FORMER DRAPE MASTER

FEASIBILITY STUDY REPORT

WORK ASSIGNMENT D007622-23

FORMER DRAPE MASTER — SITE NO. 221114
ASTORIA — QUEENS, NY

Prepared for:
NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
625 Broadway, Albany, New York

Basil Seggos, Commissioner

DIVISION OF ENVIRONMENTAL REMEDIATION
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December 2016

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LIST OF ACRONYMS AND ABBREVIATIONS

amsl	above mean sea level
bgs	below ground surface
CPCs	chemicals of potential concern
DER	Division of Environmental Remediation
DCE	dichloroethene
FS	Feasibility Study
HHEA	Human Health Exposure Assessment
ISCO	In-Situ Chemical Oxidation
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mV	millivolts
NOD	natural oxidant demand
NYCRR	New York Code Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OM&M	operation, maintenance and monitoring
PCE	tetrachloroethene
PSA	Preliminary Site Assessment
RAOs	remedial action objectives
RI	Remedial Investigation
SCGs	standards, criteria, and guidance
SCO	soil cleanup objectives
sf	square feet
Site	Former Drape Master Site
SMP	Site Management Plan
SSD	subslab depressurization
SVE	soil vapor extraction
TCE	trichloroethene
TMV	toxicity, mobility or volume
TOGS	Technical and Operational Guidance Series
µg/L	micrograms per liter
UIC	underground injection control
URS	URS Corporation
UST	underground storage tank
VC	vinyl chloride
VOCs	volatile organic compounds
ZVI	zero-valent ion

EXECUTIVE SUMMARY

This Feasibility Study (FS) report was prepared by URS Corporation (URS) for the Former Drape Master Site (Site), located in Astoria, Queens County, New York. The site was historically used for a dry cleaning service and still is presently. Tetrachloroethene (PCE) was previously used in dry cleaning operations as a cleaning solvent. No other facilities or businesses situated immediately adjacent to the site historically are known to have used PCE. Results of the Remedial Investigation (RI) prepared by URS (July 2015) and previous investigations indicated the presence of PCE and related degradation products in soil vapor and groundwater at the site.

The horizontal extent of groundwater contamination in the aquifer has been delineated. PCE and its degradation products (e.g., trichloroethene [TCE] and cis-1,2-dichloroethene [*cis*-1,2-DCE]) have migrated offsite via groundwater. VOC contamination has exceeded applicable standards, criteria, and guidance (SCGs) in both soil vapor and groundwater.

The remedial goal for the site is to eliminate or mitigate all significant threats to public health and the environment presented by the contaminants disposed at the site. Numerical cleanup goals for the site are based on Part 375 criteria for unrestricted future use. To meet the remedial goal for the site, the following RAOs were established for groundwater and soil vapor/indoor air:

- Mitigate impacts to public health resulting from existing, or the potential for, soil vapor intrusion into buildings at a site.

- Prevent contact with or inhalation of volatiles from contaminated groundwater and/or other contaminated water.

- Restore the groundwater aquifer to pre-disposal/pre-release conditions, to the extent practicable.

In order to meet the remedial goal and remedial action objectives for the site, the following remedial alternatives were developed:

- **Alternative 1** – No Action
- **Alternative 2** – In-Situ Groundwater Treatment through ISCO
- **Alternative 3** – In-Situ Groundwater Treatment through Enhanced Bioremediation

- **Alternative 4** – In-Situ Groundwater Treatment through Chemical Reduction

These alternatives were evaluated against the New York State Department of Environmental Conservation (NYSDEC) criteria: Overall Protection of Public Health and the Environment; Compliance with Standards; Criteria and Guidance; Long-term Effectiveness and Permanence; Reduction of Toxicity, Mobility and Volume with Treatment; Short-term Effectiveness (including green remediation and sustainability); Implementability; Land Use; and Cost.

1.0 INTRODUCTION

1.1 Contract Authority

URS prepared this Feasibility Study (FS) report for the Former Drape Master Site located in Astoria, Queens County, New York. The report was prepared for the New York State Department of Environmental Conservation (NYSDEC) as Work Assignment D007622-23.

1.2 Scope of Feasibility Study

This FS report evaluates the remedial action for the contaminants found to be present at and in the vicinity of the site. This FS was developed to meet the requirements set forth in the New York State Code Rules and Regulations (NYCRR) 6 NYCRR 375, and NYSDEC Department of Environmental Remediation (DER) DER-10 Technical Guidance for Site Investigation and Remediation. This FS specifies the remedial goal and remedial action objectives, identifies potential remedial technologies feasible for use at this site, and develops remedial alternatives that meet the remedial action objectives. Remedial alternatives will be evaluated in sufficient detail such that the NYSDEC can prepare a Proposed Remedial Action Plan and issue a Record of Decision.

1.3 Report Organization

This document has been organized consistent with NYSDEC DER-10 and includes the following sections:

- Executive Summary
- Introduction
- Site Description and History
- Remedial Goal and Remedial Action Objectives
- Identification and Screening of Remedial Technologies
- Development and Description of Alternatives
- Detailed Analysis of Alternatives.

2.0 SITE DESCRIPTION AND HISTORY

This section presents a site description and a summary of site conditions and site history.

2.1 Site Description

The site is located at 89-01 Astoria Boulevard in a mixed residential/commercial neighborhood of Astoria, New York. The site is identified as Block 1101 and Lot 45 on the New York City Tax Map with zoning designations as R6B and C1-1, which allows for low- to medium-density residential and commercial uses. A site location map is shown in Figure 2-1.

The site consists of a 5,200 square foot (sf) two-story building with a basement. The first floor is occupied by an active laundromat, with storage in the basement. Within the basement, groundwater is present in a sump. In the past, groundwater seeped into the basement floor, but was stopped when a second floor slab was constructed. Apartments are located on the second floor of the building. Commercial properties, many with residences on the upper floors, are located along Astoria Blvd. Residential properties are located on the side streets. A site plan is shown in Figure 2-2. LaGuardia Airport is located approximately 2,000 feet (ft) to the north.

As discussed below, contaminated groundwater is the primary concern at this site; the contaminated groundwater plume extends far beyond the extent of the Former Drape Master (or laundromat) property. For the purpose of this FS, the "site" refers to laundromat building and the entire extent of the contaminated groundwater plume.

The topography of the site area is relatively flat along Astoria Blvd and rises several feet to the north. The nearest water body is Bowery Bay located approximately 4,000 ft to the northeast. Groundwater occurs at a depth of approximately 10 ft below ground surface (bgs) with regional flow to the west-northwest toward Bowery Bay. The site area is underlain by silts, sands or historic fill material. Bedrock occurs at an estimated depth of more than 100 ft bgs.

2.2 Site History

The Former Drape Master Site has a history of previous use as a dry cleaner. Investigations to characterize subsurface contaminant conditions began in 2006. Previous investigations were performed by Hydro Tech Environmental Corporation (Hydro Tech) in 2006, EnviroTrac Environmental Services (EnviroTrac) in 2009, and Shaw Environmental & Infrastructure Engineering of New York, P.C. (Shaw) in 2011. An Environmental Data Resources, Inc. (EDR) report obtained by Shaw indicated that several different dry cleaning services were historically operational at the site, including: Murjers Drapery Specialists Inc., Drapery King, Coit Drapery Cleaners, and Drape Master of America.

According to the EDR report, a spill, dated October 13, 2005, was reported at the site due to equipment failure. According to information in the report, a NYSDEC representative visited the site on October 13, 2005 as a follow up from previous visits in July and August 2005. The visit was performed to confirm that the dry cleaning company had removed its hazardous waste to an approved off-site facility and decontaminated the dry cleaning machines and any other contaminated equipment or areas noted during the July and August 2005 visits. During the inspection, it was determined that the above-mentioned machinery and hazardous waste had been removed; however, the inspector found that "a part of a filter associated with an old dry cleaning machine was leaking dry cleaning chemicals directly to the floor" and there was a strong odor of dry cleaning chemicals within the building. The operator on site was instructed to "immediately take steps to stop the leak and clean up the spill". The hazmat unit within the New York City Department of Environmental Protection (DEP) and Division of Law Enforcement was notified and the spill was reported to the NYSDEC's spill hotline. These agencies responded immediately and issued notices of violation and summons. According to the EDR report, the unnamed dry cleaner had gone out of business and had not managed their hazardous waste properly.

The site was listed as a small quantity generator (SQG). According to the EDR report, Drape Master of America had several violations including compliance and records violations associated with their shipment of halogenated solvents.

The site is adjacent to several properties that are identified as using dry cleaning products: Airline Cleaners, Inc. located approximately 1/8 mile upgradient from the subject property; Jamel Cleaners located approximately 1/10 mile east/southeast upgradient from the subject property; Sunil Cleaners located approximately 1/8 to 1/4 mile east/southeast upgradient from the subject property; and MTA bus company located approximately 1/8 to 1/4 mile west/northwest of the subject property.

2.3 Site Geology

Figure 2-3 presents north-south geologic cross section A-A' through the site and Figure 2-4 presents a west-east geologic cross section B-B' through the site as developed during the RI. Figure 2-5 identifies the locations of the lines of cross sections.

The topography of the site is relatively flat along Astoria Blvd and rises substantially to the northeast. The ground surface elevation on the corner of Astoria Blvd and 89th Street, at monitoring well MW-11 in front of the site building, is approximately 23.4 ft above mean sea level (amsl). The ground surface rises to the northeast where the elevation at monitoring well MW-04 is approximately 37.3 ft amsl.

The site is located within the Coastal Plain physiographic province of New York State. The site area is underlain by Pleistocene age glacial outwash deposits. Underlying formations consist of the Upper Glacial Till which is underlain by the Raritan clay. Bedrock is estimated to occur at estimated depths greater than 100 ft.

Geologic conditions in the site area are generally characterized by fine to coarse brown sand with varying amounts of silt and gravel. The deepest boring, MW-07, was advanced to a depth of 41 ft bgs and did not encounter bedrock. Drilling observations indicated that as much as 13 ft of fill overlies the natural deposits. The fill appeared to be reworked sand and gravel with varying amounts of anthropogenic material including concrete and brick.

2.4 Site Hydrogeology

Groundwater occurs under unconfined conditions. Within the on-site building, groundwater is present in the sump in the basement, and prior to the construction of a second floor slab, seeped into the basement. In the monitoring wells, the measured depth to groundwater ranges from approximately 6 ft bgs at monitoring well MW-15 located on the west side of the site building, to approximately 22 ft bgs at monitoring well MW-04, located on the north side of the site building. As shown in the groundwater elevation contour map for water level measurements recorded during the July 2014 groundwater sampling events (Figure 2-6), overall groundwater flow is to the west-southwest. Based on this data, the highest hydraulic gradient was approximately 0.01 ft/ft.

The minimal displacement of water during the hydraulic conductivity testing, along with rapid recovery during well development and purging prior to sampling, indicates a moderately high hydraulic conductivity of the sand and gravel formation. Based on the presence of sand and gravel, the estimated hydraulic conductivity would be on the order of 10^{-3} centimeters per second (cm/sec) or greater.

2.5 Previous Investigations

Several investigations were performed prior to the RI and are summarized below.

2.5.1 2006 Hydro Tech Investigation

In October 2006, Hydro Tech installed and sampled six groundwater monitoring wells adjacent to and within the Former Drape Master building. Analytical results from the sampling event indicated elevated levels of chlorinated VOCs (CVOCs), primarily PCE, trichloroethene (TCE), and cis-1,2-dichloroethene (cis-1,2-DCE) in the central and northeastern portions of the site. In addition to chlorinated solvents, the analytical results indicated elevated levels of 1,2,4-trimethylbenzene and naphthalene in monitoring wells located near the southeastern portion of the site; these constituents were noted as being normally indicative of gasoline contamination. According to the Hydro Tech report, the site had no known historical gasoline usage so the contamination was attributed to an off-site source. Based on these results, Hydro Tech recommended that the results be provided to the NYSDEC for review and comment. As indicated in the EDR, several petroleum-related spills were identified as being located within 1/8 mile of the site.

2.5.2 2009 EnviroTrac Investigation

In March 2009, EnviroTrac intended to conduct a soil vapor intrusion and groundwater investigation at the site. However, due to the presence of shallow groundwater immediately beneath the basement floor, soil vapor samples could not be collected. Three groundwater samples, two indoor air, and one outdoor air sample were collected during this investigation. Analytical results indicated elevated levels of PCE in one of the basement ambient air samples and in the groundwater samples. Based on these results, EnviroTrac recommended that the data be reviewed by the NYSDEC and/or the New York State Department of Health (NYSDOH) to determine if additional investigation was required.

2.5.3 2011 Shaw Investigation

In 2011, the NYSDEC retained Shaw to complete a focused investigation. Based on the results of the previous investigations, the NYSDEC concluded that the probable source of the chlorinated solvent contamination was off-site and required further investigation.

The Shaw investigation included the advancement 11 direct-push borings to evaluate soil vapor, groundwater, and soil conditions at the site. Shaw had intended to advance two soil borings in the building basement but was not granted access to the interior of the building. The following investigative points were advanced at the site:

- Five borings were advanced to approximately 7 to 8 ft bgs and completed as permanent soil vapor points (SV-1 through SV-5).

- Four borings around the footprint of the building and across 89th Street were advanced to depths ranging from 25 to 32 ft bgs and completed as monitoring wells MW-01, MW-04, MW-05 and MW-06.

- Two borings (i.e., GW-2 and GW-3) were advanced to a depth of approximately 20 ft bgs to allow for the collection of groundwater samples – these borings were not completed as wells.

- Nine of the 11 soil borings were augmented by the use of Membrane Interface Probe (MIP) analysis. The MIP locations and associated borings/soil vapor points/monitoring wells are as follows:

    - MIP-1 – SV-4
    - MIP-2 – SV-1
    - MIP-3 – SV-2
    - MIP-4 – GW-2 - No associated soil vapor point
    - MIP-5 – SV-3
    - MIP-6 – No associated soil vapor point
    - MIP-7 – SV-5/MW-05
    - MIP-8 – MW-06 - No associated soil vapor point
    - MIP-9 – MW-04 - No associated soil vapor point.

None of the soil samples contained contaminants at concentrations above the regulatory criteria.

Groundwater analytical results included detections of cis-1,2-DCE, chloroform, TCE, and PCE at concentrations above the NYSDEC Groundwater Standards.

Analytical results from the soil vapor samples indicated detections of TCE, PCE, 1,1,1-trichloroethane (1,1,1-TCA), chloroform, 1,1-dichloroethene (1,1-DCE), cis-1,2-DCE, and methyl tert-butyl ether (MTBE – a gasoline contaminant).

Based on the findings of the investigation, Shaw concluded the following:

- There were no analytes detected above the Soil Cleanup Objectives.

- Analytes exceeding the NYSDEC groundwater quality standards were found in five of the six groundwater samples collected. Contaminants exceeding the NYSDEC groundwater quality standards included cis-1,2-DCE, TCE, and PCE.

- All soil vapor samples (SV-1, SV-2, SV-3, SV-4, SV-5) contained TCE, 1,2-DCE, and/or PCE. The highest concentrations of PCE were detected in soil vapor points SV-1 and SV-2 located on Astoria Blvd adjacent to the Former Drape Master building.

- The results indicated that the laundromat building was the likely source of the observed impacts.

2.6 Standards, Criteria, and Guidance

For each medium, detected concentrations of individual contaminants were compared to applicable standards, criteria and guidance values (SCGs). The SCGs determined during the RI for the individual media are identified below.

Two sources of soil SCGs are considered appropriate for this site: the Part 375 Soil Cleanup Objectives (SCOs) and the CP-51 soil cleanup criteria. Hereafter, mention of Part 375 includes incorporation of CP-51 criteria values.

Part 375 Unrestricted Use Criteria are considered to assist in the development of a remedial alternative capable of achieving unrestricted future use as required by DER-10 Section 4.4 (b) 3 ii. In addition, soil criteria for the Protection of Groundwater are considered as SCGs for contaminants which exceed groundwater SCGs.

The SCGs for groundwater are the Class GA standards and guidance values presented in the NYSDEC Technical & Operational Guidance Series (TOGS) 1.1.1 – Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations. In addition to groundwater samples, sump samples were collected from the Former Drape Master building as well as a nearby building (not identified as part of this investigation). These samples are discussed in section 2.7.2. Because the sump samples are essentially groundwater samples, the results are also compared to the TOGS 1.1.1 criteria.

There are no criteria for soil vapor analytical data. The decision matrices of the Guidance for Evaluating Soil Vapor Intrusion in the State of New York, Final, (NYSDOH, October 2006) were utilized as SCGs when comparing indoor air and subslab sampling results.

2.7 Nature and Extent of Contamination

The nature and extent of contamination was presented in the RI Report prepared by URS in July 2015. Additional sampling of subslab soil vapor and indoor air in the onsite building and the potentially impacted nearby residence will be conducted during the 2015/2016 heating season following the implementation of mitigation measures by the building owner. The findings of the RI and the additional sampling are presented in this section and provide the estimated areas, volumes, and quantities appropriate for remediation.

2.7.1 Soil

Based upon the Remedial Investigation, the soils investigated do not appear to have been impacted by site operations. The chlorinated solvent release(s) likely occurred in the basement of the Former Drape Master building or in a fenced storage area immediately adjacent to the western side of the building. Consequently, there were likely no impacts to surface soils. Therefore, there is not a potential completed exposure pathway for surface soil and ground surface material.

Figure 2-7 shows the locations and results for the soil samples collected during the RI. No chlorinated solvents were detected in the soil samples. Only two organic compounds, both SVOCs, were detected at concentrations exceeding the criteria. Benzo(a)fluoranthene and indeno(1,2,3-cd)pyrene were detected in the soil sample from MW-09 at concentrations of 1.2 milligrams per kilogram (mg/kg) and 0.55 mg/kg, respectively, which are just slightly above their respective criterion of 1 mg/kg for benzo(a)fluoranthene and 0.5 mg/kg for indeno(1,2,3-cd)pyrene. Iron was the only inorganic compound detected at concentrations above Unrestricted Use criteria; there is no Protection of Groundwater criterion for iron. Iron was detected at concentrations above the Unrestricted Use criterion of 2,000 mg/kg in BB-1 (8,600 mg/kg), MW-09 (21,000 mg/kg), and MW-11 (9,400 mg/kg).

2.7.2 Groundwater and Sump Water

Figure 2-8 shows the locations of groundwater samples (both grab and monitoring well samples) collected during the RI from the shallow groundwater zone and the results that exceed the groundwater SCGs. The SCGs for PCE, TCE, and/or cis-1,2-DCE were exceeded in eight of the 12 monitoring wells sampled in July 2014. The highest PCE concentrations are in the groundwater under the building. Figure 2-9 shows the estimated extent of the groundwater PCE plume above 100 µg/L. The plume is assumed to be within the shallow groundwater zone to a depth of approximately 15 feet. The figure shows that the plume extends beneath the laundromat building and primarily to the northwest and southeast.

Water samples from basement drainage sumps were collected at the Former Drape Master building and a nearby building in February 2015. It is noted that, historically, the basement of the Former Drape Master building had flooding problems. The sump water collected from the Former Drape Master basement contains elevated levels of PCE.

The RI found that groundwater conditions at the site are aerobic with a neutral pH and positive oxidation-reduction potential, and therefore unfavorable for reductive dechlorination of CVOCs. VOCs detected at concentrations above SCGs are primarily PCE and TCE, which are not naturally degraded under aerobic conditions.

2.7.3 Soil Vapor, Indoor Air, and Subslab Soil Vapor

Soil vapor sample locations are shown on Figure 2-10. The soil vapor results indicated the presence of elevated levels of PCE, TCE, and cis-1,2-DCE in samples collected from soil vapor points adjacent to and in the vicinity of the site. The data show the highest soil vapor concentrations closest to the Former Drape Master site. The sample results from SV-9 showed that butane was detected at an elevated level of 18,000 $\mu g/m^3$, and 2,2,4-trimethylpentane was detected at an elevated level of 3,000,000 $\mu g/m^3$. The elevated concentrations of these two compounds, associated with gasoline releases, resulted in elevated detection levels for all other VOCs and essentially masked the potential detections of other VOCs that may be present in the SV-9 sample.

Figure 2-10 presents indoor air and subslab analytical results. Indoor air samples indicated elevated levels of PCE in the basement of the Former Drape Master building. Elevated levels of PCE were also detected in the subslab sample collected from Building 1 (not identified as part of this investigation), but not in the indoor air samples. Based on the RI results, per the NYSDOH guidance decision matrix, Building 1 (off-site residence) should be monitored and the laundromat basement should be mitigated.

2.8 Summary of Qualitative Human Health Exposure Assessment

2.8.1 Identification of CPCs and Routes of Exposure

A Qualitative Human Health Exposure Assessment (HHEA) was presented in the RI. The HHEA provided a summary of potential exposure pathways and potentially toxicological effects that may result from exposure to contaminants attributable to former site activities under current and potential future site conditions. The HHEA used data and information collected from the RI, together with data collected as part of previous investigations, to assess human health exposure in the immediate and surrounding areas. Chemicals of potential concern (CPCs) for the site consist of CVOCs in the groundwater, sump water, indoor air, and soil vapor. The CVOCs include cis-1,2-DCE, TCE, and PCE. CVOCs present the greatest exposure through inhalation, but can also provide exposure through dermal contact and ingestion.

2.8.2 Potentially Exposed Receptors and Exposure Pathways

The site is currently occupied by an active laundromat and rental apartments. Adjacent structures include residences, a VFW lodge, gas station, automobile repair shop, and a restaurant/catering business. Under current and/or future conditions, human contact with the site can be expected to occur primarily by three types of receptors: onsite residents; nearby construction/utility workers who may be involved in construction/repairs to existing buildings or systems or future buildings or systems; commercial building occupants, both transient and permanent.

The majority of the surface in the site area is covered by buildings, pavement, and/or concrete. Access to surface soils is present only at residential properties that have gardens and/or lawns. These surface soils were not sampled as part of the RI or during previous investigations. The chlorinated solvent release(s) likely occurred in the basement of the Former Drape Master building or in the fenced storage area immediately adjacent to the western side of the building. Consequently, there were likely no impacts to the surface soils. Therefore, there is not a potential completed exposure pathway for surface soil and ground surface material

An ambient outdoor air sample was collected during soil vapor and indoor air sampling at the site. No elevated contaminant levels were detected in the samples. Therefore, there is no exposure pathway.

Indoor air samples were collected from four buildings. Elevated PCE concentrations were detected in the primary and duplicate samples from the laundromat basement. There is a potentially completed indoor air pathway under current and future conditions to onsite employees, patrons, and residents.

There is a potential completed exposure pathway for construction/utility workers who could come into contact with soil vapors during intrusive activities nearby and/or in basements of the laundromat and nearby buildings both under current and future conditions. There is also a potential completed exposure pathway in the future if site conditions or use of the basement change.

