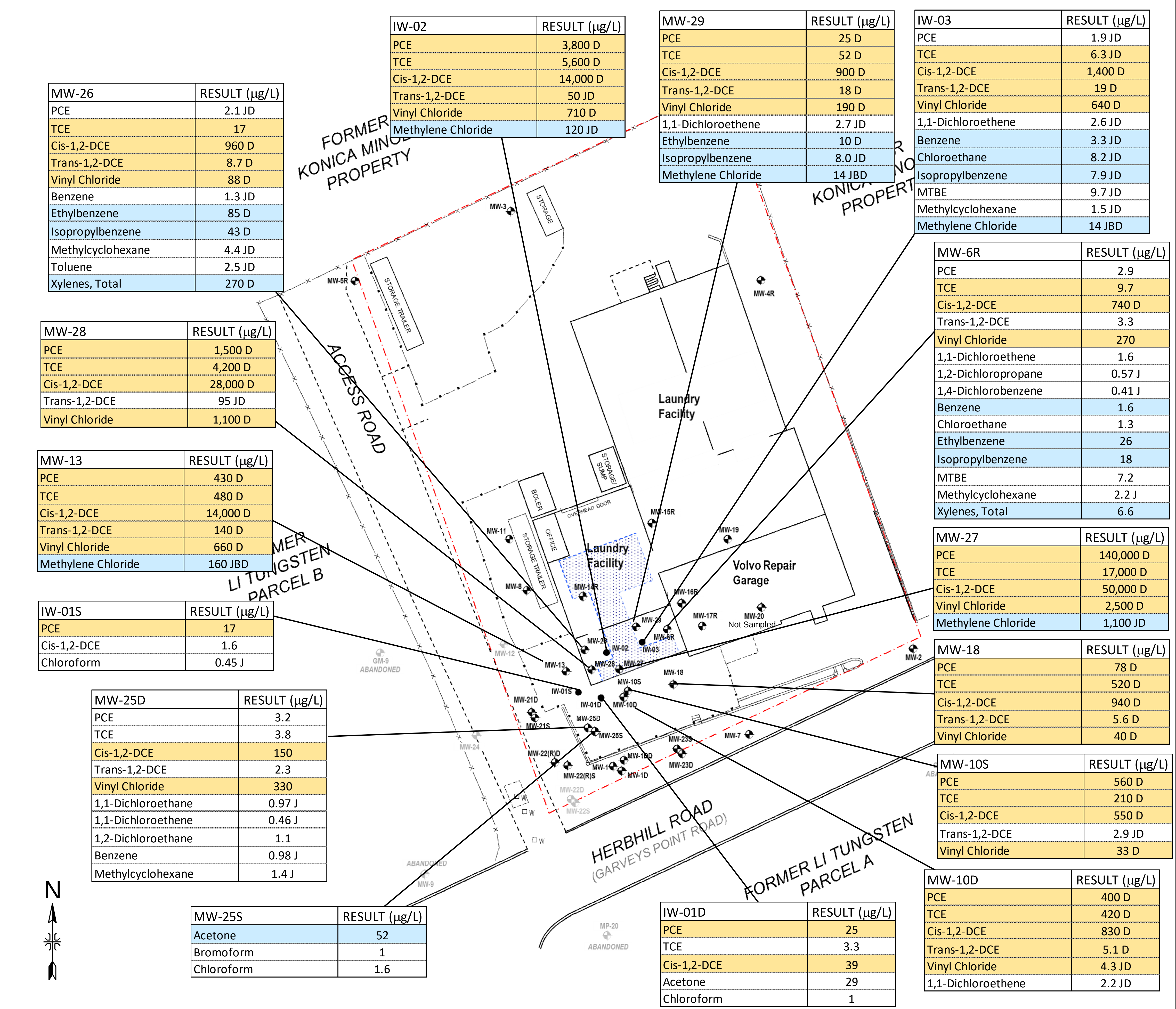
0 30 60
Approximate Scale in Feet

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Summary of VOC Detections in Groundwater Samples – October-November 2017; Upgradient Area Wells

ARCADIS Design & Consultancy for natural and built assets

7a
FIGURE



MW-26	RESULT (µg/L)
PCE	2.1 JD
TCE	17
Cis-1,2-DCE	960 D
Trans-1,2-DCE	8.7 D
Vinyl Chloride	88 D
Benzene	1.3 JD
Ethylbenzene	85 D
Isopropylbenzene	43 D
Methylcyclohexane	4.4 JD
Toluene	2.5 JD
Xylenes, Total	270 D

IW-02	RESULT (µg/L)
PCE	3,800 D
TCE	5,600 D
Cis-1,2-DCE	14,000 D
Trans-1,2-DCE	50 JD
Vinyl Chloride	710 D
Methylene Chloride	120 JD

MW-29	RESULT (µg/L)
PCE	25 D
TCE	52 D
Cis-1,2-DCE	900 D
Trans-1,2-DCE	18 D
Vinyl Chloride	190 D
1,1-Dichloroethene	2.7 JD
Ethylbenzene	10 D
Isopropylbenzene	8.0 JD
Methylene Chloride	14 JBD

IW-03	RESULT (µg/L)
PCE	1.9 JD
TCE	6.3 JD
Cis-1,2-DCE	1,400 D
Trans-1,2-DCE	19 D
Vinyl Chloride	640 D
1,1-Dichloroethene	2.6 JD
Benzene	3.3 JD
Chloroethane	8.2 JD
Isopropylbenzene	7.9 JD
MTBE	9.7 JD
Methylcyclohexane	1.5 JD
Methylene Chloride	14 JBD

MW-28	RESULT (µg/L)
PCE	1,500 D
TCE	4,200 D
Cis-1,2-DCE	28,000 D
Trans-1,2-DCE	95 JD
Vinyl Chloride	1,100 D

MW-6R	RESULT (µg/L)
PCE	2.9
TCE	9.7
Cis-1,2-DCE	740 D
Trans-1,2-DCE	3.3
Vinyl Chloride	270
1,1-Dichloroethene	1.6
1,2-Dichloropropane	0.57 J
1,4-Dichlorobenzene	0.41 J
Benzene	1.6
Chloroethane	1.3
Ethylbenzene	26
Isopropylbenzene	18
MTBE	7.2
Methylcyclohexane	2.2 J
Xylenes, Total	6.6

MW-13	RESULT (µg/L)
PCE	430 D
TCE	480 D
Cis-1,2-DCE	14,000 D
Trans-1,2-DCE	140 D
Vinyl Chloride	660 D
Methylene Chloride	160 JBD

MW-27	RESULT (µg/L)
PCE	140,000 D
TCE	17,000 D
Cis-1,2-DCE	50,000 D
Vinyl Chloride	2,500 D
Methylene Chloride	1,100 JD

IW-01S	RESULT (µg/L)
PCE	17
Cis-1,2-DCE	1.6
Chloroform	0.45 J

MW-18	RESULT (µg/L)
PCE	78 D
TCE	520 D
Cis-1,2-DCE	940 D
Trans-1,2-DCE	5.6 D
Vinyl Chloride	40 D

MW-25D	RESULT (µg/L)
PCE	3.2
TCE	3.8
Cis-1,2-DCE	150
Trans-1,2-DCE	2.3
Vinyl Chloride	330
1,1-Dichloroethane	0.97 J
1,1-Dichloroethene	0.46 J
1,2-Dichloroethane	1.1
Benzene	0.98 J
Methylcyclohexane	1.4 J

MW-10S	RESULT (µg/L)
PCE	560 D
TCE	210 D
Cis-1,2-DCE	550 D
Trans-1,2-DCE	2.9 JD
Vinyl Chloride	33 D

MW-25S	RESULT (µg/L)
Acetone	52
Bromoform	1
Chloroform	1.6

IW-01D	RESULT (µg/L)
PCE	25
TCE	3.3
Cis-1,2-DCE	39
Acetone	29
Chloroform	1

MW-10D	RESULT (µg/L)
PCE	400 D
TCE	420 D
Cis-1,2-DCE	830 D
Trans-1,2-DCE	5.1 D
Vinyl Chloride	4.3 JD
1,1-Dichloroethene	2.2 JD

LEGEND

- CHAIN-LINK FENCE
- WOOD-PICKET FENCE
- PROPERTY BOUNDARY (SURVEY)
- MW-9 GROUNDWATER MONITORING WELL
- MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL
- 2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING

Notes:

J – Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

B – Compound was found in laboratory blank and sample (indicates potential laboratory contaminant)

D – Result is based on dilution of the sample.

ug/L – Micrograms per liter.

Primary Contaminant/CVOC exceeding respective NYS Class GA Standard or Guidance Value

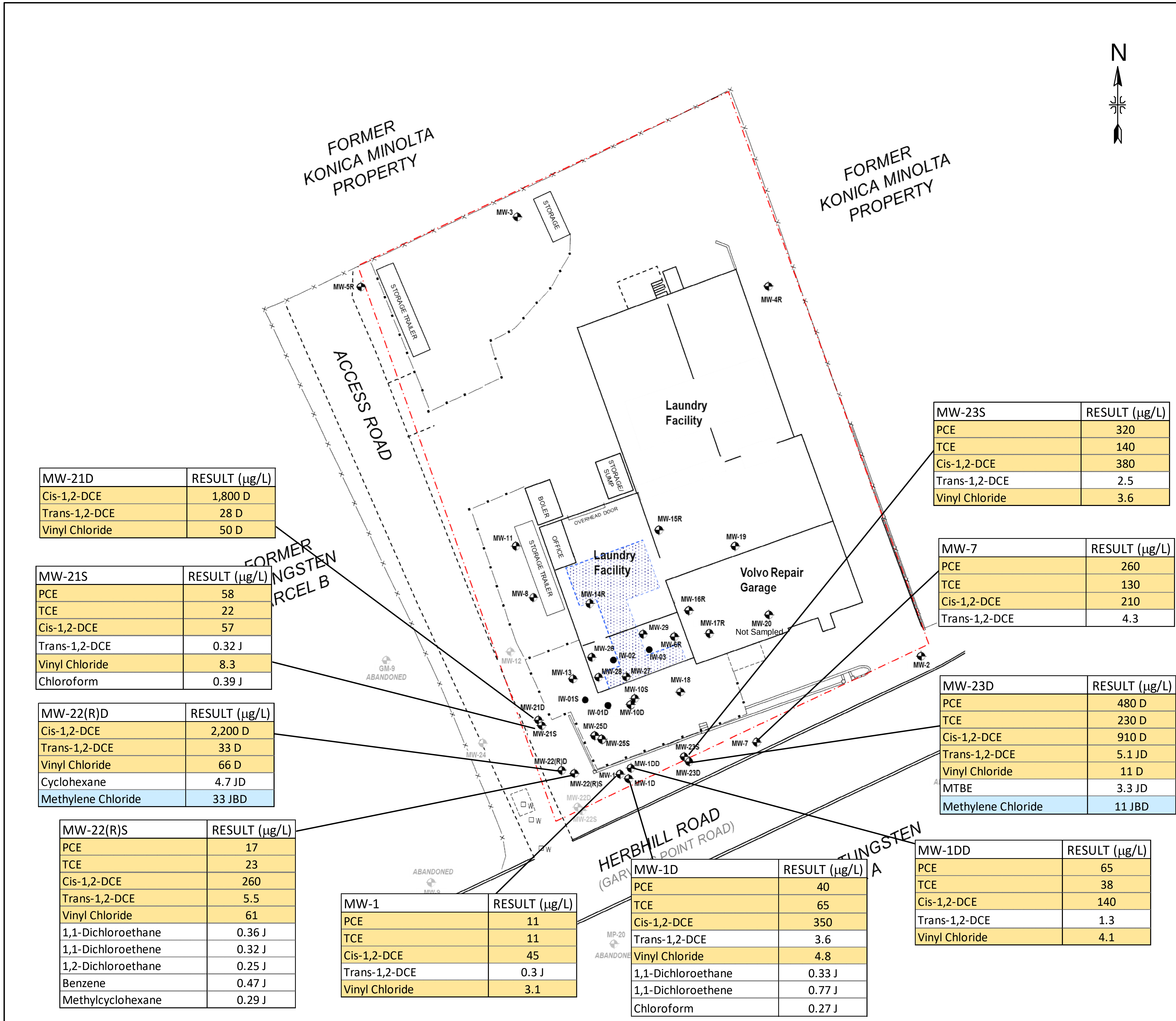
Other detected VOC exceeding respective NYS Class GA Standard or Guidance Value

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Summary of VOC Detections in Groundwater Samples – October-November 2017; Source Area Wells

ARCADIS Design & Consultancy for natural and built assets

7b
FIGURE



MW-21D	RESULT (µg/L)
Cis-1,2-DCE	1,800 D
Trans-1,2-DCE	28 D
Vinyl Chloride	50 D

MW-21S	RESULT (µg/L)
PCE	58
TCE	22
Cis-1,2-DCE	57
Trans-1,2-DCE	0.32 J
Vinyl Chloride	8.3
Chloroform	0.39 J

MW-22(R)D	RESULT (µg/L)
Cis-1,2-DCE	2,200 D
Trans-1,2-DCE	33 D
Vinyl Chloride	66 D
Cyclohexane	4.7 JD
Methylene Chloride	33 JBD

MW-22(R)S	RESULT (µg/L)
PCE	17
TCE	23
Cis-1,2-DCE	260
Trans-1,2-DCE	5.5
Vinyl Chloride	61
1,1-Dichloroethane	0.36 J
1,1-Dichloroethene	0.32 J
1,2-Dichloroethane	0.25 J
Benzene	0.47 J
Methylcyclohexane	0.29 J

MW-1	RESULT (µg/L)
PCE	11
TCE	11
Cis-1,2-DCE	45
Trans-1,2-DCE	0.3 J
Vinyl Chloride	3.1

MW-1D	RESULT (µg/L)
PCE	40
TCE	65
Cis-1,2-DCE	350
Trans-1,2-DCE	3.6
Vinyl Chloride	4.8
1,1-Dichloroethane	0.33 J
1,1-Dichloroethene	0.77 J
Chloroform	0.27 J

MW-1DD	RESULT (µg/L)
PCE	65
TCE	38
Cis-1,2-DCE	140
Trans-1,2-DCE	1.3
Vinyl Chloride	4.1

MW-23S	RESULT (µg/L)
PCE	320
TCE	140
Cis-1,2-DCE	380
Trans-1,2-DCE	2.5
Vinyl Chloride	3.6

MW-7	RESULT (µg/L)
PCE	260
TCE	130
Cis-1,2-DCE	210
Trans-1,2-DCE	4.3

MW-23D	RESULT (µg/L)
PCE	480 D
TCE	230 D
Cis-1,2-DCE	910 D
Trans-1,2-DCE	5.1 JD
Vinyl Chloride	11 D
MTBE	3.3 JD
Methylene Chloride	11 JBD

LEGEND

CHAIN-LINK FENCE

WOOD-PICKET FENCE

PROPERTY BOUNDARY (SURVEY)

MW-9 GROUNDWATER MONITORING WELL

MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL

2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING

Notes:

J – Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

B – Compound was found in laboratory blank and sample (indicates potential laboratory contaminant)

D – Result is based on dilution of the sample.

ug/L – Micrograms per liter.

