WEST SIDE CORP. SITE OPERABLE UNIT 2

STATION 24 TREATMENT SYSTEM OPERATIONS REPORT

WORK ASSIGNMENT D007622-1

WEST SIDE CORP. SITE
JAMAICA

SITE NO. 241026
QUEENS COUNTY, NY

Prepared for:
NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
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DIVISION OF ENVIRONMENTAL REMEDIATION
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G4694A

March 2013

FOCUSED FEASIBILITY STUDY REPORT

WEST SIDE CORP. SITE
OPERABLE UNIT 2 (STATION 24)
SITE NO. 241026
QUEENS COUNTY, NEW YORK

Prepared for:

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
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ALBANY, NEW YORK 12233

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ABBREVIATIONS

amsl	above mean sea level
bgs	below ground surface
DO	dissolved oxygen
ERH	electrical resistance heating
FFS	Focused Feasibility Study
ft	feet
gpm	gallons per minute
GWET	groundwater extraction and treatment
NYCDEP	New York City Department of Environmental Protection
NYCRR	New York State 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
ORP	oxidation/reduction potential
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PCE	tetrachloroethene
PID	photoionization detector
ppb	parts per billion (micrograms per liter [ug/L])
RAOs	remedial action objectives
RI	Remedial Investigation
ROD	Record of Decision
SCGs	standards, criteria, and guidance
SVE	soil vapor extraction
TMV	toxicity, mobility or volume
TOGS	Technical and Operational Guidance Series
UIC	Underground and Injection Control
URS	URS Corporation – New York
USEPA	United States Environmental Protection Agency
VI	vapor intrusion
VOCs	volatile organic compounds

1.0 INTRODUCTION AND BACKGROUND

1.1 General

URS Corporation (URS) has prepared this *Focused Feasibility Study* (FFS) for the New York State Department of Environmental Conservation (NYSDEC) for Operable Unit 2 (OU2) of the West Side Corporation Site (No. 241026). As part of work assignment D007622-1 of the URS standby engineering services contract with the NYSDEC, URS operated the groundwater extraction and treatment system constructed for OU2 following construction completion of the system in July 2012 through the period ending November 19, 2012.

URS has been tasked with developing an FFS to compare the in situ chemical oxidation (ISCO) technology using sodium permanganate injection as an alternative to the existing groundwater extraction and treatment system. This FFS was prepared by URS and is based on information and data presented in the *West Side Corporation Operable Unit No. 2 Final Offsite Plume Delineation and Investigation* prepared by Malcolm Pirnie, Inc., March 2009, and in the *West Side Corp. Site Operable Unit 2 Station 24 Treatment System Operations Report* prepared by URS, December 2012.

1.2 Site History and Description

The 4.5 acre West Side Corporation site (OU1) is located at 107-10 180th Street in the City of Jamaica, Borough of Queens, New York, and is surrounded by a combination of industrial, commercial, and residential properties (Figure 1-1). The West Side Corp. property was the location of a former distributor of tetrachloroethene (PCE) for the dry cleaning industry. Due to spills and/or poor housekeeping practices, PCE had been released to the ground and detected at percent levels. In July 2000, the NYSDEC signed a Record of Decision (ROD) which selected a remedy to clean up the soil and groundwater on the on-site property. In September 2002, an Explanation of Significant Differences was issued by the NYSDEC revising the OU1 remedy. By 2005, NYSDEC completed a remediation of the OU1 using electrical resistance heating (ERH), bringing the PCE contamination to non-detect levels in the source area.

A second ROD was signed in February 2002 that addressed contaminated groundwater that has migrated from the site to the south-southwest (OU2). OU2 is the subject of this report.

(The third operable unit, OU3, pertaining to soil gas at various locations within the groundwater plume, is not included in this report.)

The shallow geology beneath the study area is a single unconfined sand and gravel aquifer consisting of medium to coarse grained sands of Pleistocene age locally known as the Upper Glacial Aquifer. Soil samples collected during previous investigation showed the aquifer material to be very consistent throughout the OU2 study area. The depth to the top of the underlying Gardiner's clay layer, which is an undulating surface throughout the study area, increases southward from OU1 to OU2 ranging from 62 feet to 105 feet below ground surface (bgs). For the purposes of this FFS, the average depth to the Gardiner's clay layer in OU2 is considered to be 90 feet bgs.

The regional direction of groundwater flow is south-southwest from the site. When the OU2 recovery wells are not operating, the depth to groundwater was found to be 10 to 14 feet bgs throughout the study area. Water table elevations ranged from 22 feet above mean sea level (amsl) at OU1 to 15 feet amsl at the south edge of OU2 as presented in the March 2009 Malcolm Pirnie Report. While the recovery wells were operating, such as in November 2012, water table elevations ranged from approximately 9.5 feet amsl (depth of 17.67 feet bgs) near OU1 (MW-08) to approximately 12.6 feet amsl (depth of 7.84 feet bgs) near the south edge of OU2 (W-15S).

The horizontal groundwater gradient in 2009 was measured to be 0.0018 feet/foot along the plume's south-southwest heading. Given this gradient, an average hydraulic conductivity of 1,000 gallons per day/ft^2 and an average effective porosity of 30%, the rate of groundwater flow in the aquifer was estimated at 0.80 ft/day. Water levels measured between shallow, intermediate, and deep wells in each monitoring well cluster were consistent, with differences ranging from 0.01 to 0.18 feet, indicating no significant vertical gradient under non-pumping conditions.

1.3 Historical Groundwater PCE Data

In 2000, GZA Environmental investigated the offsite migration of PCE and discovered groundwater contamination extending approximately ½ mile south of the West Side site, where dissolved PCE concentrations in shallow depths were as high as 4,400 parts per billion (ppb) beneath a residential area.

Subsequent to this finding, URS conducted a groundwater investigation between May 2005 and October 2006 and installed 8 shallow monitoring wells (W-01 through W-08) to monitor groundwater beneath the residential area. URS also conducted an expanded groundwater sampling effort beyond the downgradient edge of the shallow PCE plume in March 2007 with installation and sampling of 49 direct-push groundwater probes.

In 2008, Malcolm Pirnie conducted 2 Geoprobe® investigations in 2 phases. The first investigation in May 2008 included the installation of borings B1 to B20 along transects of 177th, 175th and 172nd Streets. Groundwater samples were collected from 2 depths at each boring from 10 to 12 feet bgs and from 25 to 27 feet bgs. Results did not reveal the plume's leading edge. Results are presented in Table 1-1 and shown on Figure 1-2. PCE concentrations were typically not detected in shallow (10 to 12 feet bgs) groundwater samples except along the closest transect to OU1 where PCE concentrations ranged from non-detect (ND) to 110 ppb. Deeper groundwater samples (25 to 27 feet bgs) had greater PCE concentrations with values ranging from 7 to 3,500 ppb. Results indicated the leading edge of the plume extended beyond 172nd Street and most of its mass was deeper in the aquifer. Two additional borings (B3A and B8A) were advanced adjacent to existing borings B3 and B8 and groundwater samples were collected at 30, 37, 44, 51 and 58 feet bgs. PCE concentrations up to 1,200 ppb were observed.

In July 2008, the second investigation included installation of borings B21 to B50 along transects of 172nd, 169th, and 166th Streets. Groundwater samples were collected from the water table to the anticipated depth of the Gardiner's clay layer found at 62 to 105 feet bgs. The highest PCE concentrations were detected in B20 along 172nd Street with concentrations of 20,991 ppb and 16,643 ppb at depths of 65 feet and 51 feet, respectively. The leading edge of the PCE plume appeared in 2009 to occur to the east of 166th Street as indicated on Figure 1-3. PCE concentrations versus depths are shown on Figures 1-4 through 1-6 for transects A-A', B-B', and C-C', respectively.

The direction of plume movement as shown on these figures indicates that groundwater contamination follows the south/southwesterly regional flow direction. PCE contamination extends deeper into the aquifer and becomes more widely dispersed with increasing distance from OU1. As indicated on cross-section A-A', the leading edge of the plume in 2008 was located downgradient of 169th Street, where PCE concentrations were low to ND in many groundwater samples. As PCE was not detected on 166th Street, the leading edge of the plume was interpreted

to be located between 169th and 166th Streets. Cross-sections indicate the greatest mass of PCE located in the vicinity of 172nd Street. The highest concentrations of PCE were observed along Transect B-B' where two distinct masses of dissolved PCE appeared to lie from 30 to 70 feet bgs, with the highest concentrations greater than 5,000 ppb and 10,000 ppb. PCE contamination observed farther downgradient at 169th Street (Transect C-C') appeared to show one distinct mass from 40 to 80 feet bgs, with the highest PCE concentrations greater than 1,000 ppb.

Additionally, Malcolm Pirnie installed 44 groundwater monitoring wells in clusters at shallow (~12-22 feet bgs), intermediate (~35-45 feet bgs), and deep (~70-80 feet bgs) intervals at 14 locations to complement the previously-installed monitoring wells. In June/July 2008, intermediate and deep wells were installed adjacent to the five existing offsite shallow wells (W-01, W-02, W-03, W-04, W-06); and shallow, intermediate and deep well triplets were installed at new cluster locations W-07, W-08, W-09). In August 2008, groundwater monitoring well clusters were installed at W-10 through W-15. As indicated on Figures 1-7 through 1-9, PCE contamination in shallow (~12-22 feet bgs) groundwater wells extends from the OU1 source area to approximately 2,000 feet downgradient in the vicinity of 173rd Street, where PCE was no longer detected. The highest concentrations in intermediate (~40-50 feet bgs) groundwater wells were observed from 177th Street to 174th Street where PCE concentrations were greater than 1,000 ppb. The highest concentrations in deep groundwater wells indicated the bulk of PCE contamination was located between 172nd and 175th Streets, and that the leading edge of the plume in the deep zone is slightly further downgradient than 166th Street.

1.4 Groundwater Extraction and Treatment System

The groundwater extraction and treatment (GWET) system was designed to hydraulically contain the PCE plume migrating from the OU1 source area. Due to a combination of the natural groundwater flow gradient to the south and the artificial gradient imposed by extraction wells formerly operated on the adjacent New York City Department of Environmental Protection (DEP) Station 24 property, the plume was estimated based on 2008 data to extend for approximately 3,500 feet downgradient of the site. To hydraulically contain the plume, Malcolm Pirnie designed a GWET system that was estimated through modeling to establish a stagnation point approximately 2,000 to 2,500 feet downgradient of the extraction wells. The stagnation point represents the location of the groundwater divide. North-northeast of the divide, groundwater flows towards the extraction wells. South-southwest of the divide, groundwater

continues to flow towards Jamaica Bay and is not captured by the extraction wells. The GWET system included two recovery wells on the Station 24 property, treating the extracted water with activated carbon and discharging the water to a storm sewer that discharged to Bergen Basin in Jamaica Bay.

Construction of the system was completed in 2012, and it operated for approximately 3 months until November 2012. During operations, each recovery well extracted groundwater at the design rate of approximately 750 to 770 gallons per minute (gpm) for each pump for a total of approximately 1,520 gpm or 730,000 gallons when operated for an eight hour day, or 2,200,000 gallons when operated for a twenty-four hour day.

As presented in the *West Side Corp. Site OU2 Station Treatment System Operations Report* (URS, 2012), during 2012 operations, URS sampled the water from each extraction well and the combined effluent from the carbon treatment system initially on a daily basis, and then on a weekly basis. Analytical data showed that PCE concentrations for influent from extraction well No. 1 ranged from 89 ppb to 230 ppb (µg/L) and from extraction well No. 2 from 28 ppb to 47 ppb. At an estimated annual cost of extraction well operation of $2 million, this corresponds to about $2,800 per pound of contaminant removed. These influent concentrations were substantially lower than the originally estimated influent concentrations of 2,400 ppb estimated during the design (Malcolm Pirnie, 2004) which were based on plume concentrations at that time. At the design influent concentration, removal costs would have been much lower at about $125 per pound of contaminant. However, in the intervening years since the design basis was established, the plume near the source had attenuated due to the removal of the source at OU1.

The location of a groundwater divide, and hence the extent of hydraulic containment, during pumping operations was estimated using groundwater level measurements. Figure 1-10 shows the actual groundwater elevation contours observed during system operation (blue contours) and the groundwater elevation contours estimated by modeling during design (green contours). The inferred capture area, shown in Figure 1-11 is estimated to recover groundwater from between 900 and 1,300 feet south-southwest of the extraction wells, roughly half as far as had been predicted by modeling.

1.5 2012 Groundwater PCE Data

URS sampled 51 monitoring wells for VOCs three times during the groundwater extraction and treatment operation period, in August, September, and November, 2012. PCE results are shown on Figure 1-12. Contamination was found to be consistently highest in the intermediate zone, with the highest concentrations found in monitoring wells W-10I at 3,900 ppb and W-13I at 1,700 ppb located along the southerly edge of the monitoring area and approximately 3,000 feet downgradient of OU1.

Figures 1-13 through 1-15 provide PCE contours in the shallow, intermediate and deep zones. These figures based, on 2012 data, are compared to the 2009 PCE contours provided on Figures 1-7 through 1-9 as discussed below.

- Shallow groundwater zone: In contrast to the results of the 2008 sampling, there is no longer a 1,000 ppb PCE contour as the maximum detected concentration was 670 ppb in W-04S. The areal extent of the 100 ppb PCE contour is much smaller, and approximately in the location of the previous 1,000 ppb contour. The 10 ppb PCE contour has approximately the same areal extent. All of the shallow groundwater contamination is within the capture zone of the GWET system.

- Intermediate groundwater zone: In contrast to the results of the 2008 sampling, the highest PCE concentrations in this depth zone no longer are present near the recovery wells. The highest concentrations of PCE have migrated downgradient as evidenced by the 1,000 ppb contour estimated at south of 111th Avenue and west of 175th Street to at least 168th Street. This portion of the intermediate depth plume, containing PCE at up to 3,900 ppb is beyond the capture zone of the GWET system. The 100 ppb PCE contour extends farther south beyond W-13I. The estimated southernmost edge of the 100 ppb PCE contour is shown on Figure 1-14. The 10 ppb PCE contour in all likelihood follows the 100 ppb PCE contour; the estimated southernmost edge of the 10 ppb contour is shown on Figure 1-14.

- Deep groundwater zone: PCE concentrations appear to be lower near the source area with the exception of W-01D (420 ppb in 2012 compared to 7.4 ppb in 2008). There still is no 1,000 ppb PCE contour. The 100 ppb PCE contours incorporate the small area around W-

01D, and south of the source area incorporating W-08D (120 ppb) and W-10D (160 ppb). The 2012 100 ppb contour has shifted to the south and east of the similar 2009 100 ppb contour. The 10 ppb PCE contour has expanded to the west and south as PCE was detected in monitoring wells where it was previously not detected (W-12D, W-13D). The location of the southernmost edge of the 10 ppb contour is estimated as shown on Figure 1-15. Less than half of the deep portion of the plume is within the GWET system capture zone.

2.0 REMEDIAL GOAL AND OBJECTIVES

2.1 2002 OU2 ROD and Remediation Area

A ROD was signed in February 2002 for the site. Remedial goals for the site were identified as:

- Eliminate, to the extent practicable, further migration of contaminated overburden groundwater.
- Reduce, to the extent practicable, the level of contamination in the groundwater.
- Attain, to the extent practicable, the cleanup goals for groundwater quality (groundwater standards).
- Prevent, to the extent practicable, the potential for exposure through inhalation to organic vapors that could migrate from the water table into off-site residences.

As part of the OU2 remedy, the ROD addressed contaminated groundwater that had migrated from the OU1 site to the south-southwest in the direction of the DEP Groundwater System Station 6 site, a former drinking water production facility. In order to protect groundwater near the Station 6 former facility if it were to be operated in the future, the DEP committed to assisting the NYSDEC in the cleanup of the off-site groundwater plume by installing two high capacity recovery wells at Station 24. The recovery wells were to be used to hydraulically contain the PCE plume and prevent it from further migrating toward Station 6 for if and when the facility becomes operational. (Station 6 location is shown on Figure 1-1.) Recovered groundwater would be treated at the proposed Station 24 treatment facility, sampled and disposed of into Bergen Basin through the sewer system.

In accordance with the ROD, a groundwater extraction and treatment system was designed to hydraulically contain the PCE plume migrating from the OU1 source area. Details of the GWET system are provided in Section 1.4. The effective remediation area of the GWET system may be considered to be the area between the extraction wells and the downgradient groundwater divide created by the operation of the extraction wells. Based on water level information in November 2012, the groundwater divide is estimated to exist near 111th Avenue to

the south and 174th Street to the west. The 10 ppb and 100 ppb PCE plumes in the shallow groundwater zone are generally to the east and north of this groundwater divide indicating that they are within the capture zone of the GWET system. However, the portions of the PCE plume in the intermediate and deep groundwater zones described by the 10 ppb, 100 ppb, and 1,000 ppb isopleths are beyond the groundwater divide for the GWET system, indicating the PCE plumes in the intermediate and deep zones have migrated beyond the capture zone of the GWET system.

2.2 2013 Revised OU2 Remediation Area

Based on information provided in Section 1.5 and on 2012 analytical data, dissolved PCE is present across a greater areal extent and farther south from OU1 as shown on Figure 1-13 for shallow groundwater, Figure 1-14 for intermediate groundwater, and Figure 1-15 for deep groundwater.

- The leading edge of the 10 ppb PCE plume in the shallow zone is approximately between 173rd and 174th Streets and north of 111th Avenue; the leading edge of the 100 ppb PCE plume is along 175th Street and south of 110th Avenue.

- The leading edges of the 10 ppb, 100 ppb, and 1,000 ppb PCE plumes in the intermediate zone are estimated to be north of Linden Avenue and east of 167th Street.