Under the current use scenario, groundwater is not known to be used as a potable water supply or for any other known industrial purposes in the vicinity of the site. Therefore, it is not a completed exposure pathway under the current use scenario. It is not anticipated that in the future that on-site groundwater would be used for potable purposes. Construction/utility workers may be exposed to groundwater contaminants during future intrusive activities through dermal contact or inhalation both under current and future conditions. Also, contact with contaminated groundwater through sump flooding may create an exposure pathway.

Table 2-1 shows potentially complete pathways and potential receptors for the current and future use scenarios.

3.0 REMEDIAL GOAL AND REMEDIAL ACTION OBJECTIVES

3.1 Remedial Goal

In accordance with DER-10, the remedial goal for site remediation is as follows:

- The remedy will eliminate or mitigate all significant threats to public health and the environment presented by the contaminants disposed at the site.

3.2 Remedial Action Objectives

In order to meet the remedial goal, remedial action objectives (RAOs) were developed to protect public health and the environment and provide the basis for selecting technologies and developing alternatives. In order to develop site-specific RAOs, the generic RAOs presented in DER-10 were considered for the potential mediums of concern (soil vapor/indoor air and groundwater).

Soil Vapor/Indoor Air: Sampling has identified some structures that contained VOC vapors at levels that resulted in actions being taken to reduce potential exposure to contaminants through soil vapor intrusion. Soil vapor RAO for Public Health Protection is:

- Mitigate impacts to public health resulting from existing, or the potential for, soil vapor intrusion into buildings at a site.

Groundwater: As shown in Figure 2-8, some groundwater samples exhibited VOC contamination above SCGs. The RAOs for groundwater are:

- Prevent contact with or inhalation of volatiles from contaminated groundwater and/or other contaminated water.

- Restore the groundwater aquifer to pre-disposal/pre-release conditions, to the extent practicable.

3.3 Areas of Contamination Addressed

Based on the RI and other previous investigations summarized in Section 2, and the RAOs presented in Section 3.2, the areas and depth of contamination to be addressed are described in the following sections.

3.3.1 Groundwater

Figure 2-8 shows the VOC contaminants detected in groundwater at the site above the SCGs (predominantly PCE along with TCE and cis-1,2-DCE). Based on this data, Figure 2-9 shows the estimated extent of the PCE plume in groundwater at a concentration above 100 µg/L. The extent of the PCE plume also encompasses the other dissolved phase VOC contaminants in the groundwater. As shown, the greatest impacts are located under laundromat building and to the northwest and southeast of the building. The area of this plume is on the order of 45,000 square feet, or approximately 120 feet by 375 feet. The plume is assumed to be within the shallow groundwater zone to a depth of approximately 15 feet.

Most treatment technologies are generally ineffective at treating groundwater contaminated with PCE and other VOCs at concentrations less than 100 µg/L. Once any source areas or areas of higher contamination have been addressed, natural attenuation is generally the best method to address the remaining contamination. Addressing the extent of the PCE contamination above 100 µg/L will significantly reduce the risks associated with the groundwater. Therefore 100 µg/L of PCE was chosen as the extent of treatment for the purpose of this FS. However, the evaluation of the various technologies and alternatives in the following sections are valid regardless of the extent of the treatment that is finally selected for implementation at this site, with the exception of the final costs of the alternatives.

3.3.2 Soil Vapor/Indoor Air

Elevated soil vapor concentrations for PCE, TCE, and cis-1,2-DCE are present throughout the site and closely resemble the profile and distribution of the dissolved phase impacts to the groundwater. The highest soil vapor concentrations are immediately south, southeast, and west of the laundromat building.

Elevated indoor air and/or subslab soil vapor concentrations for PCE, TCE, and cis-1,2-DCE are present in the laundromat building as well as in some nearby buildings. The highest indoor air concentrations were within the laundromat building. Based on the PCE concentration in the indoor air samples from the laundromat building, the PCE within this building should be mitigated. However, typical subslab mitigation systems are not feasible in this building due to the high groundwater level below the basement floor. Subsequent to the RI, the NYSDEC directed the owner of the building to mitigate the PCE by sealing the sump and all other openings into the basement to prevent contaminated groundwater (and thus the associated vapors) from intruding into the building.

Two of the three buildings adjacent to the laundromat building also showed elevated levels of PCE, but not at concentrations that require mitigation systems. Elevated levels of PCE in the subslab of Building 1 indicate this building should be monitored. Building 3 showed slightly elevated PCE levels in the indoor air; therefore reasonable measures should be taken to reduce exposure. Building 2 did not show elevated levels of the CPCs in the indoor air, and therefore warrants no action.

Once the mitigation measures are in place at the laundromat building, additional indoor air and/or subslab sampling will be conducted in this building and in Building 1. The results of the sampling will be used to evaluate the effectiveness of the mitigation measures in meeting the RAOs for soil vapor and indoor air.

Soil vapor and indoor air will not be evaluated further in this FS since mitigation measures have been directed for the affected properties.

3.4 General Response Actions

General response actions are broad response categories capable of satisfying the remedial action objectives for the site.

No Action: A no action response does not necessarily satisfy the RAOs, but is included to provide a baseline for comparison with other alternatives.

Institutional Controls: Institutional controls are non-physical measures that provide protection to human health and the environment by identifying contamination and reducing exposure. Institutional controls are implemented via Site Management Plans (SMPs).

Exposure Point Mitigation: Remedial measures may be implemented at the point of exposure to provide protection to human health and the environment by mitigating exposure to contaminated material.

Containment: Containment measures are those remedial actions intended to contain and/or isolate contaminants without treating, disturbing or removing the contamination. These measures satisfy the objectives by preventing migration from, or direct human exposure to, contaminated media.

Removal: Removal and disposal measures remove contamination from the site for subsequent treatment and/or disposal.

Treatment: Treatment measures include technologies whose purpose is to reduce the toxicity, mobility, or volume of contaminants by directly altering, isolating, or destroying those contaminants.

4.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

This section identifies specific remedial technologies and process options for each medium to be addressed (i.e., groundwater and soil vapor), and evaluates their effectiveness and technical implementability in meeting the RAOs for this site. Technologies that are not effective or not technically implementable are dropped from further consideration. Technologies that are implementable and that can meet the RAOs either alone or in conjunction with other technologies will be carried forward into the development of alternatives.

4.1 Identification and Screening of Technologies for Groundwater

This section identifies remedial technologies that could be implemented for groundwater at the site. Technologies are identified according to the general response actions presented in Section 3.4.

4.1.1 No Action

A no action response does not necessarily satisfy the RAOs, but is included to provide a baseline for comparison with other alternatives.

4.1.2 Institutional Controls

Institutional controls do not directly address the contamination in the groundwater, but instead are non-physical measures used to prevent exposure to the contamination. Institutional controls for the site would likely include an environmental easement or other legal and administrative means to restrict the use of property and/or groundwater, identify the contamination, and reduce potential exposure. Institutional controls are identified in an SMP which also identifies any engineering controls and any site operations, maintenance and monitoring to be conducted. Whether implemented as a stand-alone option or in conjunction with other remedial measures, an SMP would:

- Identify all institutional controls and engineering controls for the site to be implemented and complied with.
- Require the implementation and maintenance of the mitigation measures already directed for the for the laundromat building.
- Prohibit the use of groundwater underlying the site without approval by NYSDOH and without treatment to render it safe for the intended purpose.

- Include requirements to complete and submit to the NYSDEC periodic certification with long-term monitoring results.

- Identify procedures for the health and safety of employees, patrons, construction/utility workers, and residents of onsite and nearby buildings who may come into contact with the contaminated groundwater via dermal contact and/or ingestion during work-related activities at the site and/or offsite locations.

Effectiveness: There currently are no known exposure routes to groundwater. Although groundwater onsite and in the vicinity is not utilized for potable or other purposes, it is possible that private wells could be installed in the future. An SMP with institutional controls including an environmental easement would be effective in meeting the RAO for preventing contact with groundwater contaminated with VOCs during future work-related activities for construction workers, employees, and residents. However, institutional controls would not be effective in meeting the RAO of restoring the groundwater aquifer to pre-disposal/pre-release conditions.

Implementability: Institutional controls to some degree will be required for all alternatives at this site as part of an SMP.

Cost: The cost for institutional controls would be relatively low.

Conclusion: Institutional controls by themselves would not meet all RAOs, but would be useful in conjunction with other technologies. Institutional controls are retained for use at the site.

4.1.3 Exposure Point Mitigation

Exposure point mitigation generally consists of small remedial/treatment systems that are implemented at each point of use or point of exposure to the groundwater. Subsequent to the RI, the NYSDEC directed the owner of the laundromat building to seal the sump and all other openings in the basement to prevent groundwater (and the associated vapors) from intruding into the building. Similar exposure point mitigation options for groundwater are not applicable for any other buildings in the area. Since groundwater is not used for potable purposes in the vicinity of the site, exposure point mitigation systems are generally not applicable for groundwater use.

Conclusion: Since a exposure point mitigation has already been directed for the one applicable building, exposure point mitigation will not be retained for consideration.

4.1.4 Containment

Groundwater containment technologies aim to limit the migration of contaminated groundwater. Containment can be accomplished through physical isolation or hydraulic control.

4.1.4.1 Physical Isolation

Physical isolation for groundwater typically includes installing barriers such as sheet piling or slurry walls around the area of contaminated groundwater. These technologies are particularly effective on small source areas that have not migrated significantly.

Effectiveness: Physical isolation of the plume via barriers would not be particularly effective in preventing contact with contaminated groundwater due to the extent of the contaminant plume and the fact that it has migrated beyond the laundromat building and below the adjacent streets and other buildings. Physical isolation would not meet the RAO of restoring the groundwater aquifer to pre-disposal/pre-release conditions.

Implementability: Physical isolation of the groundwater plume would not be implementable at this site due to the extent and location of the plume across multiple properties and below the adjacent streets. Additionally, the urban nature of the site and the presence of subsurface utilities would make subsurface barriers difficult to install.

Cost: Physical isolation of the groundwater plume would have relatively high construction costs.

Conclusion: Containment via physical isolation will not be retained for consideration.

4.1.4.2 Hydraulic Control

Hydraulic control utilizes extraction of groundwater via wells or trenches to reverse the natural hydraulic gradients and thus prevent plume migration. Extracted groundwater often requires treatment prior to discharge. Field tests would be required to better estimate the actual aquifer parameters before the design of an extraction and treatment system. The field tests would include installing a recovery well and conducting pumping tests.

Effectiveness: Hydraulic containment of the plume eventually would be effective in meeting the RAOs for the site since the contaminated water would be removed and the size of the plume eventually would shrink. However, it is a relatively high cost alternative for groundwater remediation considering the long term operation and maintenance.

Implementability: Hydraulic containment via groundwater extraction would be difficult to implement since it would require suitable locations for extraction wells or trenches, conveyance piping, treatment systems, and other components that may be difficult to implement given the urban nature of the surrounding area.

Cost: Hydraulic containment would have relatively high construction costs in addition to relatively high long-term operational costs.

Conclusion: Hydraulic containment will not be retained for consideration.

4.1.5 Removal

The primary means of physically removing groundwater contamination are either as a liquid via groundwater extraction or as a vapor after being volatilized via air sparging.

4.1.5.1 Groundwater Extraction

Groundwater extraction for contaminant removal is essentially the same technology as hydraulic control as evaluated in the previous section. However, if the goal is removal versus containment, the extraction system may be more extensive and/or operate at a higher flow rate. Other options for this technology include multi-phase extraction (simultaneous extraction of soil vapor and groundwater), recirculation wells (where the water is treated and returned), and surfactant/solvent flushing (generally used to address free phase contamination not yet dissolved in the groundwater). Extraction via pumping wells is the typical method for groundwater removal as a liquid. Collection trenches installed perpendicular to the plume flow direction have also been used for groundwater removal. Collected groundwater would have to be treated prior to discharge.

Effectiveness: Groundwater extraction eventually would be effective in meeting the RAOs for the site since the contaminated water would be removed and the size of the plume would shrink.

Implementability: Groundwater extraction would be difficult to implement since it would require suitable locations for extraction wells or trenches, conveyance piping, treatment systems, and other components that may be difficult to implement given the urban nature of the surrounding area.

Cost: Groundwater extraction would have relatively high construction costs in addition to relatively high long-term operational costs.

Conclusion: Groundwater extraction will not be retained for consideration.

4.1.5.2 Air Sparging

Air sparging removes VOCs from groundwater by injecting air below the contaminated water; the air rises through the contaminated water and transfers the VOCs from the groundwater into the air. The contaminated air is then collected with a vapor extraction system located in the vadose zone above the sparging area. The air would be sparged into the aquifer via vertical injection wells and then collected using either vertical or horizontal vapor extraction wells installed in the vadose zone.

Effectiveness: PCE and other VOCs are readily amenable to removal via air sparging. Because it quickly and efficiently removes the contamination from groundwater, air sparging would be effective in achieving all RAOs for groundwater in those areas that it could be implemented. Effective sparging requires the complete capture of sparged vapors to prevent the uncontrolled release and migration of contaminant vapors or the accumulation of vapors beneath or within the nearby buildings. Thus air sparging may not be effective in treating contaminated groundwater located below the adjacent streets and other buildings where access for the installation of adequate sparge and extraction wells may be difficult. Utility lines and other subsurface structures can lead to short-circuiting and reduced effectiveness of the vapor collection system.

Implementability: Installation of the vapor extraction system would pose a significant implementability challenge. Air sparging requires a tight, regular pattern of air injection wells throughout the area to be treated, including within the building footprints. Extraction wells must also be carefully located to ensure that contaminants liberated from the groundwater are captured and treated. Access within the buildings would be required for installation of the air injection wells, vapor extraction wells, and piping for both air supply and vapor extraction.

Although sparge points could be provided by vertical injection wells, horizontal extraction wells would be required because the vadose zone is shallow and vertical wells would not be as effective for the capture of the vapors. The horizontal wells would have to be installed below the existing buildings, either by cutting trenches in the existing basement floors or by horizontally drilling beneath the structure. Outside of the buildings, a vapor extraction system would be nearly difficult to implement due to the presence of immediately adjacent buildings, public sidewalks, and numerous utilities.

For both the air injection and vapor extraction systems, the blowers, condensers, off-gas treatment units, and other ancillary equipment would have to be located outside in a separate building or container. There would be significant impacts to the affected residents or business operations during the initial installation of the well, piping, and systems. Operation of the systems may create noise, air emissions, and other unacceptable long-term impacts to the adjacent residents.

Cost: The cost for air sparging with vapor extraction would be moderate to expensive based on the difficulty of installation with the limited space available for wells and system piping.

Conclusion: Treatment via air sparging will not be retained for consideration.

4.1.6 Treatment

The treatment technologies being considered for this site all destroy the contaminants by converting them to less toxic end products. The destruction of organic contaminants can be through either oxidation or reduction processes. All of the treatment technologies being considered would be implemented via in-situ treatment.

4.1.6.1 In Situ Chemical Oxidation

In-situ chemical oxidation (ISCO) delivers oxidants into the groundwater to oxidize the contaminants to innocuous compounds such as water, carbon dioxide, and chloride ions. The principal oxidants used in environmental remediation are hydrogen peroxide, ozone, Fenton's reagent, potassium or sodium permanganate, and sodium persulfate. Within these chemical approaches there are proprietary oxidants such as RegenOx™, Klozur®, and Cool-Ox™.

The ISCO oxidants are typically are delivered into the groundwater either via permanent injection wells or via direct injection with injection rods advanced by direct-push equipment or a drill rig.

Effectiveness: All ISCO approaches are dependent upon aqueous phase contact between the delivered oxidant materials and the contaminant. If the injected oxidant does not reach the contaminated groundwater, then the oxidation processes cannot destroy the contamination. Therefore, the ability to achieve adequate subsurface distribution closely determines the effectiveness of the approach.

All of the available oxidants are effective in oxidizing the contaminants at the site; all have the ability to treat the chlorinated compounds present. However, there are differences among the various oxidants including:

- The pH range in which the oxidant is effective
- Whether the oxidant is corrosive and potentially damaging to utilities and other subsurface structures
- Whether the oxidation reaction generates heat and thus could vaporize the more volatile contaminants or create other unintended consequences
- Whether a catalyst or activator is required to initiate the oxidation process

For the purpose of this feasibility study, permanganate was selected over the other oxidants because it can be used over a wide range of pH values, does not require a catalyst, and is a long-lasting oxidant. It has the potential to remain active in the subsurface for months, allowing it to diffuse and otherwise travel throughout the groundwater more effectively.

Implementability: Injection of ISCO reagents requires a tight, regular pattern of injection points throughout the desired area of treatment. Oxidant materials would be delivered by injection wells since multiple injection events likely would be required. Considering the location and extent of the contaminated groundwater plume at this site, the most effective injection system would include injection wells within the footprint of the laundromat building and other nearby buildings since that is the most contaminated area. Access within the building would be preferred; however, directional drilling from outside the building also may be feasible. Access would only be needed on a temporary basis, impacting the business operation for a relatively short time (e.g., a matter of days) for the initial well installation. Multiple injection events would be conducted, with access to the buildings required for each injection event. Due to relatively shallow depth of contamination and soil conditions which are amenable to easier drilling, installation of injection wells would not be difficult. The wells within the buildings could be installed using a smaller hydraulic power direct-push unit.

Cost: The costs for ISCO are moderate.

Conclusion: Treatment via ISCO will be retained for consideration. For the development and analysis of remedial alternatives, oxidation by permanganate will be selected as the process option considered for the analysis since it is effective and longer lasting.

4.1.6.2 Enhanced Bioremediation

Enhanced bioremediation can be implemented to promote either aerobic or anaerobic degradation of contaminants in groundwater. In the case of chlorinated VOCs, biodegradation only occurs under anaerobic conditions via a process known as reductive dechlorination. Indigenous anaerobic microbes substitute hydrogen for each chlorine atom on the contaminant molecules, thus sequentially dechlorinating the molecules. The chlorinated compounds are converted through a series of daughter products until they are finally converted to ethene and ethane.

Reductive dechlorination naturally occurs at slow and unstable rates. Enhanced bioremediation involves creating ideal conditions in the subsurface environment in order to facilitate the naturally occurring processes. Adding hydrogen to the groundwater increases the population of microbes and accelerates the natural rate of the process. Amendment materials used to implement enhanced bioremediation include the following, alone or in combination:

- Biostimulants (e.g., electron donor materials use to create suitable anaerobic aquifer conditions and provide microbial food) such as emulsified vegetable oil (EVO), soluble plant carbon, and sodium lactate-based materials.

- Bioaugmentation via the addition of microbial culture (e.g., introduction of laboratory grown bacteria known to degrade target contaminants) such as *Dehalococcoides* (DHC), which is typically only introduced following aquifer conditioning to anaerobic conditions.

- Activated carbon to aid in the removal of contaminants and to provide a media on which to sustain biological processes

There are differences among the various biostimulation products including:

- Whether the product is rapid release or a more sustained release
- The effective life of the product in the subsurface
- Whether multiple injection events are required
- The viscosity and injectability of the product

For aquifer conditioning and biostimulation, EVO products include: EOS® from EOS remediation, SRS™ from Terra Systems, Inc., and Newman Zone® from Remediation and Natural Attenuation Services, Inc. Each of these products consists principally of a vegetable oil mixture that has been emulsified to serve as a long-term carbon source (acting as an electron donor) and small amounts of sodium lactate for short-term biostimulation, and a variety of other additives and vitamins.

Products in the sodium lactate electron donor category include HRC® products from Regenesis and WilCLEAR® by JRW Bioremediation. The HRC® products typically have increased longevity within the subsurface (months to years); whereas WilCLEAR® is a quickly dissolving lactate solution that is typically consumed very rapidly (weeks to months).

Following biostimulation or aquifer conditioning activities, bioaugmentation, using laboratory grown culture, may be necessary to supplement the naturally occurring microbes and thus improve the effectiveness of the technology. Microbial cultures for reductive dechlorination are commercially available from several vendors including KB-1® from SiREM and Bio-Dechlor INOCULUM® (BDI) from Regenesis. Microbial cultures are typically introduced once suitable aquifer conditions have been established (e.g., ORP of less than –100 mV and pH between 6 and 8). Dechlorinating bacteria are found at many sites naturally, even where aquifer conditions may not be suitable for complete degradation to occur.

A relatively new remediation technology is the injection of activated carbon via a product such as PlumeStop® Liquid Activated Carbon™ from Regenesis. The product consists of fine particles of activated carbon suspended in water with organic polymer agent that promotes dispersion of the product throughout the groundwater. Once in the subsurface, the carbon binds to the aquifer material and begins to absorb contaminants from the groundwater. The concentrated contaminants then biodegrade at an accelerated rate. Once the contaminants have degraded, the carbon is free to absorb additional contaminants from the groundwater.

Effectiveness: Enhanced bioremediation is an effective technology for the treatment of chlorinated contaminants, provided that adequate subsurface distribution is achieved. Many electron donors have longevity of months to years. Bacteria predominantly reside on soil particles and self-distribute (i.e., bloom) as aquifer conditions become suitable. At other sites, this has allowed greater distribution over time within low permeability zones, increasing treatment effectiveness. Based on the oxidizing condition of the aquifer and the relative lack of daughter products, for the purpose of the FS it is assumed that both biostimulation and bioaugmentation would be required in order to implement and sustain effective anaerobic bioremediation.

Implementability: Injection of bioremediation products requires a tight, regular pattern of injection points throughout the desired area of treatment. Due to the longevity of the product, typically only one injection event is required; materials would be delivered by direct-push injection points. Considering the location and extent of the contaminated groundwater plume at this site, the most effective injection system would include injection points within the footprint of the laundromat building and other nearby buildings since that is the most contaminated area. Access within the building would be preferred;

however, directional drilling from outside the building also may be feasible. Access would only be needed on a temporary basis, impacting the business operation for a relatively short time (e.g., a matter of days). Due to relatively shallow depth of contamination and soil conditions which are amenable to easier drilling, installation of injection points would not be difficult. The points within the buildings could be installed using a smaller hydraulic power direct-push unit.

Cost: The costs of enhanced bioremediation are moderate.

Conclusion: Treatment via enhanced bioremediation will be retained for consideration. For the purpose of this FS it is assumed that both biostimulation and bioaugmentation would be required. The use of PlumeStop is also assumed since it provides a rapid reduction the contamination in the groundwater and thus would help in addressing the vapor issues.

4.1.6.3 In-situ Chemical Reduction

In-situ chemical reduction (ISCR) works by supplying an excess of hydrogen atoms to substitute for each chlorine atom on the contaminant molecules, thus sequentially dechlorinating the molecules. The chlorinated compounds are converted through a series of daughter products until they are finally converted to ethene and ethane. The process proceeds via a chemical reaction as opposed to a biological process. However, the same reagents that support direct chemical reduction also stimulate the biological reduction processes.