Primary Contaminant/CVOC exceeding respective NYS Class GA Standard or Guidance Value

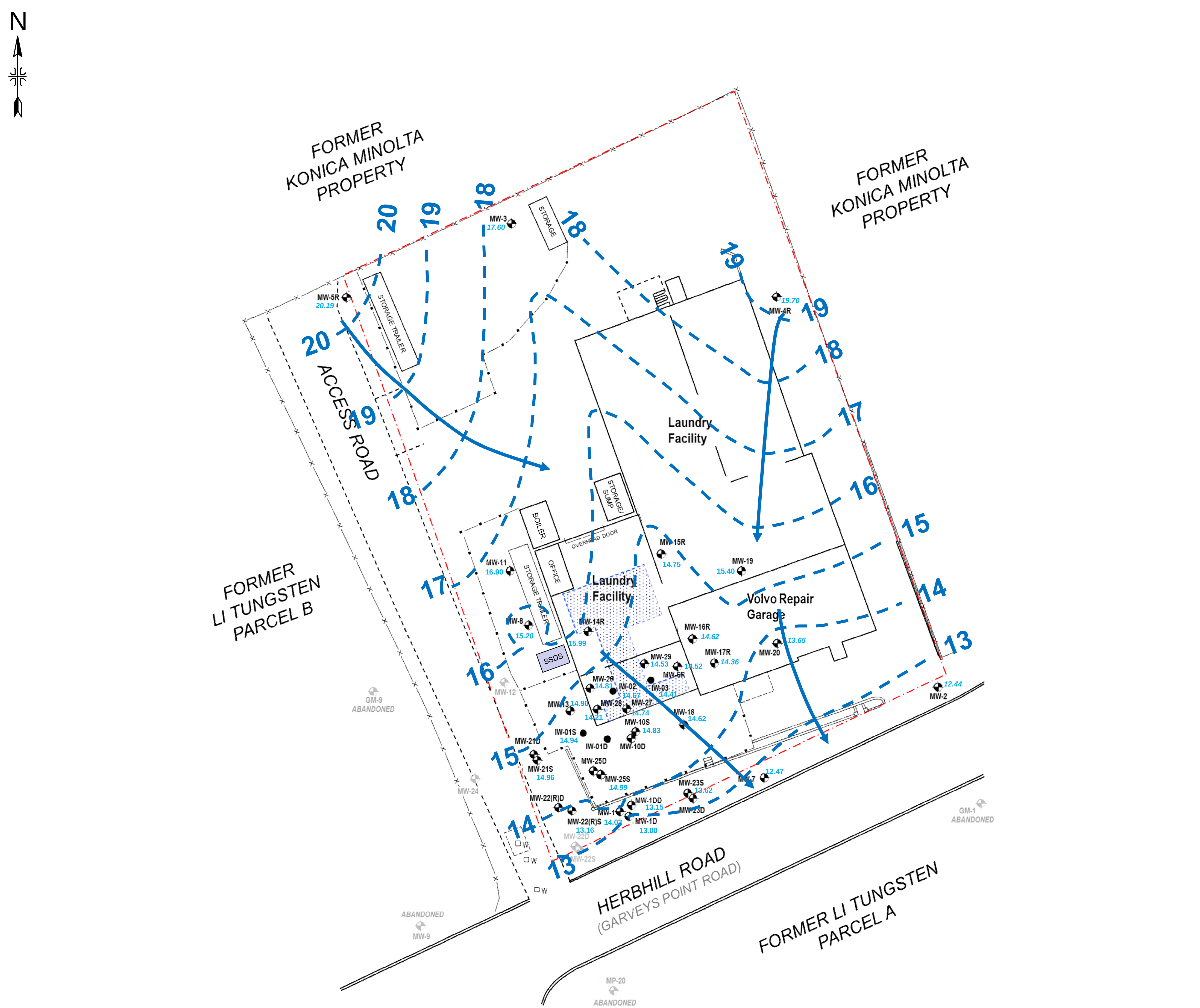
Other detected VOC exceeding respective NYS Class GA Standard or Guidance Value

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Summary of VOC Detections in Groundwater Samples – October-November 2017; Down-Gradient Area Wells

ARCADIS Design & Consultancy for natural and built assets

7c
FIGURE



LEGEND

CHAIN-LINK FENCE

WOOD-PICKET FENCE

PROPERTY BOUNDARY (SURVEY)

MW-9 GROUNDWATER MONITORING WELL

MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL

2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING

19 APPROXIMATE GROUNDWATER ELEVATION ISOCONTOUR (FEET AMSL)

APPROXIMATE GROUNDWATER FLOW DIRECTION

Notes:

15.25 – Groundwater Elevation, in feet above mean sea level (MSL); NAVD 1988.

0 30 60

Approximate Scale in Feet

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Shallow Groundwater Surface Contours (October-November 2017)

ARCADIS Design & Consultancy for natural and built assets

8

FIGURE

MW-5R	RESULT (ng/L)
PFOA	120
PFOS	52
Total PFAS	403.05

MW-3	RESULT (ng/L)
PFOA	310
PFOS	310
Total PFAS	973.2

MW-15R	RESULT (ng/L)
PFOA	100
PFOS	380
Total PFAS	762

MW-4R	RESULT (ng/L)
PFOA	25
PFOS	56
Total PFAS	116.3

MW-14R	RESULT (ng/L)
PFOA	130
PFOS	1200
Total PFAS	2068.6

MW-11	RESULT (ng/L)
PFOA	120
PFOS	1,800
Total PFAS	2,493

MW-8	RESULT (ng/L)
PFOA	93
PFOS	1,700
Total PFAS	2,082

MW-13	RESULT (ng/L)
PFOA	96
PFOS	230
Total PFAS	680.2

MW-21D	RESULT (ng/L)
PFOA	59
PFOS	110
Total PFAS	281

MW-21S	RESULT (ng/L)
PFOA	110
PFOS	480
Total PFAS	982.0

MW-22(R)D	RESULT (ng/L)
PFOA	42
PFOS	86
Total PFAS	203.0

MW-22(R)S	RESULT (ng/L)
PFOA	36
PFOS	140
Total PFAS	257.0

MW-19	RESULT (ng/L)
PFOA	7
PFOS	17
Total PFAS	55.8

MW-16R	RESULT (ng/L)
PFOA	190
PFOS	320
Total PFAS	1,159

MW-17R	RESULT (ng/L)
PFOA	150
PFOS	450
Total PFAS	1,001

MW-2	RESULT (ng/L)
PFOA	6.8
PFOS	15
Total PFAS	35.1

MW-7	RESULT (ng/L)
PFOA	60
PFOS	150 B
Total PFAS	342.81

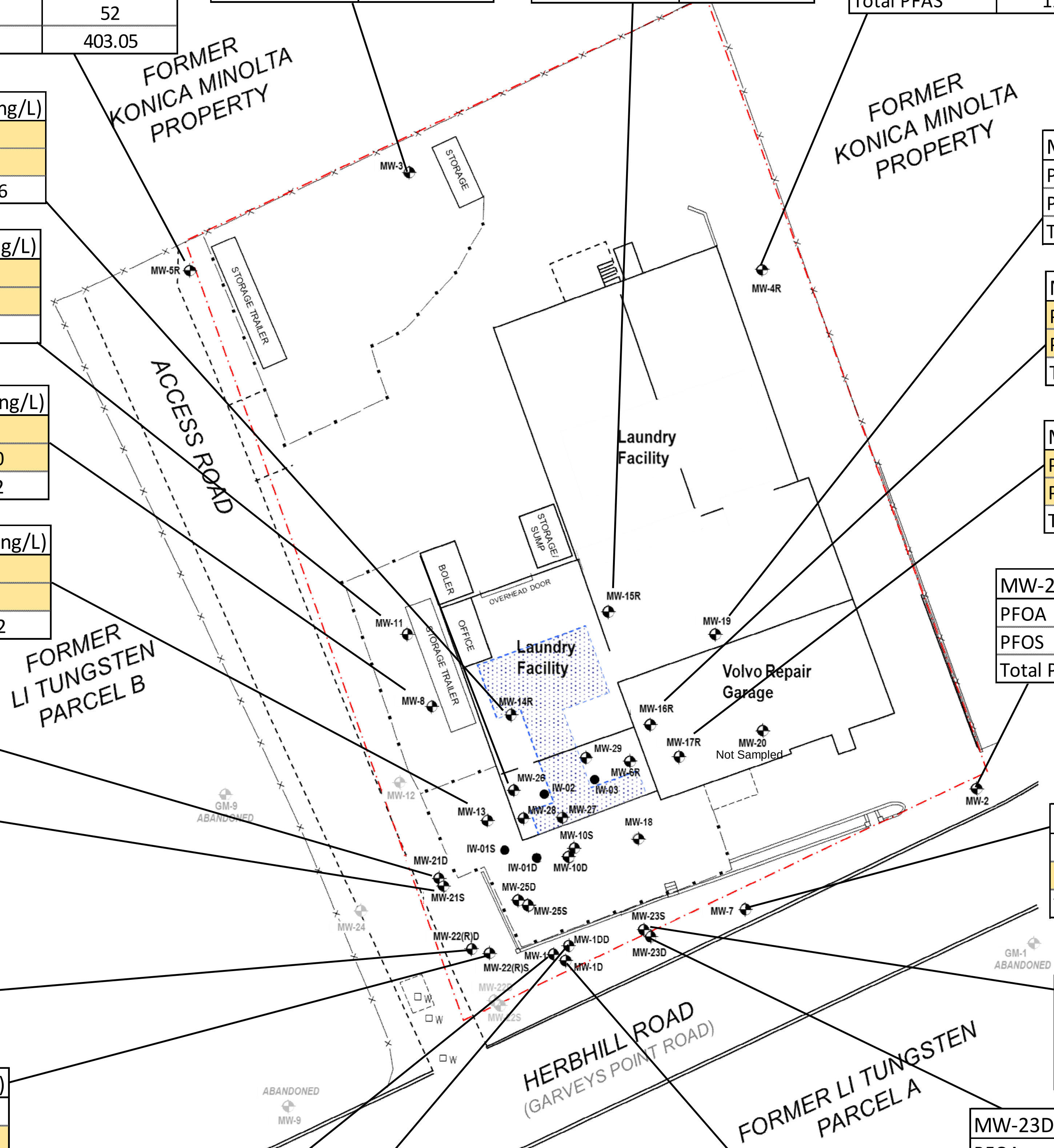
MW-23S	RESULT (ng/L)
PFOA	51
PFOS	94
Total PFAS	273.6

MW-23D	RESULT (ng/L)
PFOA	65
PFOS	130 B
Total PFAS	318.1

MW-1	RESULT (ng/L)
PFOA	86
PFOS	230
Total PFAS	498.2

MW-1DD	RESULT (ng/L)
PFOA	65
PFOS	94
Total PFAS	221.9

MW-1D	RESULT (ng/L)
PFOA	52
PFOS	100
Total PFAS	270.8



LEGEND

- CHAIN-LINK FENCE
- WOOD-PICKET FENCE
- PROPERTY BOUNDARY (SURVEY)
- MW-9 GROUNDWATER MONITORING WELL
- MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL
- 2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING
- EXCEEDS USEPA HEALTH ADVISORY LEVEL FOR DRINKING WATER OF 70 ng/L FOR PFOA/PFOS

Notes:

IW-03 reported as DW-03 within analytical reports
ng/l – nanograms per liter

N

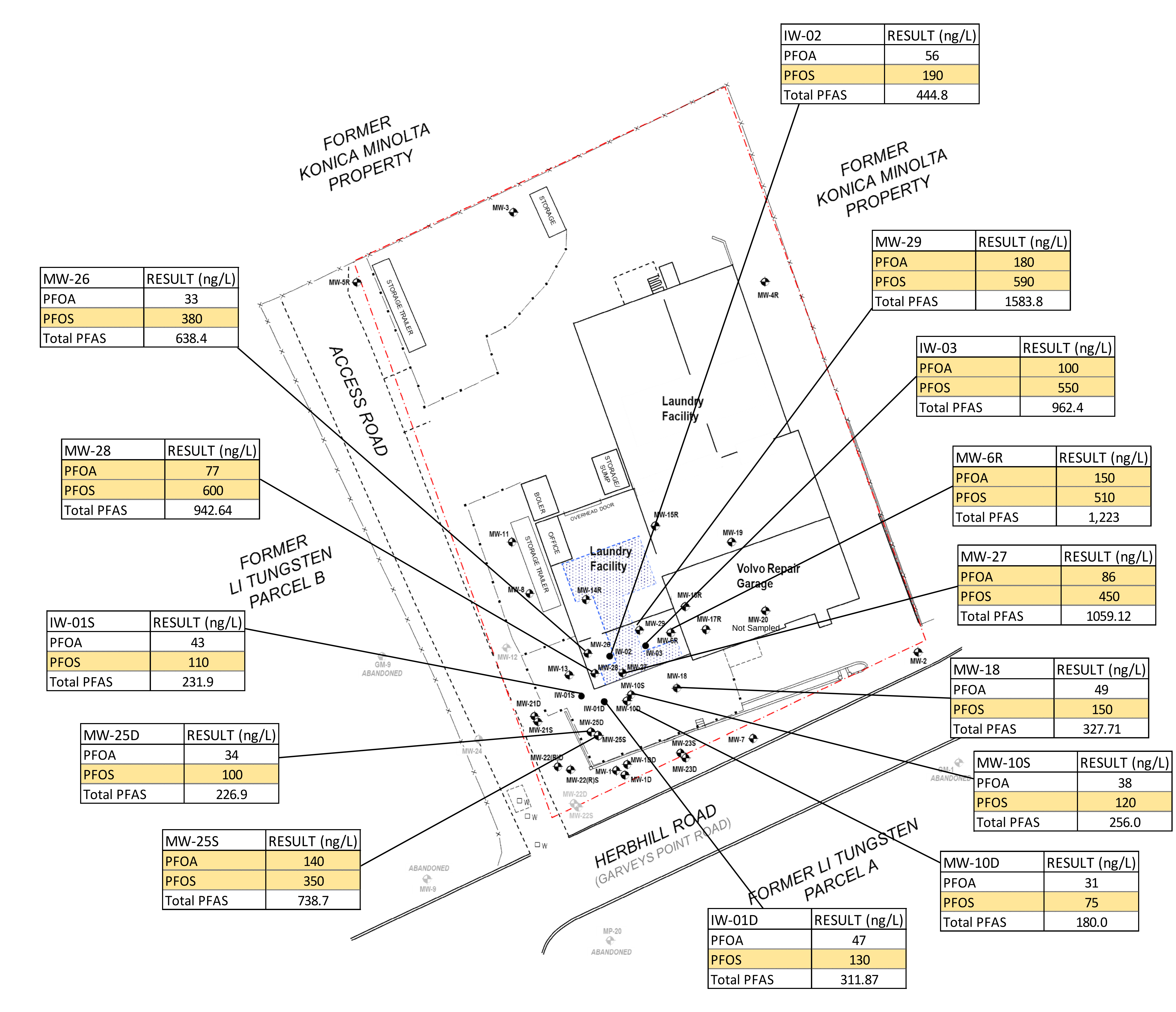
0 30 60
Approximate Scale in Feet

Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Summary of PFOA, PFOS and total Perfluoroalkyl Substances (PFAS) in Groundwater Samples – November 2017

ARCADIS Design & Consultancy for natural and built assets

10a
FIGURE



IW-02	RESULT (ng/L)
PFOA	56
PFOS	190
Total PFAS	444.8

MW-26	RESULT (ng/L)
PFOA	33
PFOS	380
Total PFAS	638.4

MW-29	RESULT (ng/L)
PFOA	180
PFOS	590
Total PFAS	1583.8

IW-03	RESULT (ng/L)
PFOA	100
PFOS	550
Total PFAS	962.4

MW-28	RESULT (ng/L)
PFOA	77
PFOS	600
Total PFAS	942.64

MW-6R	RESULT (ng/L)
PFOA	150
PFOS	510
Total PFAS	1,223

MW-27	RESULT (ng/L)
PFOA	86
PFOS	450
Total PFAS	1059.12

IW-01S	RESULT (ng/L)
PFOA	43
PFOS	110
Total PFAS	231.9

MW-18	RESULT (ng/L)
PFOA	49
PFOS	150
Total PFAS	327.71

MW-25D	RESULT (ng/L)
PFOA	34
PFOS	100
Total PFAS	226.9

MW-10S	RESULT (ng/L)
PFOA	38
PFOS	120
Total PFAS	256.0

MW-25S	RESULT (ng/L)
PFOA	140
PFOS	350
Total PFAS	738.7

MW-10D	RESULT (ng/L)
PFOA	31
PFOS	75
Total PFAS	180.0

IW-01D	RESULT (ng/L)
PFOA	47
PFOS	130
Total PFAS	311.87

LEGEND

- CHAIN-LINK FENCE
- WOOD-PICKET FENCE
- PROPERTY BOUNDARY (SURVEY)
- MW-9 GROUNDWATER MONITORING WELL
- MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL
- 2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING
- EXCEEDS USEPA HEALTH ADVISORY LEVEL FOR DRINKING WATER OF 70 ng/L FOR PFOA/PFOS

Notes:

IW-03 reported as DW-03 within analytical reports
ng/l – nanograms per liter

N

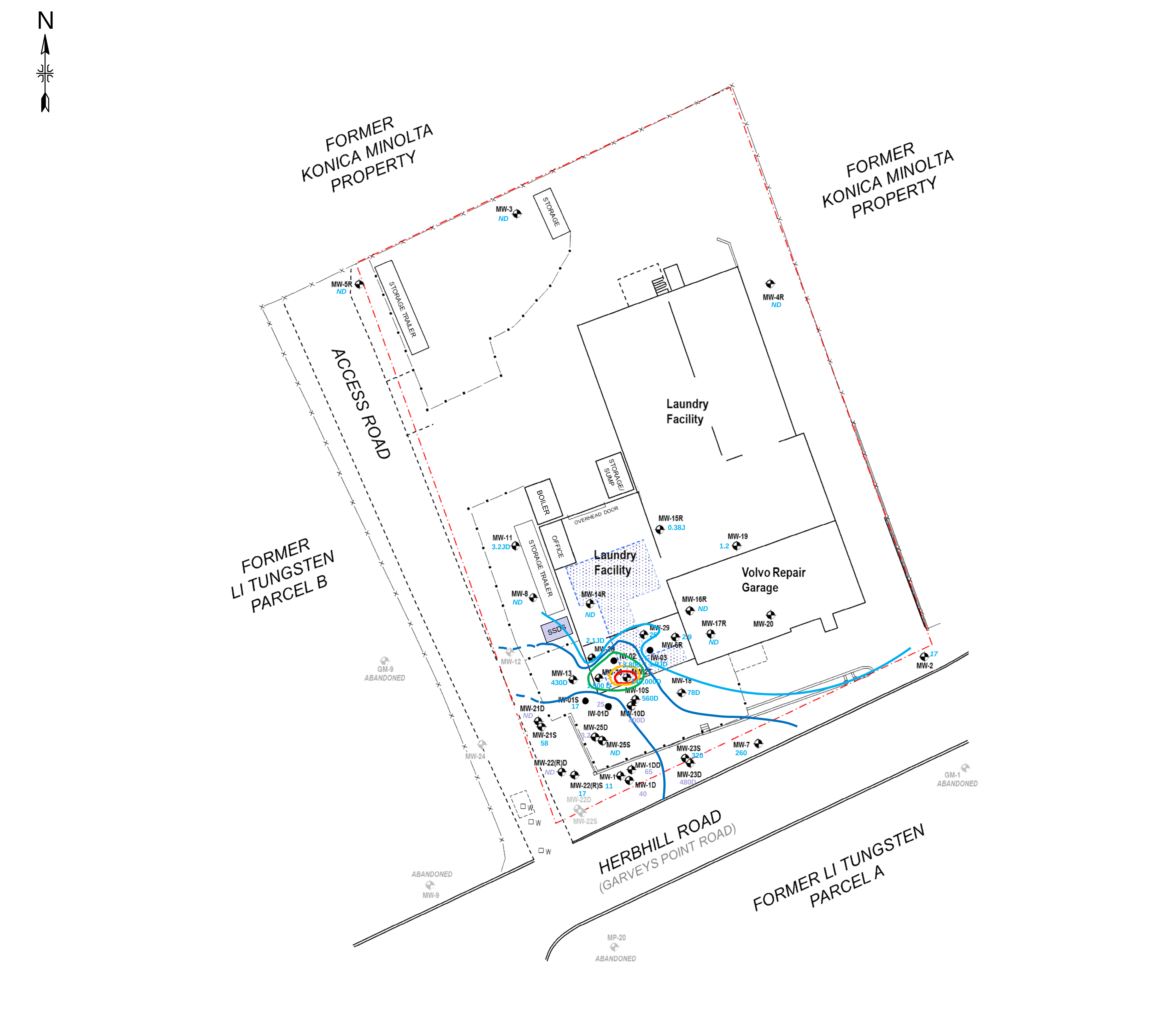
0 30 60
Approximate Scale in Feet

Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Summary of PFOA, PFOS and total Perfluoroalkyl Substances (PFAS) in Groundwater Samples – November 2017

ARCADIS Design & Consultancy for natural and built assets

10b
FIGURE



LEGEND

- CHAIN-LINK FENCE
- WOOD-PICKET FENCE
- PROPERTY BOUNDARY (SURVEY)
- MW-9 GROUNDWATER MONITORING WELL
- MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL
- 2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING

Notes:

J – Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

B – Compound was found in laboratory blank and sample (indicates potential laboratory contaminant)

D – Result is based on dilution of the sample.