- The leading edge of the 10 ppb PCE plume in the deep zone is estimated to be just west of 166th Street and north of Linden Avenue; the leading edge of the 100 ppb PCE plume is east of Merrick Boulevard and is estimated to be south of Sayres Avenue.

Vapor intrusion into off-site residences is possible from PCE in the shallow groundwater zone at the concentrations detected. Residences in the vicinity of the shallow plume area have been tested for vapor intrusion. Residents whose homes had PCE vapor concentrations at levels exceeding NYSDOH guidelines were offered mitigation systems; however, not all residents opted to have the mitigation systems installed. To provide for long-term protection of human health and to meet the remedial goal of preventing the potential for vapor intrusion, remediation of groundwater within the 10 ppb PCE plume in the shallow groundwater zone should be considered.

3.0 IDENTIFICATION OF SELECTED TREATMENT TECHNOLOGIES

The scope of this Focused Feasibility Study is limited to two treatment technologies: the existing GWET system, and one alternative treatment technology. The one alternative treatment technology, which has been shown to be effective and implementable at similar sites on Long Island for PCE plumes in the Upper Glacial Aquifer, is in situ chemical oxidation (ISCO).

3.1 Groundwater Extraction and Treatment

The existing GWET system was operated for three months in 2012. The GWET could be restarted and continue operation. The recovery wells extracted groundwater at the design rate of approximately 750 to 770 gpm for each pump for a total of approximately 1,520 gpm or 2,200,000 gallons when operated for twenty-four hours per day. PCE present in the influent from both extraction wells ranged from 28 to 230 ppb. Collected water was treated at OU1 with activated carbon prior to discharge to the storm sewer. Effluent samples from the treatment system and a sample at the storm sewer discharge point at Bergen Basin Jamaica Bay were collected and analyzed. No VOCs were detected in any of the effluent samples. Low estimated values of PCE at < 2 ppb were detected in the sample collected at Bergen Basin, but were not considered to be from the West Side site since the outfall contains water from many sources throughout Queens.

Effectiveness: The GWET system is effective at removing PCE from groundwater within the capture zone, estimated to be north of 111th Avenue and 174th Street. The PCE plume within the shallow zone is within this area. However, the plumes in the intermediate and deep zones are beyond the reach of the GWET system capture zone.

Implementability: The GWET system is already constructed and operational.

Cost: Since the GWET system has already been constructed and operated, there is no capital cost associated with GWET. Operation and maintenance costs associated with operating the GWET system are estimated at $2,000,000 per year. The overall operation, maintenance and monitoring (OM&M) cost would include a round of groundwater monitoring for VOCs in the existing (48) monitoring wells which is estimated at $5,000 annually.

3.2 ISCO

ISCO has been successfully employed at other sites in the New York City metropolitan area using permanganate injection. Permanganate is a common oxidant and has demonstrated significant effectiveness in oxidizing chlorinated ethenes such as PCE. As compared to other in situ chemical oxidation treatment technologies (e.g., Fenton's reagent), permanganate remains dissolved in groundwater until it encounters compounds (such as PCE) or naturally occurring organic or inorganic compounds to oxidize. Therefore, it has the potential to be effective for longer periods of time following injection and/or to move farther from the point of injection. Further, it can travel with groundwater to reach areas not accessible via surface injection (e.g., beneath buildings).

Effectiveness: Permanganate injection is effective in reducing the PCE concentrations within the treatment areas. Its effectiveness is only limited by the extent to which the permanganate can be brought into contact with the plume. Injection wells would be located within the shallow, intermediate and/or deep groundwater zones within the areal extent of the plume areas depending on the scope of the alternative.

Implementability: Injection wells would be installed in the shallow, intermediate, and deep groundwater zones, as needed, within the identified plume areas. Wells would be installed within the public access areas (sidewalks).

Cost: Permanganate injection will be discussed in detail in Section 4.2; however, the material itself presents the highest cost. A cost quote for material delivered to the site was received for this FFS. The cost for material and delivery alone of 5% permanganate solution to the site ready for injection is between $3.10 and $3.30 per gallon.

4.0 FOCUSED ALTERNATIVES

Two alternatives are considered for the West Side Corp. OU2 downgradient PCE plume:

- Alternative 1 – Existing Groundwater Extraction and Treatment System
- Alternative 2 – Sodium Permanganate Injection

For Alternative 2, several options have been developed differing in the degree to which they remediate the intermediate and deep groundwater zones. All Alternative 2 options will, at a minimum, include remediation within the 10 ppb PCE plume in the shallow zone to address the vapor intrusion exposure pathway. The alternatives are described in this section with regards to: size and configuration, time for remediation, spatial requirements, options for disposal, permitting requirements, and limitations.

All alternatives include continuation of the current indoor air monitoring and continued evaluation of the soil vapor intrusion exposure pathway.

4.1 Alternative 1 – Existing GWET System

Alternative 1 is continued operation of the existing groundwater extraction and treatment system. This alternative includes remediation within the 10 ppb PCE plume in the shallow groundwater zone which addresses the vapor intrusion exposure pathway after many years of pumping. Current indoor air monitoring will be continued in support of the evaluation of the soil vapor intrusion exposure pathway.

Size and Configuration

- Two recovery wells consisting of 40-horsepower Flowserve turbine pumps were installed in 12-inch diameter wells screened from the Gardiner's clay layer (~60 feet bgs) to the water table (~10 feet bgs).
- A sequestering agent delivery system injects a proprietary agent directly to the wells to keep iron in solution so that it does not foul the well screens or the carbon. The sequestering agent is stored in 2,500 gallon tanks in an existing DEP garage from where metering pumps deliver the agent via buried delivery lines.

- Three sets of carbon treatment units are present, each containing a pair of 20,000 pound carbon vessels and valving to select which are used as lead and lag, and to allow backflushing with city water.

- The GWET system would continue to extract approximately 1,520 gpm of groundwater on a 24-hr per day basis. Collected water would be treated and discharged to an adjacent storm sewer connected to an outfall in Bergen Basin in Jamaica Bay.

Time for Remediation

- Operation of the GWET system would continue until PCE concentrations in the groundwater monitoring wells and influent were determined to meet SCGs or be below acceptable levels which is estimated to be 20 years.

Spatial Requirements

- Construction is completed so there are no additional spatial requirements.

Options for Disposal

- Spent carbon is disposed offsite.

- Treated groundwater is discharged to an adjacent storm sewer with ultimate discharge to Jamaica Bay.

Permit Requirements

- No additional permits are required. The following existing permits would continue:

    1. SPDES permit for discharge of treated groundwater to adjacent storm sewer that ultimately discharges to Jamaica Bay.
    2. Chemical Bulk Storage Permit No. 2-000504 for the sequestering agent storage tanks.
    3. NYC Department of Building permits for office trailers.

4. Fire Department of New York Permit No. 2011129282 for operation of compressor used for carbon transfer.

5. NYCDEP Permit No. 551344 for a water meter to measure city water usage during backflush operation.

Limitations

- The effective remediation area of GWET may be considered to be the area between the extraction wells and the downgradient groundwater divide near 111th Avenue to the south and 174th Street to the west. The 10 ppb and 100 ppb PCE plumes in the shallow groundwater zone are to the east and north of this groundwater divide indicating that they are within the remediation area of the GWET system. However, the PCE plumes for the intermediate and deep groundwater zones for both 10 ppb and 100 ppb are beyond the groundwater divide for the GWET system, indicating the PCE plumes in the intermediate and deep zones have migrated beyond the remediation area for the GWET system.

- Extraction and treatment of over 1,500 gpm is a significant quantity of water on a continual basis.

Ecological Impacts

- There would be no change from current conditions.

4.2 Alternative 2 – ISCO Using Permanganate

Alternative 2 includes injection of sodium permanganate into injection wells. All three Alternative 2 options include remediation within the 10 ppb PCE plume in the shallow zone to address, at a minimum, the vapor intrusion exposure pathway. Two of the three options address groundwater contamination in the intermediate groundwater zone; one option addresses groundwater contamination in the deep groundwater zone. The options are presented as the following alternatives.

Alternative 2A - Injection within the 10 ppb PCE plume in the shallow groundwater zone. This alternative addresses the shallow portions of the plume that are most likely to contribute to the vapor intrusion exposure pathway.

Alternative 2B – Injection within the 10 ppb PCE plume in the shallow groundwater zone and within the 1,000 PCE plume in the intermediate groundwater zone. This alternative builds upon the scope of Alternative 2A by adding treatment of the most contaminated portion (1,000 ppb) of the plume in the intermediate groundwater zone.

Alternative 2C – Injection within the 10 ppb PCE plume in the shallow groundwater zone and within the 100 ppb PCE plumes in the intermediate and deep groundwater zones. This alternative builds upon the scope of Alternative 2A by adding treatment within the (100 ppb) plume in the intermediate and deep zones.

4.2.1 Alternative 2A

This alternative includes injection within the 10 ppb PCE plume in the shallow groundwater zone. Current indoor air monitoring will be continued in support of the evaluation of the soil vapor intrusion exposure pathway.

Size and Configuration

- A network of injection wells are proposed within the 10 ppb PCE plume in the shallow groundwater zone. As indicated on Figure 4-1, these wells are located along 174th, 175th, 176th, and 177th Streets.

- Injection well locations would be approximately 60 feet apart based on an effective radius of influence of 30 feet. This spacing has been utilized to remediate PCE plumes within the Upper Glacial Aquifer for similar projects on Long Island. A total of 60 shallow injection wells are proposed as indicated on Table 4-1.

- As presented in Appendix A, the volume of 5% permanganate solution to be injected is approximately 500,000 gallons for the shallow zone. This volume is established based on the natural oxidant demand being the main factor in determining permanganate requirement. This value is established assuming 10% of the natural oxidant demand will consume permanganate, but also includes a conservative safety factor of 5. The amount of oxidant demand is calculated based on the volume of the aquifer within an assumed 30-foot radius of influence of each injection well.

- As indicated on Table 4-2, two injection events would be used to inject the required amount of material into the shallow zone.

- Two new monitoring well clusters are proposed south of Linden Avenue downgradient of the leading edge of the PCE plume to assist in delineating the plume and assess the effectiveness of remediation.

- Performance monitoring would be conducted monthly for 5 months following the injection event for: color and field parameters (pH, specific conductivity, dissolved oxygen (DO), and oxidation/reduction potential [ORP]) in all injection and monitoring wells in the vicinity of, or downgradient of, injection wells.

- Approximately 6 months following the first injection, a round of groundwater samples would be collected and analyzed for VOCs, metals and alkalinity to determine the performance of the injection event and the need for revisions to subsequent injection events.

- The second and any subsequent injection events would follow a similar performance monitoring schedule.

Time for Remediation

- Design and installation of the injection well system would require less than one year.

- Each injection event may require a period of 4 months. Two injection events with performance monitoring could be completed within 2 years.

- While manifolds may be utilized to shorten the injection times, they have not been included as their feasibility and impact on the community would have to be evaluated.

Spatial Requirements

- It is anticipated that injection wells would be installed within the public access areas (i.e., sidewalks) within the remediation area.

- Injection events would be designed to limit disruptions to residents of the area; however, numerous trucks would be required for material delivery to the wells.

Options for Disposal

- Spoils (soil cuttings and drill water) from injection well installation would be drummed and disposed off-site.

Permit Requirements

- 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).
- Work and traffic permits may be required.

Limitations

- Due to the close proximity of nearby residences, the construction activities identified above will have impacts on nearby property owners and roadways.
- The design and scheduling of the injection activities will have to be carefully planned to avoid the presence of permanganate in the shallow groundwater during flooding events.
- While manifolds may be utilized to shorten the injection times, they have not been included as their feasibility and impact on the community would have to be evaluated.
- The locations of injection wells may be limited due to the presence of utilities.

Ecological Impacts

This alternative is not anticipated to have any significant impacts on ecological resources.

4.2.2 Alternative 2B

This alternative includes injection within the 10 ppb PCE plume in the shallow groundwater zone and within the 1,000 PCE plume in the intermediate groundwater zone. Current

indoor air monitoring will be continued in support of the evaluation of the soil vapor intrusion exposure pathway.

Size and Configuration

- A network of injection wells are proposed within the 10 ppb PCE plume in the shallow groundwater zone. As indicated on Figure 4-2, these wells are located along 174th, 175th, 176th, and 177th Streets.

- A network of injection wells are proposed within the 1,000 ppb PCE plume in the intermediate groundwater zone. As indicated on Figure 4-2 these wells are located on Sayres Ave immediately east and west of Merrick Blvd.

- Injection well locations would be approximately 60 feet apart (based on an effective radius of influence of 30 feet). This spacing has been utilized to remediate PCE plumes within the Upper Glacial Aquifer for similar projects on Long Island. A total of 60 shallow and 24 intermediate injection wells are proposed as indicated on Table 4-1.

- As presented in Appendix A, the volume of 5% permanganate solution to be injected is approximately 500,000 gallons for the shallow zone and 300,000 gallons for the intermediate zone. This volume is established based on the natural oxidant demand being the main factor in determining permanganate requirement. This value is established assuming 10% of the natural oxidant demand will consume permanganate, but also includes a conservative safety factor of 5. The amount of oxidant demand is calculated based on the volume of the aquifer within an assumed 30-foot radius of influence of each injection well.

- As indicated on Table 4-2, two injection events would be used for the shallow zone and 3 injection events would be used for the intermediate zone to inject the required amount of material.

- Two new monitoring well clusters are proposed south of Linden Avenue downgradient of the leading edge of the PCE plume to assist in delineating the plume and assess the effectiveness of remediation.

- Performance monitoring would be conducted monthly for 5 months following the injection event for: color and field parameters (pH, specific conductivity, dissolved oxygen (DO), and oxidation/reduction potential [ORP]) in all injection and monitoring wells in the vicinity of, or downgradient of, injection wells.

- Approximately 6 months following the first injection, a round of groundwater samples would be collected and analyzed for VOCs, metals and alkalinity to determine the performance of the injection event and the need for revisions to subsequent injection events.

- The second and third injection events, and any subsequent injection events, would follow a similar performance monitoring schedule.

Time for Remediation

- Design and installation of the injection well system would require less than one year.

- Each injection event may require a period of 6 months. Three injection events with performance monitoring could be completed within 3 years.

- While manifolds and extra crews may be utilized to shorten the injection times, they have not been included as their feasibility and impact on the community would have to be evaluated.

Spatial Requirements

- It is anticipated that injection wells would be installed within the public access areas (i.e., sidewalks) within the remediation area.

- Injection events would be designed to limit disruptions to residents of the area; however, numerous trucks would be required for material delivery to the wells.

Options for Disposal

- Spoils (soil cuttings and drill water) from injection well installation would be drummed and disposed off-site.

Permit Requirements

- 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).
- Work and traffic permits may be required.

Limitations

- Due to the close proximity of nearby residences, the construction activities identified above will have impacts on nearby property owners and roadways.
- The design and scheduling of the injection activities will have to be carefully planned to avoid the presence of permanganate in the shallow groundwater during flooding events.
- The locations of injection wells may be limited due to the presence of utilities.

Ecological Impacts

- This alternative is not anticipated to have any significant impacts on ecological resources.

4.2.3 Alternative 2C

This alternative includes injection within the 10 ppb PCE plume in the shallow groundwater zone and within the 100 PCE plume in the intermediate and deep groundwater zones. Current indoor air monitoring will be continued in support of the evaluation of the soil vapor intrusion exposure pathway.

Size and Configuration

- A network of injection wells are proposed within the 10 ppb PCE plume in the shallow groundwater zone. As indicated on Figure 4-3, these wells are located along 174th, 175th, 176th, and 177th Streets.

- A network of injection wells are proposed within the 100 ppb PCE plume in the intermediate groundwater zone. As indicated on Figure 4-3 these wells are located on Sayres Ave immediately east and west of Merrick Blvd, along 111th Ave, and along 174th, 175th, 176th and 177th Streets.

- A network of injection wells are proposed within the 100 ppb PCE plume in the deep groundwater zone. As indicated on Figure 4-3, these wells are located Sayres Ave east of Merrick Blvd, and along 174th and 175th Avenues.

- Injection well locations would be approximately 60 feet apart (based on an effective radius of influence of 30 feet). This spacing has been utilized to remediate PCE plumes within the Upper Glacial Aquifer for similar projects on Long Island. A total of 60 shallow and 100 intermediate and 36 deep injection wells are proposed as indicated on Table 4-1.

- As presented in Appendix A, the volume of 5% permanganate solution to be injected is approximately 500,000 gallons for the shallow zone, 1,225,000 gallons for the intermediate zone, and 450,000 gallons for the deep zone. This volume is established based on the natural oxidant demand being the main factor in determining permanganate requirement. This value is established assuming 10% of the natural oxidant demand will consume permanganate, but also includes a conservative safety factor of 5. The amount of oxidant demand is calculated based on the volume of the aquifer within an assumed 30-foot radius of influence of each injection well.

- As indicated on Table 4-2, two injection events would be required for the shallow zone and 3 injection events would be required for the intermediate and deep zones to inject the required amount of material.

- Two new monitoring well clusters are proposed south of Linden Avenue downgradient of the leading edge of the PCE plume to assist in delineating the plume and assess the effectiveness of remediation.

- Performance monitoring would be conducted monthly for 5 months following the injection event for: color and field parameters (pH, specific conductivity, dissolved

oxygen (DO), and oxidation/reduction potential [ORP]) in all injection and monitoring wells in the vicinity of, or downgradient of, injection wells.

- Approximately 6 months following the first injection, a round of groundwater samples would be collected and analyzed for VOCs, metals and alkalinity to determine the performance of the injection event and the need for revisions to subsequent injection events.

- The second and third injection events, and any subsequent injection events, would follow a similar performance monitoring schedule.

Time for Remediation

- Design and installation of the injection well system would require less than one year.