Chemical reducing materials typically include zero-valent iron (ZVI), a granular or powdered material proven to degrade target compounds such as PCE and TCE via reductive dechlorination. Surface contact is required between the target contaminant and the ZVI material surface. Products such as BOS 100 from Remediation Products, Inc. utilize granular activated carbon (e.g., non-soluble carbon for contaminant adsorption) with iron precipitates on the carbon surface to facilitate abiotic reduction. Treatment using ZVI with abiotic dechlorination alone requires substantial subsurface distribution for contact between the contaminant and the ZVI materials. Therefore, this is often implemented using a permeable reactive barrier or very tight spacing across the target treatment area.

Additionally, ZVI can be used for aquifer conditioning, primarily in the ability of ZVI to create reducing conditions (e.g., ORP of less than –200 millivolts [mV]). Several products combine ZVI with an electron donor to support both abiotic and biological dechlorination processes. These combination products include EHC® (e.g., soluble plant carbon and ZVI) from PeroxyChem Inc. and EZVI (nano-scale ZVI suspended in emulsified oil) from Toxicological & Environmental Associates (TEA), Inc.

Following aquifer conditioning activities, bioaugmentation, using laboratory grown culture, may be necessary to meet SCGs and/or remedial action objectives. Microbial cultures for reductive dechlorination are commercially available from several vendors including KB-1® from SiREM and Bio-Dechlor INOCULUM® (BDI) from Regenesis. Microbial cultures are typically introduced once suitable aquifer conditions have been established (e.g., ORP of less than –100 mV and pH between 6 and 8).

Effectiveness: In situ chemical reduction is effective in dechlorinating the chlorinated contaminants present at the site, provided adequate subsurface distribution is achieved. Many electron donors have longevity of months to years. The process also stimulates biological processes and thus would be able to address the contamination via several mechanisms. Bacteria predominantly reside on soil particles and self-distribute (i.e., bloom) as aquifer conditions become suitable. At other sites, this has allowed greater distribution over time within low permeability zones, increasing treatment effectiveness. Based on the oxidizing condition of the aquifer and the relative lack of daughter products, for the purpose of the FS it is assumed that bioaugmentation would be required.

Implementability: Injection of dechlorination products requires a tight, regular pattern of injection points throughout the desired area of treatment. Because only one injection event typically is required, materials would be delivered by direct-push injection points. Considering the location and extent of the contaminated groundwater plume at this site, the most effective injection system would include injection points within the footprint of the laundromat building and other nearby buildings since that is the most contaminated area. Access within the building would be preferred; however, directional drilling from outside the building also may be feasible. Access would only be needed on a temporary basis, impacting the business operation for a relatively short time (e.g., a matter of days). Due to relatively shallow depth of contamination and soil conditions which are amenable to easier drilling, installation of injection points would not be difficult. The points within the buildings could be installed using a smaller hydraulic power direct-push unit.

Materials containing ZVI typically require higher injection pressures to deliver powdered or granular materials. This would require increased access to buildings during injection events, but could still be implemented with limited impacts.

Cost: The costs of in situ chemical reduction are moderate.

Conclusion: Treatment via in situ chemical reduction will be retained for consideration. For the purpose of this FS it is assumed that bioaugmentation would be required.

4.2 Identification of Technologies for Soil Vapor/Indoor Air

As noted above, soil vapor and indoor air will not be evaluated in this FS since mitigation measures have been directed for the laundromat building, currently the only affected property. Once the mitigation measures are in place at the laundromat building, additional indoor air and/or subslab sampling will be conducted in this building and in Building 1. The results of the sampling will be used to evaluate the effectiveness of the mitigation measures in meeting the RAOs for soil vapor and indoor air.

4.3 Summary of Remedial Technologies

Remedial technologies retained for use in the development of alternatives include:

- No Action
- Institutional Controls (SMPs)
- In-Situ Groundwater Treatment through ISCO
- In-Situ Groundwater Treatment through Enhanced Bioremediation
- In-Situ Groundwater Treatment through Chemical Reduction

5.0 DEVELOPMENT AND DESCRIPTION OF ALTERNATIVES

This section identifies and describes the remedial alternatives to be considered and evaluated for the site. The alternatives were developed based on the remedial technologies considered feasible in the previous section and based on input from the NYSDEC in regard to the quantity and type of remedial technologies to be evaluated. Each of the alternatives is described in detail below.

5.1 Development of Alternatives

The following remedial alternatives were developed to meet the remedial goal and remedial action objectives for groundwater at this site. The alternatives present a range of technologies that each attain the RAOs via different processes and with increasing complexity and potentially improved performance.

Alternative 1 – No Action

Alternative 2 – In-Situ Groundwater Treatment through ISCO

Alternative 3 – In-Situ Groundwater Treatment through Enhanced Bioremediation

Alternative 4 – In-Situ Groundwater Treatment through Chemical Reduction

Alternatives 2 through 4 are assumed to include some level of Institutional Controls via an SMP in combination with the remedial technology shown.

5.2 Description of Alternatives

Alternatives are described in accordance with DER-10 with regard to: size and configuration, time for remediation, spatial requirements, options for disposal, permitting requirements, limitations, and ecological impacts.

5.2.1 Alternative 1 - No Action

Under this alternative, no remedial actions would be implemented to address the groundwater contamination at the site. The contaminants present in the groundwater would continue to attenuate by natural processes such as biodegradation, dispersion, dilution, and volatilization, each of which are slowly occurring over time at varying degrees. No monitoring would be conducted.

Size and Configuration

- No remedial construction or other remedial action would be implemented.

Time for Remediation

- Since no remedial construction or other remedial action would be implemented, no time would be required to implement this alternative. The time for this alternative to achieve the RAOs could be on the order of decades since any of the existing attenuation processes are likely slow.

Spatial Requirements

- There are no spatial requirements.

Options for Disposal

- There are no materials requiring disposal.

Permit Requirements

- No permits would be required for this alternative.

Limitations

- This alternative would not meet the RAOs for groundwater for many years.

Ecological Impacts

- This alternative is not anticipated to have any negative impacts on fish and wildlife resources.

5.2.2 Alternative 2: In-Situ Groundwater Treatment through ISCO

This alternative comprises injection of an oxidant into the aquifer to chemically react with the chlorinated VOC contamination.

During the RI, URS collected data on the aquifer chemical/physical parameters of pH, ORP, DO, and conductivity as well as the inorganic parameters of iron, manganese, alkalinity, nitrate, and sulfate. These data are presented in Table 5-1. Overall, the indicator parameters suggest that the site is amenable for chemical oxidation. For the purposes of this FS it is assumed that permanganate will be used as the oxidant. As discussed in Section 4.1.6.1, there are other oxidants, including persulfate and peroxides. The final choice of amendment would be made during the design phase of the project.

Potassium and sodium permanganate are both options for remediation of groundwater. Potassium permanganate is less expensive and is delivered as a solid. However, potassium permanganate needs to be mixed into solution onsite, and is limited to a maximum injection concentration of about 4%. This would require more than 64,000 gallons of 4% potassium permanganate solution to be injected. Potassium permanganate is also on the Department of Homeland Security (DHS) Chemicals of Interest. Sodium permanganate is received onsite as a concentrated liquid. Although dilution may be required prior to injection, no solid/liquid mixing is required. Additionally, sodium permanganate may be injected at concentrations up to 20%, requiring less water to be injected into the aquifer, thus reducing the extent of contaminant displacement. Sodium permanganate is not on the DHS list. Sodium permanganate is selected as the oxidant for this alternative for these reasons. However, while sodium permanganate is simpler to prepare, additional safety and material compatibility issues would need to be considered in the design and implementation.

The concentration of contaminant in the aquifer typically has little impact on the total quantity of oxidant required for remediation since the oxidants do not specifically target the chlorinated compounds. The oxidant reacts with many of the naturally occurring organic and inorganic compounds in the soil. The demand for oxidant from these other compounds in the soil is referred to as the natural oxidant demand (NOD) of the soil. NOD may consume more than 99% of the oxidant delivered into the subsurface.

The oxidant is injected into the aquifer via direct-push borings or injection wells. Injection wells would be utilized at this site based on the urban nature of the site and since multiple injection events will likely be required. Injection wells allow for better control of the injection and can be used over multiple injection events. Injection wells also can be used for monitoring groundwater parameters and for potential implementation of additional remedial actions in the future, if necessary.

Because oxidation requires contact between the contaminant and the oxidant to be effective, the injection wells ideally would be installed in a regular grid pattern over the extent of the desired treatment area. A large portion of the contaminant plume at this site extends beneath adjacent buildings, streets, and sidewalks. Although injection wells located within the building(s) would be useful, they were not included for the purpose of this FS since they would require access agreements with the owners of the affected buildings and coordination with the businesses operating in those locations. Additionally, the groundwater at this site is relatively shallow and directly below the basement floor at the laundromat building. It is possible that the process of injecting in the basements of the buildings would cause daylighting of the oxidant and/or contaminated groundwater into the basements via other injection wells, cracks in the floors, utility lines, etc. The actual availability and suitability of the building basements, parking lots, and other areas of the site for injection should be determined and considered during the design phase of the project. However, for the purpose of this FS, it is assumed that all injection wells will be located within the public sidewalk. The sidewalks are generally located in the center of the plume and wells in those areas should have a reasonable chance of treating a large extent of the contaminant plume. The wells are conservatively assumed to be spaced relatively close together to improve the effectiveness in treating the entire plume from the sidewalks.

Size and Configuration

- A pre-design investigation and/or pilot study may be conducted to select the appropriate oxidant and refine the dosage information based on the determination of NOD and other critical design factors. Well placement and spacing may also be verified during the pre-design phase of the project.

- No site-specific NOD analyses were performed on soils from the site; however, typical NOD values for this type of soil are 1 milligram per kilogram (mg/kg). Based on this assumed NOD, calculations presented in Appendix A show approximately 48,160 pounds of sodium permanganate would be required.

- For the purpose of this FS, it is assumed that the injection wells will only be installed in the public sidewalks. It is assumed that no injection wells are located in the laundromat, other buildings, or parking areas at the site. At a conservative 10-foot linear spacing (shown on Figure 5-1) a total of 45 wells would be required. The wells are assumed to be 4-inch diameter PVC and installed to a depth of 15 feet into the groundwater. The wells would only be screened in the saturated zone.

- Oxidant would arrive in a tanker truck and be transferred to storage and dilution tanks (if required), and from there dispensed to the injection points. The injections would be conducted at each injection well. No piping or distribution system would be installed.

- At a 5% solution, 44,140 gallons of sodium permanganate solution would be injected into the aquifer. The solution would be injected among the approximately 45 injection points as shown on Figure 5-1. Not all the oxidant would be injected at once. Injecting the oxidant over time in smaller doses and at lower concentrations has been shown to be more effective than injecting all of the oxidant during one event. The oxidant solution would be injected in a minimum of three events, with 50% of the volume injected in the first event, 25% in the second event, and 25% in the third event. This allows the remaining contamination levels to be determined between events and then successively polished, potentially reaching lower end concentrations.

- A monitoring program including sampling and analysis of the groundwater would be performed during the estimated one year implementation period. Monitoring after each injection event and throughout the year would provide data to tailor the future injection events. Analysis of the groundwater would determine the degree of any rebound that occurs after each of the injection events.

- A five year period of monitoring is included to assess the effectiveness of remediation and to monitor for any rebound that may occur.

- An SMP would be prepared to ensure that the mitigation measures directed for the laundromat building are in place and effective. Periodic indoor air monitoring would be conducted to ensure that no other buildings require mitigation. Institutional controls to prohibit groundwater use and to ensure protection of the public during work-related activities at the site would be developed. Annual groundwater monitoring would be conducted for 30 years or until site SCGs are achieved.

Time for Remediation

- ISCO is a nearly instantaneous chemical reaction that occurs once the oxidant comes into contact with an oxidizable compound. The rate of treatment is governed by the rate of convective and diffusive transport of the oxidant within the aquifer. Typically, months are allowed to pass between injections to allow for a maximum extent of oxidant migration prior to reinjection of subsequent rounds. Complete degradation of the plume may take longer at this site since the injection wells are located in less than optimum locations along the sidewalks and since the oxidant has to travel further to reach the extent of the contaminant plume. Smaller, but more frequent injection events also may prove to be more useful in these conditions. Therefore, the overall duration of ISCO treatment is assumed to be on the order of up to one year. Both a one-year onsite direct read and sampling and analysis program, and a five-year onsite and offsite monitoring period are included to assess effectiveness. Annual groundwater monitoring would be conducted for 30 years or until site SCGs are achieved.

- Up to two months may be required for installation of the injection wells in the sidewalk.

- The duration of each injection event is expected to be on the order of two to three weeks including time for set-up and clean-up before and after the actual injections.

Spatial Requirements

- During injection events, nearly full access to the site would be required. Although only one injection location at a time may be serviced, the contractor would inject at multiple locations per day and would shift from one point to another. Ideally the injections are not conducted sequentially at adjacent locations but are staggered throughout the plume to minimize the possibility of daylighting. Entire portions of the sidewalk would likely be closed during the injection events. Adequate safety and spill controls would be maintained at each injection point.

- No long-term access to the site would be required for this alternative. The injection wells would be the only semi-permanent structures at the site and they would remain in the sidewalk only for the duration of the injections and monitoring. Permanent monitoring wells would remain at the site.

- A storage and staging area would be required for the two month installation of the injection wells and for the two to three week duration of each injection event. Treatment reagents, mixing equipment, and injection equipment would be staged onsite for the duration of the injections. This would include storage tanks, mixing skids, delivery trucks, secondary containment, and other safety considerations. Fencing and security for this area would be required. Ideally the staging area would need to be located within very close proximity to the site, as well as in close proximity to a source of water for the mixing of the reagents. Alternatively, it may be possible to receive pre-mixed/diluted permanganate solution at the site. Logistics for product delivery would be determined during the design phase.

- If injection wells within the buildings were to be included as part of the implementation design, it would require access to injection locations within the basement of the structures and the equipment and items stored within the basement would have to be moved and temporarily stored. Depending upon the access to the basement and the quantity of material to be moved, there may be some temporary impacts to the business operations. Impacts would likely be the greatest during the installation of the injection wells.

Permit Requirements

- Injection may require submission of an Inventory of Injection Wells Form 7520-16 as part of the Underground Injection Control (UIC) program operated by the United States Environmental Protection Agency (USEPA). Injection wells incidental to aquifer remediation and experimental technologies are distinguished from hazardous waste injection wells and are designated as Class V under the Underground Injection Control (UIC) program. Class V wells covered by the Federal UIC program are authorized by rule and do not require a separate UIC permit.
- Permits would likely be required for the drilling and installation of the injection wells in the sidewalks.

Limitations

- The primary limitation to this alternative is the presence of the building(s) and the streets. Accomplishing the injections only from points located within the sidewalk prevents injection throughout the complete extent of the contaminant plume. However, the permeable nature of the saturated zone below the site should allow the treatment reagents to disperse and eventually treat the majority of the target area. It is also likely that injection locations in addition to those in the sidewalk can be identified during the design process.
- Utilities and other obstructions are likely to be encountered in the sidewalk areas. All injection points would have to be carefully installed to avoid impacting utilities and other subsurface structures. The injection wells would have to be periodically checked to ensure that they do not shift or heave and become trip hazards. Repair or replacement of the sidewalk would likely be required following the removal of the injection points.

Ecological Impacts

- This alternative is not anticipated to have any negative impacts on fish and wildlife resources.

5.2.3 Alternative 3: In-Situ Groundwater Treatment through Enhanced Bioremediation

This alternative involves the injection of products into the aquifer to promote the biological degradation of the chlorinated VOC contamination. In addition to the bioremediation products, PlumeStop Liquid Activated Carbon would be injected throughout the plume area. PlumeStop is a highly sorptive medium that disperses throughout the plume to rapidly reduce the contaminant concentrations in the groundwater. The product then enhances the biodegradation of the sorbed contamination. Because PlumeStop is a Regenesis product, and presently is only injected by Regenesis technicians, it would be used in conjunction with Regenesis' enhanced bioremediation product, HRC.

PlumeStop is a black liquid composed of very fine particles of activated carbon suspended in water using organic polymer dispersion agents. After injection into the subsurface, the product quickly disperses throughout the groundwater and coats the soil matrix. The carbon then absorbs and removes contaminants from the groundwater. The captured contaminants are captured and concentrated on the carbon where accelerated biodegradation processes destroy the contaminants. The carbon product is the available for the adsorption and destruction of additional contamination.

HRC is a lactic acid based hydrogen release compound engineered specifically to enhance the in-situ anaerobic bioremediation processes. The product enhances bioremediation through the controlled release of hydrogen. Bioaugmentation with Regenesis BDI product would also be included. Regenesis would inject all three products concurrently, during one injection event.

As with the other technologies, the concentration of contamination in the aquifer has little impact on the total quantity of product required for remediation since the products do not specifically target the chlorinated compounds. Competing electron acceptors include DO, nitrate, dissolved manganese, iron (III), and sulfate.

Since only one injection event is envisioned, the remedial amendments would be injected via direct-push borings instead of injection wells. As with the other Alternatives, the ideal injection would be via a regular grid pattern over the extent of the desired treatment area. A large portion of the contaminant plume at this site extends beneath adjacent buildings, streets, and sidewalks. It may be possible to install some angled points to install the PlumeStop and HRC product below a small portion of the adjacent buildings. Although injection points located within the building(s) would be useful, they were not included for the purpose of this FS since they would require access agreements with the owners of the affected buildings and coordination with the businesses operating in those locations. Additionally, the groundwater at this site is relatively shallow and directly below the basement floor at the laundromat building. It is possible that the process of injecting in the basements of the buildings would cause daylighting of the product and/or contaminated groundwater into the basements via other injection points, cracks in the floors, utility lines, etc. The actual availability and suitability of the building basements for injection should be determined and considered during the design phase of the project. Based on the nature of the product, PlumeStop can be injected via low pressure or gravity feed as compared to the high pressure required for the injection of many reductive dechlorination products which are highly viscous. Therefore it may be possible to inject PlumeStop in the basements of the buildings at the site with less chance for daylighting.

For the purpose of this FS, it is assumed that all injection borings will be located within the public sidewalk. The sidewalks are generally located in the center of the plume and injection in those areas should have a reasonable chance of treating a large extent of the contaminant plume. The injections are conservatively assumed to be spaced relatively close together to improve the effectiveness in treating the entire plume from the sidewalks.

Size and Configuration

- A pre-design investigation and/or pilot study may be conducted to select the appropriate oxidant and refine the dosage information. The placement and spacing of the direct push injection borings may also be verified during the pre-design phase of the project.
- Vendor information and calculations are included in Appendix A. The dosage recommended by Regenesis includes 24,000 pounds of PlumeStop, 2,820 pounds of HRC, and 36 liters of BDI. PlumeStop is shipped as a liquid in either plastic totes or drums. HRC is supplied in 30 pounds pails, and the BDI in 18 liter kegs.
- The PlumeStop and other agents would be injected using direct push equipment. For the purpose of this FS, it is assumed that the injection points will only be located in the public sidewalks. It is assumed that no injection points are located in the laundromat, other buildings, or parking areas at the site. At a conservative 10-foot linear spacing (shown on Figure 5-2), the total number of injection points would be on the order of 45.
- At each injection point, Regenesis would inject 639 gallons of PlumeStop, 5.8 gallons of HRC, and 0.8 liters of BDI.

- The level of effort for sampling and monitoring would be similar in scope and duration as for Alternative 2. A five year period of monitoring is included to assess the effectiveness of remediation and to monitor for any rebound that may occur.

- An SMP would be prepared to ensure that the mitigation measures directed for the laundromat building are in place and effective. Periodic indoor air monitoring would be conducted to ensure that no other buildings require mitigation. Institutional controls to prohibit groundwater use and to ensure protection of the public during work-related activities at the site would be developed. Annual groundwater monitoring would be conducted for 30 years or until site SCGs are achieved.

Time for Remediation

- The duration of the PlumeStop and EHC injection event is expected to be on the order of three to four weeks, including time for set-up and clean-up before and after the actual injections.

- While PlumeStop would provide improved contaminant reduction soon after injection of the product, it is assumed that the overall duration and time required to achieve the target final concentrations will be only slightly shorter than for HRC alone. HRC destroys the chlorinated VOCs via enhanced bioremediation which requires a period of time in order for the ideal conditions and bioremediation processes to establish. The overall duration of the remediation and the time required in order for the groundwater to meet the desired criteria is expected to be on the order of one to two years, somewhat longer than for the ISCO due to the difficulty in placing the PlumeStop and HRC in ideal locations to reach the extent of the groundwater plume.

- Both a one-year onsite direct read and sampling and analysis program, and a five-year onsite and offsite monitoring period are included to assess effectiveness. Annual groundwater monitoring would be conducted for 30 years or until site SCGs are achieved.

Spatial Requirements

- During the injection event, nearly full access to the site would be required. Although only one injection location at a time may be serviced, the contractor would inject at multiple locations per day and would shift from one point to another. Ideally the injections are not conducted sequentially at adjacent locations but are staggered throughout the plume to minimize the possibility of daylighting. Entire portions of the sidewalk would likely be closed during the injection event. Adequate safety and spill controls would be maintained at each injection point.

- No long-term access to the site would be required for this alternative. The injection points are only temporary and the sidewalk would likely be repaired or replaced shortly after the completion of the injections. Permanent monitoring wells would remain at the site.

- A storage and staging area would be required for the three to four week duration of the injection event. Treatment reagents, mixing equipment, and injection equipment would be staged onsite for the duration of the injections. This would include storage tanks, mixing skids, delivery trucks, secondary containment, and other safety considerations. Fencing and security for this area would be required. Ideally the staging area would need to be located within very close proximity to the site, as well as in close proximity to a source of water for the mixing of the reagents. The storage requirements for this alternative would likely be somewhat larger than that required for the ISCO alternative.

- If injections within the building(s) were to be included as part of the implementation design, it would require access to injection locations within the basement of the structure and the equipment and items stored within the basement would have to be moved and temporarily stored. Depending upon the access to the basement and the quantity of material to be moved, there may be some temporary impacts to the business operations. Impacts would only be for the duration of the one injection event.

Permit Requirements

- Injection may require submission of an Inventory of Injection Wells Form 7520-16 as part of the UIC program operated by the USEPA. Injection wells incidental to aquifer remediation and experimental technologies are distinguished from hazardous waste injection wells and are designated as Class V under the UIC program. Class V wells covered by the Federal UIC program are authorized by rule and do not require a separate UIC permit. This would be verified as part of the design process.

- Permits would likely be required for the drilling and installation of the injection points in the sidewalks.