Concentration Isocontour of Tetrachloroethene (PCE) in Groundwater – µg/L

- 100,000
- 10,000
- 1,000
- 100
- 10

Dashed where inferred – based on historic data. Contours non-depth-dependent.

0 30 60
Approximate Scale in Feet

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Site Distribution of Groundwater Chlorinated VOCs (October-November 2017); PCE

ARCADIS Design & Consultancy for natural and built assets

9a
FIGURE

LEGEND

CHAIN-LINK FENCE

WOOD-PICKET FENCE

PROPERTY BOUNDARY (SURVEY)

MW-9 GROUNDWATER MONITORING WELL

MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL

2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING

Notes:

J – Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

B – Compound was found in laboratory blank and sample (indicates potential laboratory contaminant)

D – Result is based on dilution of the sample.

ug/L – Micrograms per liter (all values shown).

Concentration Isocontour of cis-1,2-Dichloroethene (DCE) in Groundwater – µg/L

- 100,000
- 10,000
- 1,000
- 100
- 10

Dashed where inferred – based on historic data.
Contours non-depth-dependent.

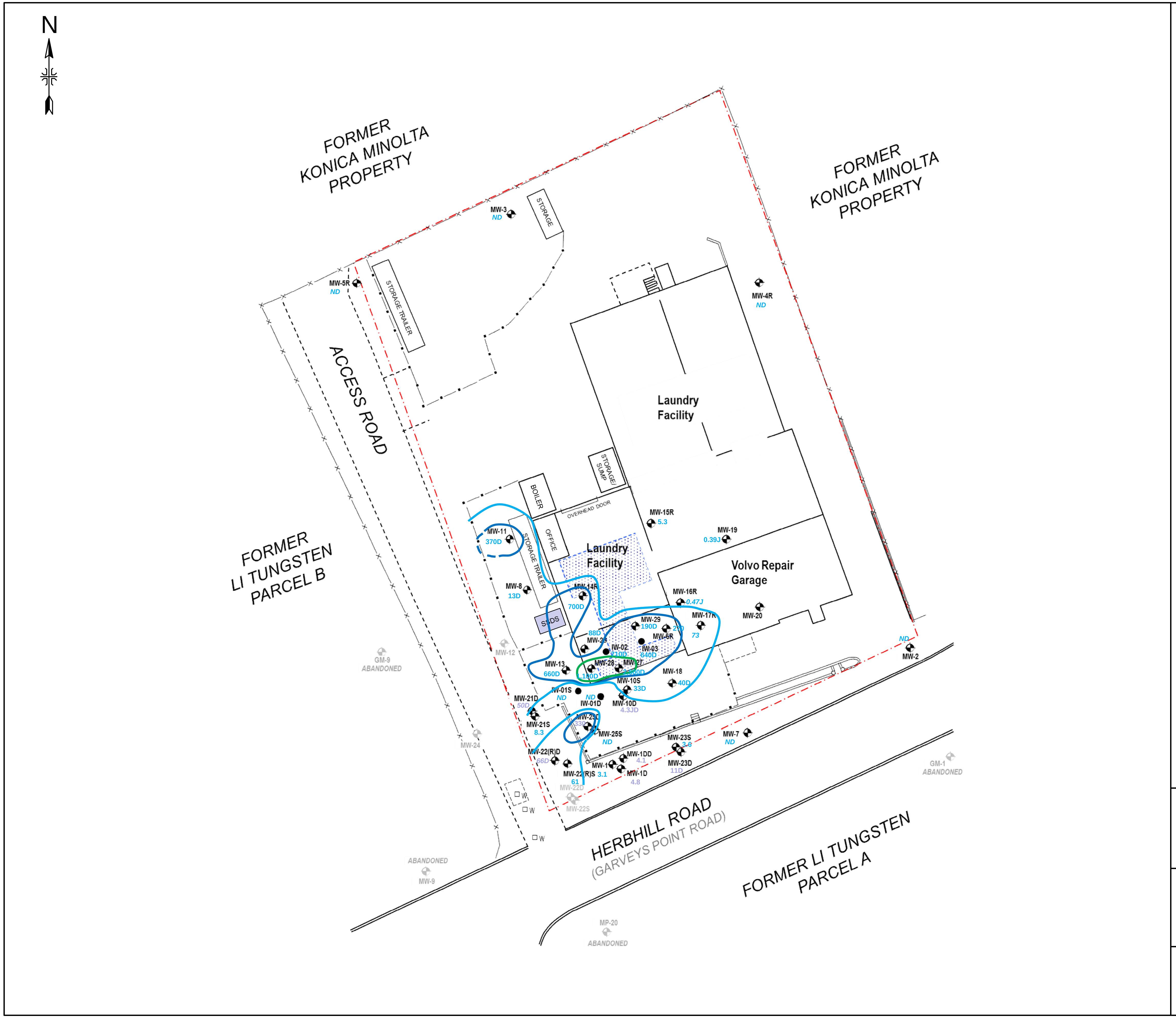
0 30 60
Approximate Scale in Feet

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Site Distribution of Groundwater Chlorinated VOCs (October-November 2017); Cis-1,2-DCE

ARCADIS Design & Consultancy for natural and built assets

9b
FIGURE



LEGEND

- CHAIN-LINK FENCE
- WOOD-PICKET FENCE
- PROPERTY BOUNDARY (SURVEY)
- MW-9 GROUNDWATER MONITORING WELL
- MW-8 MISSING/ DAMAGED GROUNDWATER MONITORING WELL
- 2005 IRM EXCAVATION AREA/ SVE SYSTEM SUB-SLAB PIPING

Notes:

J – Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

B – Compound was found in laboratory blank and sample (indicates potential laboratory contaminant)

D – Result is based on dilution of the sample.

ug/L – Micrograms per liter (all values shown).

Concentration Isocontour of Vinyl Chloride in Groundwater – µg/L

- 100,000
- 10,000
- 1,000
- 100
- 10

Dashed where inferred – based on historic data.
Contours non-depth-dependent.

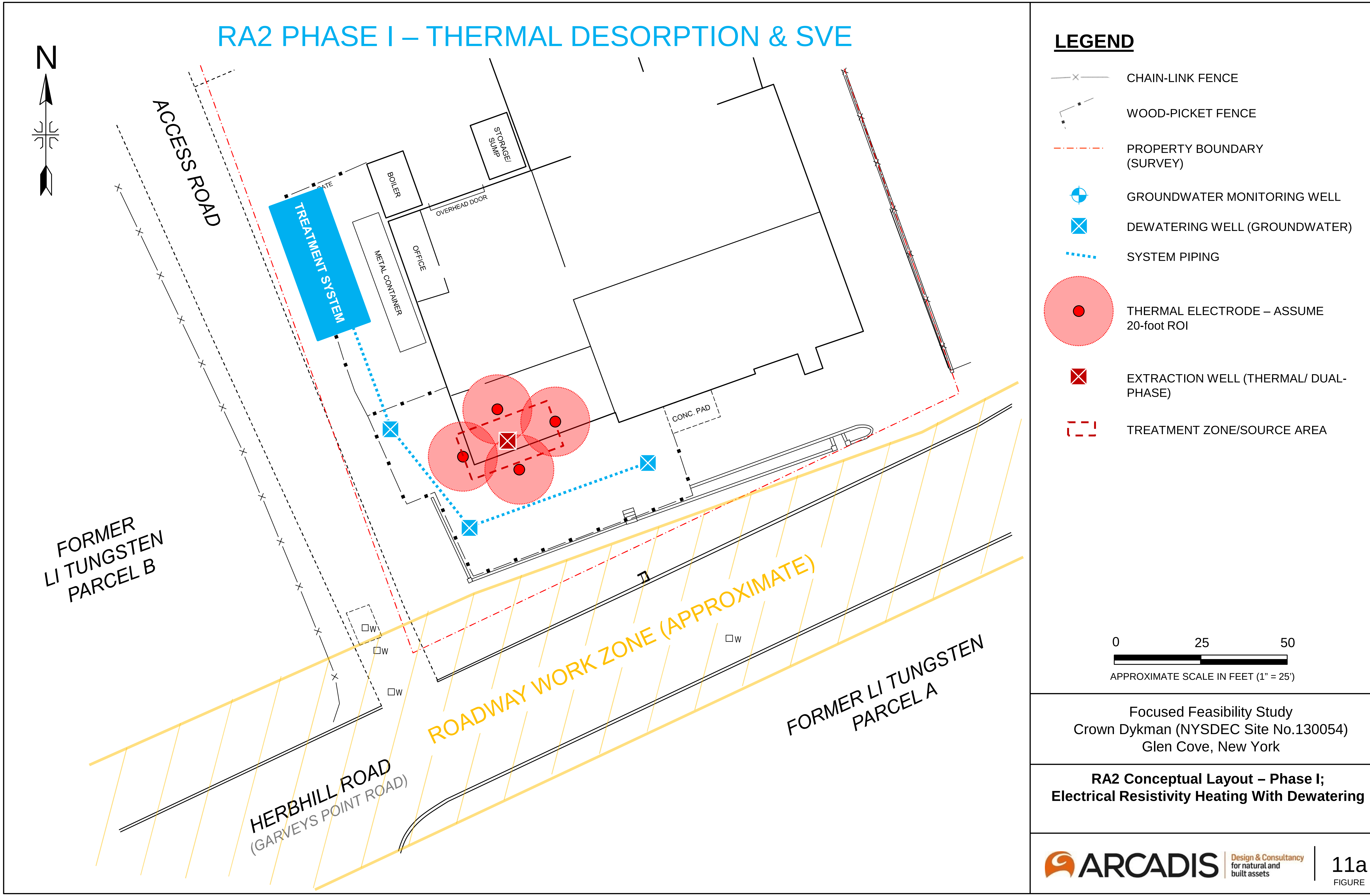
0 30 60
Approximate Scale in Feet

Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

Site Distribution of Groundwater Chlorinated VOCs (October-November 2017); Vinyl Chloride

ARCADIS Design & Consultancy for natural and built assets

9c
FIGURE



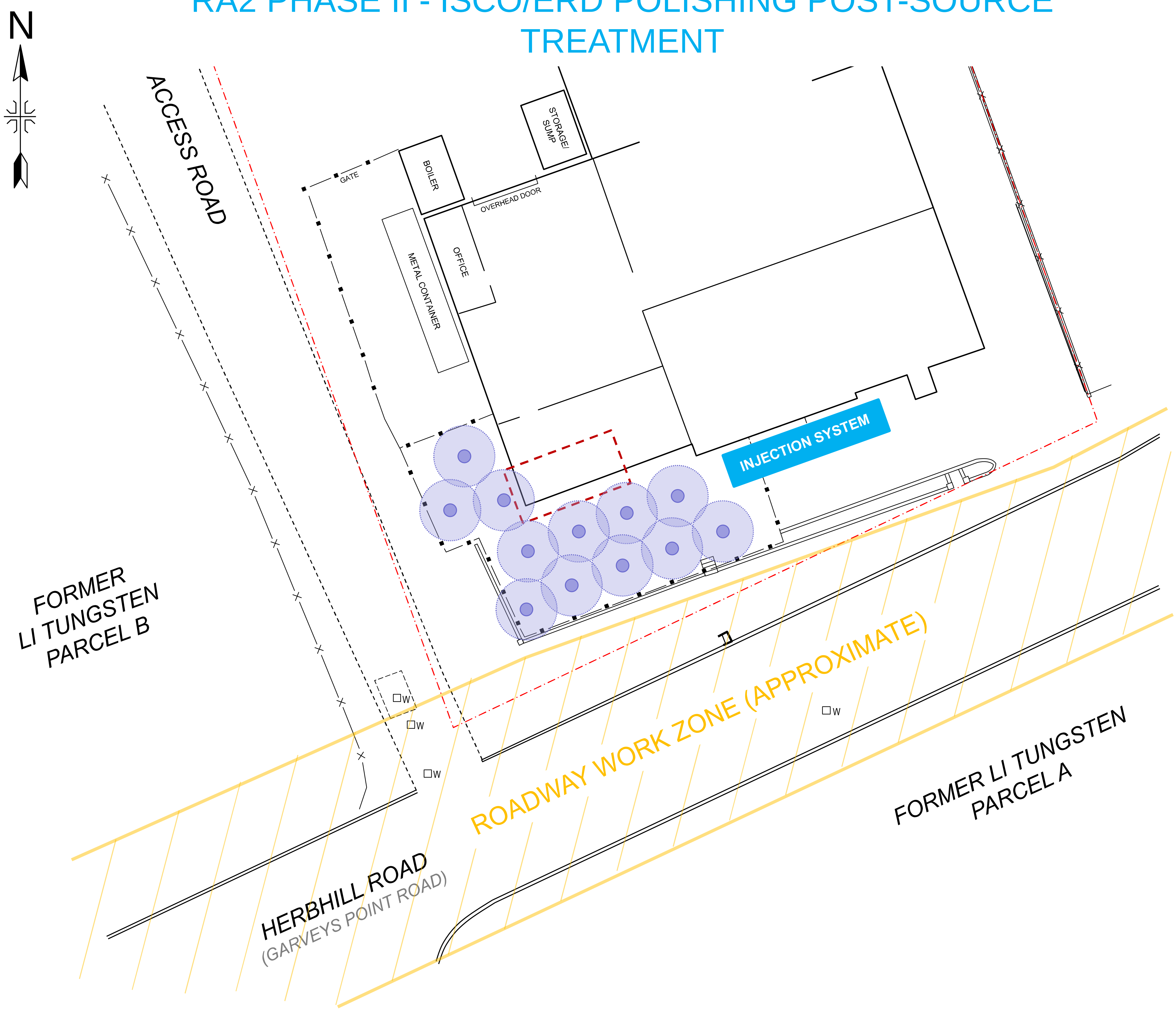
Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

RA2 Conceptual Layout – Phase I;
Electrical Resistivity Heating With Dewatering

ARCADIS Design & Consultancy for natural and built assets

11a
FIGURE

RA2 PHASE II - ISCO/ERD POLISHING POST-SOURCE TREATMENT



LEGEND

CHAIN-LINK FENCE

WOOD-PICKET FENCE

PROPERTY BOUNDARY (SURVEY)

GROUNDWATER MONITORING WELL

ISCO/ERD INJECTION WELL

TREATMENT ZONE/SOURCE AREA

0 25 50

APPROXIMATE SCALE IN FEET (1" = 25')