- Each injection event may require a period of 6 months assuming two crews. Three injection events with performance monitoring could be completed within 3 years.

- While manifolds and extra crews may be utilized to shorten the injection times, their feasibility and impact on the community would have to be evaluated.

Spatial Requirements

- It is anticipated that injection wells would be installed within the public access areas (i.e., sidewalks) within the remediation area.

- Injection events would be designed to limit disruptions to residents of the area; however, numerous trucks would be required for material delivery to the wells.

Options for Disposal

- Spoils (soil cuttings and drill water) from injection well installation would be drummed and disposed off-site.

Permit Requirements

- 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).
- Work and traffic permits may be required.

Limitations

- Due to the close proximity of nearby residences, the construction activities identified above will have impacts on nearby property owners and roadways.
- The design and scheduling of the injection activities will have to be carefully planned to avoid the presence of permanganate in the shallow groundwater during flooding events.
- The locations of injection wells may be limited due to the presence of utilities.

Ecological Impacts

- This alternative is not anticipated to have any significant impacts on ecological resources.

5.0 DETAILED ANALYSIS OF ALTERNATIVES

5.1 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.

5.1.1 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 standards, criteria, and guidance (SCGs). This evaluation focuses on how a specific alternative achieves protection over time and how potential site risks are reduced. The analysis includes how the contamination is to be eliminated, reduced, or controlled.

5.1.2 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 contaminants detected and the location of the site.

5.1.3 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, adequacy of controls used to manage residual contamination, and the reliability of controls used to manage residual contamination.

5.1.4 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 contamination at the site.

5.1.5 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 action, environmental impacts that result from the remedial action, and the time required until the remedial action objectives are achieved.

5.1.6 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, off-site treatment, and storage and disposal services.

5.1.7 Cost

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

5.1.8 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.

5.1.9 Land Use

This criterion addresses the current, intended, and reasonably anticipated future land use in the area as impacted by the remediation.

5.2 Alternative 1 – Existing GWET System

5.2.1 Overall Protection of Public Health and the Environment

The existing GWET system may be operated until groundwater meets SCGs or acceptable levels and will be effective in the long-term in the area of highest concentrations in the shallow groundwater zone (i.e. the hydraulic capture zone north and east of the groundwater divide at approximately 111th Avenue and 174th Street. Alternative 1 would not remediate the PCE plume or meet SCGs downgradient of the groundwater divide or within the highest concentrations in the intermediate groundwater zone, and therefore would not protect human health or the environment downgradient. It addresses the vapor intrusion exposure pathway in the long term through ongoing vapor intrusion (VI) monitoring and mitigation, and after many years of pumping through contaminant removal from groundwater.

5.2.2 Compliance with SCGs

Following a long term of groundwater extraction and treatment, Alternative 1 would meet SCGs for groundwater for the highest concentration area in the shallow groundwater zone (i.e. the hydraulic capture zone), but is not effective in meeting SCGs downgradient of the groundwater divide or within the highest concentrations in the intermediate groundwater zone.

5.2.3 Long-term Effectiveness and Permanence

Since remediation of source soils at OU1 is complete, additional aquifer contamination from source material should not occur and groundwater remediation is considered effective and permanent. Through groundwater extraction and treatment, the potential for soil vapor intrusion would be reduced in the long term as PCE concentrations were reduced. Operation of the GWET system would be effective in the long-term; however, residual PCE contamination in groundwater would remain and continue to migrate downgradient of the groundwater divide. This alternative is

not considered effective or permanent in the long-term at removing all groundwater PCE contamination.

5.2.4 Reduction of Toxicity, Mobility and Volume with Treatment

The extraction wells hydraulically contain a portion of the PCE plume thereby limiting its mobility in the aquifer. However, downgradient of the groundwater divide the PCE plume would continue to migrate. Treatment of extracted groundwater would reduce the toxicity and volume of PCE contamination in groundwater north of the divide in the shallow and potentially the intermediate groundwater zone (within the zone of groundwater extraction).

5.2.5 Short-term Effectiveness

As construction is already completed for this alternative, there would be no additional impacts to workers or the community.

5.2.6 Implementability

Since there are no additional construction activities and the system was previously operated successfully, there are no construction or operation implementation issues with this alternative. Approvals and permits for the GWET system are already in place.

5.2.7 Cost

Since the GWET system has already been constructed and operated, there is no capital cost associated with GWET. Operation and maintenance costs associated with operating the GWET system are estimated at $2,000,000 per year. Annual groundwater monitoring of the existing 48 monitoring wells is estimated at $5,000. It is anticipated that GWET would continue for a period of at least 20 years.

5.2.8 Land Use

There are no land use issues associated with this alternative.

5.3 Alternative 2A

5.3.1 Overall Protection of Public Health and the Environment

This alternative includes injection within the 10 ppb PCE plume in the shallow groundwater zone. This alternative is considered protective of public health and the environment addressing the vapor intrusion exposure pathway through ongoing VI monitoring and mitigation, and through remediating shallow overburden groundwater. Alternative 2A would not remediate the PCE plume or meet SCGs in the intermediate or deep groundwater zones.

5.3.2 Compliance with SCGs

Groundwater SCGs would be met within the highest concentration area in the shallow groundwater zone following injection within the 10 ppb PCE plume area. SCGs would not be met for groundwater within the intermediate or deep zones.

5.3.3 Long-term Effectiveness and Permanence

Since remediation of source soils at OU1 is complete, additional aquifer contamination from source material should not occur. Permanganate injection in groundwater downgradient of the source area is an effective and permanent treatment technology for the shallow groundwater zone. This alternative is not considered effective or permanent in the long-term at removing groundwater PCE contamination in the intermediate or deep groundwater zones.

5.3.4 Reduction of Toxicity, Mobility and Volume with Treatment

Alternative 2A utilizes in situ treatment through permanganate injection to reduce the toxicity and volume of PCE contamination in the shallow groundwater and soil vapor. However, downgradient of the groundwater divide the PCE plume in the intermediate and deep groundwater zones would continue to migrate.

5.3.5 Short-term Effectiveness

Installation of the injection wells and the injection events pose short-term risks and disruptions to workers and the community. These could be managed through an appropriate

health and safety program, with controls, and community air monitoring. Noise and disruption of daily traffic patterns will occur.

5.3.6 Implementability

A utility survey within the area would be required to assist with injection well location. Injection wells would be installed within the public access (i.e., sidewalk) areas within the remediation zone. Injection wells are proposed within the Upper Glacial Aquifer terminating above the Gardiner's clay layer found at a depth of 62 to 105 feet bgs within the study area. An average depth of 90 feet bgs is used for the cost estimate. Submission of an Inventory of Injection Wells Form 7520-16 as part of the Underground Injection Control program operated by the USEPA would be required.

Two injection events would be used to inject the required amount of material; however, even with multiple events, injection at each well will continue beyond 8 hours. Manifolds and multiple crews working may be considered for use during implementation to reduce the time frame. Two injection events of 4 months each would be used to inject the required amount of material. The time for design, construction, and injection is expected to be approximately 3 years.

5.3.7 Cost

Estimated capital and OM&M costs for Alternative 2A are presented on Table 5-1. The total capital cost is $4,600,000. Annual OM&M costs of $5,000 for Alternative 2A include 5 years of groundwater monitoring post-injection to evaluate the long-term performance of the alternative for the Five Year Review.

5.3.8 Land Use

There are no land use issues associated with this alternative.

5.4 Alternative 2B

5.4.1 Overall Protection of Public Health and the Environment

This alternative includes injection within the 10 ppb PCE plume in the shallow groundwater zone and within the 1,000 ppb PCE plume in the intermediate groundwater zone.

This alternative is considered protective of public health and the environment addressing the vapor intrusion exposure pathway through ongoing VI monitoring and mitigation, and through remediating the highest concentrations in the shallow and intermediate groundwater zones (greater than 10 ppb PCE in the shallow zone and greater than 1,000 ppb PCE in the intermediate zone). Alternative 2B would not fully remediate the PCE plume or meet SCGs in the intermediate and deep groundwater zones as it does not address the deep zone and targets only the most contaminated portion of the intermediate zone.

5.4.2 Compliance with SCGs

Groundwater SCGs would be met within the highest concentration area of the shallow groundwater zone following injection within the 10 ppb PCE plume area. SCGs would not be fully met for groundwater within the intermediate or deep zones; however, permanganate injection would significantly reduce contamination levels within the area of highest intermediate zone contamination.

5.4.3 Long-term Effectiveness and Permanence

Since remediation of source soils at OU1 is complete, additional aquifer contamination from source material should not occur. Permanganate injection in groundwater downgradient of the source area is an effective and permanent treatment technology for the most contaminated portions of the shallow and intermediate groundwater zones. This alternative not targeted to treat all PCE present above SCGs in the deep groundwater zone nor the portions of the intermediate zone with less than 1,000 ppb of PCE.

5.4.4 Reduction of Toxicity, Mobility and Volume with Treatment

Alternative 2B utilizes in situ treatment through permanganate injection to reduce the toxicity and volume of PCE contamination in soil vapor and in the areas of highest concentrations in the shallow and intermediate groundwater zones

5.4.5 Short-term Effectiveness

Installation of the injection wells and the injection events pose short-term risks and disruptions to workers and the community. These could be managed through an appropriate

health and safety program, with controls, and community air monitoring. Noise and disruption of daily traffic patterns will occur.

5.4.6 Implementability

A utility survey within the area would be required to assist with injection well location. Injection wells would be installed within the public access (i.e., sidewalk) areas within the remediation zone. Injection wells are proposed within the Upper Glacial Aquifer terminating above the Gardiner's clay layer found at a depth of 62 to 105 feet bgs within the study area. An average depth of 90 feet bgs is used for the cost estimate. Submission of an Inventory of Injection Wells Form 7520-16 as part of the Underground Injection Control program operated by the USEPA would be required.

Three injection events would be used to inject the required amount of material; however, even with multiple events, injection at each well will continue beyond 8 hours. Manifolds and multiple crews working may be considered for use during implementation to reduce the time frame. Three injection events of 6 months each would be used to inject the required amount of material. The time for design, construction, and injection is expected to be approximately 4 years.

5.4.7 Cost

Estimated capital and OM&M costs for Alternative 2B are presented on Table 5-1. The total capital cost is $7,200,000. Annual OM&M costs of $5,000 for Alternative 2B include 5 years of groundwater monitoring post-injection to evaluate the long-term performance of the alternative for the Five Year Review.

5.4.8 Land Use

There are no land use issues associated with this alternative.

5.5 Alternative 2C

5.5.1 Overall Protection of Public Health and the Environment

This alternative includes injection within the 10 ppb PCE plume in the shallow groundwater zone and within the 100 ppb PCE plumes in the intermediate and deep groundwater

zones. This alternative is considered protective of public health and the environment addressing vapor intrusion through ongoing VI monitoring and mitigation, and through remediating the highest concentrations in the shallow (greater than 10 ppb PCE), intermediate (greater than 100 ppb PCE), and deep (greater than 100 ppb PCE) groundwater zones.

5.5.2 Compliance with SCGs

Groundwater SCGs would be met within the highest concentration area of the shallow groundwater zone following injection within the 10 ppb PCE plume area. SCGs would not be fully met for groundwater within the intermediate or deep zones; however, permanganate injection would significantly reduce contamination levels within the area of highest intermediate and deep zone contamination.

5.5.3 Long-term Effectiveness and Permanence

Since remediation of source soils at OU1 is complete, additional aquifer contamination from source material should not occur. Permanganate injection in groundwater downgradient of the source area is an effective and permanent treatment technology for the shallow, intermediate and deep groundwater zones, although it is not targeted to treat all PCE present above SCGs in the intermediate and deep groundwater zones.

5.5.4 Reduction of Toxicity, Mobility and Volume with Treatment

Alternative 2C utilizes in situ treatment through permanganate injection to reduce the toxicity and volume of PCE contamination in shallow groundwater and soil vapor, and within the intermediate and deep groundwater zones.

5.5.5 Short-term Effectiveness

Installation of the injection wells and the injection events pose short-term risks and disruptions to workers and the community. These could be managed through an appropriate health and safety program, controls, and community air monitoring. Noise and disruption of daily traffic patterns will occur.

5.5.6 Implementability

A utility survey within the area would be required to assist with injection well location. Injection wells would be installed within the public access (i.e., sidewalk) areas within the remediation zone. Injection wells are proposed within the Upper Glacial Aquifer terminating above the Gardiner's clay layer found at a depth of 62 to 105 feet bgs within the study area. An average depth of 90 feet bgs is used for the cost estimate. Submission of an Inventory of Injection Wells Form 7520-16 as part of the Underground Injection Control program operated by the USEPA would be required.

Three injection events would be used to inject the required amount of material; however, even with multiple events, injection at each well will continue beyond 8 hours. Manifolds and multiple crews working would be required during implementation to reduce the time frame. Three injection events of 6 months each would be used to inject the required amount of material assuming two crews. The time for design, construction, and injection is expected to be approximately 4 years.

5.5.7 Cost

Estimated capital and OM&M costs for Alternative 2C are presented on Table 5-1. The total capital cost is $19,200,000. Annual OM&M costs of $5,000 for Alternative 2C include 5 years of groundwater monitoring post-injection to evaluate the long-term performance of the alternative for the Five Year Review.

5.5.8 Land Use

There are no land use issues associated with this alternative.

5.6 Comparative Analysis of Alternatives

A comparison of the alternatives in light of the evaluation criteria follows

5.6.1 Overall Protection of Public Health and the Environment

The existing GWET system of Alternative 1 may be operated until SCGs are met in groundwater and be effective and permanent in the long-term, but only within the effective

remediation area extending about 900 to 1,300 feet downgradient from the recovery wells, to approximately to 111th Avenue and 174th Street. Alternative 1 addresses the vapor intrusion exposure pathway through ongoing VI monitoring and mitigation, and after many years of operation of the GWET system through removal of shallow contamination. Alternatives 2A, 2B, and 2C are protective of public health and the environment addressing the vapor intrusion exposure pathway through ongoing VI monitoring and mitigation, and also through remediating groundwater via oxidative destruction of the PCE. Alternatives 2A, 2B, and 2C provide the same protection to human health from the vapor intrusion exposure pathway from the shallow groundwater zone.

In terms of groundwater remediation, all alternatives provide protection to human health and the environment in the shallow groundwater zone through groundwater remediation. However, alternatives 2A, 2B and 2C would require a substantially shorter remediation time to achieve this protection as compared to Alternative 1. Alternative 2C provides the greatest protection, followed by Alternative 2B and then 2A.

5.6.2 Compliance with SCGs

Alternative 1 would meet SCGs for groundwater within the effective remediation area, but is not effective in meeting SCGs downgradient of the groundwater divide. Groundwater SCGs would be met in the shallow groundwater zone for Alternatives 2A, 2B and 2C following injection within the 10 ppb PCE plume area. SCGs would not be met for groundwater within the intermediate or deep zones for Alternatives 2A, 2B or 2C, but would be reduced to more acceptable levels within the highest concentrations of the intermediate plume for Alternative 2B, and within the intermediate and deep plumes for Alternative 2C.

5.6.3 Long-term Effectiveness and Permanence

Since remediation of source soils at OU1 is complete, additional aquifer contamination from source material should not occur therefore, groundwater remediation is considered effective and permanent. For Alternative 1, residual PCE contamination in groundwater would remain and would continue to migrate downgradient of the groundwater divide. Permanganate injection included in Alternatives 2A, 2B, and 2C in groundwater downgradient of the source area is an effective and permanent treatment technology for the shallow, intermediate and deep groundwater

zones. Alternative 2C provides the greatest effectiveness, followed by Alternative 2B and Alternative 2A.

5.6.4 Reduction of Toxicity, Mobility and Volume with Treatment

For Alternative 1, the extraction wells hydraulically contain a portion of the PCE plume thereby limiting its mobility in the aquifer. However, downgradient of the groundwater divide the PCE plume would continue to migrate. Groundwater treatment in Alternative 1 reduces the toxicity and volume of PCE contamination in the shallow and potentially the intermediate groundwater zones. Alternatives 2A, 2B, and 2C utilize in situ treatment through permanganate injection to reduce the toxicity and volume of PCE contamination in shallow groundwater. Alternative 2B also reduces toxicity and volume in the most contaminated intermediate groundwater zone. Alternative 2C provides the greatest reduction in the shallow, intermediate and deep groundwater zones.

5.6.5 Short-term Effectiveness

Alternative 1 poses no additional impacts to workers or the community. For Alternatives 2A, 2B and 2C, installation of the injection wells and the injection events pose short-term risks and disruptions to workers and the community. Alternatives 2A, 2B and 2C would include noise and traffic impacts to the community with Alternative 2C presenting the greatest impacts followed by Alternative 2B and 2A. These could be managed through an appropriate health and safety program, with utilizing a 5% permanganate solution, with controls and community air monitoring.

5.6.6 Implementability

Since there are no additional construction activities and the system was previously operated for 3 months, there are no construction or operation implementation issues for Alternative 1. Approvals and permits for Alternative 1 are already in place. Alternatives 2A, 2B and 2C would be more difficult to implement as they include installation of a large quantity of injection wells within the public access (i.e., sidewalk) areas in the Upper Glacial Aquifer to an approximate depth of 90 feet bgs within the remediation zone. A utility survey within the area would be required. Submission of an Inventory of Injection Wells Form 7520-16 as part of the UIC program operated by the USEPA would be required.

The total time frame for remediation for Alternative 2A is approximately 3 years; for Alternative 2B is approximately 4 years; and for Alternative 2C is approximately 4 years utilizing twice the number of crews. These are substantially shorter than for Alternative 1 with groundwater extraction and treatment operations (estimated at 20 years).