Limitations

- The primary limitation to this alternative is the presence of the building(s). Accomplishing the injections only from points located within the sidewalk prevents injection throughout the complete extent of the contaminant plume. However, the permeable nature of the saturated zone below the site should allow the anaerobic conditions to propagate beyond the placement zone and eventually treat the majority of the target area. It is also likely that injection locations in addition to those in the sidewalk can be identified during the design process.
- Utilities and other obstructions are likely to be encountered in the sidewalk areas. All injection points would have to be carefully installed to avoid impacting utilities and other subsurface structures.
- Because monitoring indicates that the aquifer is presently in an oxidative state with high ORP and high DO concentrations, it is possible that the microbial population required for effective biodegradation of PCE is limited. The relative lack of PCE breakdown products in the groundwater may be an indication that current biological activity is limited. In order to be most effective, it may be beneficial to introduce the dehalogenating bacteria into the aquifer once suitable reductive conditions have been established.
- Sources of DO in groundwater include rainwater infiltration. If significant quantities of high DO water infiltrate into the groundwater it may limit the effectiveness of the remedial agents in creating conditions suitable for a reductive environment.

Ecological Impacts

- This alternative is not anticipated to have any negative impacts on fish and wildlife resources.

5.2.4 Alternative 4: In-Situ Groundwater Treatment through Chemical Reduction

This alternative comprises injection of products into the aquifer to promote in-situ chemical reduction to chemically reduce the chlorinated VOC contamination to ethane and ethene.

During the RI, URS collected data on the aquifer chemical/physical parameters of pH, ORP, DO, and conductivity as well as the inorganic parameters of iron, manganese, alkalinity, nitrate, and sulfate. These data are presented in Table 5-1. Favorable conditions for reduction include ORP approximately -100 to -300 mV, DO less than 0.2 mg/L, and pH between 6 and 8.5. Overall, the indicator parameters suggest that the aquifer presently in an oxidative state, not reductive. As shown on Table 5-1, the average

ORP measured was 177 mV and the DO was 3.49 mg/L. The pH is acceptable at an average of 6.98. In order for this alternative to be effective, the aquifer would have to be changed to reducing conditions.

There are a variety of in situ reductive products for the treatment of groundwater. EHC as manufactured by PeroxyChem was selected as the product for evaluation under this alternative. EHC includes an organic carbon source and zero valent iron (ZVI). EHC comes as both a solid product and a liquid product. The solid product promotes both chemical reduction and stimulated biological reduction and is the longest lasting and highest power of the EHC products. The product is suitable for treating higher concentration source areas and plumes. The product is mixed into a slurry and injected into the subsurface via direct-push equipment. Due to the nature of the material, high pressure equipment is required for injection.

EHC Liquid utilizes a lecithin substrate and ferrous iron. Both EHC products stimulate biological reduction, but EHC liquid only provides indirect chemical reduction. EHC Liquid has a shorter longevity of 1-3 years as compared to 3-8+ years for the EHC. EHC Liquid is suitable for the treatment of contaminant plumes but not concentrated source areas. Because it is liquid, EHC Liquid is easier to use and can be injected at lower pressures or even gravity fed through injection wells.

For the purposes of this FS, EHC Liquid was selected as the reagent considered in this alternative based on the fact that it is much easier to prepare and inject, it is better suited to low concentration plumes, and its longevity. The suitability of this product for application at the site given the pressure required for injection, the limited available space, and other site conditions would be determined and verified during the design phase of the project.

As with ISCO, the concentration of contaminant in the aquifer typically has little impact on the total quantity of ISCR product required for remediation since the products do not specifically target the chlorinated compounds. In the case of ISCR, competing electron acceptors are DO, nitrate, dissolved manganese, iron (III) and sulfate.

As a solid product, EHC can be applied using open excavations, trenches and reactive barrier walls, soil mixing, or via injection. With the EHC Liquid, injection would be the most appropriate method. There would likely be only one injection event applied via direct-push injection rods. Injection wells can be used with EHC Liquid, but would not be practical since there likely would be only one injection event.

Since only one injection event is envisioned, the remedial amendments would be injected via direct-push borings instead of injection wells. The ideal injection would be via a regular grid pattern over the extent of the desired treatment area. A large portion of the contaminant plume at this site extends beneath adjacent buildings, streets, and sidewalks. It may be possible to install some angled points to install EHC Liquid below a small portion of the adjacent buildings. Although injection points located within the building(s) would be useful, they were not included for the purpose of this FS since they would require access agreements with the owners of the affected buildings and coordination with the businesses operating in those locations. Additionally, the groundwater at this site is relatively shallow and directly below the basement floor at the laundromat building. It is possible that the process of injecting in the basements of the buildings would cause daylighting of the product and/or contaminated groundwater into the basements via other injection points, cracks in the floors, utility lines, etc. The actual availability and suitability of the building basements for injection should be determined and considered during the design phase of the project.

For the purpose of this FS, it is assumed that all injection borings will be located within the public sidewalk. The sidewalks are generally located in the center of the plume and injection in those areas should have a reasonable chance of treating a large extent of the contaminant plume. The injections are conservatively assumed to be spaced relatively close together to improve the effectiveness in treating the entire plume from the sidewalks.

Size and Configuration

- A pre-design investigation and/or pilot study may be conducted to select the appropriate reducing agents and refine the dosage information. The placement and spacing of the direct push injection borings may also be verified during the pre-design phase of the project.

- Vendor information and calculations presented in Appendix A show that an estimated dose of 33mg/L of EHC Liquid would be required to meet the stoichiometric demand from the contaminants and competing electron acceptors. PeroxyChem (the vendor) however recommends that the product be applied a minimum rate of 1,000 mg/L in the pore water which equates to a total mass of 16,560 lbs of EHC Liquid. The product is supplied as a liquid concentrate with a dry mix for the iron components. A total of 16,560 lbs of the liquid and 3,887 lbs of the iron would be required. As prepared, 59,000 gallons of EHC solution would be injected into the aquifer. It is assumed that all injections would be conducted during one event.

- The EHC product is mixed with water to prepare a dilute solution for injection. At a 30-fold dilution, each batch would consist of 50 gallons of the EHC Liquid, 107.8 lbs of the iron mix, and 1,598 gallons of water. Various mechanical mixing methods and equipment can be employed. However, continuous mixing in smaller batches is recommended.
- Because the EHC Liquid processes can slightly acidify the aquifer, a solution of potassium bicarbonate would be injected with the EHC Liquid to buffer the pH of the aquifer and help maintain optimum conditions for the growth of the anaerobic microbes.
- The EHC Liquid would be injected using direct push equipment. The injections would be conducted in the top-down direction using injection tips to direct the product horizontally. The injections are evenly distributed over the target interval i.e., from the top of the groundwater table to 15 feet below the top of the groundwater table. The injection rate would be approximately 88 gallons per injected foot. All of the design concentrations, dilutions, and injection rates would be determined during the design process.
- For the purpose of this FS, it is assumed that the injection points will only be located in the public sidewalks. It is assumed that no injection points are located in the laundromat, other buildings, or parking areas at the site. At a conservative 10-foot linear spacing (shown on Figure 5-3) the total number of injection points would be on the order of 45.
- Because there may be limited naturally occurring anaerobic microbes at this site, bioaugmentation with appropriate microbes is included with this alternative. The microbes could be injected concurrent with the EHC Liquid or after appropriate site conditions had developed.
- The level of effort for sampling and monitoring would be similar in scope and duration as for Alternative 2. A five year period of monitoring is included to assess the effectiveness of remediation and to monitor for any rebound that may occur.
- An SMP would be prepared to ensure that the mitigation measures directed for the laundromat building are in place and effective. Periodic indoor air monitoring would be conducted to ensure that no other buildings require mitigation. Institutional controls to prohibit groundwater use and to ensure protection of the public during work-related activities at the site would be developed. Annual groundwater monitoring would be conducted for 30 years or until site SCGs are achieved.

Time for Remediation

- The duration of the EHC injection event is expected to be on the order of three to four weeks including time for set-up and clean-up before and after the actual injections.

- EHC destroys the chlorinated VOCs via both ISCR and enhanced bioremediation. ISCR is the faster reaction, but only occurs when the halogenated compound is in direct contact with the iron particle interface and therefore only occurs directly at the product placement zone. EHC also promotes indirect chemical reduction and biological reduction. These are not instantaneous reactions; a period of time is required in order for the ideal conditions and bioremediation processes to establish. The overall duration of the remediation and the time required in order for the groundwater to meet the desired criteria is expected to be on the order of one to two years, somewhat longer than for the ISCO due to the difficulty in placing the EHC in ideal locations to reach the extent of the groundwater plume.

- Both a one-year onsite direct read and sampling and analysis program, and a five-year onsite and offsite monitoring period are included to assess effectiveness. Annual groundwater monitoring would be conducted for 30 years or until site SCGs are achieved.

Spatial Requirements

- During the injection event, nearly full access to the site would be required. Although only one injection location at a time may be serviced, the contractor would inject at multiple locations per day and would shift from one point to another. Ideally the injections are not conducted sequentially at adjacent locations but are staggered throughout the plume to minimize the possibility of daylighting. Entire portions of the sidewalk would likely be closed during the injection event. Adequate safety and spill controls would be maintained at each injection point.

- No long-term access to the site would be required for this alternative. The injection points are only temporary and the sidewalk would likely be repaired or replaced shortly after the completion of the injections. Permanent monitoring wells would remain at the site.

- A storage and staging area would be required for the three to four week duration of the injection event. Treatment reagents, mixing equipment, and injection equipment would be staged onsite for the duration of the injections. This would include storage tanks, mixing skids, delivery trucks, secondary containment, and other safety considerations. Fencing and security for this area would be required. Ideally the staging area would need to be located within very close proximity to the site, as well as in close proximity to a source of water for the mixing of the reagents. The storage requirements for this alternative would likely be somewhat larger than that required for the ISCO alternative.

- If injections within the building(s) were to be included as part of the implementation design, it would require access to injection locations within the basement of the structure and the equipment and items stored within the basement would have to be moved and temporarily stored. Depending upon the access to the basement and the quantity of material to be moved, there may be some temporary impacts to the business operations. Impacts would only be for the duration of the one injection event.

Permit Requirements

- Injection may require submission of an Inventory of Injection Wells Form 7520-16 as part of the UIC program operated by the USEPA. Injection wells incidental to aquifer remediation and experimental technologies are distinguished from hazardous waste injection wells and are designated as Class V under the UIC program. Class V wells covered by the Federal UIC program are authorized by rule and do not require a separate UIC permit. This would be verified as part of the design process.

- Permits would likely be required for the drilling and installation of the injection points in the sidewalks.

Limitations

- The primary limitation to this alternative is the presence of the building(s). Accomplishing the injections only from points located within the sidewalk prevents injection throughout the complete extent of the contaminant plume. However, the permeable nature of the saturated zone below the site should allow the reductive conditions to propagate beyond the placement zone and eventually treat the majority of the target area. It is also likely that injection locations in addition to those in the sidewalk can be identified during the design process.

- Utilities and other obstructions are likely to be encountered in the sidewalk areas. All injection points would have to be carefully installed to avoid impacting utilities and other subsurface structures.

- Because monitoring indicates that the aquifer is presently in an oxidative state with high ORP and high DO concentrations, it is possible that the microbial population required for effective biodegradation of PCE are limited. The relative lack of PCE breakdown products in the groundwater may be an indication that current biological activity is limited. In order to be most effective, it may be beneficial to introduce the dehalogenating bacteria into the aquifer once suitable reductive conditions have been established.
- Sources of DO in groundwater include rainwater infiltration. If significant quantities of high DO water infiltrate into the groundwater it may limit the effectiveness of the remedial agents in creating conditions suitable for a reductive environment.

Ecological Impacts

- This alternative is not anticipated to have any negative impacts on fish and wildlife resources.

6.0 DETAILED ANALYSIS OF ALTERNATIVES

6.1 Description of Evaluation Criteria

Each of the alternatives is subjected to a detailed evaluation with respect to the criteria outlined in 6 NYCRR Part 375. A description of each of the evaluation criteria is provided below. This evaluation aids in the selection process for remedial actions in New York State.

Overall Protection of Public Health and the Environment

This criterion is an assessment of whether the alternative meets requirements that are protective of human health and the environment. The overall assessment is based on a composite of factors assessed under other evaluation criteria, particularly long-term effectiveness and permanence, 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 the source of contamination is to be eliminated, reduced, or controlled.

Compliance with Standards, Criteria, and Guidance

This criterion determines whether or not each alternative and the proposed remedial technologies comply with applicable environmental laws and SCGs pertaining to the chemicals detected in contaminated media and the location of the site.

Long-term Effectiveness and Permanence

This criterion addresses the performance of a remedial action in terms of its permanence and the quantity/nature of waste or residuals remaining at the site after implementation. An evaluation is made on the extent and effectiveness of controls required to manage residuals remaining at the site and the operation and maintenance systems necessary for the remedy to remain effective. The factors that are evaluated include permanence of the remedial alternative, magnitude of the remaining risk, and adequacy and reliability of controls used to manage residual contamination.

Reduction of Toxicity, Mobility or Volume with Treatment

This criterion assesses the remedial alternative’s use of technologies that permanently and significantly reduce toxicity, mobility, or volume (TMV) of the contamination as their principal element. Preference is given to remedies that permanently and significantly reduce the toxicity, mobility, or volume of the contaminants at the site.

Short-term Effectiveness

This criterion assesses the effects of the alternative during the construction and implementation phase with respect to the effect on human health and the environment. The factors that are assessed include protection of the workers and the community during remedial activities, environmental impacts that result from remediation, and the time required until the remedial action objectives are achieved. In addition, sustainability and green remediation concepts and techniques per DER-31 Green Remediation (NYSDEC, January 2011) are discussed.

Implementability

This criterion addresses the technical and administrative feasibility of implementing the alternative and the availability of various services and materials required during implementation. The evaluation includes the feasibility of construction and operation, the reliability of the technology, the ease of undertaking additional remedial action, monitoring considerations, activities needed to coordinate with regulatory agencies, availability of adequate equipment, services and materials, offsite treatment, and storage and disposal services.

Land Use

This criterion addresses the current, intended, and reasonably anticipated future land use of the site and surroundings. The current and continued use of the site is as an active laundromat, with storage in the basement. The second floor is apartments. Commercial properties, many with residences on the upper floors, are located along Astoria Blvd. Residential properties are located on the side streets.

Cost

Capital costs and operation, maintenance, and monitoring costs (OM&M) are estimated for each alternative and presented as present worth using a 5% discount rate for duration of future activities.

Community and State Acceptance

Concerns of the State and the Community will be addressed separately in accordance with the public participation program developed for this site.

6.2 Alternative 1 – No Action

Under this alternative, contaminated groundwater would remain onsite above SCGs. Soil vapor and the presence of indoor air contaminants would continue to some extent, although mitigation of the laundromat building has already been directed by the NYSDEC. No construction would be required.

6.2.1 Overall Protection of Public Health and the Environment

This alternative is not protective of public health and the environment. Potentially completed exposure pathways were identified for soil vapor intrusion, groundwater and basement flooding water for residents, and during work-related activities. Although the NYSDEC has directed the installation of mitigation measures in the laundromat building, the degree of protection to the public health and the environment is less since the contamination would remain in the groundwater. No groundwater monitoring would be conducted.

6.2.2 Compliance with SCGs

This alternative would not meet groundwater SCGs in the foreseeable future.

6.2.3 Long-Term Effectiveness and Permanence

This alternative is not effective in the long term.

6.2.4 Reduction of Toxicity, Mobility and Volume with Treatment

Any natural processes which are currently active in groundwater would continue to reduce contaminant levels over time. However, based on the oxidative state of the aquifer and other monitoring data available, it is expected that any existing natural processes are minimal and would not destroy the majority of the contamination within the foreseeable future.

6.2.5 Short-Term Effectiveness

As there is no construction associated with this alternative, there would be no short-term impacts to workers or the community during construction. Any existing risks at the site would remain for a very long time.

6.2.6 Implementability

This alternative would be difficult to implement due to administrative issues, especially State and local approvals. The RAOs would not be met and groundwater contamination would remain above SCGs.

6.2.7 Land Use

This alternative would not be protective for continued site use.

6.2.8 Cost

There is no remediation cost associated with this alternative.

6.3 Alternative 2: In-Situ Groundwater Treatment through ISCO

Under this alternative, the saturated zone would be treated through ISCO via sodium permanganate, destroying the VOC contamination. An SMP would be prepared to ensure that the mitigation measures directed for the laundromat building are in place and effective.

6.3.1 Overall Protection of Public Health and the Environment

The NYSDEC has directed the installation of mitigation measures in the laundromat building to protect the building occupants. Periodic indoor air monitoring would be conducted to ensure that no other buildings require mitigation. This alternative would be protective of public health and the environment through in-situ treatment of VOC contamination in the saturated zone. The mitigation measures to prevent groundwater seepage and vapor intrusion into the laundromat building will protect against the vapor intrusion exposure pathway until the contaminant concentrations in the groundwater have been reduced.

6.3.2 Compliance with SCGs

In situ treatment would significantly reduce contaminant concentrations in the groundwater, but SCGs would not be met for many years until natural processes attenuate the contamination remaining following treatment. Following implementation of the mitigation measures at the laundromat building, concentrations of indoor air contaminants are expected to be in compliance with NYSDOH guidance.

6.3.3 Long-Term Effectiveness and Permanence

ISCO has been shown to be an effective technology for the chlorinated VOC contaminants present at the site. Some rebound of the groundwater contaminants may occur if there is significant contamination in the soil matrix. Monitoring over a five year period is included to assess the effectiveness of proposed remedial measures. Residual contamination above the SCGs may remain for an extended time. Institutional controls would restrict exposure to contamination, while remediation and natural processes reduce contaminant concentrations. Annual groundwater monitoring would be conducted for 30 years or until site SCGs are achieved.

6.3.4 Reduction of Toxicity, Mobility and Volume with Treatment

ISCO achieves permanent degradation of groundwater contaminants in those areas where it can be effectively implemented. However, there would residual contamination in the treatment area and those areas of the site where the ISCO is not implemented.

6.3.5 Short-Term Effectiveness

There may be some small potential impacts to the public and workers during installation of the injection wells and while performing injection and sampling events. However, these can easily be controlled by limiting access to the laundromat building and adjacent sidewalks during these activities. RAOs would be met following groundwater treatment, although this would be on the order of several years. To decrease greenhouse gas (GHG) emissions, to the extent practicable, construction vehicles will be chosen which have high fuel efficiency and/or that utilize alternative fuel types (e.g. low sulfur diesel). Vehicle idling time will also be minimized to the extent practicable. Carus Corporation is the only North American manufacturer of permanganate and offers the lowest carbon footprint for permanganate production in the world.

6.3.6 Implementability

The presence of an active business and moderately congested Astoria Blvd. presents implementability issues during construction and injection events. Measures would have to be taken to reduce the disruption of business operations within the buildings and surrounding areas.

The installation of injection wells at the site would allow for easier implementation of additional remedial actions, if required. However, since the wells would be installed in a public sidewalk, they would have to be periodically checked and maintained to make sure that they do not heave or crack and present a trip hazard to the public.

6.3.7 Land Use

This alternative would protective for continued site use in conjunction with the implementation of an SMP.

6.3.8 Cost

Estimated capital and OM&M costs for Alternative 2 are presented in Table 6-1. The total capital cost is $608,900; annual OM&M costs are $41,700 the first five years and $7,300 thereafter, for an average annual OM&M costs of $13,070; the total present worth of Alternative 2 is $870,600. Cost details are presented in Appendix B.

6.4 Alternative 3: In-Situ Groundwater Treatment through Enhanced Bioremediation

Under this alternative, the saturated zone would be treated through enhanced bioremediation via PlumeStop and HRC to destroy the VOC contamination. An SMP would be prepared to ensure that the mitigation measures directed for the laundromat building are in place and effective.

6.4.1 Overall Protection of Public Health and the Environment

The NYSDEC has directed the installation of mitigation measures in the laundromat building to protect the building occupants. Periodic indoor air monitoring would be conducted to ensure that no other buildings require mitigation. This alternative would be protective of public health and the environment through in-situ treatment of VOC contamination in the saturated zone. The mitigation measures to prevent groundwater seepage and vapor intrusion into the laundromat building will protect against the vapor intrusion exposure pathway until the contaminant concentrations in the groundwater have been reduced.

6.4.2 Compliance with SCGs

In situ treatment would significantly reduce contaminant concentrations in the groundwater, but SCGs would not be met for many years until natural processes attenuate the contamination remaining following treatment. Following implementation of the mitigation measures at the laundromat building, concentrations of indoor air contaminants are expected to be in compliance with NYSDOH guidance.

6.4.3 Long-Term Effectiveness and Permanence

Enhanced bioremediation has been shown to be an effective technology for the chlorinated VOC contaminants present at the site. The use of the PlumeStop would serve to reduce contaminant concentrations in the groundwater until the biological processes have established and help to prevent rebound of the groundwater contaminants from the soil matrix. Monitoring over a five year period is included to assess the effectiveness of proposed remedial measures. Residual contamination above the SCGs may remain for an extended time. Institutional controls would restrict exposure to contamination, while remediation and natural processes reduce contaminant concentrations. Annual groundwater monitoring would be conducted for 30 years or until site SCGs are achieved.

6.4.4 Reduction of Toxicity, Mobility and Volume with Treatment

Bioremediation would eventually achieve permanent degradation of groundwater contaminants in those areas where it can be effectively implemented. However, there would residual contamination in the treatment area and those areas of the site where the ISCO is not implemented.

6.4.5 Short-Term Effectiveness

There may be some small potential impacts to the public and workers during the injection and sampling events. However, these can easily be controlled by limiting access to the laundromat building and adjacent sidewalks during these activities. RAOs would be met following groundwater treatment, although this would be on the order of several years. To decrease GHG emissions, to the extent practicable, construction vehicles will be chosen which have high fuel efficiency and/or that utilize alternative fuel types (e.g. low sulfur diesel). Vehicle idling time will also be minimized to the extent practicable.

6.4.6 Implementability

The presence of an active business and moderately congested Astoria Blvd. presents implementability issues during construction and injection events. Measures would have to be taken to reduce the disruption of business operations within the buildings and surrounding areas.

Additional injection borings could be conducted at the site to implement additional remedial actions, if required. Since the injection points would be installed in a public sidewalk, they would have to be carefully backfilled and repaired to make sure that they do not present a trip hazard to the public.

6.4.7 Land Use

This alternative would protective for continued site use in conjunction with the implementation of an SMP.

6.4.8 Cost

Estimated capital and OM&M costs for Alternative 3 are presented in Table 6-1. The total capital cost is $403,300; annual OM&M costs are $41,700 the first five years and $7,300 thereafter, for an average annual OM&M costs of $13,070; the total present worth of Alternative 3 is $665,000. Cost details are presented in Appendix B.

6.5 Alternative 4: In-Situ Groundwater Treatment through Chemical Reduction

Under this alternative, the saturated zone would be treated through In-situ Chemical Reduction via EHC Liquid to destroy the VOC contamination. The technology would also enhance the bioremediation processes at the site. An SMP would be prepared to ensure that the mitigation measures directed for the laundromat building are in place and effective.