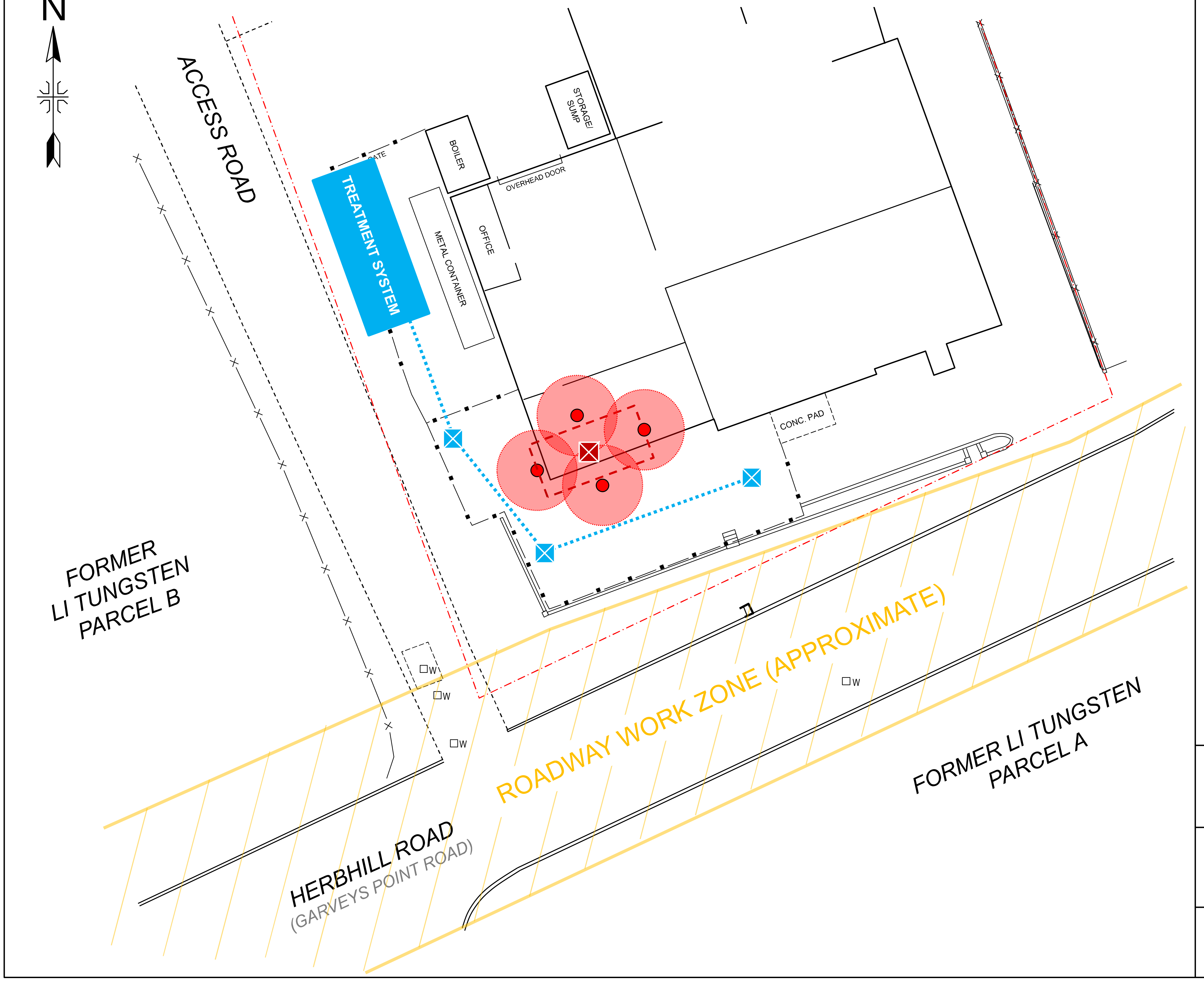
Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

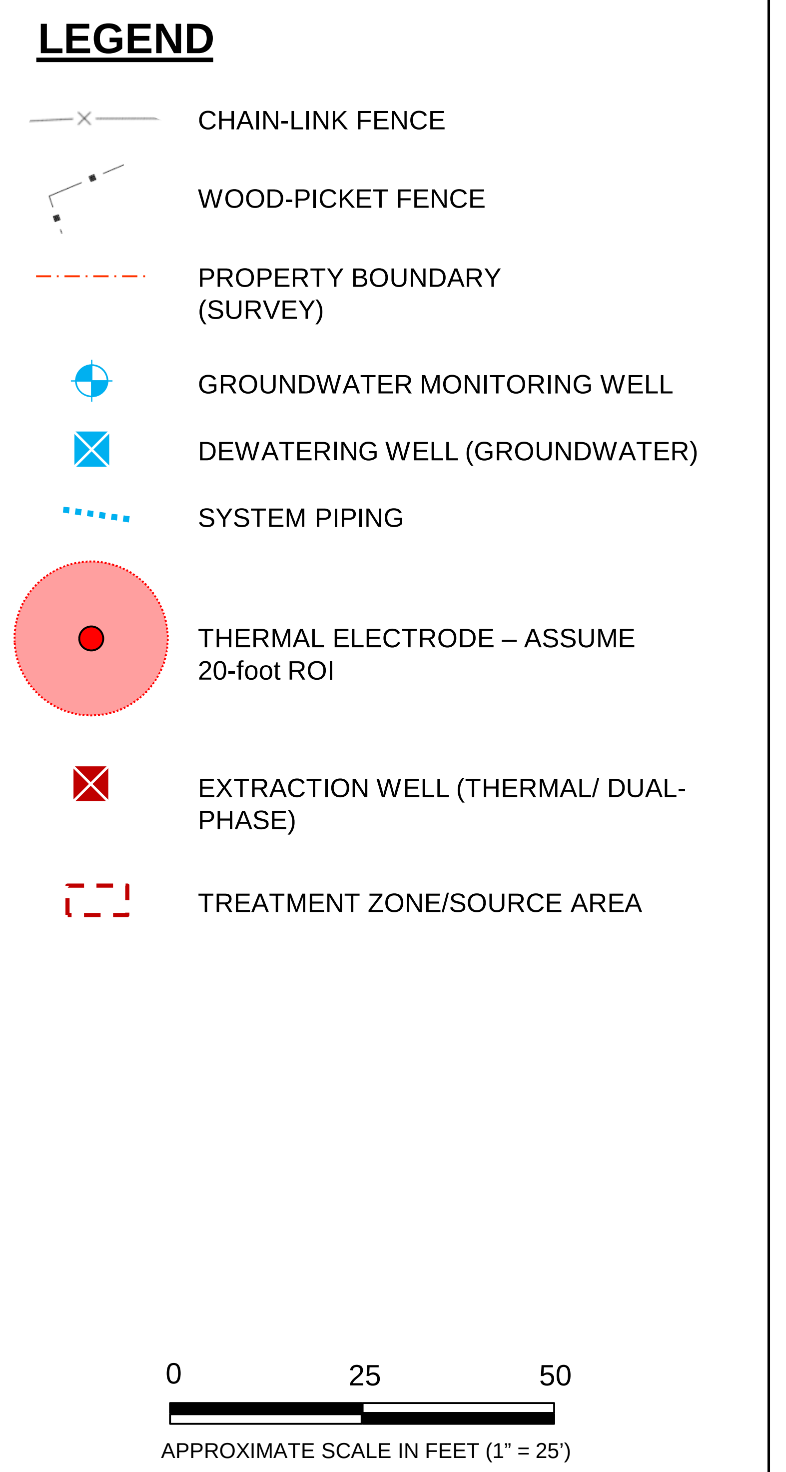
RA2 Conceptual Layout – Phase II; Downgradient ISCO Polishing – Sodium Permanganate Injections

ARCADIS Design & Consultancy for natural and built assets

11b
FIGURE

RA3 PHASE I – THERMAL DESORPTION & SVE





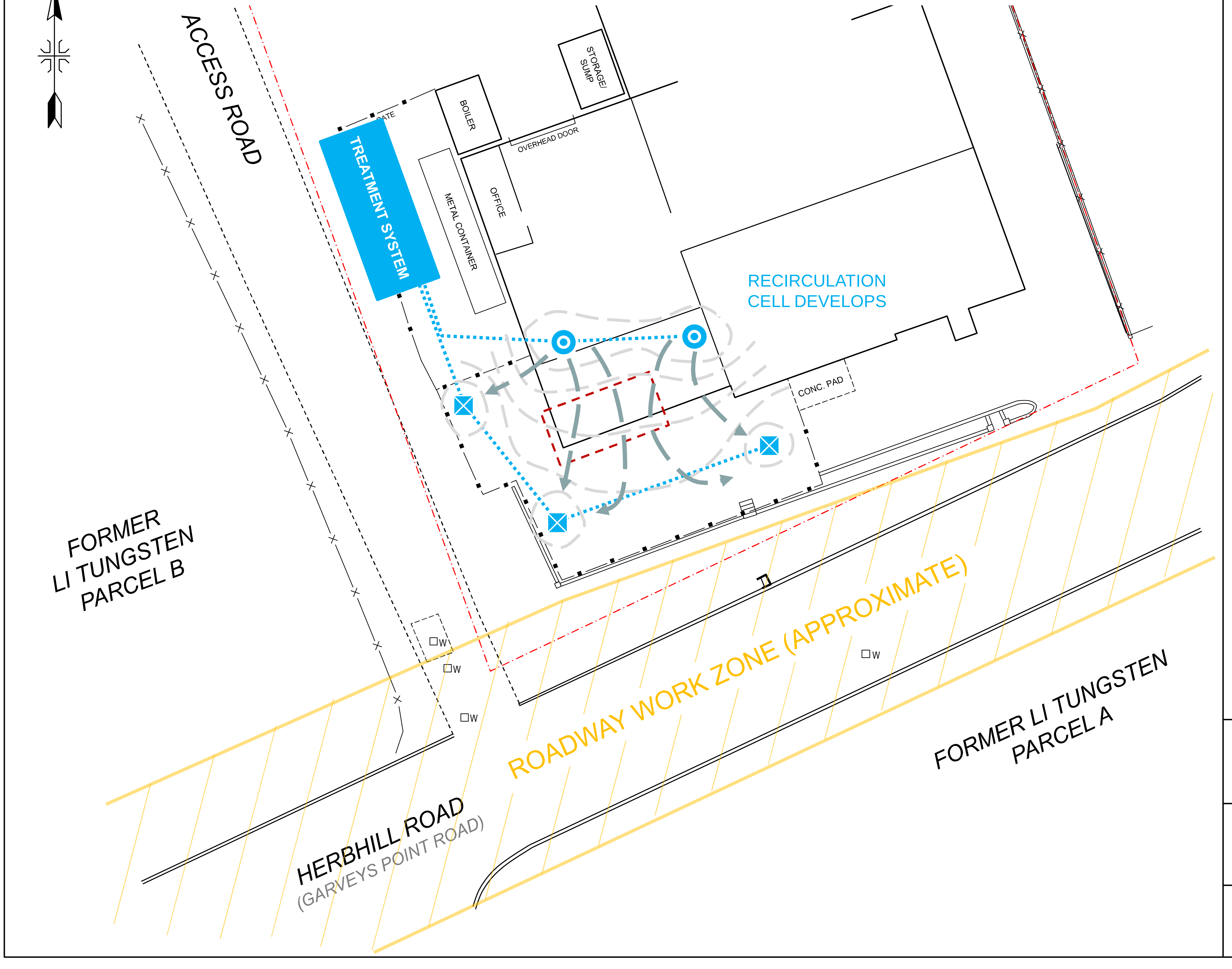
Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

RA3 Conceptual Layout – Phase I;
Electrical Resistivity Heating With Dewatering

ARCADIS Design & Consultancy for natural and built assets

12a
FIGURE

RA3 PHASE II - DIRECTED GROUNDWATER RECIRCULATION POLISHING



LEGEND

CHAIN-LINK FENCE
WOOD-PICKET FENCE
PROPERTY BOUNDARY (SURVEY)
GROUNDWATER MONITORING WELL
INJECTION WELL
DEWATERING WELL
SYSTEM PIPING
TREATMENT ZONE/SOURCE AREA
DGR Groundwater Flow Path (Simulated)
DGR Groundwater Isocontour (Simulated)

0 25 50
APPROXIMATE SCALE IN FEET (1" = 25')

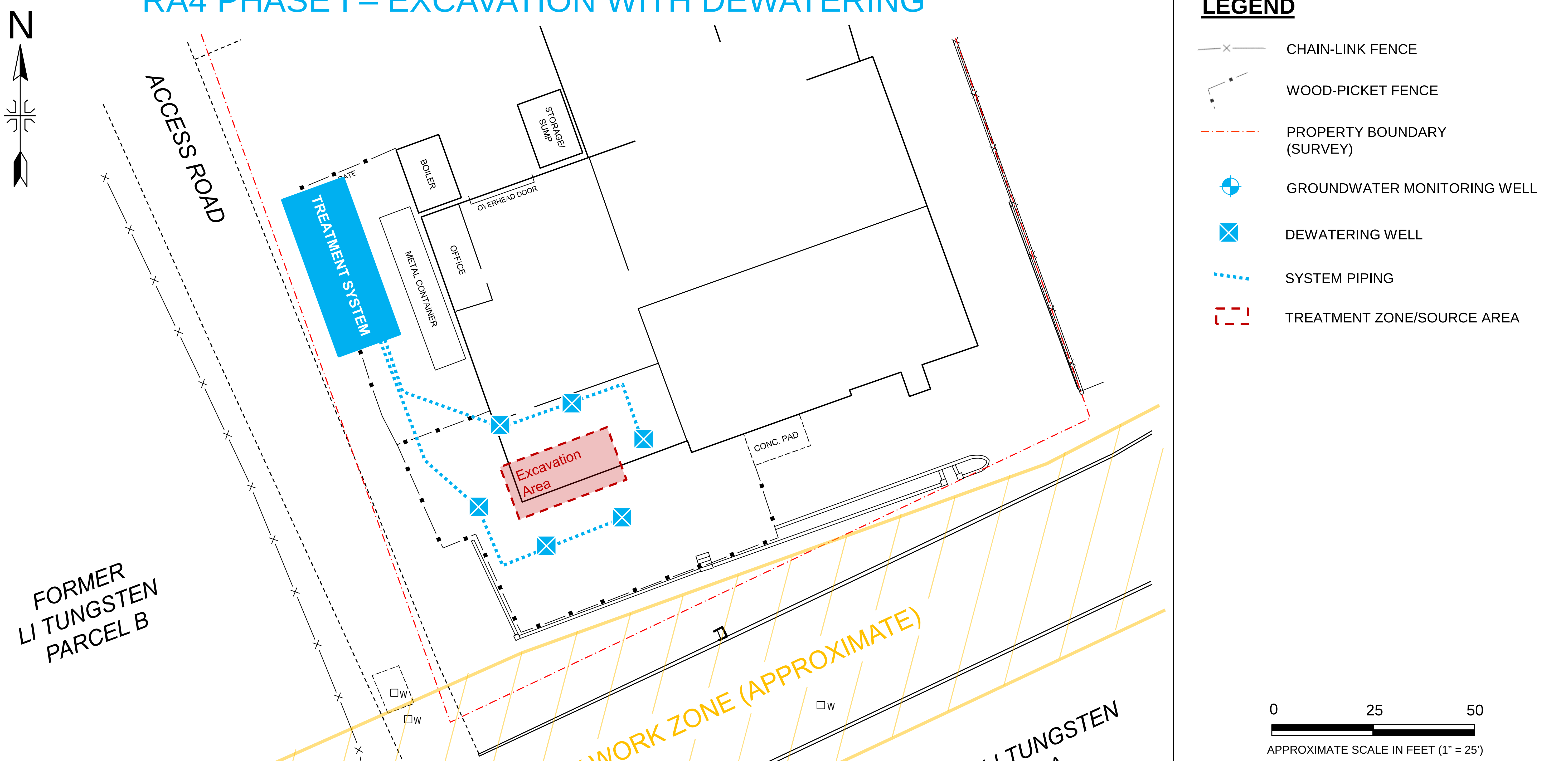
Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

RA3 Conceptual Layout – Phase II; Downgradient Directed Groundwater Recirculation