5.6.7 Cost

The total present worth of alternatives are presented on Table 5-2 using a 5 percent discount rate and a 20 year operation period for the Alternative 1 GWET system and 5 years of groundwater monitoring for Alternatives 2A, 2B, and 2C. Alternative 1 presents the highest present worth cost followed by Alternatives 2C, then 2B, and finally 2A with the lowest present worth cost.

5.6.8 Land Use

None of the alternatives negatively impacts land use within the remediation area.

6.0 RECOMMENDED REMEDY

Selection of a recommended remedy considers the effectiveness of the alternative and the benefits for protection of human health and the environment, as well as the impacts, time and cost required to implement each alternative.

6.1 Basis for Recommendation

Alternatives 1, 2A, 2B, and 2C all address the remedial action objective associated with the vapor intrusion exposure pathway in the long term through ongoing VI monitoring and mitigation and groundwater remediation. Alternative 1 requires a longer time period to fully address the vapor intrusion exposure pathway as it requires many years of pumping to remove contamination from shallow groundwater. Alternatives 2A, 2B, and 2C, which include equal levels of remediation in the shallow groundwater zone, address the vapor intrusion exposure pathway in a shorter time frame (3 to 4 years as compared to 20 years for Alternative 1). By including remediation of the intermediate groundwater zone in Alternatives 2B and 2C, these alternatives provide a greater level of protection from soil vapor which could migrate from the intermediate groundwater zone to the shallow groundwater zone and into the residences.

Alternatives 1, 2A, 2B, and 2C all include groundwater remediation through treatment in order to meet the remedial action objectives of limiting further migration of contaminated overburden groundwater and reducing the level of groundwater contamination to SCGs. Alternative 1 includes a substantial quantity of groundwater extraction and treatment (1,500 gpm) over a period of 20 years. At the end of this time period, SCGs would be met within the effective remediation area north and east of the groundwater divide at approximately 111th Avenue and 174th Street. Contamination beyond this groundwater divide would not be reduced and would continue to migrate. Alternative 2A provides groundwater remediation of the highest concentrations in the shallow groundwater zone within the same remediation area as Alternative 1 through 60 shallow injection wells, but within the shorter time period of 3 years. Contamination within the intermediate and deep groundwater zones would not be reduced and would continue to migrate. Alternative 2B provides groundwater remediation of not only the highest concentrations in the shallow groundwater zone through 60 shallow injection wells, but also in the intermediate

groundwater zone. The additional level of effort to achieve this remediation requires 24 injection wells in the intermediate groundwater zone and one year. For Alternative 2B, contamination in the areas of highest concentrations in the shallow and intermediate groundwater zones would be reduced; contamination in the less contaminated intermediate and deep groundwater zones would continue to migrate. Alternative 2C provides groundwater remediation of not only the highest concentrations in the shallow and intermediate groundwater zones, but also groundwater exceeding the 100 ppb PCE plume in the intermediate and deep groundwater zones. The additional level of effort to achieve this remediation, as compared to Alternative 2A, is 100 intermediate and 36 deep injection wells. In order to inject the quantity of material required to remediate the greater depth and areal extent, twice the number of work crews would be required during a 4 year period. For Alternative 2C, contamination in the shallow, intermediate, and deep groundwater zones would be reduced with the least potential for continued migration.

Alternatives 2A, 2B, and 2C are preferred over Alternative 1 since they meet the remedial action objectives for the soil vapor intrusion pathway and groundwater in a shorter time period and at a lower cost. Alternatives 2A, 2B, and 2C are equal in shallow groundwater zone remediation. Alternatives 2B and 2C provide greater levels of groundwater remediation; however, there would be substantial added time, effort, and cost required for Alternative 2C to install an additional 100 injection wells in the intermediate zone and 36 injection wells in the deep zone, as compared to 24 intermediate injection wells for Alternative 2B. Alternative 2C would result in greater impacts to the community through longer times for construction, and doubling the manpower, injection material and trucks during injection events.

Alternative 2B, which addresses the soil vapor intrusion pathway and provides groundwater remediation within the highest concentrations in the shallow and intermediate groundwater zones within 3 years with fewer implementation impacts is the recommended remedy for the site.

6.2 Recommended Remedy Components

The components of the Recommended Remedy (Alternative 2B) are shown on Figure 6-1. The components of the recommended remedy are as follows:

- A network of injection wells are proposed within the 10 ppb PCE plume in the shallow groundwater zone. As indicated on Figure 4-2, these wells are located along 174th, 175th, 176th, and 177th Streets.

- A network of injection wells are proposed within the 1,000 ppb PCE plume in the intermediate groundwater zone. As indicated on Figure 4-2 these wells are located on Sayres Ave immediately east and west of Merrick Blvd.

- Injection well locations would be approximately 60 feet apart (based on an effective radius of influence of 30 feet). This spacing has been utilized to remediate PCE plumes within the Upper Glacial Aquifer for similar projects on Long Island. A total of 60 shallow and 24 intermediate injection wells are proposed as indicated on Table 4-1.

- As presented in Appendix A, the volume of 5% permanganate solution to be injected is approximately 500,000 gallons for the shallow zone and 300,000 gallons for the intermediate zone. This volume is established based on the natural oxidant demand being the main factor in determining permanganate requirement. This value is established assuming 10% of the natural oxidant demand will consume permanganate, but also includes a conservative safety factor of 5. The amount of oxidant demand is calculated based on the volume of the aquifer within an assumed 30-foot radius of influence of each injection well.

- As indicated on Table 4-2, two injection events would be used for the shallow zone and 3 injection events would be used for the intermediate zone to inject the required amount of material.

- Two new monitoring well clusters are proposed south of Linden Avenue downgradient of the leading edge of the PCE plume to assist in delineating the plume and assess the effectiveness of remediation.

- Performance monitoring would be conducted monthly for 5 months following the injection event for: color and field parameters (pH, specific conductivity, dissolved

oxygen (DO), and oxidation/reduction potential [ORP]) in all injection and monitoring wells in the vicinity of, or downgradient of, injection wells.

- Approximately 6 months following the first injection, a round of groundwater samples would be collected and analyzed for VOCs, metals and alkalinity to determine the performance of the injection event and the need for revisions to subsequent injection events.

- The second and third injection events, and any subsequent injection events, would follow a similar performance monitoring schedule.

The total capital cost of the recommended alternative is approximately $7,200,000, annual OM&M costs are approximately $5,000, and the total present worth is approximately $7,222,000.

6.3 Pre-Design Investigations

A utility survey will be necessary prior to excavation activities.

Collection of site-specific Natural Oxidant Demand values will be conducted.

A round of groundwater data will be collected in order to confirm the location of the highest concentrations of PCE in the shallow and intermediate groundwater zones.

Two new monitoring well clusters will be located and installed south of Linden Avenue to assist in delineating the leading edge of the plume.

REFERENCES

URS Corporation, April 2013. *West Side Corp. Site OU2 Station Treatment System Operations Report* prepared for the NYSDEC.

Malcolm Pirnie, Inc. March 2009. *West Side Corporation Operable Unit No. 2 Final Offsite Plume Delineation and Investigation* prepared for the NYSDEC.

TABLES

TABLE 1-1

PCE Concentrations in Geoprobes B1 to B20

BORE	B-1		B-2		B-3/3A		B-4		B-5	
177th Street	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE
	12	ND	12	75	12	110	12	9	12	ND
	27	54	27	270	27	350	27	700	27	300
					30	63				
					37	560				
					44	830				
					51	380				
					58	170				

BORE	B-6		B-7		B-8/8A		B-9		B-10	
177th Street	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE
	12	10	12	ND	12	ND	12	ND	12	ND
	27	850	27	990	27	820	27	430	27	120
					30	1200				
					37	820				
					44	580				
					51	350				
					58	300				

BORE	B-11		B-12		B-13		B-14		B-15	
172nd Street	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE
	12	ND	12	ND	12	ND	12	ND	12	ND
	27	230	27	61	27	30	27	20	27	7

BORE	B-16		B-17		B-18		B-19		B-20	
172nd Street	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE
	12	ND	12	ND	12	ND	12	ND	12	ND
	27	180	27	210	27	330	27	970	27	3500

Notes:
Depths in feet (ft) below ground surface (bgs)
PCE concentrations in parts-per-billion (ppb)

Source: Malcolm Pirnie, 2009 - Table 5-1

TABLE 1-1

PCE Concentrations in Geoprobes B21 to B50

BORE	B-21		B-22		B-23		B-24		B-25	
	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE
	16	2.2	15	5.4	16	3.2	16	2.3	16	6.0
	23	427	22	2.3	23	1.5	23	132	23	500
	30	8320	29	548	30	87	30	1263	30	41
	37	6066	36	5505	37	397	37	6390	37	119
	44	3667	43	7105	44	91	45	6393	44	1125
	51	-	50	1957	51	1972	52	1875	51	1575
	58	2016	57	2144	58	809	59	670	58	534
	65	1560	64	263	65	220	66	262	65	132
BORE	**B-26**		**B-27**		**B-28**		**B-29**		**B-30**	
	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE
	16	2.5	16	ND	16	ND	16	ND	16	ND
	23	3.8	23	49	23	4.7	23	3.5	23	ND
	30	1507	30	99	30	13	30	31	30	74
	37	3814	37	421	37	94	37	45	37	380
	44	13139	44	7227	44	172	44	4309	44	1235
	51	5064	51	16643	51	414	51	412	51	689
	58	2132	58	9215	58	1683	58	1374	58	200
	65	937	65	20991	66	238	66	1611	66	14
BORE	**B-31**		**B-32**		**B-33**		**B-34**		**B-35**	
	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE
	16	ND	16	ND	16	ND	16	ND	16	ND
	23	2.1	23	ND	23	ND	23	ND	23	ND
	30	20	30	90	30	6.6	30	ND	30	ND
	37	157	37	109	37	8.9	37	ND	37	ND
	44	74	44	7.1	44	2.0	44	1.2	44	ND
	51	73	51	5.3	51	1.9	51	8.2	51	ND
	58	10	58	5.7	58	11	58	7.3	58	ND
	66	8.1	66	9.5	66	6.6	66	2.8	65	ND

Notes:
Depths in feet (ft) below ground surface (bgs)
PCE concentrations in parts-per-billion (ppb)

Source: Malcolm Pirnie, 2009 - Table 5-2

TABLE 1-1

PCE Concentrations in Geoprobes B21 to B50 (Continued)

BORE	B-36		B-37		B-38		B-39		B-40	
	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE
	16	ND	23	ND	16	ND	16	ND	23	ND
	23	ND	30	2.7	23	ND	23	ND	30	ND
	30	ND	37	7.4	30	ND	30	5.3	37	ND
	37	2.2	44	23	37	ND	37	12	44	6.7
	44	85	51	114	44	18	44	435	51	9.7
	51	15	58	160	51	117	51	1241	58	228
	58	335	65	784	58	758	58	853	65	238
	65	814	-	-	65	467	65	4743	72	1116
BORE	**B-41**		**B-42**		**B-43**		**B-44**		**B-45**	
	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE
	23	ND	23	ND	16	ND	16	ND	16	ND
	30	5.4	30	1.5	23	ND	23	ND	23	ND
	37	7.4	37	3.4	30	ND	30	ND	30	ND
	44	26	44	17	37	ND	37	ND	37	ND
	51	73	51	36	44	ND	44	ND	45	ND
	58	171	58	161	51	ND	51	ND	51	ND
	65	334	66	256	58	ND	58	ND	58	ND
	72	100	72	147	66	ND	61	ND	66	ND
BORE	**B-46**		**B-47**		**B-48**		**B-49**		**B-50**	
	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE	Depth	PCE
	16	ND	16	ND	16	ND	16	ND	16	ND
	23	ND	23	ND	23	ND	23	ND	23	ND
	30	ND	30	ND	30	ND	30	ND	30	ND
	37	ND	37	ND	37	ND	37	ND	37	ND
	44	ND	44	ND	44	ND	44	ND	44	ND
	51	ND	51	ND	51	ND	51	ND	51	ND
	58	ND	54	ND	58	ND	58	ND	58	ND
	66	ND	-	-	-	-	61	ND	66	ND

Notes:
Depths in feet (ft) below ground surface (bgs)
PCE concentrations in parts-per-billion (ppb)

Source: Malcolm Pirnie, 2009 - Table 5-2

Table 4-1
Proposed Number of Injection Wells

Injection wells at 60-foot intervals				Alternative 2A			Alternative 2B			Alternative 2C		
	Shallow	Inter	Deep	Shallow	Inter	Deep	Shallow	Inter	Deep	Shallow	Inter	Deep
Along 177th St N to S												
109th - 110th (600 ft)	11	11		11			11			11	11	
110th - 111th (600 ft)	5	5		5			5			5	5	
Along 176th St N to S												
109th - 110th (600 ft)	11	11		11			11			11	11	
110th - 111th (600 ft)	11	11		11			11			11	11	
Along 175th St N to S												
110th - 111th (600 ft)	11	11		11			11			11	11	
110th - 111th (420 ft)			8									8
Along 174th St N to S												
110th - 111th (600 ft)	11	11		11			11			11	11	
110th - 111th (300 ft)			5									5
111th - 112th (600 ft)		10	10								10	10
Along 111th St N to S												
172nd - 173rd (300 ft)		6									6	
Along Sayres Ave W to E East of Merrick Blvd												
250 ft		5	5					5			5	5
200 ft		4	4					4			4	4
200 ft		4	4					4			4	4
Along Sayres Ave W to E West of Merrick Blvd												
200 ft		4						4			4	
200 ft		4						4			4	
150 ft		3						3			3	
	Shallow	Inter	Deep	Shallow	Inter	Deep	Shallow	Inter	Deep	Shallow	Inter	Deep
TOTALS	**60**	**100**	**36**	**60**			**60**	**24**		**60**	**100**	**36**

Note: Spacing at 60-foot intervals refers to a 30-foot radius of influence

Well Screen Depths: Shallow: 12 - 22 feet bgs Intermediate: 35 - 45 feet bgs Deep: 70 - 80 feet bgs
Groundwater Zones: Shallow: 10 - 30 feet bgs Intermediate: 30 - 60 feet bgs Deep: 60 - 90 feet bgs

ALTERNATIVE 2A - 60 Shallow injection wells within 10 ppb PCE plume

ALTERNATIVE 2B - 60 Shallow injection wells within 10 ppb PCE plume
24 Intermediate injection wells along Sayres Ave within 1,000 ppb PCE plume

ALTERNATIVE 2C- 60 Shallow injection wells within 10 ppb PCE plume
100 Intermediate injection wells within 100 ppb PCE plume (includes 1,000 ppb PCE plume)
36 Deep injection wells within 100 ppb PCE plume

Table 4-2
Remedial Alternative Components

Alternative 2A						
	# of Injection Wells	Gallons 5% Permanganate Solution	@ 8 gpm required injection hrs per well	Productivity Reduction	# of Injection Events	Manhours per Injection Event (assume 2 person crew)
Shallow Intermediate Deep	60	500,000	18	0.75	2	1,440

Alternative 2B						
	# of Injection Wells	Gallons 5% Permanganate Solution	@ 8 gpm required injection hrs per well	Productivity Reduction		Manhours per Injection Event (assume 2 person crew)
Shallow Intermediate Deep	60 24	500,000 300,000	18 27	0.75 0.75	2 3	1,440 576

Alternative 2C						
	# of Injection Wells	Gallons 5% Permanganate Solution	@ 8 gpm required injection hrs per well	Productivity Reduction	# of Injection Events	Manhours per Injection Event (assume 2 person crew)
Shallow Intermediate Deep	60 100 36	500,000 1,225,000 450000	18 26 27	0.75 0.75 0.75	2 3 3	1,440 2,312 864

Table 4-3
Performance Monitoring
Well Schedule

Frequency of Groundwater Sample Collection	Baseline Monitoring Prior to 1st Injection Event						Prior to 2nd Injection Event						Prior to Subsequent Injection Events
Parameters		Month 1	Month 2	Month 3	Month 4	Month 5	Month 6 (approx)	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6 (approx)
VOCs, Metals, Alkalinity	x						x						x
Color		x	x	x	x	x	x	x	x	x	x	x	x
Field Parameters (pH, DO, ORP, Specific Conductivity)	x	x	x	x	x	x	x	x	x	x	x	x	x

Baseline Monitoring	Shallow	Intermediate	Deep
W-01	S	I	D
W-02	S	I	D
W-03	S	I	D
W-04	S	I	D
W-05	S		
W-06	S	I	D
W-07	S	I	D
W-08	S	I	D
W-09	S	I	D
W-10	S	I	D
W-11		I	D
W-12	S	I	D
W-13	S	I	D
W-14	S	I	D
W-15	S	I	D
MW-24-5	S	I	D
MW-24-6	S	I	D
New Monitoring Well P1	S	I	D
New Monitoring Well P2	S	I	D
Totals	18	18	18
Total # of Groundwater Samples			**54**
Total # of Sampling Locations			**19**

Prior to Injection Events	Shallow	Intermediate	Deep	Total # of Samples	Total # of Sample Locations
Baseline Monitoring Wells	18	18	18		
Alternative 2A	60			114	79
Alternative 2B	60	24		138	103
Alternative 2C	60	100	36	250	132