6.5.1 Overall Protection of Public Health and the Environment

The NYSDEC has directed the installation of mitigation measures in the laundromat building to protect the building occupants. Periodic indoor air monitoring would be conducted to ensure that no other buildings require mitigation. This alternative would be protective of public health and the environment through in-situ treatment of VOC contamination in the saturated zone. The mitigation measures to prevent groundwater seepage and vapor intrusion into the laundromat building will protect against the vapor intrusion exposure pathway until the contaminant concentrations in the groundwater have been reduced.

6.5.2 Compliance with SCGs

In situ treatment would significantly reduce contaminant concentrations in the groundwater, but SCGs would not be met for many years until natural processes attenuate the contamination remaining following treatment. Following implementation of the mitigation measures at the laundromat building, concentrations of indoor air contaminants are expected to be in compliance with NYSDOH guidance.

6.5.3 Long-Term Effectiveness and Permanence

Chemical reduction and enhanced bioremediation have been shown to be effective technologies for the chlorinated VOC contaminants present at the site. Some rebound of the groundwater contaminants may occur if there is significant contamination in the soil matrix. Monitoring over a five year period is included to assess the effectiveness of proposed remedial measures. Residual contamination above the SCGs may remain for an extended time. Institutional controls would restrict exposure to contamination, while remediation and natural processes reduce contaminant concentrations. Annual groundwater monitoring would be conducted for 30 years or until site SCGs are achieved.

6.5.4 Reduction of Toxicity, Mobility and Volume with Treatment

These technologies would eventually achieve permanent degradation of groundwater contaminants in those areas where it can be effectively implemented. However, there would residual contamination in the treatment area and those areas of the site where the ISCR is not implemented.

6.5.5 Short-Term Effectiveness

There may be some small potential impacts to the public and workers during the injection and sampling events. However, these can easily be controlled by limiting access to the laundromat building and adjacent sidewalks during these activities. RAOs would be met following groundwater treatment, although this would be on the order of several years. To decrease GHG emissions, to the extent practicable, construction vehicles will be chosen which have high fuel efficiency and/or that utilize alternative fuel types (e.g. low sulfur diesel). Vehicle idling time will also be minimized to the extent practicable.

6.5.6 Implementability

The presence of an active business and moderately congested Astoria Blvd. presents implementability issues during construction and injection events. Measures would have to be taken to reduce the disruption of business operations within the buildings and surrounding areas.

Additional injection borings could be conducted at the site to implement additional remedial actions, if required. Since the injection points would be installed in a public sidewalk, they would have to be carefully backfilled and repaired to make sure that they do not present a trip hazard to the public.

6.5.7 Land Use

This alternative would protective for continued site use in conjunction with the implementation of an SMP.

6.5.8 Cost

Estimated capital and OM&M costs for Alternative 4 are presented in Table 6-1. The total capital cost is $343,100; annual OM&M costs are $41,700 the first five years and $7,300 thereafter, for an average annual OM&M costs of $13,070; the total present worth of Alternative 4 is $604,800. Cost details are presented in Appendix B.

6.6 Comparative Analysis of Alternatives

The following section presents the comparative analysis of the four remedial alternatives for the site.

6.6.1 Overall Protection of Public Health and the Environment

Alternatives 2, 3, and 4 include the preparation of an SMP. With the implementation of an SMP, these alternatives would be effective in protecting the public health and the environment; Alternative 1 would not. The mitigation measures to prevent groundwater seepage and vapor intrusion into the laundromat building will protect against the vapor intrusion exposure pathway until the contaminant concentrations in the groundwater have been reduced.

Some level of contamination in groundwater above SCGs would remain on site for all alternatives. There would be no reduction in the contaminant mass under Alternative 1. Alternatives 2, 3, and 4 include in situ treatment of groundwater to greatly reduce the total mass of contamination at the site. The degree of protection provided by reducing the contaminant mass would be similar for all three of these alternatives.

6.6.2 Compliance with SCGs

Following implementation of the mitigation measures at the laundromat building, concentrations of indoor air contaminants are expected to be in compliance with NYSDOH guidance.

Some level of contamination in groundwater above SCGs would remain on site for all alternatives. In situ treatment under Alternatives 2, 3, and 4 would significantly reduce contaminant concentrations in the groundwater, but SCGs would not be met for many years until natural processes attenuate the contamination remaining following treatment. All three of the alternatives would provide a similar degree of compliance and timeframe for compliance with the SCGs. Alternative 1 would not achieve the groundwater SCGs in the foreseeable future.

6.6.3 Long-Term Effectiveness and Permanence

Institutional controls for all alternatives would be effective and permanent in the long-term. Periodic monitoring would be conducted to ensure that indoor air concentrations are acceptable. Institutional controls would restrict exposure to contamination while remediation and natural processes reduce contaminant concentrations.

Alternative 1 does not include any remedial actions for groundwater. Alternatives 2, 3, and 4 all utilize technologies that have been shown to be effective for the chlorinated VOC contaminants present in the groundwater; there would be less residual contamination with these alternatives.

Some rebound of the groundwater contaminants may occur if there is significant contamination in the soil matrix. The biological processes in Alternatives 3 and 4 may be more effective in addressing rebound as compared to the oxidation in Alternative 2. Bioremediation will continue as long as the site conditions are amenable. The agents used in Alternatives 3 and 4 have an estimated useful life of several years. However, if significant quantities of high DO water infiltrate into the groundwater, it may limit the effectiveness of the remedial agents in creating conditions suitable for a reductive environment.

For Alternative 2, once the oxidant in the groundwater has been expended or migrated away from the site, no further treatment will occur. Oxidation is more effective in treating source zones and less effective in low concentrations of contaminants. Bioremediation (Alternatives 3 and 4) is more effective at lower concentrations.

Monitoring over a five year period is included to assess the effectiveness of proposed remedial measures. Similar levels of residual contamination may remain for all three alternatives.

6.6.4 Reduction of Toxicity, Mobility and Volume with Treatment

Under Alternative 1, any natural processes which are currently active in groundwater would continue to reduce contaminant levels over time. However, based on the oxidative state of the aquifer and other monitoring data available, it is expected that any existing natural processes are minimal and would not destroy the majority of the contamination within the foreseeable future.

Alternatives 2, 3, and 4 would all use different processes to eventually achieve permanent degradation of groundwater contaminants, assuming that suitable conditions in the aquifer can be maintained.

6.6.5 Short-Term Effectiveness

As there is no construction associated with Alternative 1, there would be no short-term impacts to workers or the community during construction. Any existing risks at the site would remain for a very long time.

Alternatives 2, 3, and 4 all require construction so there would be some potential impacts to the public and workers during the injection and sampling events. However, these can easily be controlled by limiting access to the laundromat building and adjacent sidewalks during these activities. Alternative 2 would have the highest potential short-term impacts due to the installation of the injection wells and since multiple injection events would be required.

Alternative 3 would likely be the most effective alternative in the short-term due to the use of the PlumeStop product which theoretically provides a faster reduction in contaminant concentrations in the groundwater as compared to biological processes alone. The oxidation in Alternative 2 is also a faster reaction that occurs as soon as the oxidant reaches the contamination. The biological processes in Alternatives 3 and 4 are slower.

6.6.6 Implementability

Alternative 1 would be the most difficult to implement since it likely would be difficult to obtain State and local approvals.

Alternatives 2, 3, and 4 would all have similar concerns in regard to implementability. The presence of an active business and moderately congested Astoria Blvd. presents issues during construction and injection events. Measures would have to be taken to reduce the disruption of business operations within the buildings and surrounding areas. Injection borings in Alternatives 3 and 4 would be somewhat preferred over the injection wells of Alternative 2, since the wells present a longer-term presence at the site and would have to be periodically checked and maintained to verify that they do not become damaged or a trip hazard to the public. Alternative 2 would also require multiple mobilizations, injection events, etc., and thus would require additional coordination to prevent disruptions to the neighboring businesses and the public.

Alternative 3 may be more difficult to implement from a contractual standpoint since Regenesis is the only vendor of PlumeStop and the only contractor that can inject the product. Alternatives 2 and 4 are available from different vendors (although as somewhat different products) and can be injected by any qualified contractor.

Additional remedial actions could be implemented in conjunction with all four alternatives, if required.

6.6.7 Land Use

Alternative 1 would not be protective for continued site use. Alternatives 2, 3, and 4 would be protective for continued site use in conjunction with the implementation of an SMP.

6.6.8 Cost

Alternative 1 has no costs, but does not achieve any of the RAOs for groundwater.

Alternative 2 has the highest capital cost since the construction of injection wells is greater than for injection borings, since multiple injection events are assumed, and since the product can be more expensive.

The capital costs for Alternatives 3 and 4 are both in the same general range. The time, effort, and costs for the injection borings are similar for both alternatives. The costs for the materials are similar.

Since there is no operations and maintenance for any of the alternatives, the OM&M costs would consist only of monitoring and would be essentially the same for Alternatives 2, 3, and 4.

7.0 REFERENCES

New York State Department of Environmental Conservation. 2010. DER-10, Technical Guidance for Site Investigation and Remediation. December.

NYSDEC. 2011 DER-31 Green Remediation.

NYSDEC. 2006. Subpart 375-6 Remedial Program Soil Cleanup Objectives. December.

NYSDOH, Guidance for Evaluating Soil Vapor Intrusion in the State of New York, dated October 2006.

TABLES

Table 2-1 Potentially Complete Exposure Pathways

Potentially Contaminated Media	**Potential Routes of Exposure**	**Potential Receptors**	**Potential Pathway Complete**
Soil Vapor/Indoor Air	Inhalation of CVOCs from soil/groundwater that migrate into onsite building	Onsite employees and laundromat patrons	Yes, the Former Drape Master building is occupied
Groundwater	Dermal contact/ inhalation	Construction/utility workers and onsite employees	Contact with groundwater may occur during intrusive activities and basement flooding
	Ingestion	None	No, no current potable water use at or near site

Table 5-1
FS Design Parameters
GROUNDWATER INDICATOR PARAMETER RESULTS
FORMER DRAPE MASTER SITE

Sample ID			MW-5	MW-5	MW-6	MW-6	MW-8	MW-8	MW-11	MW-11	MW-12	MW-12
QA/QC												
Date Sampled			5/1/2014	7/10/2014	4/28/2014	7/10/2014	4/29/2014	7/11/2014	4/29/2014	7/10/2014	4/29/2014	7/10/2014
Parameter	**Units**	**Criteria**										
Total Metals												
Arsenic	ug/l	25	ND	ND	ND	ND	ND	ND	ND	ND	ND	20
Iron	ug/l	300	**650**	**13,000**	**1,800**	**4,600**	**1,800**	**12,000**	**430**	**3,400**	**1,100**	**130,000**
Manganese	ug/l	300	ND	200	110	**330**	210	220	ND	160	51	**5,700**
Dissolved Metals												
Arsenic	ug/l	-	2.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iron	ug/l	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	ug/l	-	ND	ND	ND	ND	180	48	ND	ND	ND	ND
Wet Chemistry												
Alkalinity	mg/l	-	120	70	150	170	200	150	140	140	120	170
Chloride	mg/l	250	21	27	240	220	180	180	**280**	**290**	230	210J
Nitrate	mg/l	10	6.5	**17**	**12**	9.9	7.0	5.6	**15**	**13**	**11**	6.5
Sulphate	mg/l	250	71J	54	83	68	52	47	120	110	120	85
Total Organic Carbon	mg/l	-	11	ND	ND	ND	7.6	ND	ND	ND	ND	ND
Dissolved Gasses												
Ethane	ug/l		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethene	ug/l		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methane	ug/l		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Field Parameters												
Conductivity	mS/cm	-	0.43	0.47	1.21	1.15	1.03	0.98	1.35	1.38	1.23	1.23
Oxidation-Reduction Potential	mV	-	257	203	195	101	154	460	183	175	203	203
Dissolved-Oxygen	mg/l	-	2.06	2.13	5.04	3.98	2.7	4.68	4.35	5.89	1.61	0.069
pH		-	6	6.14	6.71	6.76	6.87	7.04	6.75	6.95	6.31	8.39
Temperature	^{o}C	-	14.61	19.3	16.5	18.1	13.44	17.5	15.85	18	16.43	17.2

Notes:

Criteria - NYSDEC TOGS (1.1.1), Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations. April 2000, Class GA.

- - No criteria

J - Reported concentration is an extimated value

ND - not detected

Bold and shading indicates parameter exceeds criterion

mg/l - milligrams per liter

ug/l - micrograms per liter

mS/cm - microSiemens per centimeter

mV - millivolt

^{o}C - degrees Celsius

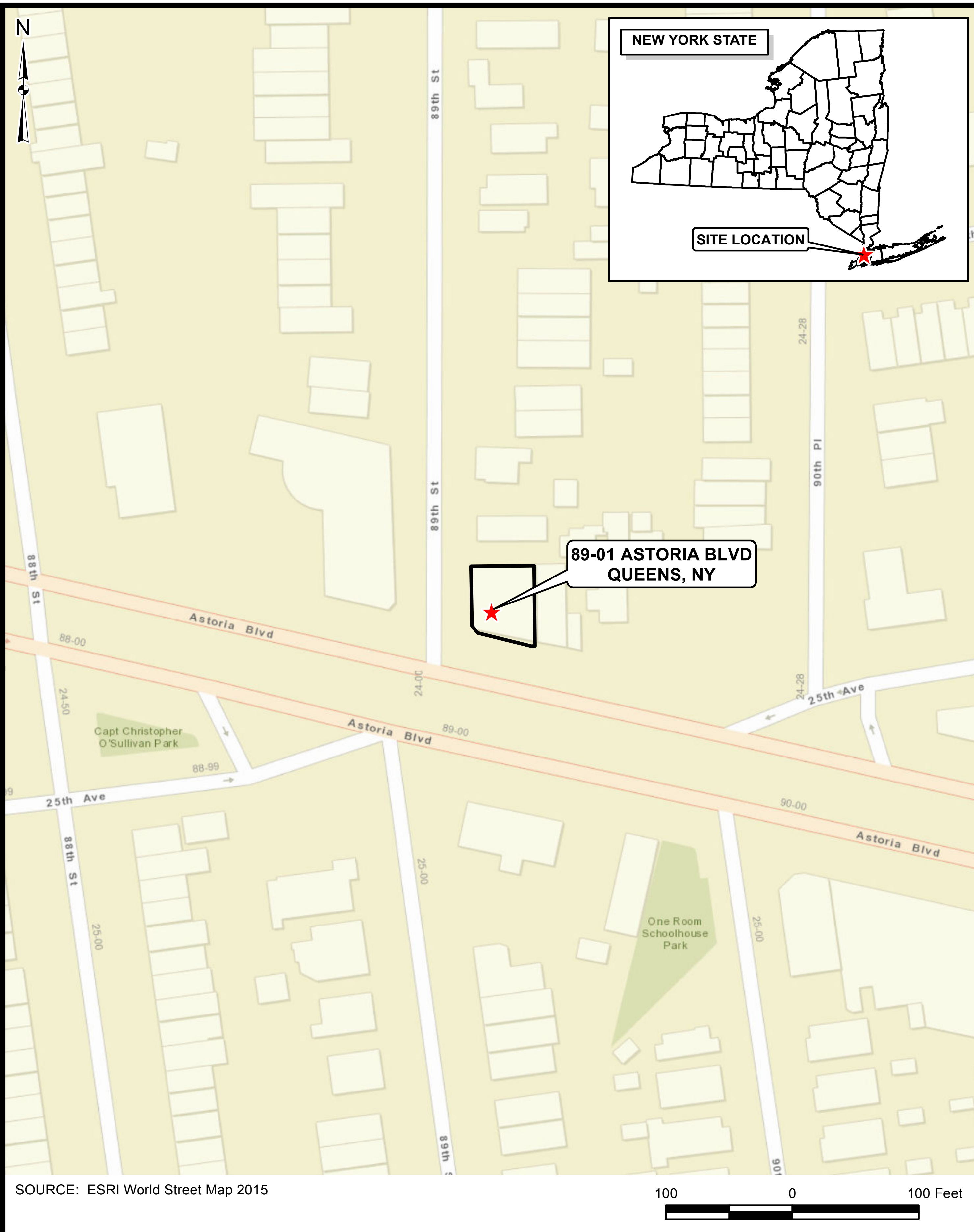
Table 6-1

REMEDIAL ALTERNATIVE COST ESTIMATES

	Alternative 1: **No Action**	Alternative 2: **In-Situ Treatment through ISCO**	Alternative 3: **In-Situ Treatment through Enhanced Bioremediation**	Alternative 4: **In-Situ Treatment through Chemcial Reduction**
1. Estimated Capital Cost	**$ -**	**$ 608,894**	**$ 403,281**	**$ 343,115**
Annual OM&M Cost Years 1-5	$ -	$ 41,724	$ 41,724	$ 41,724
2. Present Worth OM&M Years 1-5	**$ -**	**$ 180,643**	**$ 180,643**	**$ 180,643**
Annual OM&M Cost Years 6-30	$ -	$ 7,339	$ 7,339	$ 7,339
3. Present Worth OM&M Years 6-30	**$ -**	**$ 81,042**	**$ 81,042**	**$ 81,042**
Average Annual OM&M Cost	$ -	$ 13,070	$ 13,070	$ 13,070
Present Worth OM&M	$ -	$ 261,685	$ 261,685	$ 261,685
Total Present Worth (@5%)	**$0**	**$870,578**	**$664,966**	**$604,800**