ARCADIS Design & Consultancy for natural and built assets

12b
FIGURE

RA4 PHASE I – EXCAVATION WITH DEWATERING



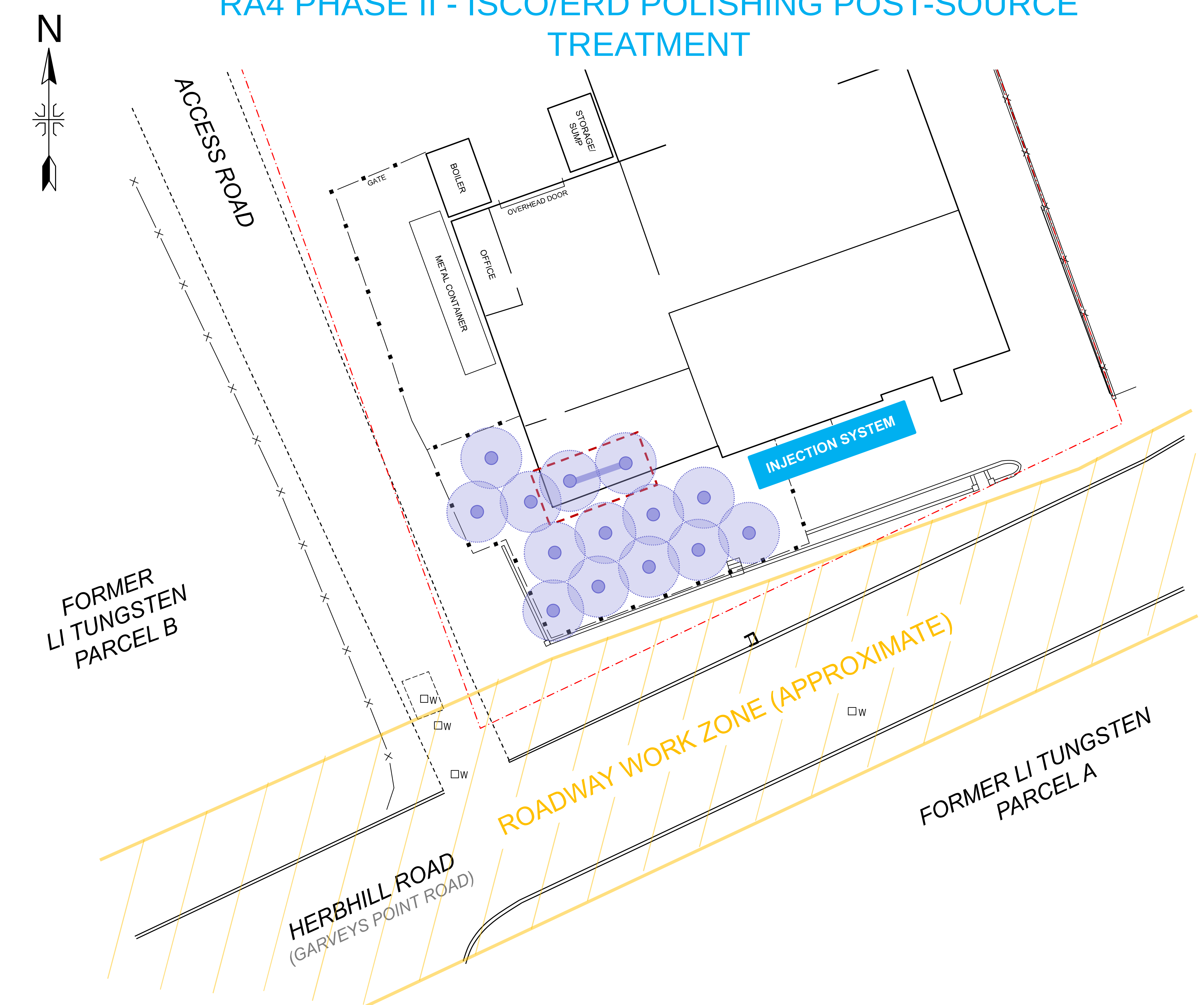
Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

RA4 Conceptual Layout – Phase I;
Source Area Excavation With Dewatering

ARCADIS Design & Consultancy for natural and built assets

FIGURE 13a

RA4 PHASE II - ISCO/ERD POLISHING POST-SOURCE TREATMENT



LEGEND

- CHAIN-LINK FENCE
- WOOD-PICKET FENCE
- PROPERTY BOUNDARY (SURVEY)
- GROUNDWATER MONITORING WELL
- ISCO/ERD INJECTION WELL
- TREATMENT ZONE/SOURCE AREA
- EXCAVATION AREA INJECTION MANIFOLD

0 25 50

APPROXIMATE SCALE IN FEET (1" = 25')

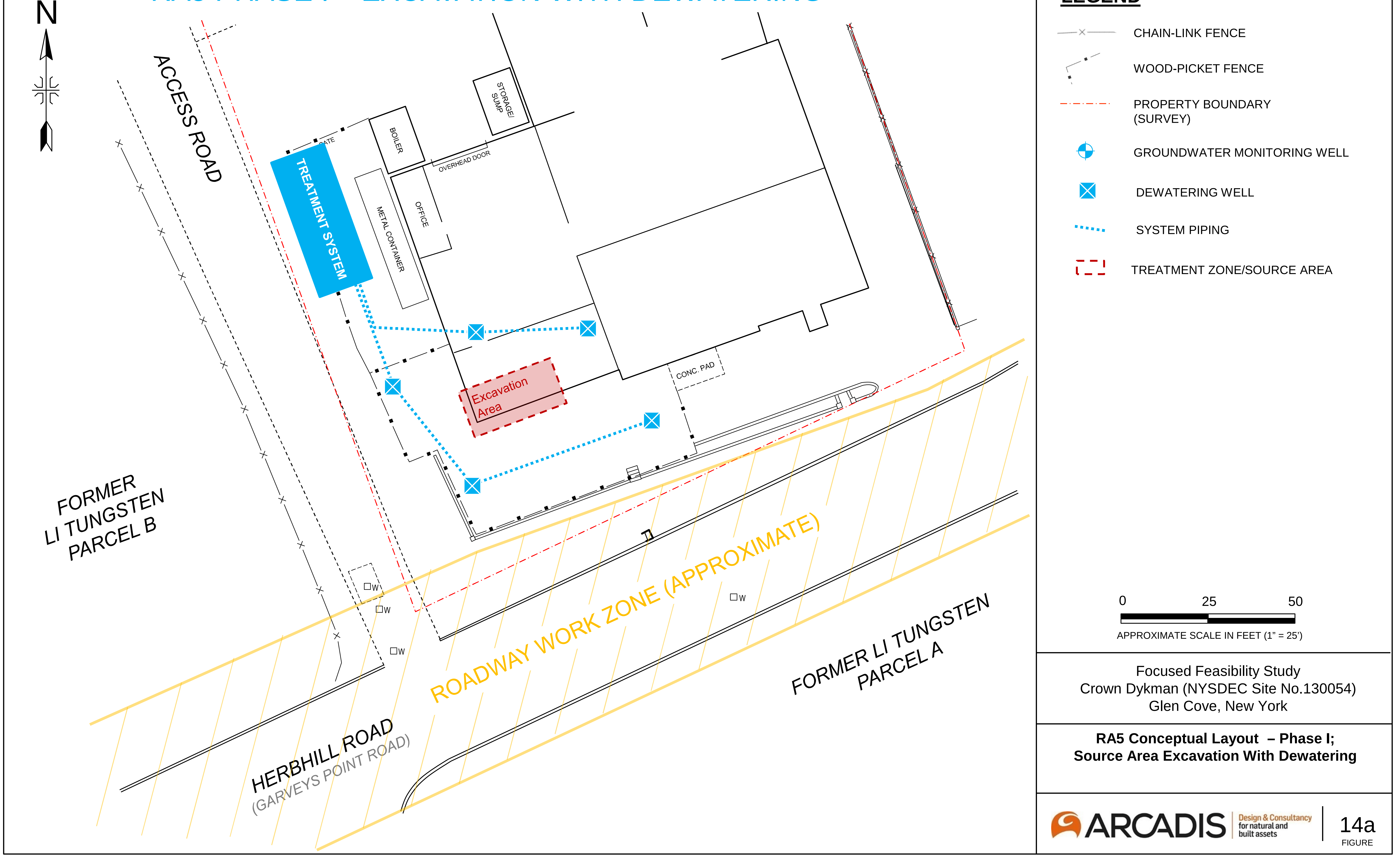
Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

RA4 Conceptual Layout – Phase II; Downgradient ISCO Polishing – Sodium Permanganate Injections

ARCADIS Design & Consultancy for natural and built assets

13b
FIGURE

RA5 PHASE I – EXCAVATION WITH DEWATERING



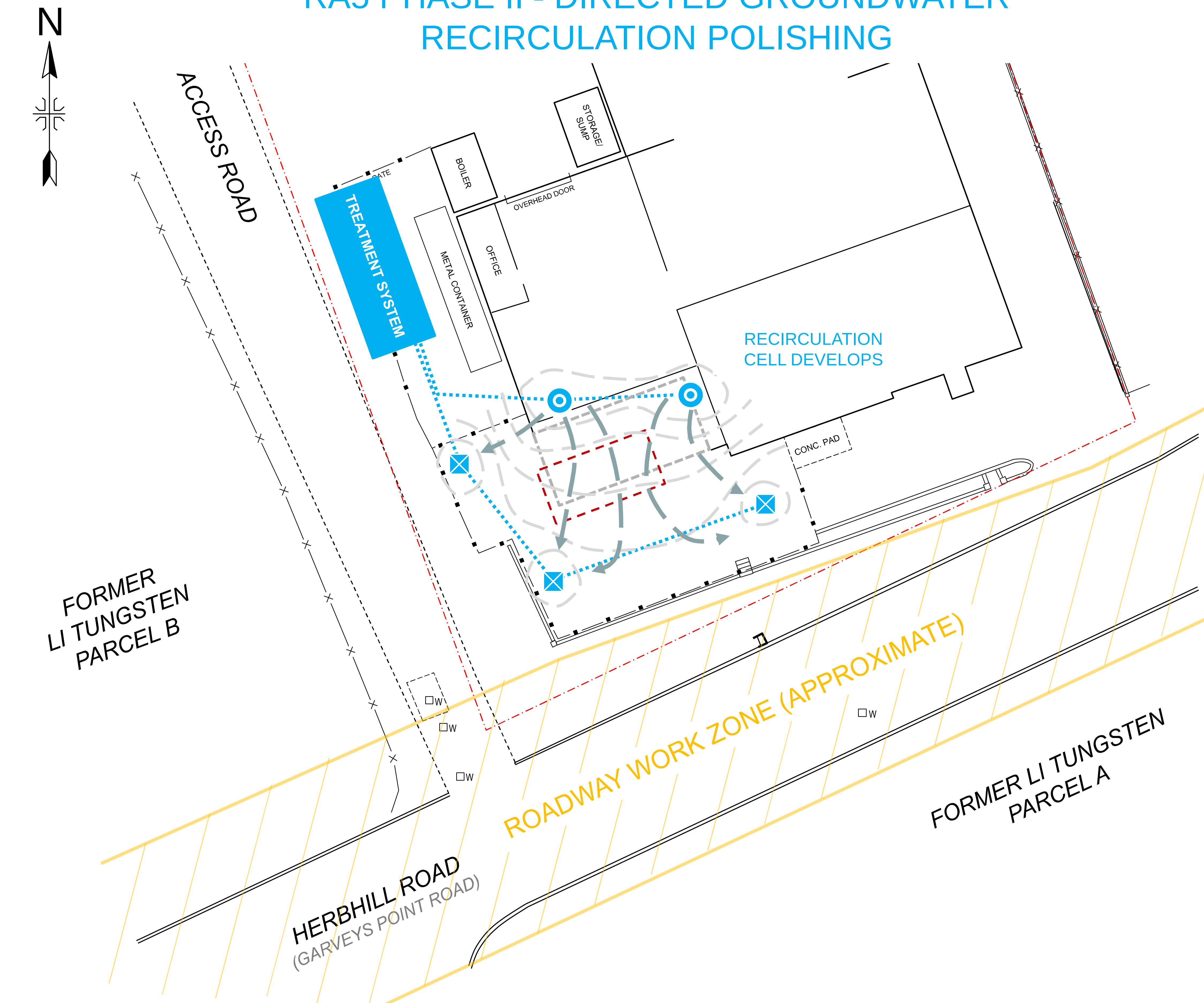
Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

RA5 Conceptual Layout – Phase I;
Source Area Excavation With Dewatering

ARCADIS Design & Consultancy for natural and built assets

14a
FIGURE

RA5 PHASE II - DIRECTED GROUNDWATER RECIRCULATION POLISHING



LEGEND

- CHAIN-LINK FENCE
- WOOD-PICKET FENCE
- PROPERTY BOUNDARY (SURVEY)
- GROUNDWATER MONITORING WELL
- INJECTION WELL
- DEWATERING WELL
- SYSTEM PIPING
- TREATMENT ZONE/SOURCE AREA
- DGR Groundwater Flow Path (Simulated)
- DGR Groundwater Isocontour (Simulated)

0 25 50

APPROXIMATE SCALE IN FEET (1" = 25')

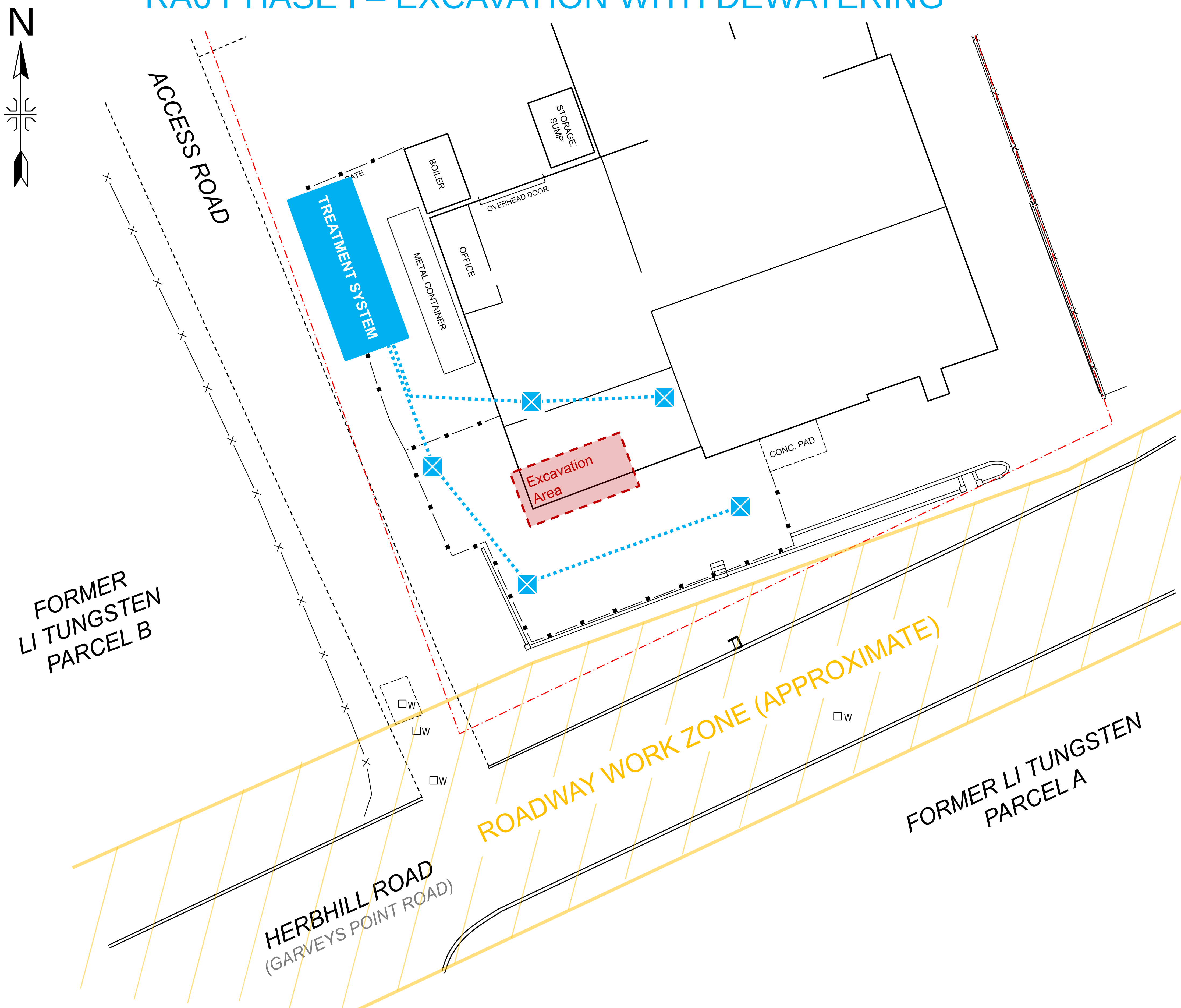
Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

RA5 Conceptual Layout – Phase II; Downgradient Directed Groundwater Recirculation

ARCADIS Design & Consultancy for natural and built assets

14b
FIGURE

RA6 PHASE I – EXCAVATION WITH DEWATERING



LEGEND

- CHAIN-LINK FENCE
- WOOD-PICKET FENCE
- PROPERTY BOUNDARY (SURVEY)
- GROUNDWATER MONITORING WELL
- DEWATERING WELL
- SYSTEM PIPING
- TREATMENT ZONE/SOURCE AREA

0 25 50

APPROXIMATE SCALE IN FEET (1" = 25')