TABLE 5-1
COST ESTIMATES FOR ALTERNATIVES 2A, 2B, 2C

			ALT 2A		ALT 2B		ALT 2C	
DESCRIPTION	**UNIT**	**UNIT PRICE FROM APPENDIX B**	**EST QTY**	**TOTAL PRICE**	**EST QTY**	**TOTAL PRICE**	**EST QTY**	**TOTAL PRICE**
Site Services	Day	NA	1	**$ 179,585**	1	**$ 281,778**	1	**$ 758,358**
Injection Well Installation	LF	170	1,800	**$ 306,000**	3,240	**$ 550,800**	11,040	**$ 1,876,800**
Sodium Permanganate Injection	Gallon	$5.50	500,000	**$ 2,750,000**	800,000	**$ 4,400,000**	2,175,000	**$ 11,962,500**
Monitoring Well Installation	LF	190	540	**$ 102,600**	540	**$ 102,600**	540	**$ 102,600**
Health and Safety	Day	427	300	**$ 128,100**	450	**$ 192,150**	750	**$ 320,250**
Mob/Demob & Site Prep	Lump Sum	Same as Site Services	1	**$ 179,585**	1	**$ 281,778**	1	**$ 758,358**
Site Survey	Lump Sum	$60,000	1	**$ 60,000**	1	**$ 60,000**	1	**$ 75,000**
Baseline Monitoring	Lump Sum	$80,000	1	**$ 80,000**	1	**$ 80,000**	1	**$ 80,000**
Performance Monitoring	Lump Sum	$250,000	1	**$ 165,000**	1	**$ 250,000**	1	**$ 750,000**
SUBTOTAL				**$ 3,950,870**		**$ 6,199,105**		**$ 16,683,865**
CONTINGENCY (15% of Subtotal)				**$ 592,631**		**$ 929,866**		**$ 2,502,580**
APPROXIMATE TOTAL CAPITAL COST				**$ 4,600,000**		**$ 7,200,000**		**$ 19,200,000**

Table 5-2
PRESENT WORTH OF ALTERNATIVES

Alternative 1 GWET	
Estimated Capital Cost	$0
Estimated Annual OM&M Cost	
GWET System Operation	$2,000,000
Annual Monitoring	$5,000
Total OM&M	$2,005,000
Period of OM&M	20 years
Present Worth (5%)	$24,986,732

Alternative 2A Permanganate Injection Within 10 ppb in shallow	
Estimated Capital Cost	$4,600,000
Estimated Annual OM&M Cost	$5,000
Period of OM&M	5 years
Present Worth (5%)	$4,621,647

Alternative 2B Permanganate Injection Within 10 ppb in shallow and 1,000 ppb in intermediate	
Estimated Capital Cost	$7,200,000
Estimated Annual OM&M Cost	$5,000
Period of OM&M	5 years
Present Worth (5%)	$7,221,647

Alternative 2C Permanganate Injection Within 10 ppb in shallow and 100 ppb in intermediate and deep	
Estimated Capital Cost	$19,200,000
Estimated Annual OM&M Cost	$5,000
Period of OM&M	5 years
Present Worth (5%)	$19,221,647

FIGURES

500 0 500 Feet

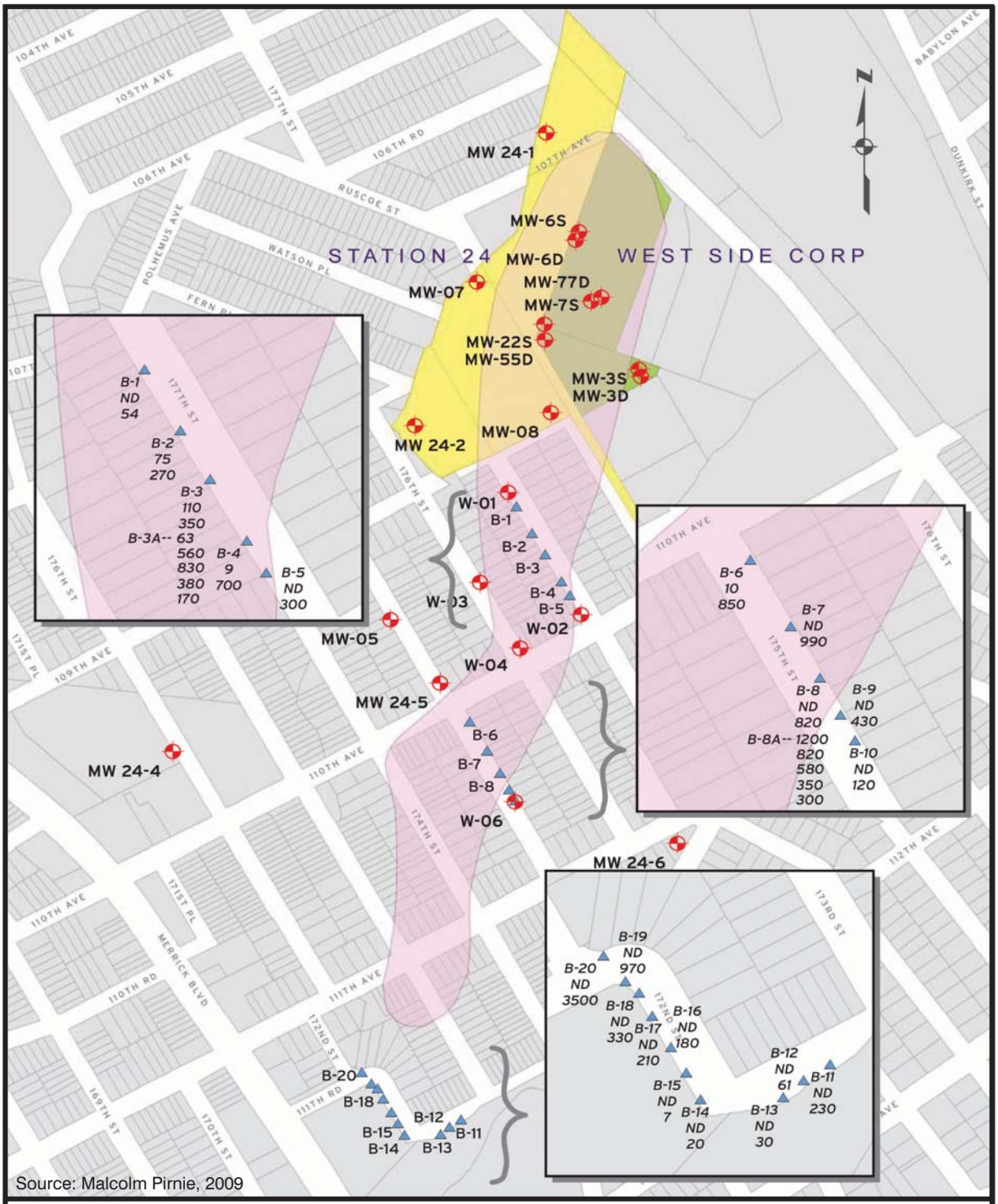
Source: Bing Maps Aerial © 2010 Microsoft Corporation

URS

WEST SIDE CORPORATION
JAMAICA, NEW YORK
SITE LOCATION

FIGURE 1-1

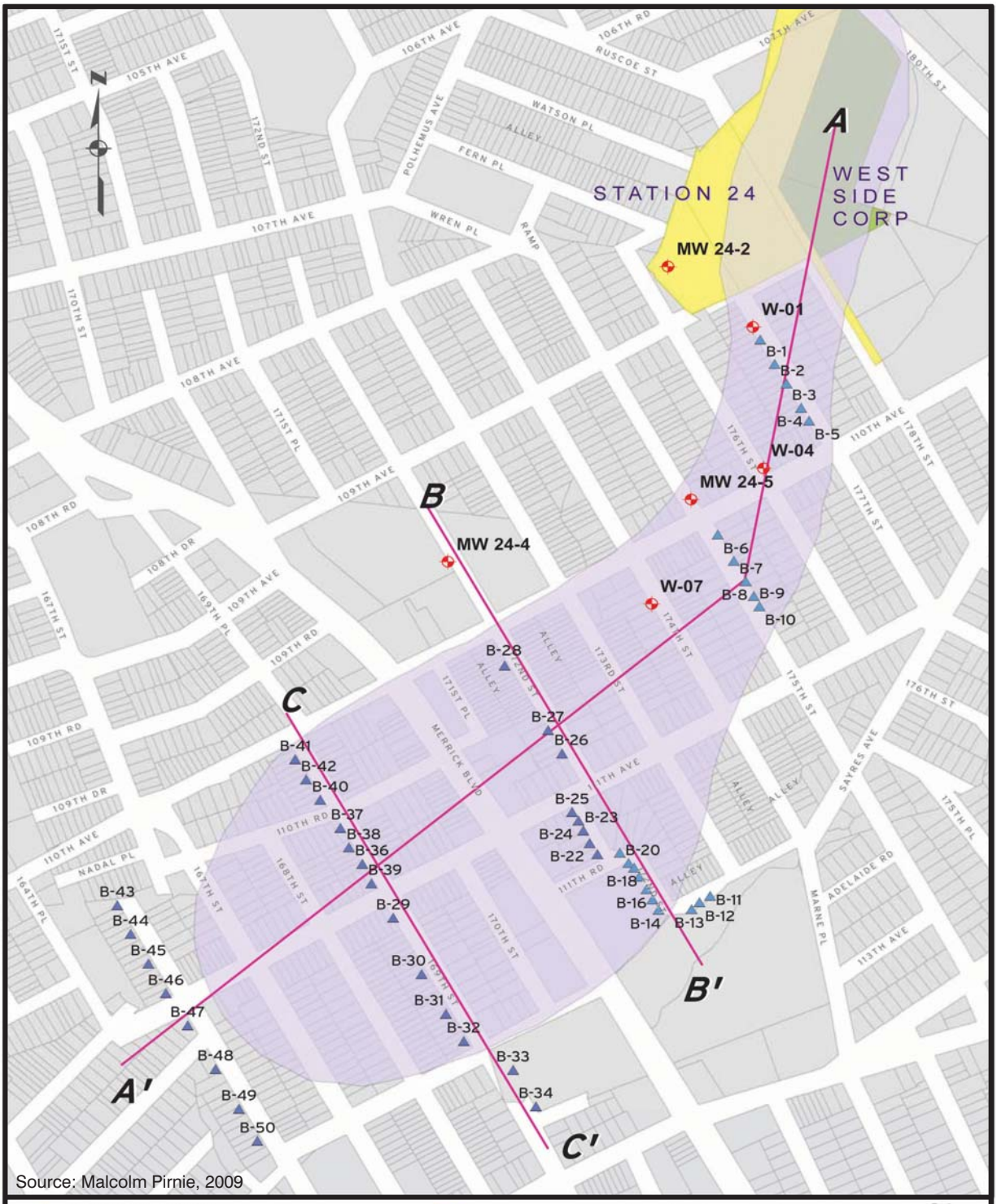
N:\11173144.00000\DB\GIS\SITE LOCATION (REV).mxd 2/4/2013



URS

GEOPROBE SAMPLE LOCATIONS B1-B20 WITH PCE DETECTIONS

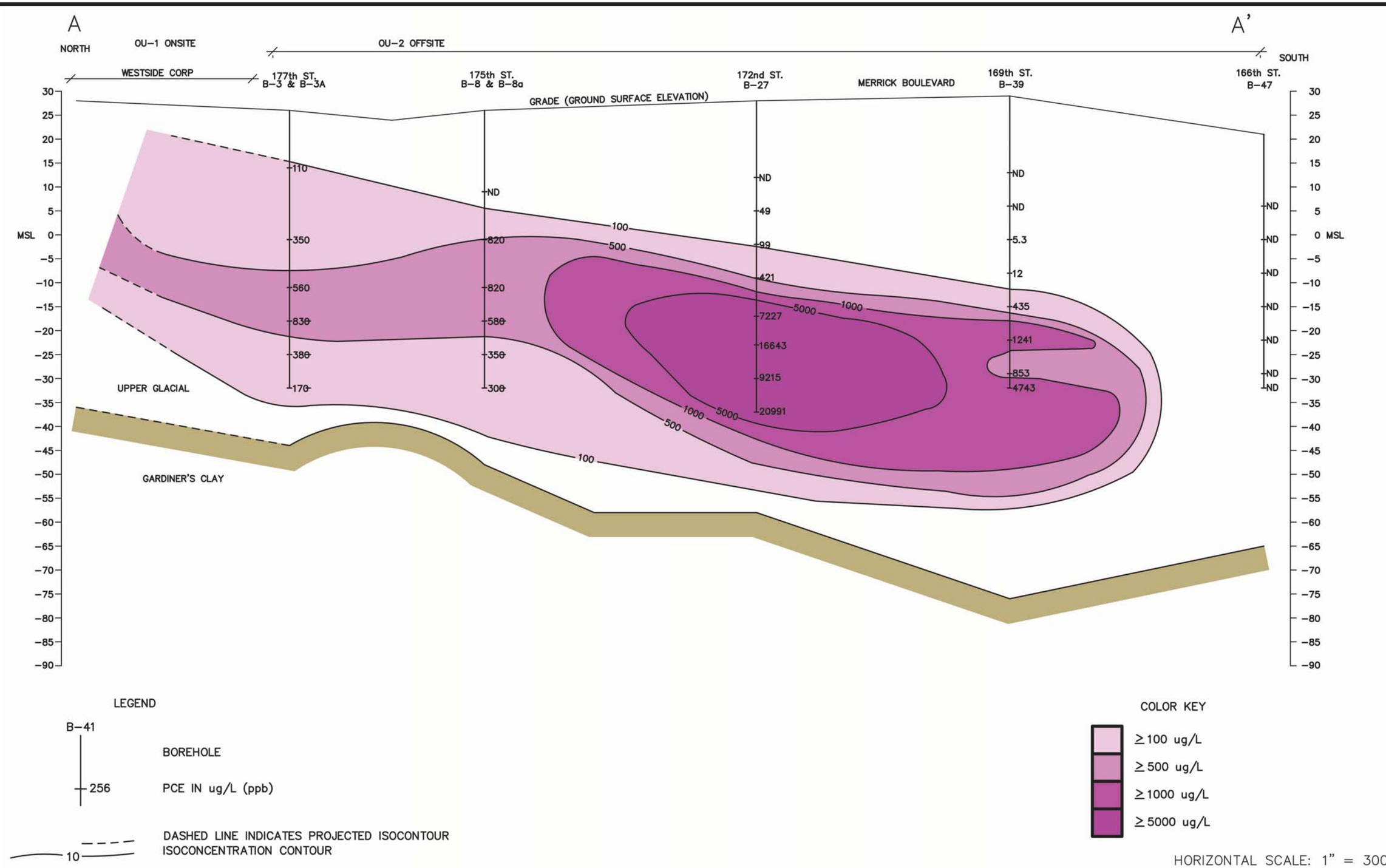
Figure 1-2



URS

GEOPROBE SAMPLE LOCATIONS B21-B50 WITH PLAN-VIEW PCE PLUME AND TRANSECT LOCATIONS

Figure 1-3



Source: Malcolm Pirnie, 2009

PCE IN GROUNDWATER CROSS-SECTION A-A'

URS

Figure 1-4

B

NORTH

B'

SOUTH

110TH AVE.

111TH AVE.

111TH RD

SAYRES AVE

MW-24-4 B-28 B-27 B-26 B-25 B-24 B-23 B-22 B-21 B-20 B-19 B-18 B-17 B-16 B-15 B-14

GRADE (GROUND SURFACE ELEVATION)

MSL

UPPER GLACIAL

GARDINER'S CLAY

LEGEND

B-41 BOREHOLE

256 PCE IN ug/L (ppb)

10 DASHED LINE INDICATES PROJECTED ISOCONTOUR ISOCONCENTRATION CONTOUR

COLOR KEY

≥ 100 ug/L

≥ 500 ug/L

≥ 1000 ug/L

≥ 5000 ug/L

≥ 10000 ug/L

HORIZONTAL SCALE: 1" = 120'

Source: Malcolm Pirnie, 2009

PCE IN GROUNDWATER CROSS-SECTION B-B'

URS

Figure 1-5

C

NORTH

C'

SOUTH

110TH AVE. | 111TH AVE. | SAYERS AVE. | LINDEN BLVD.