J:\Projects\11177058\Reports\FS Report\Final FS\Cost Estimate\Cost Estimate.xlsx

FIGURES



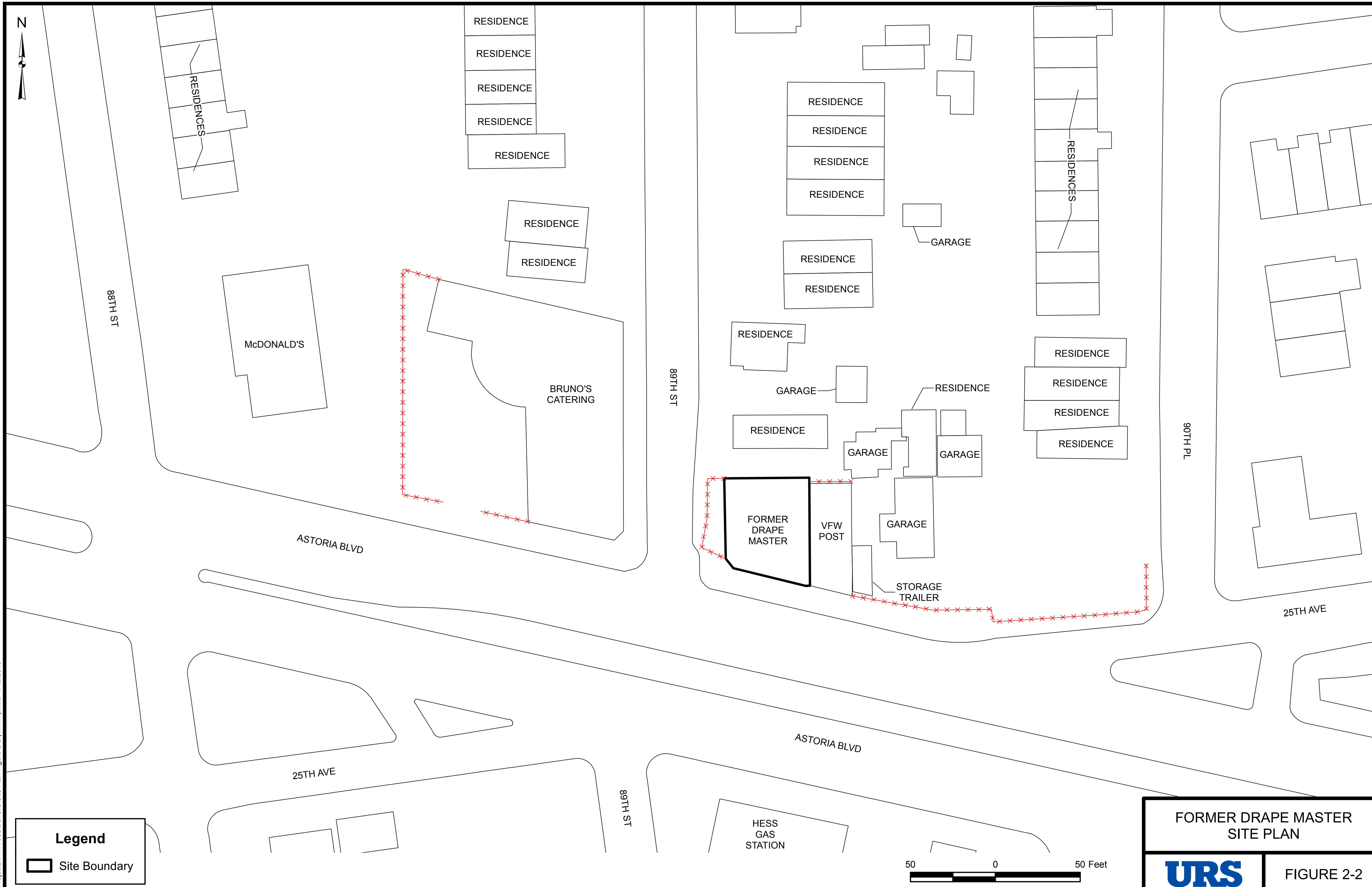
SOURCE: ESRI World Street Map 2015

J:\Projects\11177058\DB\GIS\Site Location Figure 2 - 1.mxd 4/13/2016

URS

FORMER DRAPE MASTER
SITE LOCATION

FIGURE 2-1

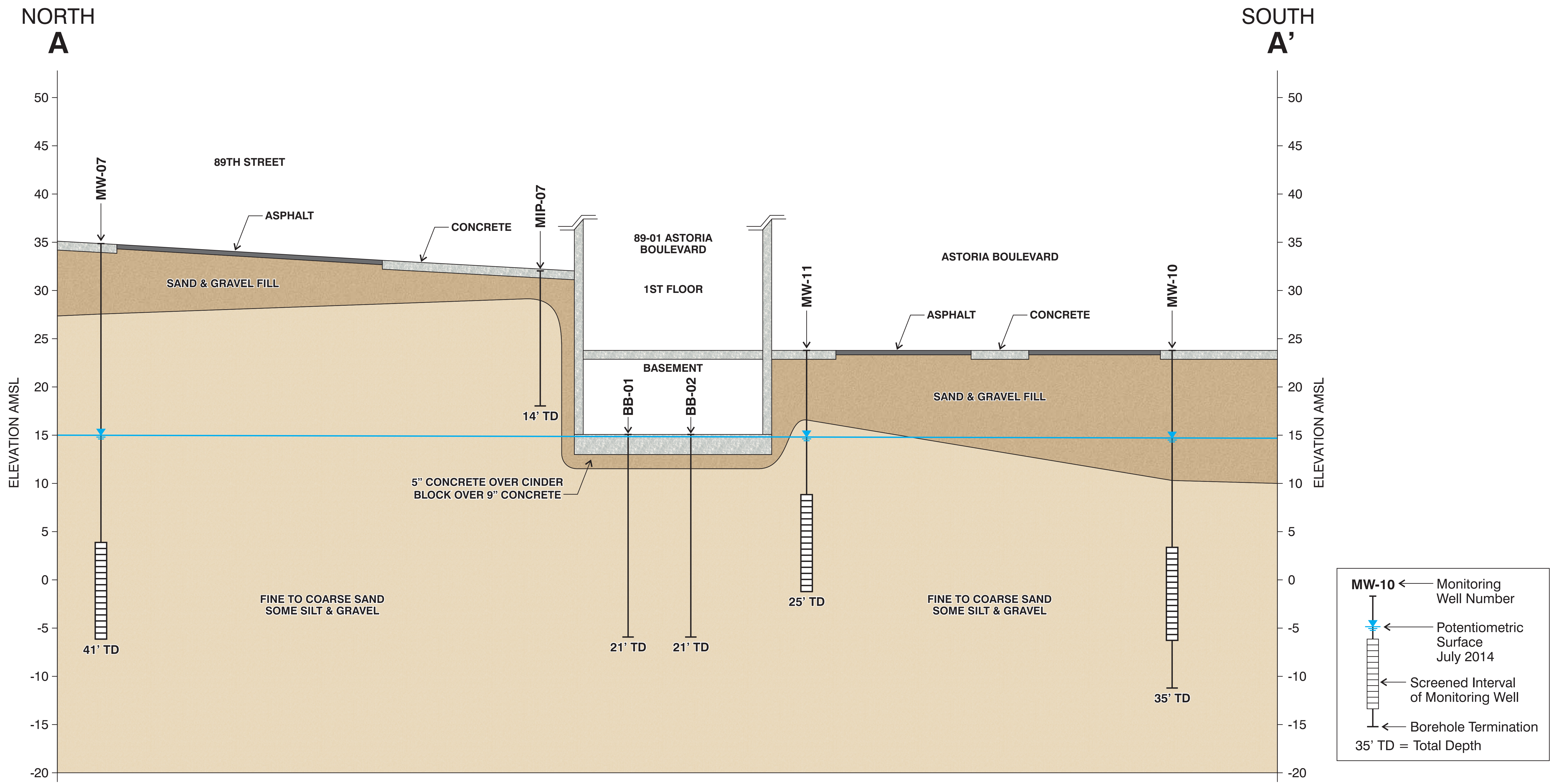


FORMER DRAPE MASTER SITE PLAN

URS

FIGURE 2-2

J:\Projects\11177058\DB\GIS\Site Plan Figure 2-2 (11X17).mxd 4/13/2016



Sand and Gravel Fill

Fine to Coarse Sand with Trace Silt & Gravel

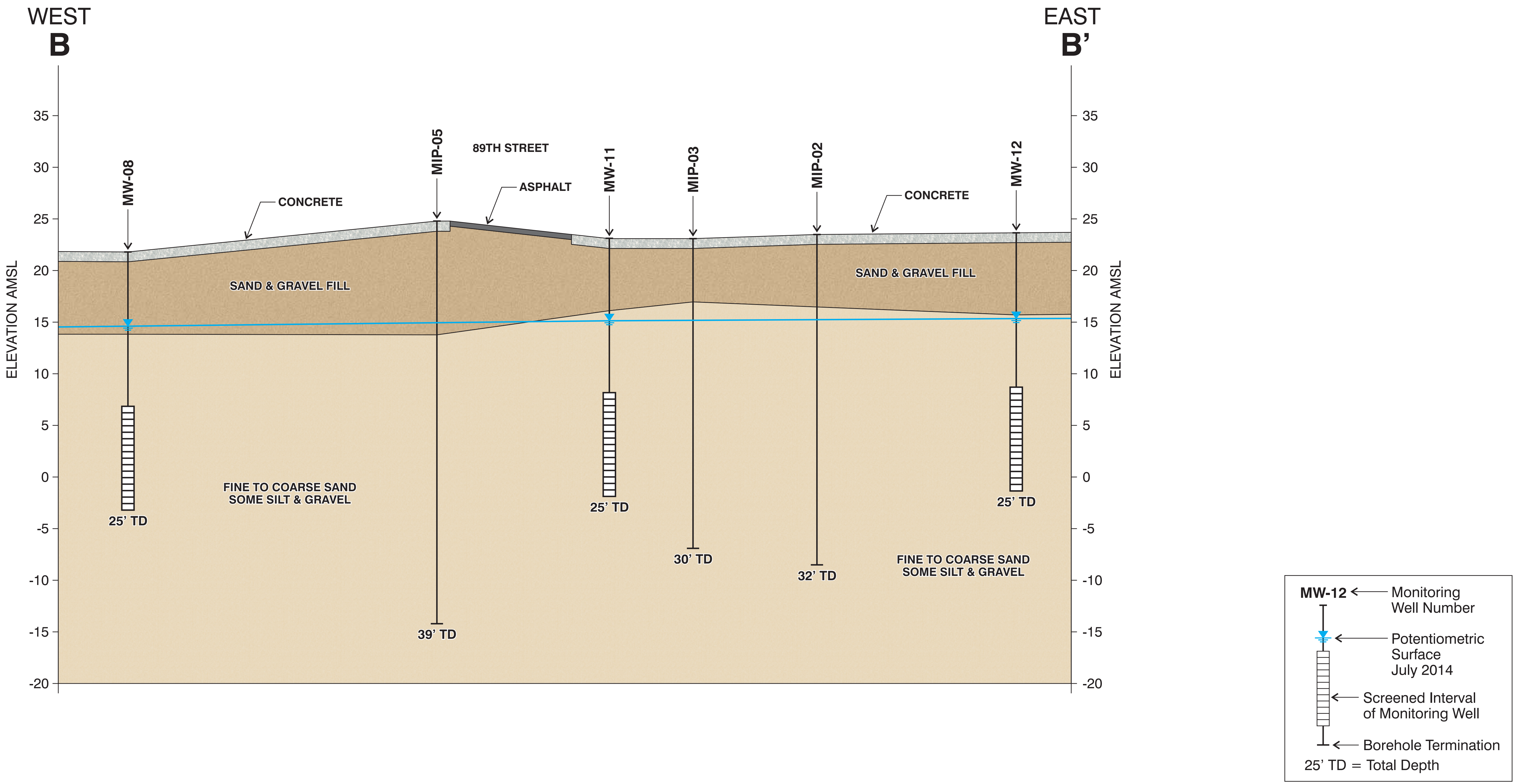
Horizontal Scale: 1" = 30'
Vertical Scale: 1" = 10'

FORMER DRAPE MASTER SITE
CROSS SECTION A-A'

URS

FIGURE 2-3

AG21040-11177058-032615-GCM



Sand and Gravel Fill

Fine to Coarse Sand with Trace Silt & Gravel

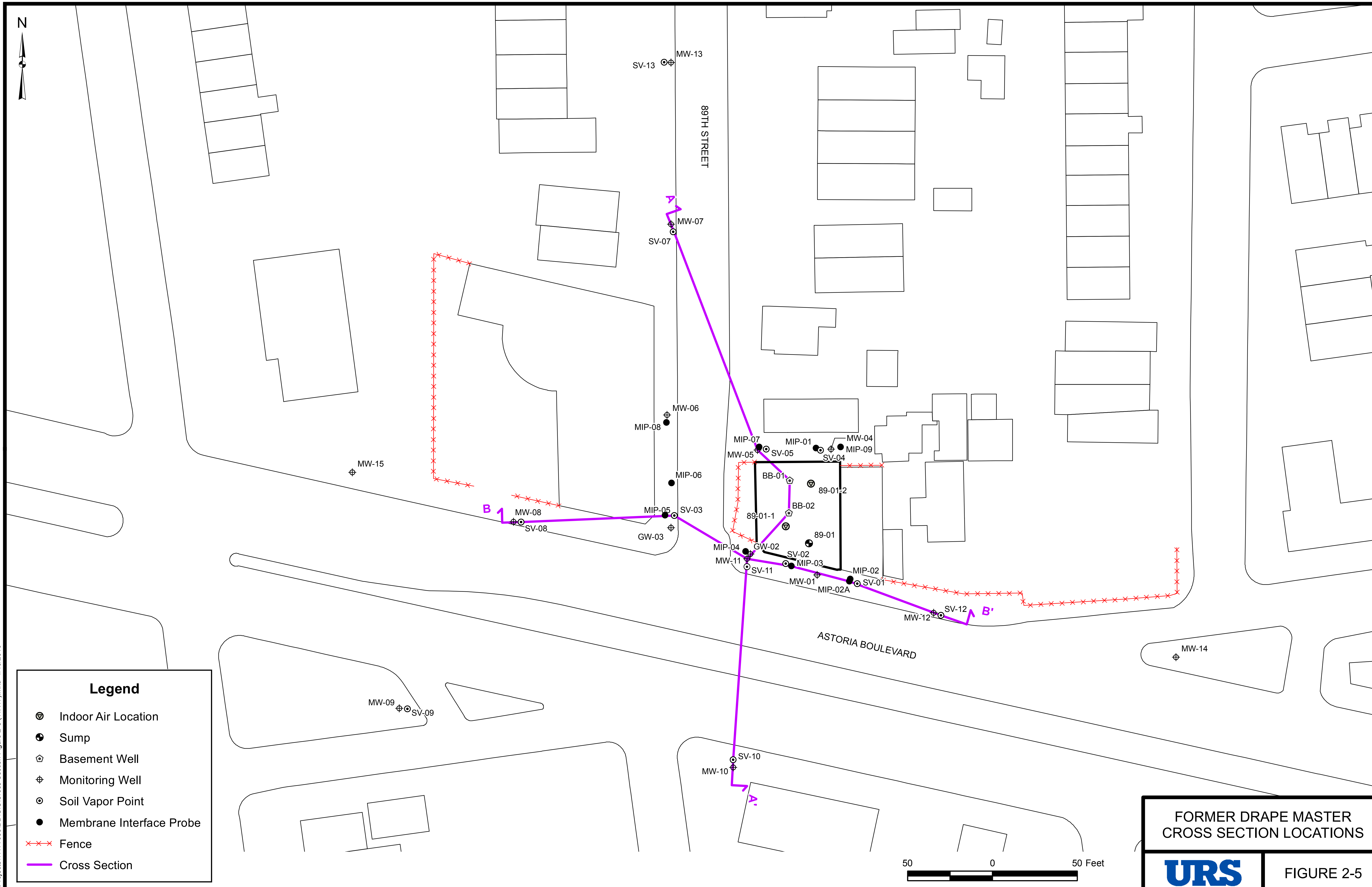
Horizontal Scale: 1" = 30'
Vertical Scale: 1" = 10'

FORMER DRAPE MASTER SITE
CROSS SECTION B-B'

URS

FIGURE 2-4

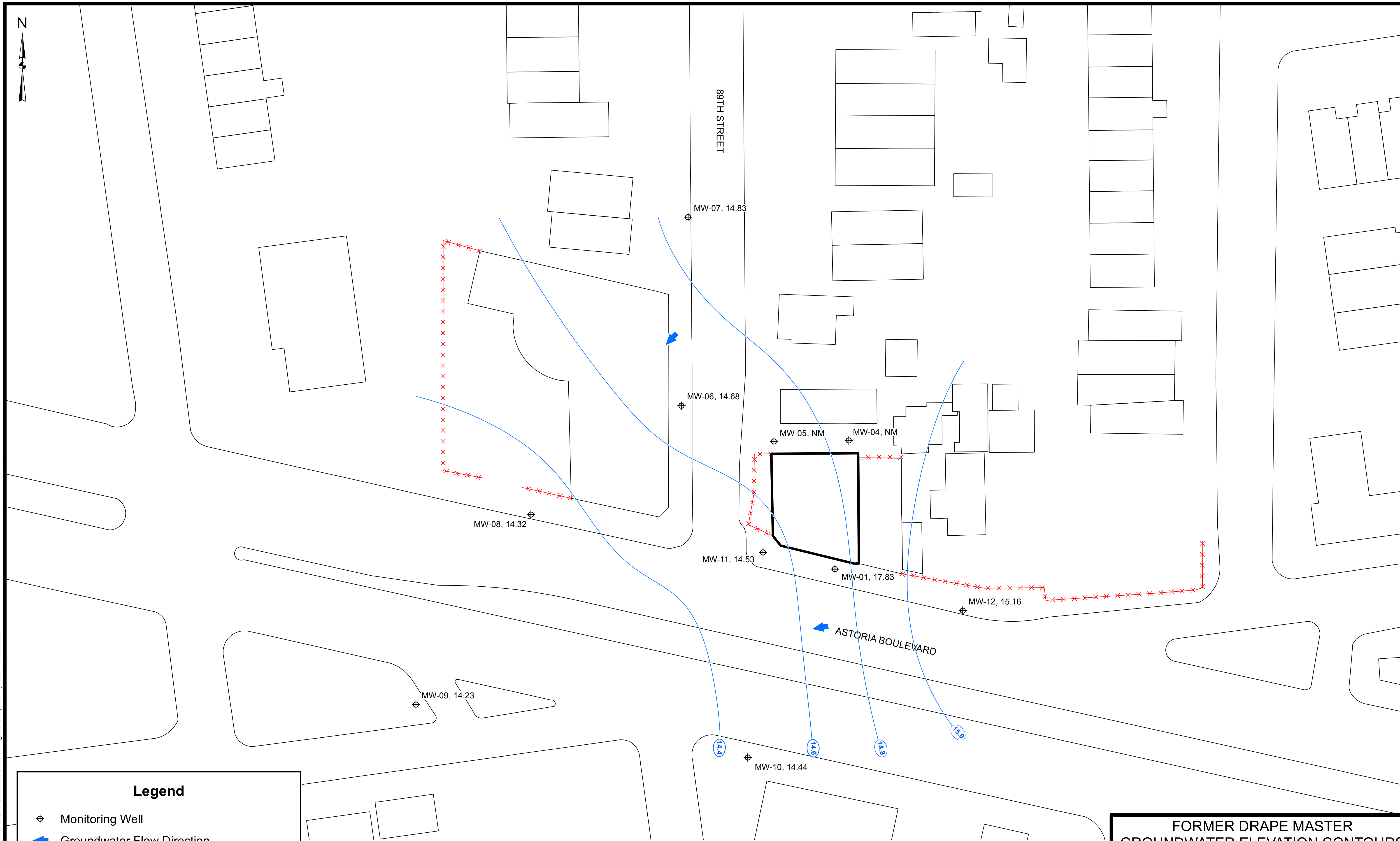
AG21041-1117058.032615-GCM



FORMER DRAPE MASTER
CROSS SECTION LOCATIONS

FIGURE 2-5

J:\Projects\11177058\DB\GIS\Cross Section Figure 2-5 (11X17).mxd 1/19/2016



Legend

- Monitoring Well
- Groundwater Flow Direction
- Fence
- Groundwater Elevation Contour (feet amsl)

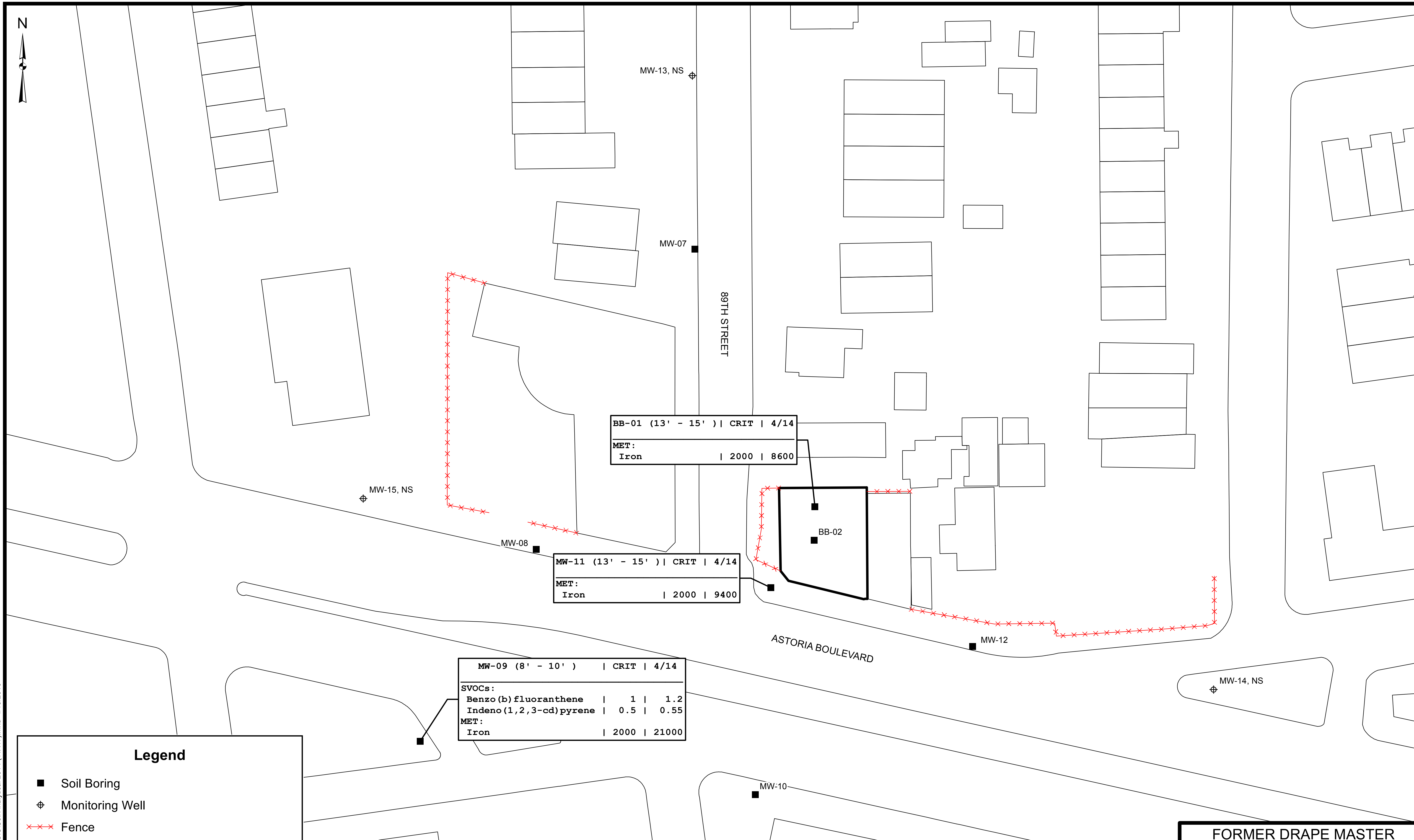
NOTES:
1. NM - Not Measured
2. MW-01 was not used to generate groundwater elevation contours due to anomalous reading.

FORMER DRAPE MASTER
GROUNDWATER ELEVATION CONTOURS
JULY 2014

URS

FIGURE 2-6

J:\Projects\11177058\DB\GIS\GW Contours 072014 Figure 2-6 (11X17).mxd 1/19/2016



Legend

- ■ Soil Boring
- ⌖ Monitoring Well
- ×–×–× Fence

Location ID — Depth — Criteria — Date

MW-09 (8' - 10') | CRIT | 4/14
SVOCs:
Benzo (b) fluoranthene | 1 | 1.2

Parameter — Concentration (mg/kg)

NOTES:
1. New monitoring wells (MW-13, MW-14, and MW-15) were Not Sampled (NS).
2. Criteria - 6 NYCRR Part 375.6, Unrestrictive Use
3. Results shown are parameters exceeding criteria.
4. No results indicate no criteria exceedances.