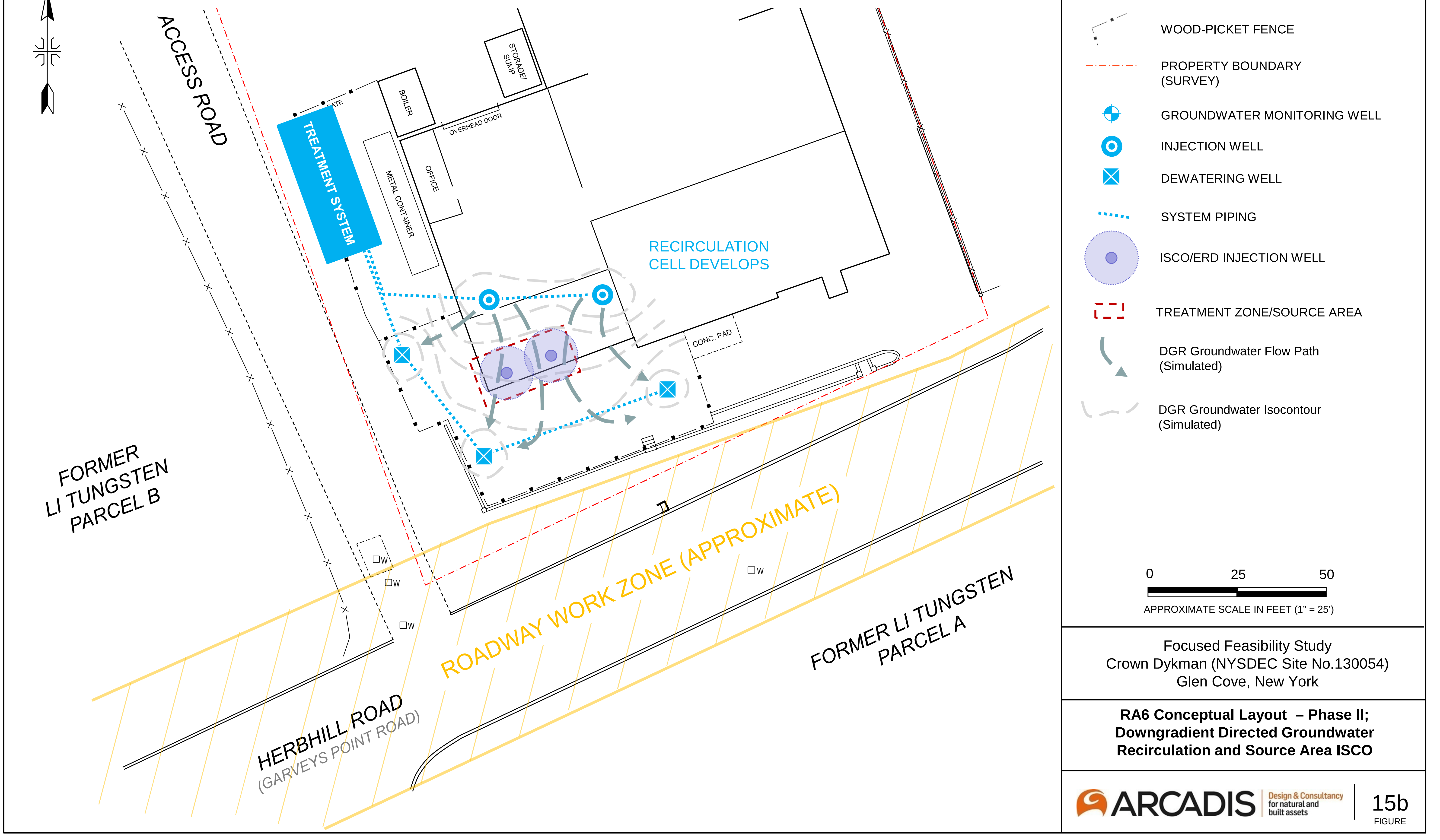
Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

RA6 Conceptual Layout – Phase I;
Source Area Excavation With Dewatering

ARCADIS Design & Consultancy for natural and built assets

15a
FIGURE

RA6 PHASE II - DIRECTED GROUNDWATER RECIRCULATION POLISHING AND SOURCE AREA ISCO



Focused Feasibility Study
Crown Dykman (NYSDEC Site No.130054)
Glen Cove, New York

RA6 Conceptual Layout – Phase II; Downgradient Directed Groundwater Recirculation and Source Area ISCO

ARCADIS Design & Consultancy for natural and built assets

15b
FIGURE

APPENDIX A

Opinion of Probable Costs – Remedial Alternatives

TABLE A-1; ESTIMATED REMEDIAL COSTS

REMEDIAL ALTERNATIVE 2 (RA2) - THERMAL SOURCE TREATMENT WITH ON-SITE GROUNDWATER ISCO POLISHING

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
I. CAPITAL COSTS							
A. SUPPORT/ GENERAL CONDITIONS							**$ 55,900**
Utility Survey	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Temporary Conditions - Construction phase	3	MO	$2,500	$ 7,500	*$ 1,500*	*$ 750*	$ 9,750
HASP Plan	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Implement HASP	3	MO	$3,500	$ 10,500	*$ 2,100*	*$ 1,050*	$ 13,650
Implement and Maintain SWPPP	3	MO	$5,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500
B. DEWATERING							**$ 320,450**
1. Recovery Wells							***$ 138,320***
Install 4-Inch Recovery Wells - 3 Wells	1	LS	$76,700	$ 76,700	*$ 15,340*	*$ 7,670*	$ 99,710
Wellhead Completion & Connections	3	EA	$2,400	$ 7,200	*$ 1,440*	*$ 720*	$ 9,360
F&I Submersible Pump, VFD and Level Control	3	EA	$7,500	$ 22,500	*$ 4,500*	*$ 2,250*	$ 29,250
2. System Piping							***$ 52,130***
Well Piping - F&I	160	LF	$35.00	$ 5,600	*$ 1,120*	*$ 560*	$ 7,280
Treatment System Discharge Piping	60	LF	$75.00	$ 4,500	*$ 900*	*$ 450*	$ 5,850
Discharge MH	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Upgrade Site sanitary system to municipal system	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Upgrade Site Building Water Piping to municipal system	1	LS	$15,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500
3. Electrical							***$ 130,000***
Site Electrical Service	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Pump Electrical	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Install Controls System	1	LS	$20,000	$ 20,000	*$ 4,000*	*$ 2,000*	$ 26,000
Install Treatment System Power	1	LS	$45,000	$ 45,000	*$ 9,000*	*$ 4,500*	$ 58,500
C. THERMAL SOURCE AREA & GROUNDWATER TREATMENT							**$ 1,942,360**
1. ERH Design/ Engineering							***$ 58,240***
Electrical Profiling	1	LS	$5,600	$ 5,600	*$ 1,120*	*$ 560*	$ 7,280
Modeling and Remedial Design	1	LS	$39,200	$ 39,200	*$ 7,840*	*$ 3,920*	$ 50,960
2. ERH Installation							***$ 859,720***
System Installation	1	LS	$224,000	$ 224,000	*$ 44,800*	*$ 22,400*	$ 291,200
Electrodes - Drilling	220	LF	$140	$ 30,800	*$ 6,160*	*$ 3,080*	$ 40,040
Extraction Well - Drilling	132	LF	$140	$ 18,480	*$ 3,696*	*$ 1,848*	$ 24,024
Sensor Wells	66	LF	$95.20	$ 6,283	*$ 1,257*	*$ 628*	$ 8,168
Piping and Manifold Construction	1	LS	$26,880	$ 26,880	*$ 5,376*	*$ 2,688*	$ 34,944
Vapor Cap	1800	SF	$11.20	$ 20,160	*$ 4,032*	*$ 2,016*	$ 26,208
Electrical - Utility Connection	1	LS	$250,000	$ 250,000	*$ 50,000*	*$ 25,000*	$ 325,000
Acceptance Testing	1	LF	$22,400	$ 22,400	*$ 4,480*	*$ 2,240*	$ 29,120
Existing Well Abandonment	11	EA	$1,120	$ 12,320	*$ 2,464*	*$ 1,232*	$ 16,016
Permitting	1	LS	$50,000	$ 50,000	*$ 10,000*	*$ 5,000*	$ 65,000
3. Groundwater Treatment System (DPE/MPE for ERH & Dewatering)							***$ 900,900***
Treatment System and Controls	1	LS	$500,000	$ 500,000	*$ 100,000*	*$ 50,000*	$ 650,000
Treatment System Enclosure	1	LS	$150,000	$ 150,000	*$ 30,000*	*$ 15,000*	$ 195,000
Treatment System HVAC	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Frac Tanks for System Commissioning	1	LS	$18,000	$ 18,000	*$ 3,600*	*$ 1,800*	$ 23,400
4. SSDS Construction (for ERH)							***$ 123,500***
SSDS Sub-slab Piping	1	LS	$50,000	$ 50,000	*$ 10,000*	*$ 5,000*	$ 65,000
System Reconnection & Upgrades	1	LS	$30,000	$ 30,000	*$ 6,000*	*$ 3,000*	$ 39,000
System Testing	1	LS	$15,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500

TABLE A-1; ESTIMATED REMEDIAL COSTS (PG. 2)

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
D. DOWNGRADIENT ON-SITE TREATMENT - SODIUM PERMANGANATE ISCO							**$ 867,295**
1. Injection and Monitoring Wells							**$ 573,820**
Injection Well Installation & Development	1	LS	264,000	$ 264,000	*$ 52,800*	*$ 26,400*	$ 343,200
Process Monitoring Well Installation & Development	1	LS	85,000	$ 85,000	*$ 17,000*	*$ 8,500*	$ 110,500
Downgradient Monitoring Well Replacements	1	LS	90,000	$ 90,000	*$ 18,000*	*$ 9,000*	$ 117,000
Well Survey	1	LS	2,400	$ 2,400	*$ 480*	*$ 240*	$ 3,120
2. Injection System							**$ 293,475**
Well Piping - F&I	500	LF	$35.00	$ 17,500	*$ 3,500*	*$ 1,750*	$ 22,750
Sodium Permanganate	35,000	lbs	$5.95	$208,250	*$ 41,650*	*$ 20,825*	$ 270,725
E. MISCELLANEOUS							**$ 875,209**
1. Site Restoration							***$ 340,600***
Characterize and Disposal of Excavated Soils	1	LS	$37,000	$ 37,000	*$ 7,400*	*$ 3,700*	$ 48,100
Site Restoration	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Slab Removal	1	LS	$200,000	$ 200,000	*$ 40,000*	*$ 20,000*	$ 260,000
2. Bond & Insurance							***$ 142,420***
Bond & Insurance - assume 3.5% of construction costs	1	LS	$109,554	$ 109,554	*$ 21,911*	*$ 10,955*	$ 142,420
City Index - Hicksville, NY (+11.3%)							$ 392,190

Total Probable Estimated Capital Cost - Alternative II	Point Estimate	**$ 4,061,215**
	Range Estimate - Low (-30%)	$ 2,842,850.24
	Range estimate - High (+50%)	$ 6,091,821.94

II. OM&M COSTS

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
A. THERMAL SYSTEM OM&M - Assumes 19 months of operation - includes dewatering							***$ 1,977,159***
Operator - per month	19	Month	$33,600	$ 638,400	*$ 127,680*	*$ 63,840*	$ 829,920
DPE/MPE OM&M	19	Month	$7,500	$ 142,500	*$ 28,500*	*$ 14,250*	$ 185,250
Water Utility	1,900,000	Gal	$0.005	$ 9,500	*$ 1,900*	*$ 950*	$ 12,350
Electrical - Utility Rate	1,345,438	kWhr	$0.100	$ 134,544	*$ 26,909*	*$ 13,454*	$ 174,907
Perimeter Air Monitoring	1	LS	$75,000	$ 75,000	*$ 15,000*	*$ 7,500*	$ 97,500
Service and License Fee	19	Month	$4,500	$ 85,500	*$ 17,100*	*$ 8,550*	$ 111,150
Part-time Air Monitoring	19	Month	$5,000	$ 95,000	*$ 19,000*	*$ 9,500*	$ 123,500
Dewatering System Sampling & Monitoring	19	Month	$10,000	$ 190,000	*$ 38,000*	*$ 19,000*	$ 247,000
Analytical Costs	19	Month	$4,800	$ 91,200	*$ 18,240*	*$ 9,120*	$ 118,560
Demobilization of Treatment System	1	LS	$29,120	$ 29,120	*$ 5,824*	*$ 2,912*	$ 37,856
Post Remediation Abandonment	19	EA	$112	$ 2,128	*$ 426*	*$ 213*	$ 2,766
Site Restoration	1	LS	$28,000	$ 28,000	*$ 5,600*	*$ 2,800*	$ 36,400
B. ISCO OM&M - Assumes 48 months of operation; 8 Injection Events; monthly monitoring & sampling; quarterly reporting							***$ 1,524,445***
Sodium Permanganate	75,000	lbs	$5.95	$446,250	*$ 89,250*	*$ 44,625*	$ 580,125
Mobile Injection System Rental	8	EA	$25,000	$200,000	*$ 40,000*	*$ 20,000*	$ 260,000
Injection Event Operations	8	EA	$10,000	$80,000	*$ 16,000*	*$ 8,000*	$ 104,000
Post-injection Sampling & Monitoring	40	EA	$8,000	$320,000	*$ 64,000*	*$ 32,000*	$ 416,000
Analytical Costs	40	EA	$2,160	$86,400	*$ 17,280*	*$ 8,640*	$ 112,320
Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000
C. Post-Treatment Monitoring - Assumes 24 months of operation							***$ 187,200***
Post-treatment Sampling & Monitoring	8	EA	$13,000	$104,000	*$ 20,800*	*$ 10,400*	$ 135,200
Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000
D. SSDS - Assumes 19 month duration over thermal system operation							***$ 124,800***
SSDS OM&M (incl. sampling/ analytical costs)	19	MO	$4,000	$76,000	*$ 15,200*	*$ 7,600*	$ 98,800
Reporting	1	LS	$20,000	$20,000	*$ 4,000*	*$ 2,000*	$ 26,000
E. Closure - Decommissioning							***$ 233,870***
Monitoring Well Decommissioning	42	EA	$1,200	$50,400	*$ 10,080*	*$ 5,040*	$ 65,520
Injection System Decommissioning	1	LS	$35,000	$35,000	*$ 7,000*	*$ 3,500*	$ 45,500
Decommissioning - Dewatering Treatment System Removal	1	LS	$50,000	$50,000	*$ 10,000*	*$ 5,000*	$ 65,000
Decommissioning - Dewatering Well Abandonment	3	EA	1500	$4,500	*$ 900*	*$ 450*	$ 5,850
Post-Closure Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000

Total Probable Estimated OM&M Cost - Alternative II	Point Estimate	**$ 4,047,474**
	Range Estimate - Low (-30%)	$ 2,833,231.99
	Range estimate - High (+50%)	$ 6,071,211.41
TOTAL ESTIMATED PROBABLE REMEDY COST (Capital + OM&M)		**$ 8,108,689**
Present Net Worth (Assuming 5% Annual ROI)		$ 7,616,066

TABLE A-2; ESTIMATED REMEDIAL COSTS

REMEDIAL ALTERNATIVE 3 (RA3) - THERMAL SOURCE TREATMENT WITH ON-SITE GROUNDWATER DGR POLISHING

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
I. CAPITAL COSTS							
A. SUPPORT/ GENERAL CONDITIONS							**$ 55,900**
Utility Survey	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Temporary Conditions - Construction phase	3	MO	$2,500	$ 7,500	*$ 1,500*	*$ 750*	$ 9,750
HASP Plan	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Implement HASP	3	MO	$3,500	$ 10,500	*$ 2,100*	*$ 1,050*	$ 13,650
Implement and Maintain SWPPP	3	MO	$5,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500
B. DEWATERING							**$ 368,290**
1. Recovery Wells (Component of DGR System)							***$ 181,610***
Install 6 Inch Recovery Wells - 3 Wells	1	LS	$110,000	$ 110,000	*$ 22,000*	*$ 11,000*	$ 143,000
Wellhead Completion & Connections	3	EA	$2,400	$ 7,200	*$ 1,440*	*$ 720*	$ 9,360
F&I Submersible Pump, VFD and Level Control	3	EA	$7,500	$ 22,500	*$ 4,500*	*$ 2,250*	$ 29,250
2. System Piping (Component of DGR System)							***$ 56,680***
Well Piping - F&I	260	LF	$35.00	$ 9,100	*$ 1,820*	*$ 910*	$ 11,830
Treatment System Discharge Piping	60	LF	$75.00	$ 4,500	*$ 900*	*$ 450*	$ 5,850
Discharge MH	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Upgrade Site sanitary system to municipal system	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Upgrade Site Building Water Piping to municipal system	1	LS	$15,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500
3. Electrical							***$ 130,000***
Site Electrical Service	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Pump Electrical	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Install Controls System	1	LS	$20,000	$ 20,000	*$ 4,000*	*$ 2,000*	$ 26,000
Install Treatment System Power	1	LS	$45,000	$ 45,000	*$ 9,000*	*$ 4,500*	$ 58,500
C. THERMAL SOURCE AREA & GROUNDWATER TREATMENT							**$ 1,955,360**
1. ERH Design/ Engineering							***$ 58,240***
Electrical Profiling	1	LS	$5,600	$ 5,600	*$ 1,120*	*$ 560*	$ 7,280
Modeling and Remedial Design	1	LS	$39,200	$ 39,200	*$ 7,840*	*$ 3,920*	$ 50,960
2. ERH Installation							***$ 859,720***
System Installation	1	LS	$224,000	$ 224,000	*$ 44,800*	*$ 22,400*	$ 291,200
Electrodes - Drilling	220	LF	$140	$ 30,800	*$ 6,160*	*$ 3,080*	$ 40,040
Extraction Well - Drilling	132	LF	$140	$ 18,480	*$ 3,696*	*$ 1,848*	$ 24,024
Sensor Wells	66	LF	$95.20	$ 6,283	*$ 1,257*	*$ 628*	$ 8,168
Piping and Manifold Construction	1	LS	$26,880	$ 26,880	*$ 5,376*	*$ 2,688*	$ 34,944
Vapor Cap	1800	SF	$11.20	$ 20,160	*$ 4,032*	*$ 2,016*	$ 26,208
Electrical - Utility Connection	1	LS	$250,000	$ 250,000	*$ 50,000*	*$ 25,000*	$ 325,000
Acceptance Testing	1	LF	$22,400	$ 22,400	*$ 4,480*	*$ 2,240*	$ 29,120
Existing Well Abandonment	11	EA	$1,120	$ 12,320	*$ 2,464*	*$ 1,232*	$ 16,016
Permitting	1	LS	$50,000	$ 50,000	*$ 10,000*	*$ 5,000*	$ 65,000
3. Groundwater Treatment System (DPE/MPE for ERH, DGR and Dewatering)							***$ 913,900***
Treatment System and Controls	1	LS	$500,000	$ 500,000	*$ 100,000*	*$ 50,000*	$ 650,000
Treatment System Enclosure	1	LS	$150,000	$ 150,000	*$ 30,000*	*$ 15,000*	$ 195,000
Treatment System HVAC	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Frac Tanks for System Commissioning	1	LS	$28,000	$ 28,000	*$ 5,600*	*$ 2,800*	$ 36,400
4. SSDS Construction (for ERH)							***$ 123,500***
SSDS Sub-slab Piping	1	LS	$50,000	$ 50,000	*$ 10,000*	*$ 5,000*	$ 65,000
System Reconnection & Upgrades	1	LS	$30,000	$ 30,000	*$ 6,000*	*$ 3,000*	$ 39,000
System Testing	1	LS	$15,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500