B-41 B-42 B-40 B-37 B-38 B-36 B-39 B-29 B-30 B-31 B-32 B-33 B-34

GRADE (GROUND SURFACE ELEVATION)

MSL

40 35 30 25 20 15 10 5 0 −5 −10 −15 −20 −25 −30 −35 −40 −45 −50 −55 −60 −65 −70 −75 −80 −85 −90

B-41	B-42	B-40	B-37	B-38	B-36	B-39	B-29	B-30	B-31	B-32	B-33	B-34
ND	ND	ND	ND	ND	ND	ND	3.5	ND	2.1	ND	ND	ND
5.4	1.5	ND	2.7	ND	ND	5.3	31	74	20	90	6.6	ND
7.4	3.4	ND	7.4	ND	2.2	12	45	380	157	109	8.9	ND
26	17	6.7	23	18	85	435	4309	1235	74	7.1	2.0	1.2
73	36	9.7	114	117		1241	412	689	73	5.3	1.9	8.2
171	161	226	160	758	335	853	1374	200	10	5.7	11	7.3
334	256	238	784	467	817	4743	1611	14	8.1	9.5	6.6	2.8
100	147	1116										

10 100 1000

UPPER GLACIAL

GARDINER'S CLAY

LEGEND

B-41 BOREHOLE

256 PCE IN ug/L (ppb)

10 DASHED LINE INDICATES PROJECTED ISOCONTOUR ISOCONCENTRATION CONTOUR

COLOR KEY

≥10 ug/L

≥100 ug/L

≥1000 ug/L

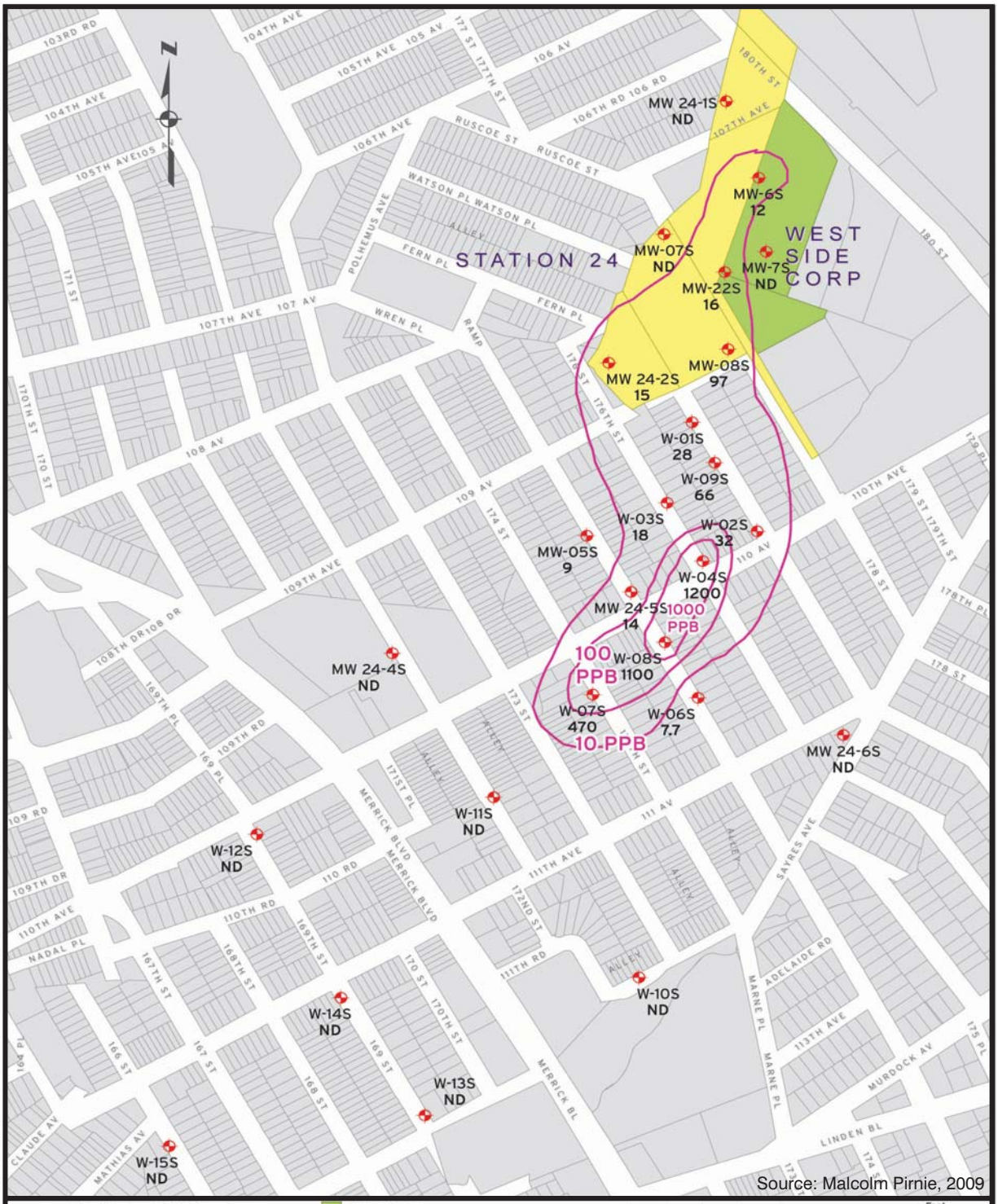
HORIZONTAL SCALE: 1" = 120'

PCE IN GROUNDWATER CROSS-SECTION C-C'