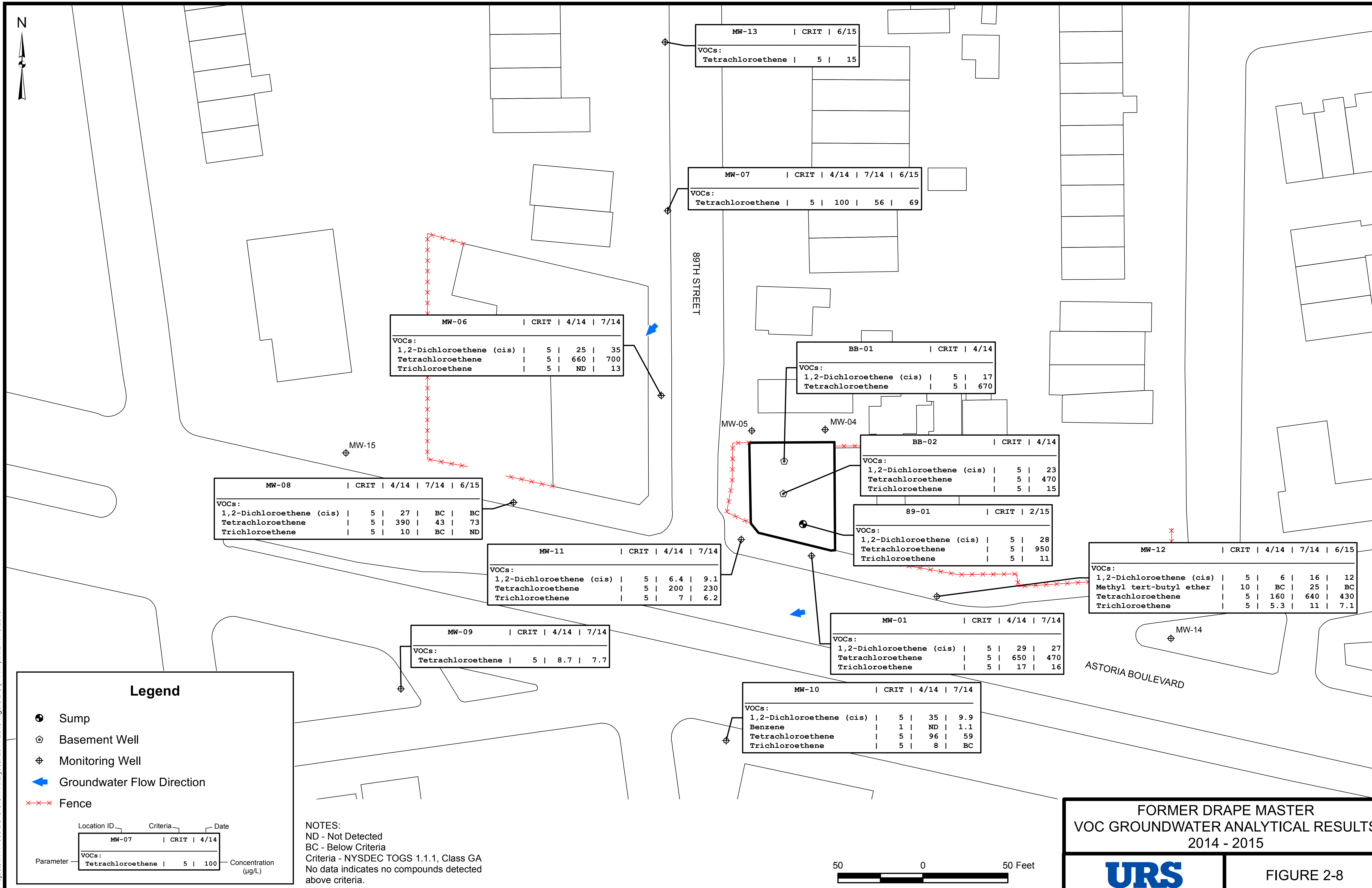
50 0 50 Feet

FORMER DRAPE MASTER
SOIL ANALYTICAL RESULTS
2014

URS

FIGURE 2-7

J:\Projects\11177058\DB\GIS\Soil Analytical 2014 (11X17).mxd 4/13/2016



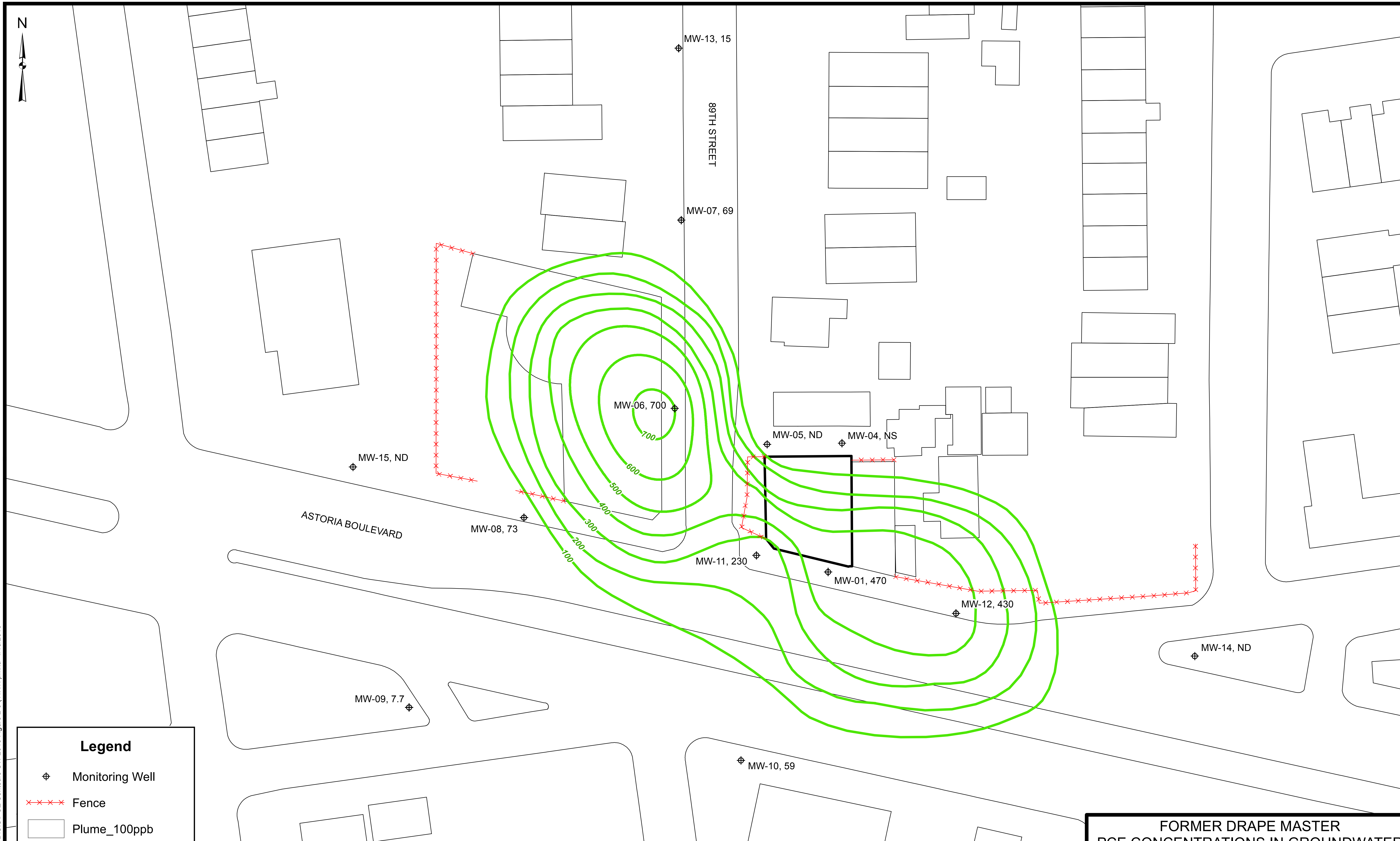
NOTES:
ND - Not Detected
BC - Below Criteria
Criteria - NYSDEC TOGS 1.1.1, Class GA
No data indicates no compounds detected above criteria.

FORMER DRAPE MASTER
VOC GROUNDWATER ANALYTICAL RESULTS
2014 - 2015

URS

FIGURE 2-8

J:\Projects\11177058\DB\GIS\GW Analytical 2014-2015 Figure 2-8 (11X17).mxd 4/13/2016



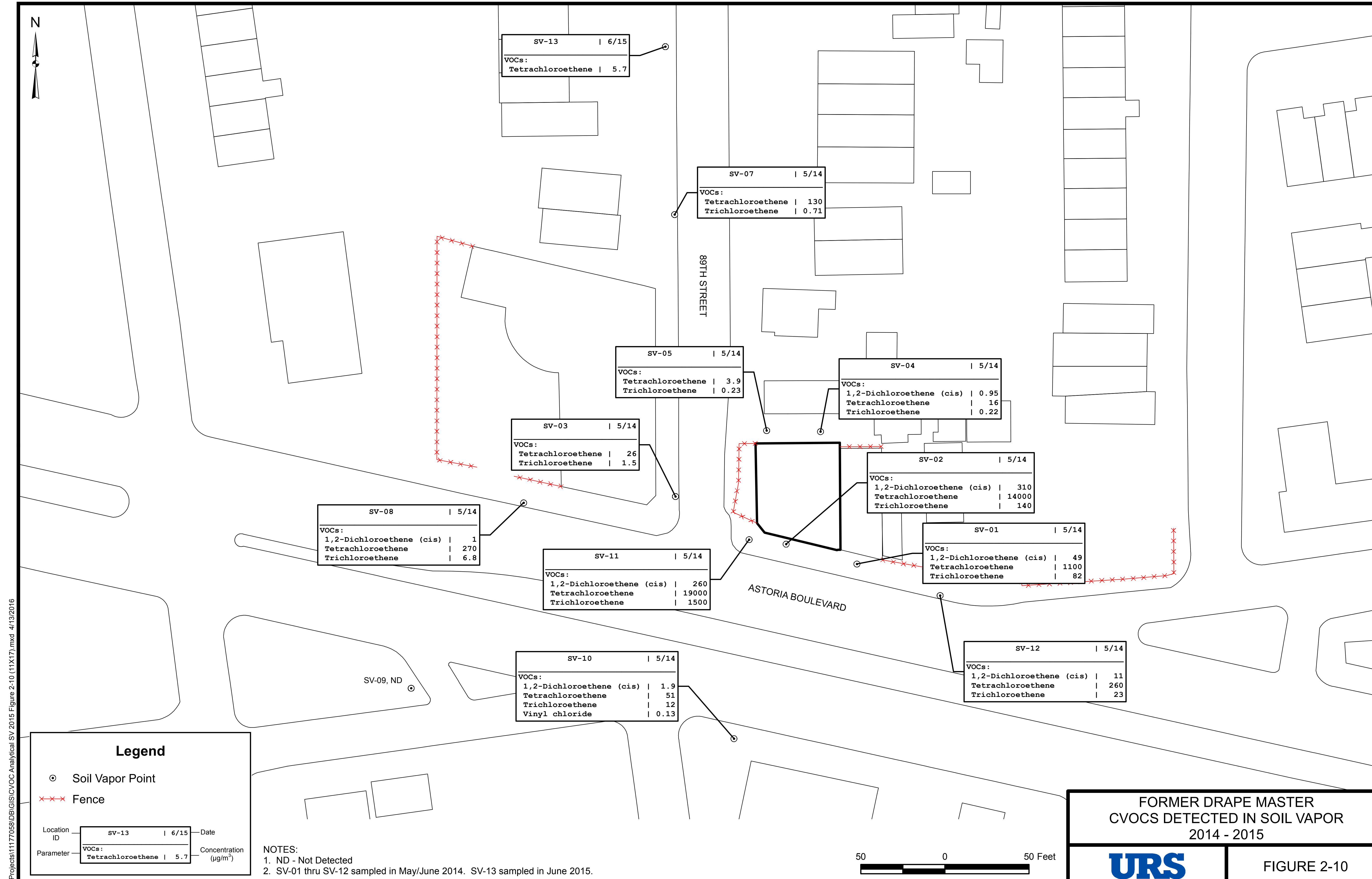
NOTES:
1. ND - Not Detected
2. NS - Not Sampled
3. Most recent PCE concentrations used for each monitoring well location

FORMER DRAPE MASTER
PCE CONCENTRATIONS IN GROUNDWATER
JULY 2014 - JUNE 2015

URS

FIGURE 2-9

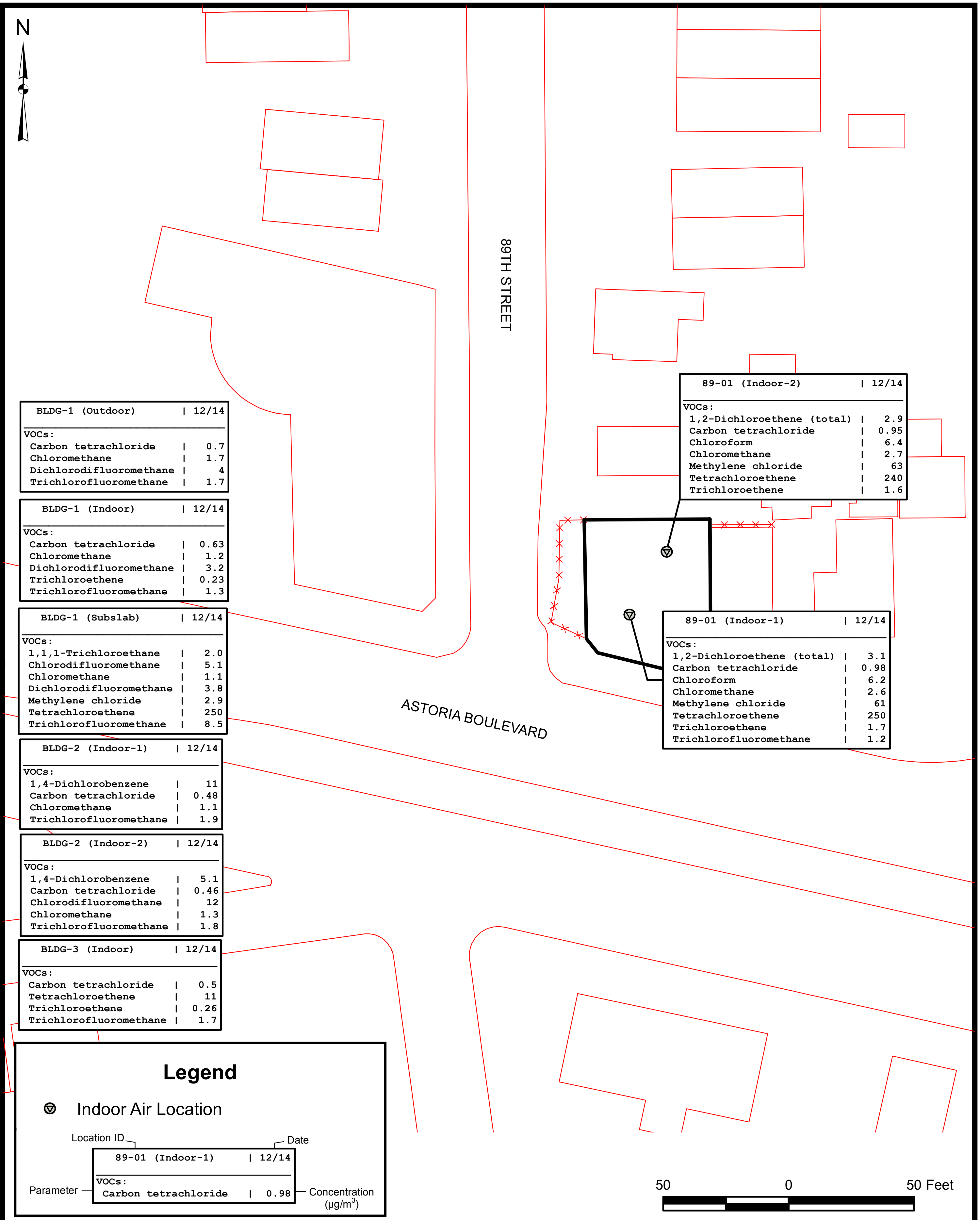
J:\Projects\11177058\DB\GIS\PCE Contours GW 2015 Figure 2-9 (11X17).mxd 4/13/2016



NOTES:
1. ND - Not Detected
2. SV-01 thru SV-12 sampled in May/June 2014. SV-13 sampled in June 2015.

FORMER DRAPE MASTER
CVOCS DETECTED IN SOIL VAPOR
2014 - 2015

FIGURE 2-10



URS

FORMER DRAPE MASTER
INDOOR AIR AND SUBSLAB ANALYTICAL RESULTS
DETECTED CHLORINATED COMPOUNDS - 2014

FIGURE 2-11

J:\Projects\11177058\DB\GIS\AI and AS Analytical Figure 2-11.mxd 4/13/2016

Legend

- Proposed Injection Well
- Monitoring Well
- Fence
- 100 Concentration (µg/L)

Location Identifier — MW-10, 59 — Tetrachloroethene Concentration (µg/L)

NOTES:
1. ND - Not Detected
2. NS - Not Sampled
3. Most recent PCE concentrations used for each monitoring well location

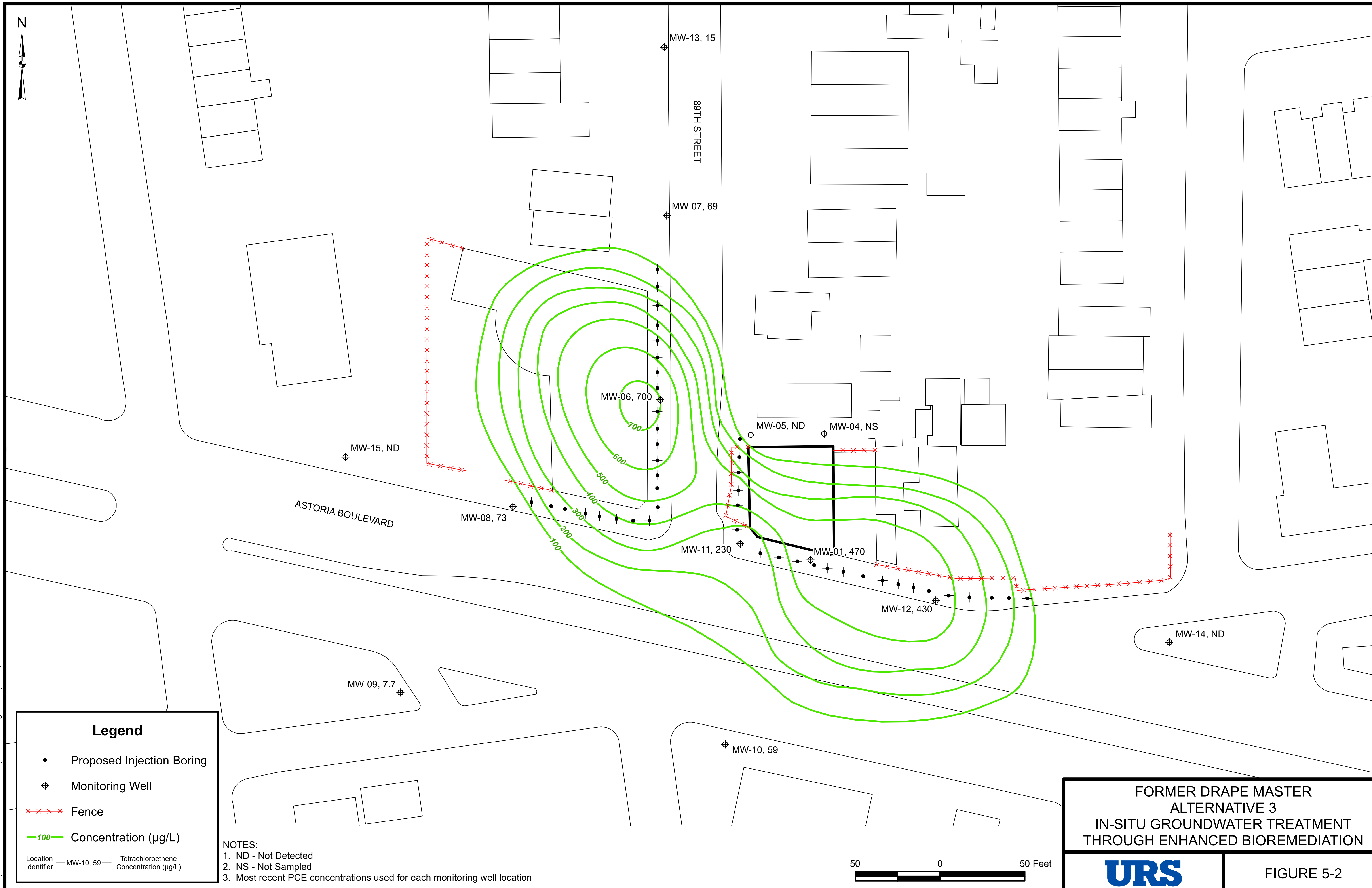
50 0 50 Feet

FORMER DRAPE MASTER
ALTERNATIVE 2
IN-SITU GROUNDWATER TREATMENT THROUGH ISCO

URS

FIGURE 5-1

J:\Projects\11177058\DB\GIS\Proposed Injection Well Figure 5-1 (11X17).mxd 4/13/2016



J:\Projects\11177058\DB\GIS\Proposed Injection Well Figure 5-2 (11X17).mxd 4/13/2016

Legend

- Proposed Injection Boring
- Monitoring Well
- Fence
- 100 Concentration (µg/L)

Location Identifier —MW-10, 59— Tetrachloroethene Concentration (µg/L)

NOTES:
1. ND - Not Detected
2. NS - Not Sampled
3. Most recent PCE concentrations used for each monitoring well location

FORMER DRAPE MASTER
ALTERNATIVE 4
IN-SITU GROUNDWATER TREATMENT
THROUGH CHEMICAL REDUCTION

URS

FIGURE 5-3

J:\Projects\11177058\DB\GIS\Proposed Injection Well Figure 5-3 (11X17).mxd 4/13/2016

APPENDIX A

VENDOR INFORMATION AND CALCULATIONS

CRT

Carus Remediation Technologies

RemOx® S and RemOx® L ISCO Reagents Estimation Spreadsheet

Input data into box with black font

Site Name: Drape Master

Date: 1/4/2016

	Estimates	Units
Treatment Area Volume		
Length	**360**	ft
Width	**120**	ft
Area	43,200	sq ft
Thickness	**15**	ft
Total Volume	24,000	cu yd
Soil Characteristics/Analysis		
Porosity	**40**	%
Total Plume Pore Volume	1,938,950	gal
Avg Contaminant Conc	**0.574**	ppm
Mass of Contaminant	9.29	lb
PNOD	**1**	g/kg
Effective PNOD	**10**	%
Effective PNOD Calculated	0.100	
PNOD Oxidant Demand	7,128.00	lb
Avg Stoichiometric Demand	**2.4**	lb/lb
Contaminant Oxidant Demand	22.29	lb
Theoretical Oxidant Demand	7,150.29	lb
Confidence Factor	**5**	
Calculated Oxidant Demand	35,751.46	

	Estimates	Units
Injection Volume for RemOx S		
Injection Concentration	**4.0%**	%
Total Volume of Injection Fluid	107,169	gal
Pore Volume Replaced	5.53	%
Amount of RemOx S Estimated:	**35,751**	**pounds**
Injection Volume for RemOx L		
Injection Concentration	**5.0%**	%
Calculated Specific Gravity	1.05	g/ml
Total Volume of Injection Fluid	73,573	gal
Pore Volume Replaced	3.79	%
Amount of RemOx L Estimated:	**80,262**	**pounds**
	7,022	**gallons**

REGENESIS

Project Info

Drape Master
Queens, NY
Dissolved Plume
Prepared For:
Donald McCall (AECOM)

Target Treatment Zone (TTZ) Info	Unit	Value
Barrier Length	ft	420
Top Treat Depth	ft	9.0
Bot Treat Depth	ft	24.0
Vertical Treatment Interval	ft	15.0
Treatment Zone Volume	ft^3	63,000
Treatment Zone Volume	cy	2,333
Soil Type	---	sand
Porosity	cm^3/cm^3	0.33
Effective Porosity	cm^3/cm^3	0.20
Treatment Zone Pore Volume	gals	155,520
Treatment Zone Effective Pore Volume	gals	94,255
Fraction Organic Carbon (foc)	g/g	0.002
Soil Density	g/cm^3	1.7
Soil Density	lb/ft^3	108
Soil Weight	lbs	6.8E+06
Hydraulic Conductivity	ft/day	14.2
Hydraulic Conductivity	cm/sec	5.01E-03
Hydraulic Gradient	ft/ft	0.004
GW Velocity	ft/day	0.28
GW Velocity	ft/yr	104

Sources of Hydrogen Demand	Unit	Value
Dissolved Phase Contaminant Mass	lbs	1
Sorbed Phase Contaminant Mass	lbs	2
Competing Electron Acceptor Mass	lbs	117
Total Mass Contributing to H_2 Demand	**lbs**	**120**

Stoichiometric Demand	Unit	Value
Stoichiometric H_2 Demand	lbs	8
Stoichiometric HRC Demand	**lbs**	**347**

Application Dosing	Unit	Value
Plume Stop to be Applied	**lbs**	**20,000**
HRC to be Applied	**lbs**	**2,820**
BDI Plus to be Applied	**Liters**	**36**

PlumeStop® Application Design Summary

Dissolved Plume	
Barrier Length (ft)	**420**
Spacing Within Barrier (ft)	10
Number of Lines	1
Application Points	**42**
Application Method	**Direct Push**
Top Application Depth (ft bgs)	9
Bottom Application Depth (ft bgs)	24
PlumeStop to be Applied (lbs)	**20,000**
PlumeStop per point (lbs)	476
PlumeStop per point (gals)	57
Mixing Water (gal)	**21,578**
Mixing Water (per pt)	514
Total Application Volume (gals)	**23,975**
Injection Volume per Point (gals)	571
Anaerobic Bioremediation - HRC	
HRC Application Points	**42**
HRC to be Applied (lbs)	**2,820**
HRC per point (lbs)	67
Total Application Volume (gals)	**260**
Injection Volume per Point (gals)	6.2
Bioagumentation - BDI Plus	
BDI Plus Application Points	**42**
BDI Plus to be Applied (Liters)	**36**
BDI Plus per point (Liters)	0.9

Field App Instructions

Technical Notes/Discussion

Prepared By: ***Andy Lowy - Design Specialist***

Assumptions/Qualifications

In generating this preliminary estimate, Regenesis relied upon professional judgment and site specific information provided by AECOM. Using this information as input, we performed calculations based upon known chemical and geologic relationships to generate an estimate of the mass of product and subsurface placement required to affect remediation of the site.