TABLE A-2; ESTIMATED REMEDIAL COSTS (PG. 2)

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
D. DOWNGRADIENT ON-SITE TREATMENT - DIRECTED GROUNDWATER RECIRCULATION							**$ 328,510**
1. Injection and Monitoring Wells							**$ 221,260**
6-inch Diameter Injection Well Installation - 2 upgradient wells	1	LS	$73,000	$ 73,000	*$ 14,600*	*$ 7,300*	$ 94,900
Wellhead completion & Connections	2	EA	$2,400	$ 4,800	*$ 960*	*$ 480*	$ 6,240
Downgradient Monitoring Well Replacements	1	LS	$90,000	$ 90,000	*$ 18,000*	*$ 9,000*	$ 117,000
Well Survey	1	LS	$2,400	$ 2,400	*$ 480*	*$ 240*	$ 3,120
2. Injection System							**$ 107,250**
Install Controls System	1	LS	$20,000	$ 20,000	*$ 4,000*	*$ 2,000*	$ 26,000
Install Injection pumps & flow meters	1	LS	$45,000	$ 45,000	*$ 9,000*	*$ 4,500*	$ 58,500
Well Piping - F&I	500	LF	$35.00	$ 17,500	*$ 3,500*	*$ 1,750*	$ 22,750
D. MISCELLANEOUS							**$ 799,455**
1. Site Restoration							***$ 340,600***
Characterize and Disposal of Excavated Soils	1	LS	$37,000	$ 37,000	*$ 7,400*	*$ 3,700*	$ 48,100
Site Restoration	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Slab Removal	1	LS	$200,000	$ 200,000	*$ 40,000*	*$ 20,000*	$ 260,000
2. Bond & Insurance							***$ 120,673***
Bond & Insurance - assume 3.5% of construction costs	1	LS	$92,826	$ 92,826	*$ 18,565*	*$ 9,283*	$ 120,673
City Index - Hicksville, NY (+11.3%)							$ 338,182

Total Probable Estimated Capital Cost - Alternative III		
	Point Estimate	**$ 3,507,515**
	Range Estimate - Low (-30%)	$ 2,455,260.74
	Range estimate - High (+50%)	$ 5,261,273.02

II. OM&M COSTS

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
A. THERMAL SYSTEM OM&M - Assumes 19 months of operation - includes dewatering							***$ 1,977,159***
Operator - per month	19	Month	$33,600	$ 638,400	*$ 127,680*	*$ 63,840*	$ 829,920
DPE/MPE OM&M	19	Month	$7,500	$ 142,500	*$ 28,500*	*$ 14,250*	$ 185,250
Water Utility	1,900,000	Gal	$0.005	$ 9,500	*$ 1,900*	*$ 950*	$ 12,350
Electrical - Utility Rate	1,345,438	kWhr	$0.100	$ 134,544	*$ 26,909*	*$ 13,454*	$ 174,907
Perimeter Air Monitoring	1	LS	$75,000	$ 75,000	*$ 15,000*	*$ 7,500*	$ 97,500
Service and License Fee	19	Month	$4,500	$ 85,500	*$ 17,100*	*$ 8,550*	$ 111,150
Part-time Air Monitoring	19	Month	$5,000	$ 95,000	*$ 19,000*	*$ 9,500*	$ 123,500
Dewatering System Sampling & Monitoring	19	Month	$10,000	$ 190,000	*$ 38,000*	*$ 19,000*	$ 247,000
Analytical Costs	19	Month	$4,800	$ 91,200	*$ 18,240*	*$ 9,120*	$ 118,560
Demobilization of Treatment System	1	LS	$29,120	$ 29,120	*$ 5,824*	*$ 2,912*	$ 37,856
Post Remediation Abandonment	19	EA	$112	$ 2,128	*$ 426*	*$ 213*	$ 2,766
Site Restoration	1	LS	$28,000	$ 28,000	*$ 5,600*	*$ 2,800*	$ 36,400
B. DGR OM&M - Assumes 72 months of operation; monthly monitoring & sampling; quarterly reporting							***$ 1,264,432***
Monthly System Inspection & Sampling	72	EA	$7,020	$505,440	*$ 101,088*	*$ 50,544*	$ 657,072
Electrical - Utility Rate	2,000,000	kWhr	$0.100	$ 200,000	*$ 40,000*	*$ 20,000*	$ 260,000
Analytical Costs	72	EA	$2,600	$187,200	*$ 37,440*	*$ 18,720*	$ 243,360
Reporting	1	LS	$80,000	$80,000	*$ 16,000*	*$ 8,000*	$ 104,000
C. Post-Treatment Monitoring - Assumes 24 months of operation							***$ 187,200***
Post-treatment Sampling & Monitoring	8	EA	$13,000	$104,000	*$ 20,800*	*$ 10,400*	$ 135,200
Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000
D. SSDS - Assumes 19 month duration over thermal system operation							***$ 124,800***
SSDS OM&M (incl. sampling/ analytical costs)	19	MO	$4,000	$76,000	*$ 15,200*	*$ 7,600*	$ 98,800
Reporting	1	LS	$20,000	$20,000	*$ 4,000*	*$ 2,000*	$ 26,000
E. Closure - Decommissioning							***$ 192,270***
Monitoring Well Decommissioning	42	EA	$1,200	$50,400	*$ 10,080*	*$ 5,040*	$ 65,520
DGR Decommissioning - Treatment System Removal	1	LS	$50,000	$50,000	*$ 10,000*	*$ 5,000*	$ 65,000
DGR Decommissioning - Well Abandonment	5	EA	1500	$7,500	*$ 1,500*	*$ 750*	$ 9,750
Post-Closure Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000

Total Probable Estimated OM&M Cost - Alternative III		
	Point Estimate	**$ 3,745,861**
	Range Estimate - Low (-30%)	$ 2,622,102.89
	Range estimate - High (+50%)	$ 5,618,791.91

TOTAL ESTIMATED PROBABLE REMEDY COST (Capital + OM&M)	**$ 7,253,377**
Present Net Worth (Assuming 5% Annual ROI)	$ 6,587,204

TABLE A-3; ESTIMATED REMEDIAL COSTS

REMEDIAL ALTERNATIVE 4 (RA4) - SOURCE REMOVAL WITH ON-SITE GROUNDWATER ISCO POLISHING

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
I. CAPITAL COSTS							
A. SUPPORT/ GENERAL CONDITIONS							**$ 55,900**
Utility Survey	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Temporary Conditions - Construction phase	3	MO	$2,500	$ 7,500	*$ 1,500*	*$ 750*	$ 9,750
HASP Plan	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Implement HASP	3	MO	$3,500	$ 10,500	*$ 2,100*	*$ 1,050*	$ 13,650
Implement and Maintain SWPPP	3	MO	$5,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500
B. DEWATERING							**$ 628,680**
1. Recovery Wells							***$ 228,150***
Install 4 Inch Recovery Wells - 5 Wells	1	LS	$126,000	$ 126,000	*$ 25,200*	*$ 12,600*	$ 163,800
Wellhead Completion & Connections	5	EA	$2,400	$ 12,000	*$ 2,400*	*$ 1,200*	$ 15,600
F&I Submersible Pump, VFD and Level Control	5	EA	$7,500	$ 37,500	*$ 7,500*	*$ 3,750*	$ 48,750
2. Groundwater Treatment System - During Source Removal							***$ 218,400***
Treatment System and Controls	1	LS	$150,000	$ 150,000	*$ 30,000*	*$ 15,000*	$ 195,000
Frac Tanks for System Commissioning	1	LS	$18,000	$ 18,000	*$ 3,600*	*$ 1,800*	$ 23,400
3. System Piping							***$ 52,130***
Well Piping - F&I	160	LF	$35.00	$ 5,600	*$ 1,120*	*$ 560*	$ 7,280
Treatment System Discharge Piping	60	LF	$75.00	$ 4,500	*$ 900*	*$ 450*	$ 5,850
Discharge MH	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Upgrade Site sanitary system to municipal system	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Upgrade Site Building Water Piping to municipal system	1	LS	$15,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500
4. Electrical							***$ 130,000***
Site Electrical Service	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Pump Electrical	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Install Controls System	1	LS	$20,000	$ 20,000	*$ 4,000*	*$ 2,000*	$ 26,000
Install Treatment System Power	1	LS	$45,000	$ 45,000	*$ 9,000*	*$ 4,500*	$ 58,500
C. SOURCE AREA EXCAVATION							**$ 420,030**
1. Site Preparation							***$ 76,700***
Mobilization	1	LS	50,000	$ 50,000	*$ 10,000*	*$ 5,000*	$ 65,000
Permitting	1	LS	5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Utility Survey	1	LS	4,000	$ 4,000	*$ 800*	*$ 400*	$ 5,200
2. Contaminated Soil Excavation and Off-Site Disposal							***$ 343,330***
Excavation Sheeting and Support at Building Foundation and Excavation Limits	2250	VSF	$50	$ 112,500	*$ 22,500*	*$ 11,250*	$ 146,250
Vibration Monitoring of Structure	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Excavation	270	CY	$25	$ 6,750	*$ 1,350*	*$ 675*	$ 8,775
Loading, Transport and Disposal	486	TON	$225.00	$ 109,350	*$ 21,870*	*$ 10,935*	$ 142,155
Laboratory Analyses (TCLP)	1	LS	$12,000	$ 12,000	*$ 2,400*	*$ 1,200*	$ 15,600
Backfill and Compaction - Select Granular Fill Backfill	270	CY	$50.00	$ 13,500	*$ 2,700*	*$ 1,350*	$ 17,550

TABLE A-3; ESTIMATED REMEDIAL COSTS (PG. 2)

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
D. DOWNGRADIENT ON-SITE TREATMENT - SODIUM PERMANGANATE ISCO							**$ 886,633**
1. Injection and Monitoring Wells							**$ 573,820**
Injection Well Installation & Development	1	LS	264,000	$ 264,000	*$ 52,800*	*$ 26,400*	$ 343,200
Process Monitoring Well Installation & Development	1	LS	85,000	$ 85,000	*$ 17,000*	*$ 8,500*	$ 110,500
Downgradient Monitoring Well Replacements	1	LS	90,000	$ 90,000	*$ 18,000*	*$ 9,000*	$ 117,000
Well Survey	1	LS	2,400	$ 2,400	*$ 480*	*$ 240*	$ 3,120
2. Injection System							**$ 312,813**
Well Piping - F&I	500	LF	$35.00	$ 17,500	*$ 3,500*	*$ 1,750*	$ 22,750
Sodium Permanganate	37,500	lbs	$5.95	$223,125	*$ 44,625*	*$ 22,313*	$ 290,063
E. MISCELLANEOUS							**$ 685,840**
1. Site Restoration							***$ 340,600***
Characterize and Disposal of Excavated Soils (non-source construction)	1	LS	$37,000	$ 37,000	*$ 7,400*	*$ 3,700*	$ 48,100
Site Restoration	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Slab Removal	1	LS	$200,000	$ 200,000	*$ 40,000*	*$ 20,000*	$ 260,000
2. Bond & Insurance							***$ 88,058***
Bond & Insurance - assume 3.5% of construction costs	1	LS	$67,737	$ 67,737	*$ 13,547*	*$ 6,774*	$ 88,058
City Index - Hicksville, NY (+11.3%)							$ 257,182

Total Probable Estimated Capital Cost - Alternative IV		
	Point Estimate	**$ 2,677,082**
	Range Estimate - Low (-30%)	$ 1,873,957.46
	Range estimate - High (+50%)	$ 4,015,623.13

II. OM&M COSTS

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	General Requirements and O&P (20%)	Construction Contingency (10%)	ITEM COST TOTAL (2018)
A. DEWATERING & TREATMENT SYSTEM OM&M - Assumes 4 months of operation during excavation							***$ 634,452***
Operator - per month	4	Month	$33,600	$ 134,400	*$ 26,880*	*$ 13,440*	$ 174,720
Water Utility	0	Gal	$0.005	$ -	*$ -*	*$ -*	$ -
Electrical - Utility Rate	40,000	kWhr	$0.100	$ 4,000	*$ 800*	*$ 400*	$ 5,200
Perimeter Air Monitoring	1	LS	$300,000	$ 300,000	*$ 60,000*	*$ 30,000*	$ 390,000
Dewatering System Sampling & Monitoring	4	Month	$10,000	$ 40,000	*$ 8,000*	*$ 4,000*	$ 52,000
Analytical Costs	4	Month	$2,410	$ 9,640	*$ 1,928*	*$ 964*	$ 12,532
B. ISCO OM&M - Assumes 36 months of operation; 6 Injection Events; monthly monitoring & sampling; quarterly reporting							***$ 1,156,334***
Sodium Permanganate	56,250	lbs	$5.95	$334,688	*$ 66,938*	*$ 33,469*	$ 435,094
Mobile Injection System Rental	6	EA	$25,000	$150,000	*$ 30,000*	*$ 15,000*	$ 195,000
Injection Event Operations	6	EA	$10,000	$60,000	*$ 12,000*	*$ 6,000*	$ 78,000
Post-injection Sampling & Monitoring	30	EA	$8,000	$240,000	*$ 48,000*	*$ 24,000*	$ 312,000
Analytical Costs	30	EA	$2,160	$64,800	*$ 12,960*	*$ 6,480*	$ 84,240
Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000
C. Post-Treatment Monitoring - Assumes 24 months of operation							***$ 187,200***
LTM Post-treatment Sampling & Monitoring	8	EA	$13,000	$104,000	*$ 20,800*	*$ 10,400*	$ 135,200
Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000
D. Closure - Decommissioning							***$ 233,870***
Monitoring Well Decommissioning	42	EA	$1,200	$50,400	*$ 10,080*	*$ 5,040*	$ 65,520
Injection System Decommissioning	1	LS	$35,000	$35,000	*$ 7,000*	*$ 3,500*	$ 45,500
Decommissioning - Dewatering Treatment System Removal	1	LS	$50,000	$50,000	*$ 10,000*	*$ 5,000*	$ 65,000
Decommissioning -Dewatering Well Abandonment	3	EA	1500	$4,500	*$ 900*	*$ 450*	$ 5,850
Post-Closure Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000

Total Probable Estimated OM&M Cost - Alternative IV		
	Point Estimate	**$ 2,211,856**
	Range Estimate - Low (-30%)	$ 1,548,299.03
	Range estimate - High (+50%)	$ 3,317,783.63

TOTAL ESTIMATED PROBABLE REMEDY COST (Capital + OM&M)	**$ 4,888,938**
Present Net Worth (Assuming 5% Annual ROI)	$ 4,704,036