URS

Figure 1-6

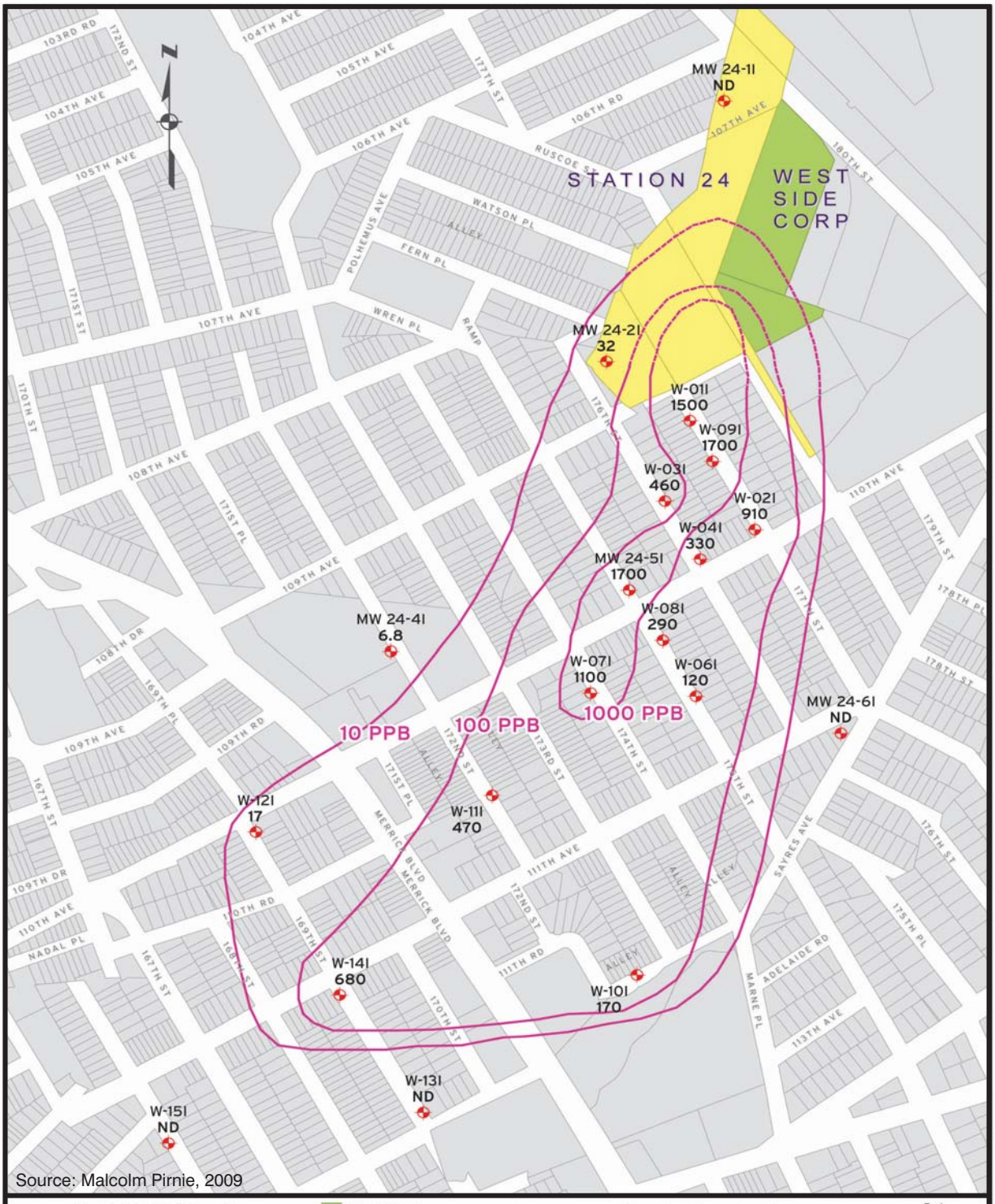
Source: Malcolm Pirnie, 2009



URS

PCE IN SHALLOW MONITORING WELLS

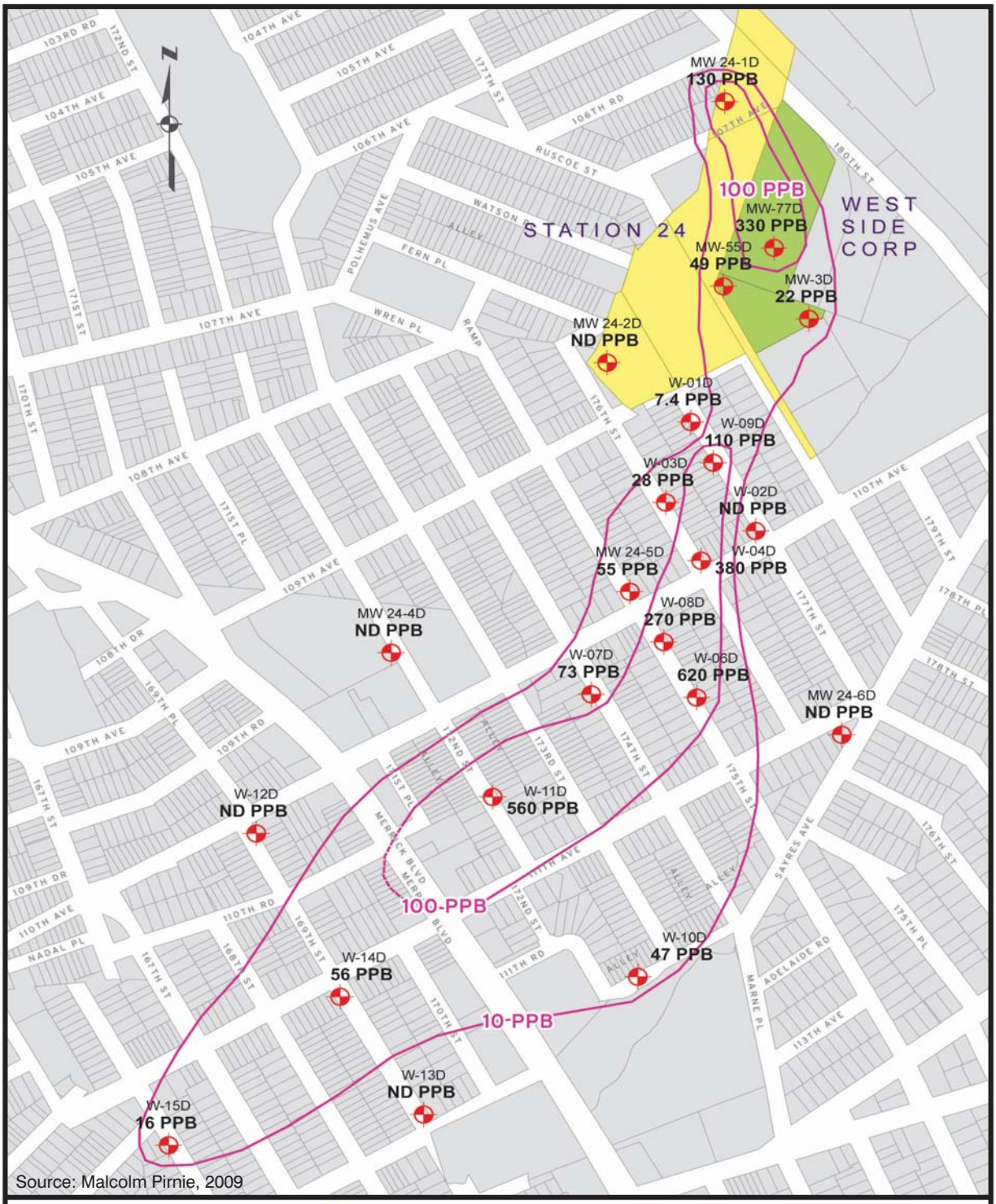
Figure 1-7



URS

PCE IN INTERMEDIATE MONITORING WELLS

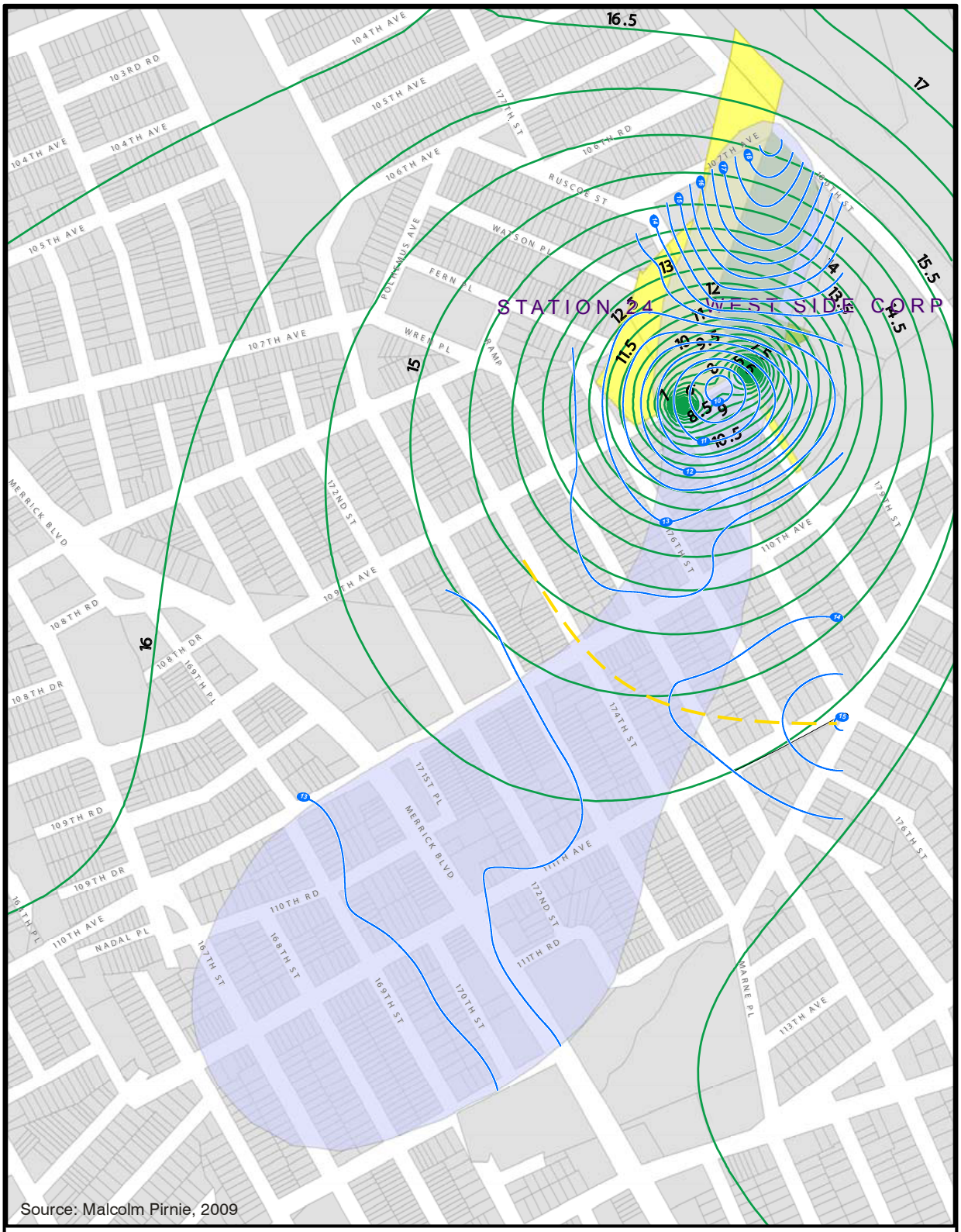
Figure 1-8



URS

PCE IN DEEP MONITORING WELLS

Figure 1-9

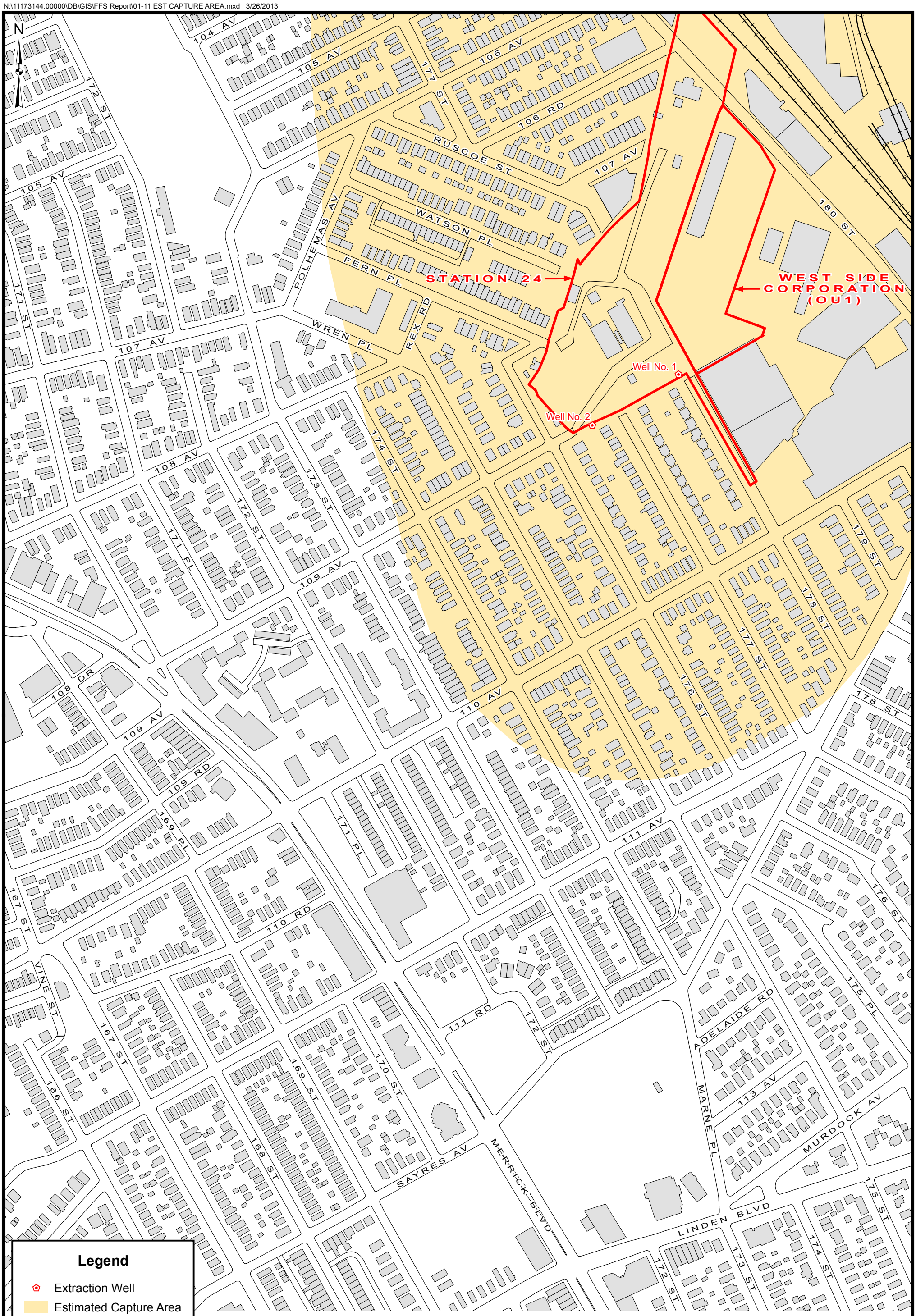


URS

STATION 24 PREDICTED GROUNDWATER CONTOURS FOLLOWING 1-YEAR OF PUMPING AND ACTUAL CONTOURS FOLLOWING 3 MONTHS OF PUMPING

Figure 1-10

N:\11173144.00000\DB\GIS\FFS Report\01-11 EST CAPTURE AREA.mxd 3/26/2013



URS

WEST SIDE CORPORATION
JAMAICA, NEW YORK
ESTIMATED CAPTURE AREA

FIGURE 1-11

N:\11173144.00000\DB\GIS\FFS Report\01-12 GROUNDWATER RESULTS (AUG 2012 - NOV 2012).mxd 3/26/2013

N

W-01S
8/22/2012, 41
9/26/2012, 76
11/7/2012, 32

W-01I
8/22/2012, 92
9/26/2012, 370
11/7/2012, 220

W-01D
8/22/2012, 170
9/26/2012, 420
11/7/2012, 56

Well No. 1

Well No. 2

W-09S
8/22/2012, 9.6
9/26/2012, 11
11/7/2012, 51

W-09I
8/22/2012, 260
9/26/2012, 330
11/7/2012, 510

W-09D
8/22/2012, 6.7
9/26/2012, 9.8
11/7/2012, 12

W-04S
8/2012, NS
9/26/2012, 63
11/7/2012, 670

W-04I
8/22/2012, 270
9/26/2012, 37
11/7/2012, 50

W-04D
8/22/2012, 36
9/26/2012, 5.7
11/7/2012, 4.5

W-02S
8/22/2012, 16
9/26/2012, 12
11/7/2012, 12

W-02I
8/22/2012, 100
9/26/2012, 25
11/7/2012, 24

W-02D
8/22/2012, ND
9/26/2012, ND
11/7/2012, ND

W-03S
8/22/2012, 6
9/26/2012, 6.9
11/12/2012, 36

W-03I
8/22/2012, 110
9/26/2012, 150
11/12/2012, 130

W-03D
8/22/2012, 0.53
9/26/2012, ND
11/12/2012, ND

W-05
8/2012, NS
9/27/2012, ND
11/2012, NS

MW-24-5S
8/22/2012, 2
9/27/2012, 0.71
11/7/2012, 1.7

MW-24-5I
8/22/2012, 89
9/27/2012, 360
11/7/2012, 410

MW-24-5D
8/22/2012, 15
9/27/2012, 17
11/7/2012, 21

MW-24-4S
8/23/2012, ND
9/28/2012, ND
11/9/2012, ND

MW-24-4I
8/23/2012, 2.7
9/28/2012, 3.2
11/9/2012, 3.5

MW-24-4D
8/23/2012, 1.9
9/28/2012, 3.6
11/9/2012, 4.3

W-07S
8/23/2012, 34
9/27/2012, 17
11/9/2012, 32

W-07I
8/23/2012, 120
9/27/2012, 160
11/9/2012, 340

W-07D
8/23/2012, 4.9
9/27/2012, 4.8
11/9/2012, 8.3

MW-24-6S
8/23/2012, ND
9/26/2012, ND
11/7/2012, ND

MW-24-6I
8/23/2012, 0.61
9/26/2012, ND
11/7/2012, ND

MW-24-6D
8/23/2012, ND
9/26/2012, ND
11/7/2012, ND

W-06S
8/23/2012, 71
9/27/2012, 15
11/9/2012, 7.2

W-06I
8/23/2012, 220
9/27/2012, 140
11/9/2012, 190

W-06D
8/23/2012, 280
9/27/2012, 370
11/9/2012, 400

W-08S
8/23/2012, 260
9/27/2012, 120
11/9/2012, 3.9

W-08I
8/23/2012, 190
9/27/2012, 340
11/9/2012, 60

W-08D
8/23/2012, 120
9/27/2012, 120
11/9/2012, 68

W-11I
8/23/2012, 40
9/28/2012, 48
11/9/2012, 65

W-11D
8/23/2012, 87
9/28/2012, 44
11/9/2012, 14

W-12S
8/23/2012, ND
9/27/2012, ND
11/2012, NS

W-12I
8/23/2012, 6.6
9/27/2012, 6.4
11/2012, NS

W-12D
8/23/2012, 5.9
9/27/2012, ND
11/2012, NS

W-14S
8/23/2012, ND
9/27/2012, ND
11/9/2012, ND

W-14I
8/23/2012, 22
9/27/2012, 21
11/9/2012, 49

W-14D
8/23/2012, 5.5
9/27/2012, 6.7
11/9/2012, 5.2

W-15S
8/23/2012, ND
9/28/2012, ND
11/12/2012, ND

W-15I
8/23/2012, 0.38
9/28/2012, 0.52
11/12/2012, 1.9

W-15D
8/23/2012, 17
9/28/2012, 21
11/12/2012, 19

W-13S
8/23/2012, ND
9/27/2012, ND
11/9/2012, ND

W-13I
8/23/2012, 1700
9/27/2012, 1700
11/9/2012, 680

W-13D
8/23/2012, 60
9/27/2012, 21
11/9/2012, 7.5

W-10S
8/23/2012, 1.8
9/28/2012, 0.65
11/9/2012, 0.46

W-10I
8/23/2012, 3000
9/28/2012, 3400
11/9/2012, 3900

W-10D
8/23/2012, 25
9/28/2012, 160
11/9/2012, 3.6

104 AV, 105 AV, 106 AV, 107 AV, 108 AV, 109 AV, 110 RD, 111 RD, 111 AV, 113 AV, 105 AV, 109 RD, 172 ST, 171 ST, 173 ST, 174 ST, 171 PL, 169 PL, 167 ST, 166 ST, 168 ST, 169 ST, 170 ST, 176 ST, 177 ST, 178 ST, 179 ST, 175 PL, 180 ST, 108 DR, 106 RD, RUSCOE ST, WATSON PL, FERN PL, WREN PL, REX RD, POLHEMAS AV, VINE ST, MERRICK BLVD, ADELAIDE RD, MARNE PL, MURDOCK AV, LINDEN BL

300 0 300 Feet

NOTES:
NS - Not Sampled
ND - Not Detected

Legend

- Monitoring Well
- Extraction Well

Location ID: W-05
Sample Date: 8/2012, NS
Tetrachloroethene (PCE) Concentration (µg/L)

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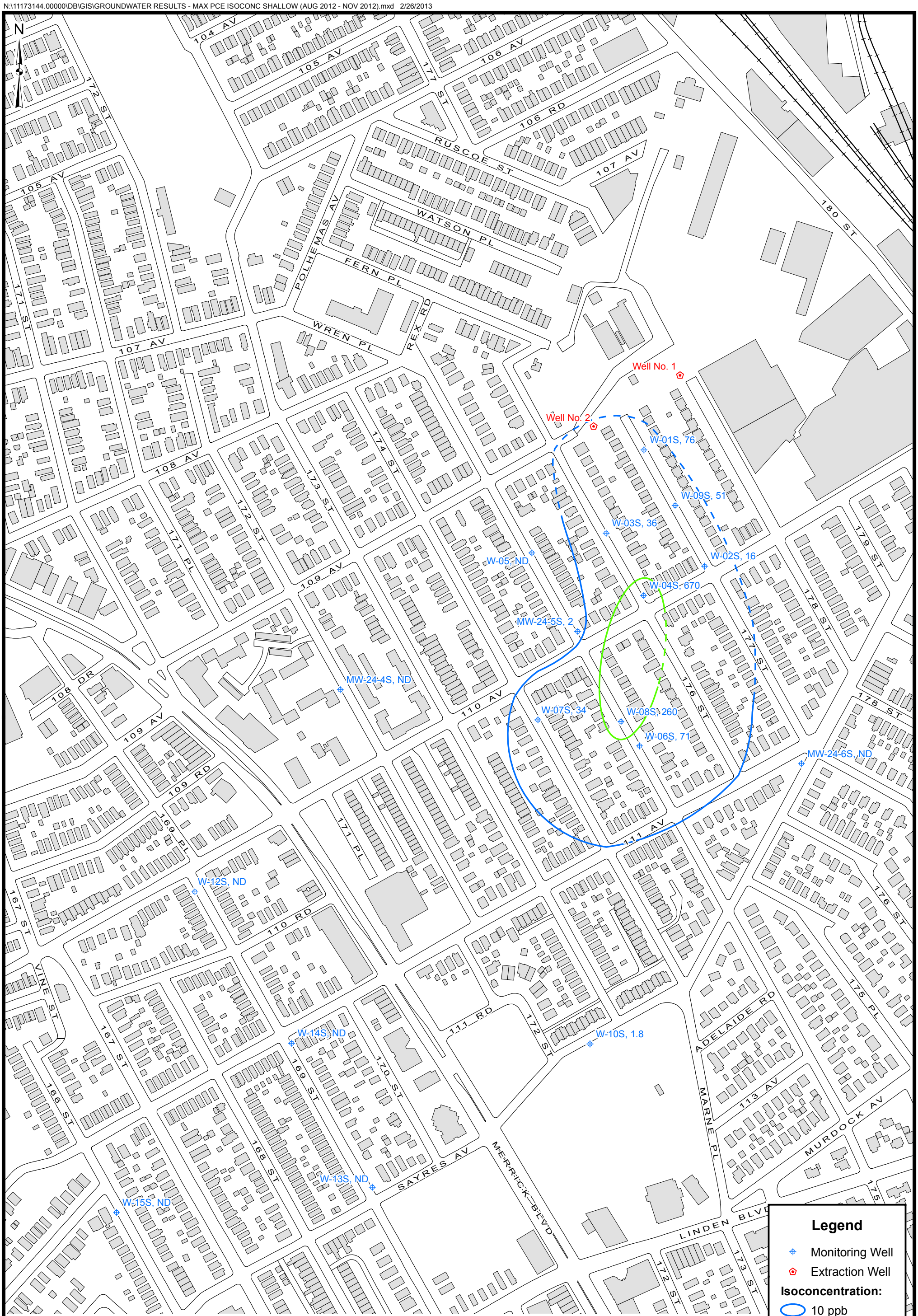
GROUNDWATER SAMPLING RESULTS FOR PCE

FIGURE 1-12

N:\11173144.00000\DB\GIS\GROUNDWATER RESULTS - MAX PCE ISOCONC SHALLOW (AUG 2012 - NOV 2012).mxd 2/26/2013



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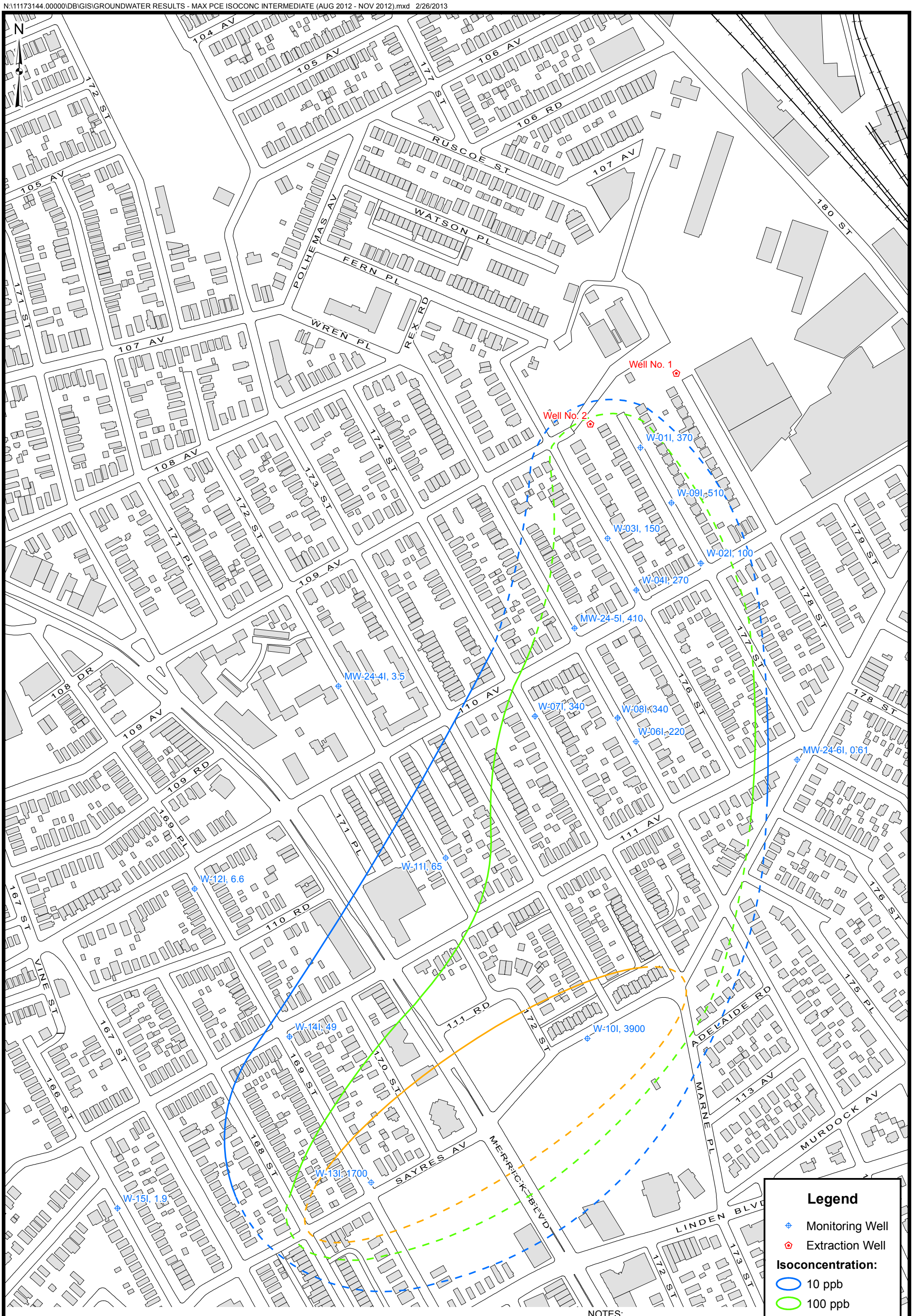
GROUNDWATER SAMPLING RESULTS FOR PCE IN SHALLOW MONITORING WELLS

FIGURE 1-13

N:\11173144.00000\DB\GIS\GROUNDWATER RESULTS - MAX PCE ISOCONC INTERMEDIATE (AUG 2012 - NOV 2012).mxd 2/26/2013



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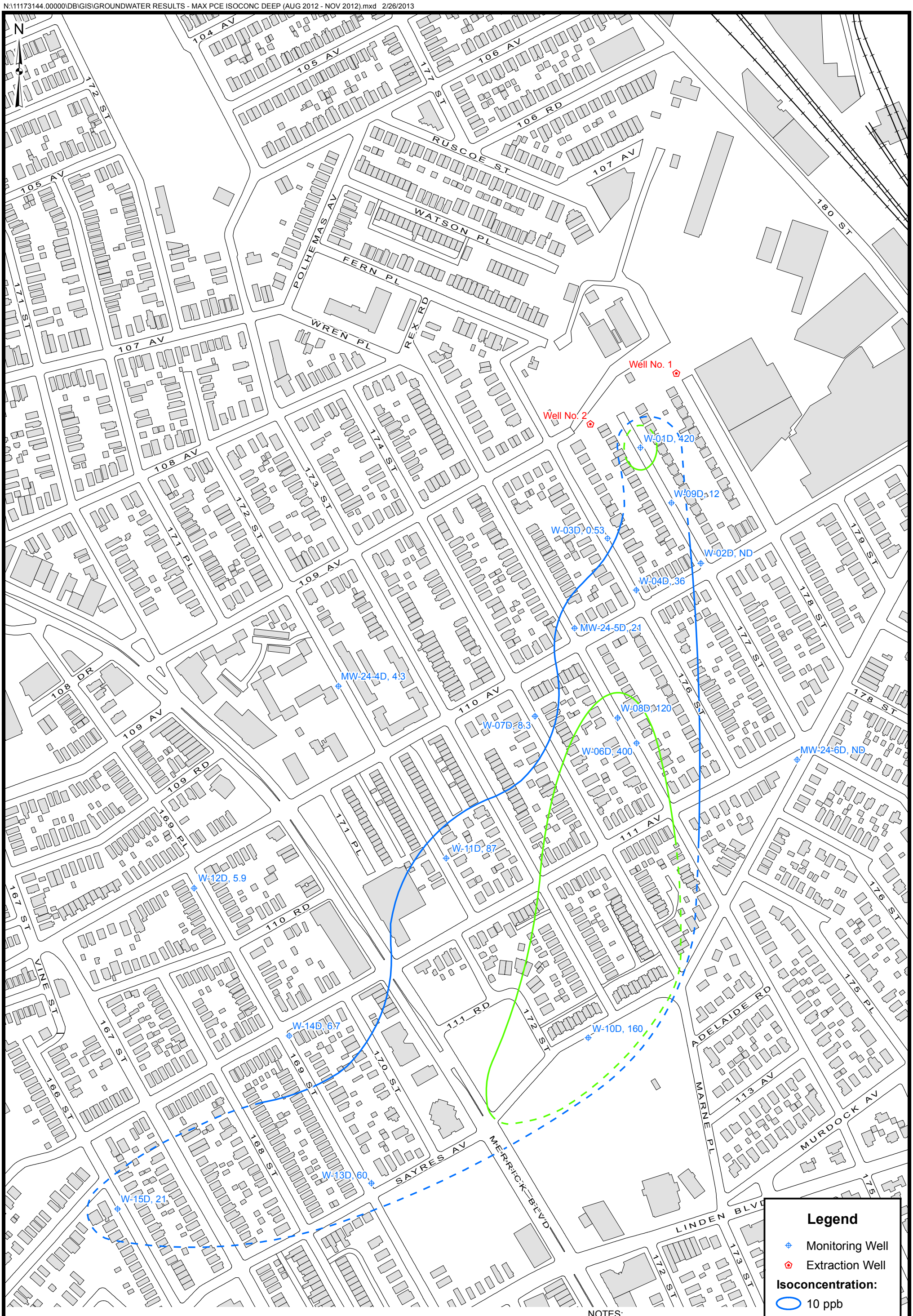
GROUNDWATER SAMPLING RESULTS FOR PCE IN INTERMEDIATE MONITORING WELLS