Purchasing Information		
Drape Master	--	Dissolved Plume
PlumeStop Required	**lbs**	**20,000**
HRC Required	**lbs**	**2,820**
BDI Plus Required	**Liters**	**36**
Estimated Tax and Freight %*	%	18%
Total Estimated Project Cost**	**$**	**$176,976**
Estimated RRS Days to Apply	**---**	**15**

***Note that the combined tax and freight costs are preliminary estimates only. Please contact your local sales manager or Customer Service at 949-366-8000 to obtain a shipping quote. You will be asked to provide a ship-to address and estimated time of delivery.**

Currently Available Packaging Options		
PlumeStopPackage Type***	**# of packages**	**lbs required**
2,000 lb reinforced plastic totes	10	20,000
400-lb poly drums	50	20,000
HRC Package Type***	**# of packages**	**lbs required**
30 lb HDPE pails	94	2,820
BDI Plus Package Type***	**# of packages**	**L required**
18-L kegs	2	36

****Total Project cost is only an estimate; actual project cost may change as the final scope and/or RRS proposal are developed.**

*****Available Package Types are subject to change.**

EHC Liquid® ISCR Reagent Demand Calculations

PeroxyChem

12-Jan-2016

Customer:	**AECOM**	**Prepared by:**	
Contact:	**Donald McCall**	**John Valkenburg, PE**	
Site Location:	**Queens, NY**	**1-517-669-5400**	
Proposal Number:	**CRM 18637**	**John.Valkenburg@peroxychem.com**	

PRODUCT OVERVIEW

EHC-L® is a cold-water soluble formulation of EHC® that is specially designed for injection via existing wells or hydraulic injection networks for the treatment of a wide range of groundwater contaminants. The base composition is controlled-release organic carbon with an organo-iron compound (both food-grade).

Packaging:

EHC-L is delivered in 2 parts and mixed together with water in the field.

Part 1: Liquid emulsion of lecithin delivered in 55-USG drums, filled with 50 USG / 420 lbs per drum.
Part 2: Water soluble powder with the organo-iron compound and other additives delivered in 24.6 lb bags.

SITE INFORMATION / ASSUMPTIONS

	Value	Unit	Comment
Treatment Area Dimensions:			
Width of targeted zone (perpendicular to gw flow)	360	ft	customer supplied
Length of targeted zone (parallel to gw flow)	120	ft	customer supplied
Depth to top of treatment zone	9	ft bgs	customer supplied
Treatment zone thickness	15	ft	customer supplied
Treatment volume	648,000	ft3	calculated value
Total Porosity	40	%	default value
Groundwater volume	259,200	ft3	calculated value
Soil bulk density	100	lbs/ft3	default value
Soil mass	32,400	ton	calculated value
Transport characteristics:			
Treatment time / design life for one application	3	years	default value
Linear groundwater flow velocity	0	ft/year	calculated value
Distance of inflowing gw over design life	0	ft	calculated value
Effective porosity for groundwater flow	15	%	default value
Volume of water passing region over design life	0	ft3	calculated value
Soil type	high permeability		customer supplied
Fraction organic carbon in soil, foc	0.001		estimated value

CONTAMINANTS OF CONCERN (COCs)

Constituent	GW (mg/L)	Soil* (mg/kg)	Total COI Mass** (lb)
PCE	0.544	0.008	9.3
DCE	0.019	0.00114	0.4
TCE	0.011	0.001177	0.3

*Unless provided, sorbed concentrations were roughly estimated based on expected groundwater concentrations, foc and Koc values. For a more refined estimate, it is recommended that actual values be verified via direct sampling of the targeted treatment interval.

**The total COI mass was estimated based on concentrations in soil and groundwater within the targeted area plus expected contributions from inflowing groundwater over the projected design life.

GEOCHEMICAL DATA

Competing Electron Acceptors	GW (mg/L)	
Dissolved oxygen	3.5	customer provided
Nitrate (as N)	10.3	customer provided
Manganese (estimated conc. Mn(II) generated)*	0.034	default value
Iron (estimated conc. Fe(II) generated)*	0	default value
Sulfate	94	customer provided

*An estimated projection of dissolved concentrations of Mn and Fe following ERD/ISCR were used to estimate H demand from the reduction of oxidized Fe and Mn minerals (typically only a portion of actual soil concentrations will be reduced).

ORP (mV)	177	
pH	6.98	

STOICHIOMETRIC DEMAND CALCULATIONS

	GW (mg/L)	Soil (mg/kg)
H2 Demand from COCs	0.03	0.00
H2 Demand from Competing Electron Acceptors	11.58	0.00
Total H2 Demand	11.61	0.00

H2 Demand from Soil within Targeted Area	0.03	lb
H2 Demand from GW within Targeted Area	187.83	lb
H2 Demand from Influx over Design Life	0.00	lb
Total Estimated H2 Demand	187.86	lb

EHC-L DEMAND CALCULATIONS

The Stoichiometric demand for the targeted area was calculated using available data presented above, noting that the Stoichiometric demand represents minimum requirements and require a complete geochemical data set to be calculated accurately. Therefore, the resulting EHC dosing required to meet the estimated Stoichiometric demand was compared to our minimum guidelines for the selected type of application, selecting the higher number.

Application type: Plume Treatment

	Value	Unit
Specific H2 capacity of ELS (100% concentrate)	349	g H2/Kg
Concentration EHC-L in GW to meet H2 demand	33.2	mg/L
Recommended minimum target conc. lecithin in pore wate	1,000	mg/L
Recommended conc. of EHC-L in pore water	1,000	mg/L
Mass of EHC-L concentrate required	16,184	lbs
Mass EHC-L per container	460	lbs
Number of Containers	36	containers
Mass EHC-L (rounded based on container size)	**16,560**	**lbs**
Mass of EHC-L dry mix (Fe component)	3,880	lbs
Mass Fe dry mix per container	24.6	lbs
Number of Fe dry mix containers required	158	bags
Mass Fe dry mix (rounded based on container size)	**3,887**	**lbs**

*Our general recommended minimum guideline for the proposed application exceeds the dose rate required based on hydrogen demand calculations and was therefore used for the purpose of this dosing calculation.

OPTIONAL pH BUFFER

If groundwater pH is below 6.5 or inoculants are to be applied together with the EHC-L, we recommend that the EHC-L injection solution be pH buffered to create optimal conditions for microbial growth. Based on laboratory tests, potassium bicarbonate, a fully soluble buffer, applied at a rate of 25 lbs / 11 kg per drum (420 lb) of EHC-L will buffer the pH of the injectate solution to circum-neutral. If baseline pH conditions were to be below 6, additional pH buffer will be needed to raise the pH of the groundwater to 7. The amount of buffer required to raise the pH of the groundwater to 7 will depend on the site-specific buffering capacity of the soil and will have to be determined by conducting a pH titration test.

Total $KHCO_3$ demand = amount $KHCO_3$ to neutralize EHC-L solution + amount needed to raise ground water / soil to a pH of 7

Soil buffering amount = KHCO3 for ground water / soil pH adjustment, which can be determined in the laboratory via titration.

	Value	Unit	
Mass $KHCO_3$ to neutralize EHC-L solution	3,943	lbs	default value
Estimated soil buffering amount	0	lbs	estimated value
Total $KHCO_3$ demand	3,943	lbs	

OPTIONAL DHC INOCULANT

Although not typically required for ISCR, DHC inoculants have shown to improve removal kinetics, in particular for potential daughter products such as cis-DCE and VC. The DHC will be added after EHC-L application, once favorable redox conditions (ORP < -75 mV, DO <0.2 mg/L, pH between 6 and 8.5) have been attained. The DHC inoculant will contain at least 5 x10E10 cfu/L of live bacteria including high numbers of dehalococcoides species with known abilities to biodegrade DCE. The target density of DHC cells in the treated aquifer is 1x10E6 cfu/L.

	Value	Unit
Dechlorinating consortium concentration in inoculant	5.00E+10	DHC/L
Design final concentration after dilution in aquifer	1.00E+06	DHC/L
Volume of Inoculant Required	147	L

COST ESTIMATE

Item	Quantity	Unit	Price[1,2]	Cost
EHC Liquid Concentrate	16,560	lbs	$4.75	$78,660
EHC Liquid Fe Dry Mix[3]	3,886.8	lbs	-	included
Shipping Estimate [4]	1	lump sum	$3,400	$3,400
Sub Total Cost				**$82,060**
Optional items:				
pH Buffer ($KHCO_3$) [5]	3,950	lbs	$2.70	$10,665
DHC Inoculum (incl. minimum) [5]	147	L	$90	$13,230
TOTAL COST [6]				**$105,955**

1) Price valid for 90 days from date at top of document. Terms: net 30 days.

2) Any applicable taxes not included. Please provide a copy of your tax exempt certificate or resale tax number when placing your order. In accordance with the law, applicable state and local taxes will be applied at the time of invoicing if PeroxyChem has not been presented with your fully executed tax exemption documentation.

3) The EHC Liquid Fe dry mix (part 2) is included in the EHC Liquid cost.

4) Shipping rate provided is an estimate. Standard delivery time can vary from 1-3 weeks from time of order, depending upon volume. Expedited transport can be arranged at extra cost. Unless requested otherwise, costs assume standard ground transport via truck, with no need for a lift gate or pallet jack.

5) Price excludes shipping. Volumes were rounded up based on container size.

6) All sales are per PeroxyChem's Terms and Conditions.

Disclaimer:

The estimated dosage and recommended application methodology described in this document are based on the site information provided to us, but are not meant to constitute a guaranty of performance or a predictor of the speed at which a given site is remediated. The calculations in the Cost Estimate regarding the amount of product to be used in your project are based on stoichiometry or default minimum guideline values, and do not take into account the kinetics, or speed of the reaction. Note that the Stoichiometric mass represents the minimum anticipated amount needed to address the constituents of concern (COCs). As a result, these calculations should be used as a general approximation for purposes of an initial economic assessment. PeroxyChem recommends that you or your consultants complete a comprehensive remedial design that takes into consideration the precise nature of the COC impact and actual site conditions.

INSTALLATION

The EHC-L will be delivered as two components, which will be mixed together in the field. The first component, a 25% liquid emulsion of organic carbon substrate or 100% concentrate, will be provided in 55-USG drums, with 50 USG/190 litres per drum. The second component is the EHC-L mix which contains the ferrous iron powder, and is delivered as a dry powder and added to the liquid component in the field. The EHC-L mix is proportioned so that one bag (24.6 lbs / 11.2 kg) of EHC L mix is added per drum of liquid emulsion.

Depending on the application method, between 10% and 100% of the effective porosity is normally targeted during EHC-L injection, with a higher percent pore fill normally targeted during low-flow injections into wells and injection networks. This is in contrast to applications via direct push technology (DPT) where normally around 10 to 15% is targeted. To facilitate the desired injection volume, the EHC-L components will be diluted in the field.

The below table shows examples of mixing recipes for the proposed container size and the resulting total injection volume and percent pore fill. Alternative packaging options are available upon request and the below mixing recipe may be scaled depending on mix batch and packaging size.

Packaging:	Drum
Mass per container (lbs):	460
Concentration as delivered:	100% concentrate

EHC-L Mixing Recipe (per container)

Dilution:	**10-fold**	**20-fold**	**30-fold**
Volume EHC-L emulsion per drum (USG)	50	50	50
Mass EHC-L mix (lbs)	107.8	107.8	107.8
Volume water per drum (USG)	496	1,047	1,598
Resulting volumeinjection solution per drum (USG)	546	1,097	1,648
Resulting EHC-L conc. (organic carbon + Fe mix)	12.3%	6.2%	4.1%
Total volume water (USG)	17,858	37,700	57,542
Total injection volume (USG)	19,658	39,500	59,342
Resulting injection volume to total pore volume	1.0%	2.0%	3.1%

Injection recommendations (can be altered):

The EHC-L solution could be injected via fixed wells or using direct push. The injection spacing would be determined based on the radius of influence achieved for the specific implementation method and lithology.

	Value	Unit	Comment
Dilution of EHC-L emulsion (can be altered)	30		can be altered
Total volume of water required	57,542	U.S. gallons	calculated value
Approximate volume of solution to inject	59,342	U.S. gallons	calculated value
Injection spacing	20	ft	customer provided
Number of injection points	108	locations	calculated value
Injection volume per point	549	U.S. gallons	calculated value
Injection volume per vertical foot	37	U.S. gallons	calculated value
Injection volume to total pore space volume	3.1	percent	calculated value

Note that the construction estimates presented above can be readily modified in the field or per recommendations from the injection contractor as required (for example, the concentration of the EHC-L solution could be changed to modify the total injection volume or the injections spacing could be altered based on installation technology).

APPENDIX B

COST ESTIMATE CALCULATIONS

APPENDIX B

Cost Estimate for Alternative 2:

In-Situ Groundwater Treatment through ISCO (Permanganate)

DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	TOTAL PRICE
Mobilization/Demob/Site Preparation	Lump Sum	$ 4,000	1	**$ 4,000**
Health and Safety	Day	$ 250	60	**$ 15,000**
Injection Wells	Each	$ 2,930	45	**$ 131,850**
Permanganate Injection, 5% solution	Gallon	$ 4.50	44,144	**$ 198,648**
Site Restoration	Lump Sum	$ 50,000	1	**$ 50,000**
Baseline Monitoring	Lump Sum	$ 10,181	1	**$ 10,181**
Well Decommissioning	Each	$ 672	45	**$ 30,240**
Prepare SMP	Lump Sum	$ 24,000	1	**$ 24,000**
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
			SUBTOTAL	**$ 463,919**
Site Services	Lump Sum	5% of Subtotal	5%	**$ 23,196**
				$ -
			SUBTOTAL	**$ 487,115**
Contingency	Lump Sum	25% of Subtotal	25%	**$ 121,779**
			ESTIMATED TOTAL CAPITAL COST	**$ 608,894**

APPENDIX B

Cost Estimate for Alternative 3:

In-Situ Groundwater Treatment through Enhanced Bioremediation (PlumeStop and HRC)

DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	TOTAL PRICE
Mobilization/Demob/Site Preparation	Lump Sum	$ 4,000	1	**$ 4,000**
Health and Safety	Day	$ 250	20	**$ 5,000**
Injection by Regenesis*	Lump Sum	$ 198,196	1	**$ 198,196**
*-Includes injection services; PlumeStop, HRC (Enhanced Anaerobic Bioremediation), and BDI (Bioaugmentation) products; shipping; etc.				
Concrete Coring	Each	$ 40	45	**$ 1,800**
Hand Clearing first 5 feet	Each	$ 313	45	**$ 14,085**
Site Restoration	Lump Sum	$ 50,000	1	**$ 50,000**
Baseline Monitoring	Lump Sum	$ 10,181	1	**$ 10,181**
Prepare SMP	Lump Sum	$ 24,000	1	**$ 24,000**
				$ -
				$ -
				$ -
			SUBTOTAL	**$ 307,262**
Site Services	Lump Sum	5% of Subtotal	5%	**$ 15,363**
				$ -
			SUBTOTAL	**$ 322,625**
Contingency	Lump Sum	25% of Subtotal	25%	**$ 80,656**
			ESTIMATED TOTAL CAPITAL COST	**$ 403,281**

APPENDIX B

Cost Estimate for Alternative 4:

In-Situ Groundwater Treatment through Chemical Reduction (EHC)

DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	TOTAL PRICE
Mobilization/Demob/Site Preparation	Lump Sum	$ 4,000	1	**$ 4,000**
Health and Safety	Day	$ 250	20	**$ 5,000**
Injection Borings (Geoprobe)	Day	$ 2,150	20	**$ 43,000**
Concrete Coring	Each	$ 40	45	**$ 1,800**
Hand Clearing first 5 feet	Each	$ 313	45	**$ 14,085**
EHC Liquid Concentrate	lbs	$ 4.75	16,560	**$ 78,660**
EHC Liquid Iron Dry Mix	lbs	included in EHC Liq. Conc. price	3,887	**$ -**
pH Buffer	lbs	$ 2.70	3,950	**$ 10,665**
DHC (Bioaugmentation)	Liters	$ 90	147	**$ 13,230**
Freight and Shipping for EHC products	Lump Sum	$ 6,800	1	**$ 6,800**
Site Restoration	Lump Sum	$ 50,000	1	**$ 50,000**
Baseline Monitoring	Lump Sum	$ 10,181	1	**$ 10,181**
Prepare SMP	Lump Sum	$ 24,000	1	**$ 24,000**
				$ -
		SUBTOTAL		**$ 261,421**
Site Services	Lump Sum	5% of Subtotal	5%	**$ 13,071**
				$ -
		SUBTOTAL		**$ 274,492**
Contingency	Lump Sum	25% of Subtotal	25%	**$ 68,623**
		ESTIMATED TOTAL CAPITAL COST		**$ 343,115**

APPENDIX B

Unit Cost: Injection Well

DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	TOTAL PRICE
				$ -
Concrete Coring	Each	$ 72.00	1	**$ 72.00**
Pre-Clear Boreholes to 5 feet bgs	Each	$ 313.00	1	**$ 313.00**
Hollow Stem Auger Drilling 6¼" ID	Foot	$ 50.00	25	**$ 1,250.00**
Well Screen, 4" Dia., PVC	Foot	$ 45.00	15	**$ 675.00**
Well Riser, 4" Dia., PVC	Foot	$ 42.00	9	**$ 378.00**
Flush Mount Casing, Cap, & Lock	Each	$ 242.00	1	**$ 242.00**
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
ESTIMATED TOTAL CAPITAL COST				**$ 2,930.00**

NOTES:
1. Unit costs include installation, material, and equipment costs.

APPENDIX B

Mobilization / Demob /
Site Preparation

DESCRIPTION	TOTAL PRICE
	$ -
Mobilization of drilling equipment (as per recent quotes):	$ **317.00**
For mobilization of all mixing and injection equipment, offices, storage, etc., staff, etc. assume 5 x the drill rig mobilization cost:	$ **1,585.00**
	$ -
Assume for other miscellaneous Site Preparation activities:	$ **2,000.00**
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
SUBTOTAL	**$ 3,902**
ESTIMATED TOTAL CAPITAL COST	**$ 4,000**

NOTES:
1. Mobilization Costs assumed to be similar for Alts 2, 3, and 4

APPENDIX B

Health and Safety

DESCRIPTION	TOTAL PRICE
	$ -
Assume a cost of $250 per day to include PPE, monitoring, and all Health and Safety provisions, based on West Side FFS	$ 250.00
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
SUBTOTAL	**$ 250**
ESTIMATED TOTAL CAPITAL COST	**$ 250**

NOTES:

APPENDIX B

Permanganate Injection

DESCRIPTION	TOTAL PRICE
	$ -
Based on West Side Corp FFS, 5% sodium permanganate solution, injected cost, per gallon:	$ 4.50
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
ESTIMATED TOTAL CAPITAL COST	**$ 4.50**

NOTES:

APPENDIX B

Unit Cost: Baseline Monitoring

DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	TOTAL PRICE
				$ -
Analysis of 13 existing monitoring wells, prior to injection				**$ -**
VOCs	Each	$ 67.00	1	**$ 67.00**
Metals	Each	$ 80.00	1	**$ 80.00**
Natural Attenuation Parameters	Each	$ 146.00	1	**$ 146.00**
				$ -
		SUBTOTAL PER WELL		**$ 293.00**
				$ -
Total Analytical (includes 4 QA/QC samples)	Each	$ 293.00	17	**$ 4,981.00**
Sample Collection	Days	$ 1,600.00	3	**$ 4,800.00**
Shipping and Miscellaneous	Lump Sum	$ 400.00	1	**$ 400.00**
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
		ESTIMATED TOTAL CAPITAL COST		**$ 10,181.00**

NOTES:

APPENDIX B

Unit Cost: Annual Monitoring, Years 1-5, Alternatives 2, 3, and 4

DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	TOTAL PRICE
				$ -
Analysis of 13 existing monitoring wells				$ -
VOCs	Each	$ 67.00	1	**$ 67.00**
Metals	Each	$ 80.00	1	**$ 80.00**
Natural Attenuation Parameters	Each	$ 146.00	1	**$ 146.00**
				$ -
SUBTOTAL PER WELL				**$ 293.00**
				$ -
Total Analytical (includes 4 QA/QC samples)	Each	$ 293.00	17	**$ 4,981.00**
Sample Collection	Days	$ 1,600.00	3	**$ 4,800.00**
Shipping and Miscellaneous	Lump Sum	$ 400.00	1	**$ 400.00**
				$ -
				$ -
SUBTOTAL PER EVENT				**$ 10,181.00**
				$ -
Per event, assuming 4 per year:	Each	$ 10,181.00	4	**$ 40,724.00**
Include indoor air samples	Each	$ 1,000.00	1	**$ 1,000.00**
				$ -
				$ -
ESTIMATED TOTAL COST				**$ 41,724.00**

NOTES:

APPENDIX B

Unit Cost: Annual Monitoring, Years 6-30, Alternatives 2, 3, and 4

DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	TOTAL PRICE
				$ -
Analysis of 13 existing monitoring wells, prior to injection				$ -
VOCs	Each	$ 67.00	1	**$ 67.00**
				$ -
				$ -
				$ -
SUBTOTAL PER WELL				**$ 67.00**
				$ -
Total Analytical (includes 4 QA/QC samples)	Each	$ 67.00	17	**$ 1,139.00**
Sample Collection	Days	$ 1,600.00	3	**$ 4,800.00**
Shipping and Miscellaneous	Lump Sum	$ 400.00	1	**$ 400.00**
Include indoor air samples	Each	$ 1,000.00	1	**$ 1,000.00**
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
				$ -
ESTIMATED TOTAL COST				**$ 7,339.00**

NOTES:

APPENDIX B

Site Restoration

DESCRIPTION	TOTAL PRICE
	$ -
Majority of site restoration will involve replacement of the sidewalk at the well locations	$ -
Assume each sidewalk flag is replaced.	$ -
45 locations @ $ 883	$ **39,735.00**
	$ -
Other miscellaneous removal and disposal, assume:	$ **10,000.00**
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
	$ -
SUBTOTAL	**$ 49,735**
ESTIMATED TOTAL CAPITAL COST	**$ 50,000**

NOTES:
1. Mobilization Costs assumed to be similar for Alts 2, 3, and 4