TABLE A-4; ESTIMATED REMEDIAL COSTS

REMEDIAL ALTERNATIVE 5 (RA5) - SOURCE REMOVAL WITH ON-SITE GROUNDWATER DGR POLISHING

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
I. CAPITAL COSTS							
A. SUPPORT/ GENERAL CONDITIONS							**$ 55,900**
Utility Survey	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Temporary Conditions - Construction phase	3	MO	$2,500	$ 7,500	*$ 1,500*	*$ 750*	$ 9,750
HASP Plan	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Implement HASP	3	MO	$3,500	$ 10,500	*$ 2,100*	*$ 1,050*	$ 13,650
Implement and Maintain SWPPP	3	MO	$5,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500
B. EXCAVATION DEWATERING							**$ 1,398,930**
1. Recovery Wells (Component of DGR System)							***$ 298,350***
Install 6 Inch Recovery Wells - 5 Wells	1	LS	$180,000	$ 180,000	*$ 36,000*	*$ 18,000*	$ 234,000
Wellhead Completion & Connections	5	EA	$2,400	$ 12,000	*$ 2,400*	*$ 1,200*	$ 15,600
F&I Submersible Pump, VFD and Level Control	5	EA	$7,500	$ 37,500	*$ 7,500*	*$ 3,750*	$ 48,750
2. Groundwater Treatment System (Component of DGR System)							***$ 913,900***
Treatment System and Controls	1	LS	$500,000	$ 500,000	*$ 100,000*	*$ 50,000*	$ 650,000
Treatment System Enclosure	1	LS	$150,000	$ 150,000	*$ 30,000*	*$ 15,000*	$ 195,000
Treatment System HVAC	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Frac Tanks for System Commissioning	1	LS	$28,000	$ 28,000	*$ 5,600*	*$ 2,800*	$ 36,400
3. System Piping (Component of DGR System)							***$ 56,680***
Well Piping - F&I	260	LF	$35.00	$ 9,100	*$ 1,820*	*$ 910*	$ 11,830
Treatment System Discharge Piping	60	LF	$75.00	$ 4,500	*$ 900*	*$ 450*	$ 5,850
Discharge MH	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Upgrade Site sanitary system to municipal system	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Upgrade Site Building Water Piping to municipal system	1	LS	$15,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500
4. Electrical							***$ 130,000***
Site Electrical Service	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Pump Electrical	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Install Controls System	1	LS	$20,000	$ 20,000	*$ 4,000*	*$ 2,000*	$ 26,000
Install Treatment System Power	1	LS	$45,000	$ 45,000	*$ 9,000*	*$ 4,500*	$ 58,500
C. SOURCE AREA EXCAVATION							**$ 420,030**
1. Site Preparation							***$ 76,700***
Mobilization	1	LS	50,000	$ 50,000	*$ 10,000*	*$ 5,000*	$ 65,000
Permitting	1	LS	5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Utility Survey	1	LS	4,000	$ 4,000	*$ 800*	*$ 400*	$ 5,200
2. Contaminated Soil Excavation and Off-Site Disposal							***$ 343,330***
Excavation Sheeting and Support at Building Foundation and Excavation Limits	2250	VSF	$50	$ 112,500	*$ 22,500*	*$ 11,250*	$ 146,250
Vibration Monitoring of Structure	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Excavation	270	CY	$25	$ 6,750	*$ 1,350*	*$ 675*	$ 8,775
Loading, Transport and Disposal	486	TON	$225.00	$ 109,350	*$ 21,870*	*$ 10,935*	$ 142,155
Laboratory Analyses (TCLP)	1	LS	$12,000	$ 12,000	*$ 2,400*	*$ 1,200*	$ 15,600
Backfill and Compaction - Select Granular Fill Backfill	270	CY	$50.00	$ 13,500	*$ 2,700*	*$ 1,350*	$ 17,550

TABLE A-4; ESTIMATED REMEDIAL COSTS (PG. 2)

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
D. DOWNGRADIENT ON-SITE TREATMENT - DIRECTED GROUNDWATER RECIRCULATION							**$ 229,580**
1. Injection and Monitoring Wells							**$ 120,120**
Downgradient Monitoring Well Replacements	1	LS	$90,000	$ 90,000	*$ 18,000*	*$ 9,000*	$ 117,000
Well Survey	1	LS	$2,400	$ 2,400	*$ 480*	*$ 240*	$ 3,120
2. Groundwater Injection System							**$ 109,460**
Install Controls System	1	LS	$20,000	$ 20,000	*$ 4,000*	*$ 2,000*	$ 26,000
Install Injection pumps & flow meters	1	LS	$45,000	$ 45,000	*$ 9,000*	*$ 4,500*	$ 58,500
Pull existing upgradient well pumps & convert to injection	1	LS	$1,700	$ 1,700	*$ 340*	*$ 170*	$ 2,210
Well Piping - F&I	500	LF	$35.00	$ 17,500	*$ 3,500*	*$ 1,750*	$ 22,750
E. MISCELLANEOUS							**$ 703,781**
1. Site Restoration							***$ 340,600***
Characterize and Disposal of Excavated Soils	1	LS	$37,000	$ 37,000	*$ 7,400*	*$ 3,700*	$ 48,100
Site Restoration	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Slab Removal	1	LS	$200,000	$ 200,000	*$ 40,000*	*$ 20,000*	$ 260,000
2. Bond & Insurance							***$ 93,209***
Bond & Insurance - assume 3.5% of construction costs	1	LS	$71,699	$ 71,699	*$ 14,340*	*$ 7,170*	$ 93,209
City Index - Hicksville, NY (+11.3%)							$ 269,973

Total Probable Estimated Capital Cost - Alternative V	Point Estimate	**$ 2,808,221**
	Range Estimate - Low (-30%)	$ 1,965,754.97
	Range estimate - High (+50%)	$ 4,212,332.09

II. OM&M COSTS

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
A. DEWATERING SYSTEM OM&M - Assumes 4 months of operation during excavation							***$ 634,452***
Operator - per month	4	Month	$33,600	$ 134,400	*$ 26,880*	*$ 13,440*	$ 174,720
Water Utility	0	Gal	$0.005	$ -	*$ -*	*$ -*	$ -
Electrical - Utility Rate	40,000	kWhr	$0.100	$ 4,000	*$ 800*	*$ 400*	$ 5,200
Perimeter Air Monitoring	1	LS	$300,000	$ 300,000	*$ 60,000*	*$ 30,000*	$ 390,000
Dewatering System Sampling & Monitoring	4	Month	$10,000	$ 40,000	*$ 8,000*	*$ 4,000*	$ 52,000
Analytical Costs	4	Month	$2,410	$ 9,640	*$ 1,928*	*$ 964*	$ 12,532
B. DGR OM&M - Assumes 72 months of operation; monthly monitoring & sampling; quarterly reporting							***$ 1,265,732***
Monthly System Inspection & Sampling	72	EA	$7,020	$505,440	*$ 101,088*	*$ 50,544*	$ 657,072
Electrical - Utility Rate	2,010,000	kWhr	$0.100	$ 201,000	*$ 40,200*	*$ 20,100*	$ 261,300
Analytical Costs	72	EA	$2,600	$187,200	*$ 37,440*	*$ 18,720*	$ 243,360
Reporting	1	LS	$80,000	$80,000	*$ 16,000*	*$ 8,000*	$ 104,000
C. Post-Treatment Monitoring - Assumes 24 months of monitoring							***$ 187,200***
Post-treatment Sampling & Monitoring	8	EA	$13,000	$104,000	*$ 20,800*	*$ 10,400*	$ 135,200
Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000
D. Closure - Decommissioning							***$ 192,270***
Monitoring Well Decommissioning	42	EA	$1,200	$50,400	*$ 10,080*	*$ 5,040*	$ 65,520
DGR Decommissioning - Treatment System Removal	1	LS	$50,000	$50,000	*$ 10,000*	*$ 5,000*	$ 65,000
DGR Decommissioning - Well Abandonment	5	EA	$1,500	$7,500	*$ 1,500*	*$ 750*	$ 9,750
Post-Closure Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000

Total Probable Estimated OM&M Cost - Alternative V	Point Estimate	**$ 2,279,654**
	Range Estimate - Low (-30%)	$ 1,595,757.80
	Range estimate - High (+50%)	$ 3,419,481.00

TOTAL ESTIMATED PROBABLE REMEDY COST (Capital + OM&M)	**$ 5,087,875**
Present Net Worth (Assuming 5% Annual ROI)	$ 4,635,826

TABLE A-5; ESTIMATED REMEDIAL COSTS

REMEDIAL ALTERNATIVE 6 (RA6) - SOURCE REMOVAL AND ISCO APPLICATION WITHIN EXCAVATION FOOTPRINT WITH ONSITE GROUNDWATER DGR POLISHING

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
I. CAPITAL COSTS							
A. SUPPORT/ GENERAL CONDITIONS							**$ 55,900**
Utility Survey	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Temporary Conditions - Construction phase	3	MO	$2,500	$ 7,500	*$ 1,500*	*$ 750*	$ 9,750
HASP Plan	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Implement HASP	3	MO	$3,500	$ 10,500	*$ 2,100*	*$ 1,050*	$ 13,650
Implement and Maintain SWPPP	3	MO	$5,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500
B. EXCAVATION DEWATERING							**$ 1,398,930**
1. Recovery Wells (Component of DGR System)							***$ 298,350***
Install 6 Inch Recovery Wells - 5 Wells	1	LS	$180,000	$ 180,000	*$ 36,000*	*$ 18,000*	$ 234,000
Wellhead Completion & Connections	5	EA	$2,400	$ 12,000	*$ 2,400*	*$ 1,200*	$ 15,600
F&I Submersible Pump, VFD and Level Control	5	EA	$7,500	$ 37,500	*$ 7,500*	*$ 3,750*	$ 48,750
2. Groundwater Treatment System (Component of DGR System)							***$ 913,900***
Treatment System and Controls	1	LS	$500,000	$ 500,000	*$ 100,000*	*$ 50,000*	$ 650,000
Treatment System Enclosure	1	LS	$150,000	$ 150,000	*$ 30,000*	*$ 15,000*	$ 195,000
Treatment System HVAC	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Frac Tanks for System Commissioning	1	LS	$28,000	$ 28,000	*$ 5,600*	*$ 2,800*	$ 36,400
3. System Piping (Component of DGR System)							***$ 56,680***
Well Piping - F&I	260	LF	$35.00	$ 9,100	*$ 1,820*	*$ 910*	$ 11,830
Treatment System Discharge Piping	60	LF	$75.00	$ 4,500	*$ 900*	*$ 450*	$ 5,850
Discharge MH	1	LS	$5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Upgrade Site sanitary system to municipal system	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Upgrade Site Building Water Piping to municipal system	1	LS	$15,000	$ 15,000	*$ 3,000*	*$ 1,500*	$ 19,500
4. Electrical							***$ 130,000***
Site Electrical Service	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Pump Electrical	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Install Controls System	1	LS	$20,000	$ 20,000	*$ 4,000*	*$ 2,000*	$ 26,000
Install Treatment System Power	1	LS	$45,000	$ 45,000	*$ 9,000*	*$ 4,500*	$ 58,500
C. SOURCE AREA EXCAVATION							**$ 420,030**
1. Site Preparation							***$ 76,700***
Mobilization	1	LS	50,000	$ 50,000	*$ 10,000*	*$ 5,000*	$ 65,000
Permitting	1	LS	5,000	$ 5,000	*$ 1,000*	*$ 500*	$ 6,500
Utility Survey	1	LS	4,000	$ 4,000	*$ 800*	*$ 400*	$ 5,200
2. Contaminated Soil Excavation and Off-Site Disposal							***$ 343,330***
Excavation Sheeting and Support at Building Foundation and Excavation Limits	2250	VSF	$50	$ 112,500	*$ 22,500*	*$ 11,250*	$ 146,250
Vibration Monitoring of Structure	1	LS	$10,000	$ 10,000	*$ 2,000*	*$ 1,000*	$ 13,000
Excavation	270	CY	$25	$ 6,750	*$ 1,350*	*$ 675*	$ 8,775
Loading, Transport and Disposal	486	TON	$225.00	$ 109,350	*$ 21,870*	*$ 10,935*	$ 142,155
Laboratory Analyses (TCLP)	1	LS	$12,000	$ 12,000	*$ 2,400*	*$ 1,200*	$ 15,600
Backfill and Compaction - Select Granular Fill Backfill	270	CY	$50.00	$ 13,500	*$ 2,700*	*$ 1,350*	$ 17,550

TABLE A-5; ESTIMATED REMEDIAL COSTS (PG. 2)

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
D. SOURCE AREA ISCO APPLICATION							**$ 74,344**
1. ISCO Assumes 24 months of operation; 4 Injection Events							
1. Injection and Monitoring Wells							**$ 74,344**
Injection Well Installation	1	LS	20,000	$ 20,000	*$ 4,000*	*$ 2,000*	$ 26,000
Sodium Permanganate	6,250	lbs	$5.95	$37,188	*$ 7,438*	*$ 3,719*	$ 48,344
E. DOWNGRADIENT TREATMENT - DIRECTED GROUNDWATER RECIRCULATION							**$ 229,580**
1. Injection and Monitoring Wells							**$ 120,120**
Downgradient Monitoring Well Replacements	1	LS	$90,000	$ 90,000	*$ 18,000*	*$ 9,000*	$ 117,000
Well Survey	1	LS	$2,400	$ 2,400	*$ 480*	*$ 240*	$ 3,120
2. Groundwater Injection System							**$ 109,460**
Install Controls System	1	LS	$20,000	$ 20,000	*$ 4,000*	*$ 2,000*	$ 26,000
Install Injection pumps & flow meters	1	LS	$45,000	$ 45,000	*$ 9,000*	*$ 4,500*	$ 58,500
Pull existing upgradient well pumps & convert to injection	1	LS	$1,700	$ 1,700	*$ 340*	*$ 170*	$ 2,210
Well Piping - F&I	500	LF	$35.00	$ 17,500	*$ 3,500*	*$ 1,750*	$ 22,750
F. MISCELLANEOUS							**$ 712,182**
1. Site Restoration							***$ 340,600***
Characterize and Disposal of Excavated Soils	1	LS	$37,000	$ 37,000	*$ 7,400*	*$ 3,700*	$ 48,100
Site Restoration	1	LS	$25,000	$ 25,000	*$ 5,000*	*$ 2,500*	$ 32,500
Slab Removal	1	LS	$200,000	$ 200,000	*$ 40,000*	*$ 20,000*	$ 260,000
2. Bond & Insurance							***$ 93,209***
Bond & Insurance - assume 3.5% of construction costs	1	LS	$71,699	$ 71,699	*$ 14,340*	*$ 7,170*	$ 93,209
City Index - Hicksville, NY (+11.3%)							$ 278,374

Total Probable Estimated Capital Cost - Alternative VI	Point Estimate	**$ 2,890,966**
	Range Estimate - Low (-30%)	$ 2,023,676.19
	Range estimate - High (+50%)	$ 4,336,448.98

II. OM&M COSTS

DESCRIPTION	QTY.	UNIT	UNIT COST (2018)	Subtotal	*General Requirements and O&P (20%)*	*Construction Contingency (10%)*	ITEM COST TOTAL (2018)
A. DEWATERING SYSTEM OM&M - Assumes 4 months of operation during excavation							***$ 634,452***
Operator - per month	4	Month	$33,600	$ 134,400	*$ 26,880*	*$ 13,440*	$ 174,720
Water Utility	0	Gal	$0.005	$ -	*$ -*	*$ -*	$ -
Electrical - Utility Rate	40,000	kWhr	$0.100	$ 4,000	*$ 800*	*$ 400*	$ 5,200
Perimeter Air Monitoring	1	LS	$300,000	$ 300,000	*$ 60,000*	*$ 30,000*	$ 390,000
Dewatering System Sampling & Monitoring	4	Month	$10,000	$ 40,000	*$ 8,000*	*$ 4,000*	$ 52,000
Analytical Costs	4	Month	$2,410	$ 9,640	*$ 1,928*	*$ 964*	$ 12,532
B. ISCO OM&M - Assumes 24 months of operation; 4 Injection Events; monthly monitoring & sampling; quarterly reporting							***$ 131,560***
Injection Event Operations	4	EA	$2,000	$8,000	*$ 1,600*	*$ 800*	$ 10,400
Post-injection Sampling & Monitoring	20	EA	$2,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000
Analytical Costs	20	EA	$2,160	$43,200	*$ 8,640*	*$ 4,320*	$ 56,160
Reporting	1	LS	$10,000	$10,000	*$ 2,000*	*$ 1,000*	$ 13,000
C. DGR OM&M - Assumes 48 months of operation; monthly monitoring & sampling; quarterly reporting							***$ 878,488***
Monthly System Inspection & Sampling	48	EA	$7,020	$336,960	*$ 67,392*	*$ 33,696*	$ 438,048
Electrical - Utility Rate	1,340,000	kWhr	$0.100	$ 134,000	*$ 26,800*	*$ 13,400*	$ 174,200
Analytical Costs	48	EA	$2,600	$124,800	*$ 24,960*	*$ 12,480*	$ 162,240
Reporting	1	LS	$80,000	$80,000	*$ 16,000*	*$ 8,000*	$ 104,000
D. Post-Treatment Monitoring - Assumes 24 months of monitoring							***$ 187,200***
Post-treatment Sampling & Monitoring	8	EA	$13,000	$104,000	*$ 20,800*	*$ 10,400*	$ 135,200
Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000
E. Closure - Decommissioning							***$ 192,270***
Monitoring Well Decommissioning	42	EA	$1,200	$50,400	*$ 10,080*	*$ 5,040*	$ 65,520
DGR Decommissioning - Treatment System Removal	1	LS	$50,000	$50,000	*$ 10,000*	*$ 5,000*	$ 65,000
DGR Decommissioning - Well Abandonment	5	EA	1500	$7,500	*$ 1,500*	*$ 750*	$ 9,750
Post-Closure Reporting	1	LS	$40,000	$40,000	*$ 8,000*	*$ 4,000*	$ 52,000

Total Probable Estimated OM&M Cost - Alternative VI	Point Estimate	**$ 2,023,970**
	Range Estimate - Low (-30%)	$ 1,416,779.00
	Range estimate - High (+50%)	$ 3,035,955.00

TOTAL ESTIMATED PROBABLE REMEDY COST (Capital + OM&M) **$ 4,914,936**

Present Net Worth (Assuming 5% Annual ROI) $ 4,756,093

Arcadis CE, Inc.

855 Route 146

Suite 210

Clifton Park, New York 12065

Tel 518 250 7300

Fax 518 250 7301

www.arcadis.com