FIGURE 1-14

N:\11173144.00000\DB\GIS\GROUNDWATER RESULTS - MAX PCE ISOCONC DEEP (AUG 2012 - NOV 2012).mxd 2/26/2013



URS

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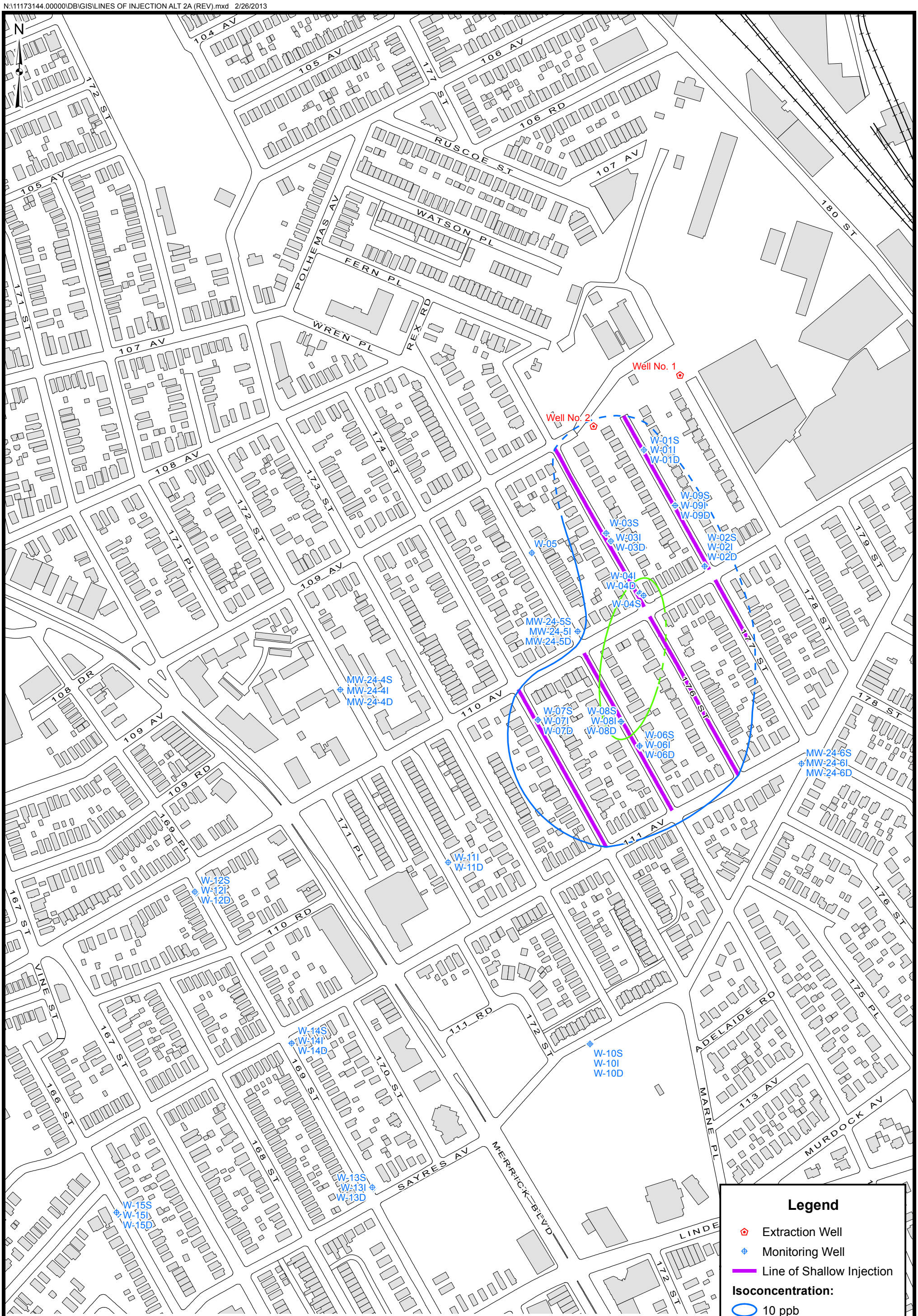
GROUNDWATER SAMPLING RESULTS FOR PCE IN DEEP MONITORING WELLS

FIGURE 1-15

N:\11173144.00000\DB\GIS\LINES OF INJECTION ALT 2A (REV).mxd 2/26/2013



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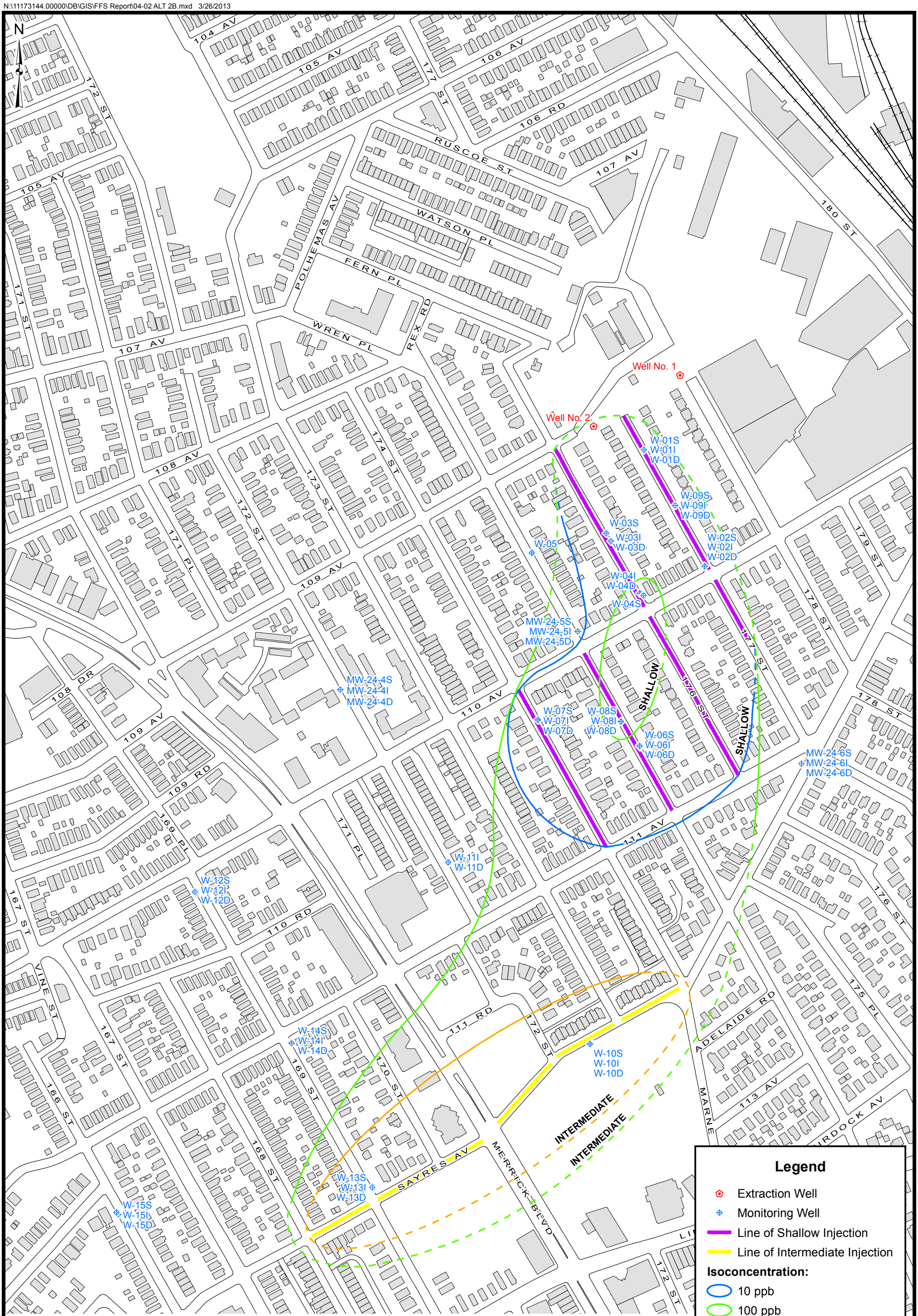
JAMAICA, NEW YORK
ALTERNATIVE 2A

FIGURE 4-1

N:\11173144.00000\DB\GIS\FFS Report\04-02 ALT 2B.mxd 3/26/2013



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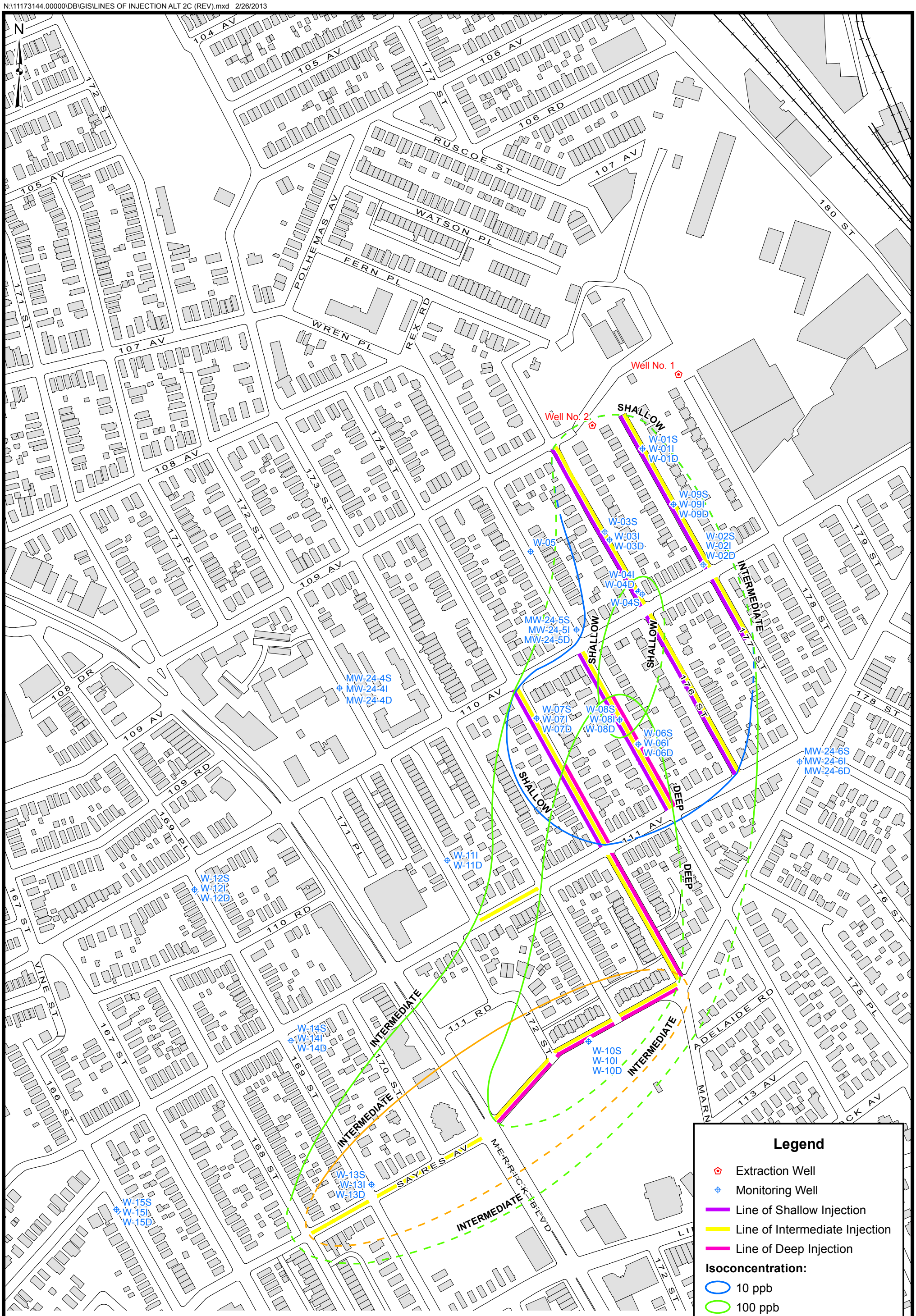
JAMAICA, NEW YORK
ALTERNATIVE 2B

FIGURE 4-2

N:\11173144.00000\DB\GIS\LINES OF INJECTION ALT 2C (REV).mxd 2/26/2013



Legend

- Extraction Well
- Monitoring Well
- Line of Shallow Injection
- Line of Intermediate Injection
- Line of Deep Injection

Isoconcentration:

- 10 ppb
- 100 ppb
- 1000 ppb

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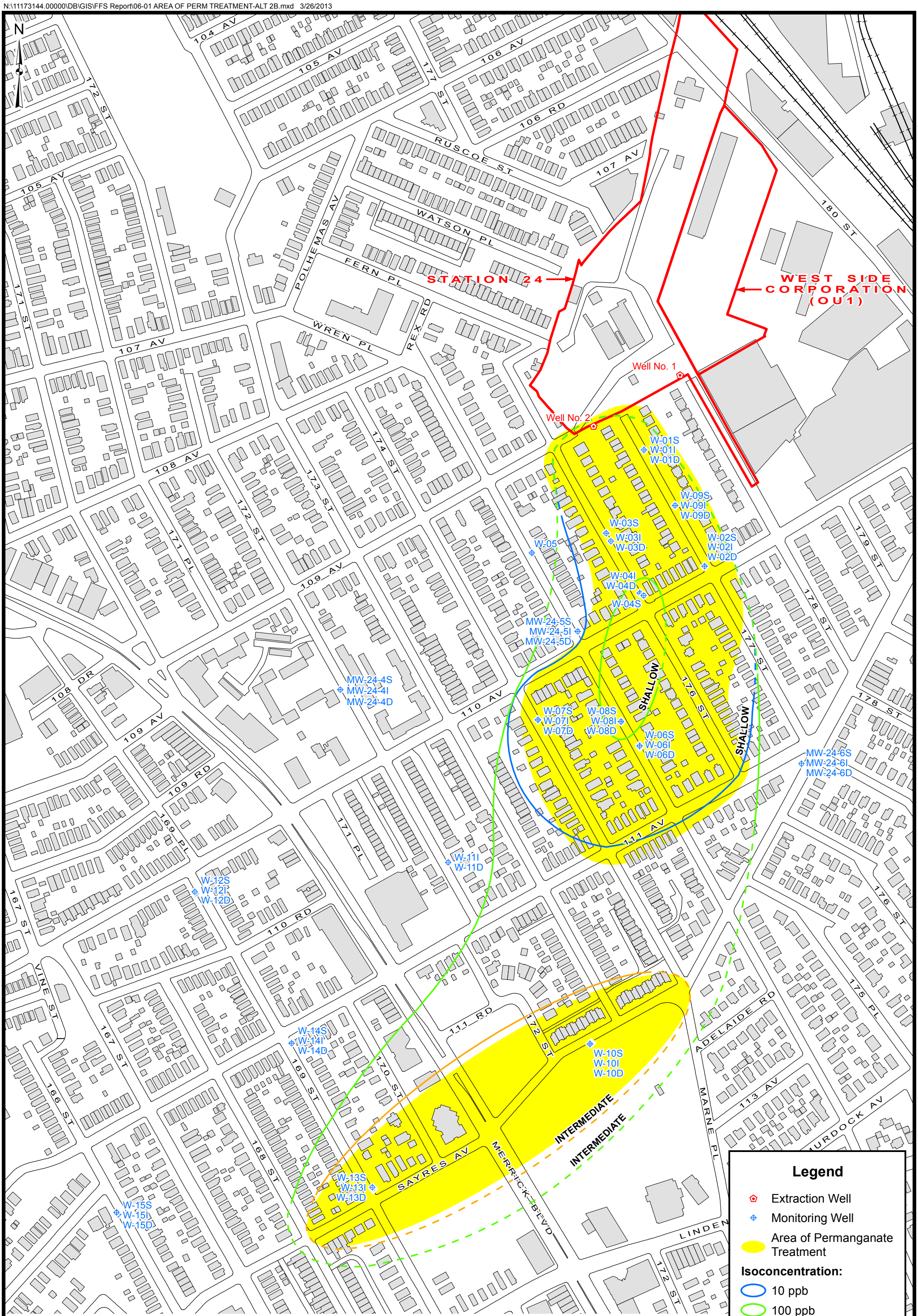
ALTERNATIVE 2C

FIGURE 4-3

N:\11173144.00000\DB\GIS\FFS Report\06-01 AREA OF PERM TREATMENT-ALT 2B.mxd 3/26/2013



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AREA OF PERMANGANATE TREATMENT - ALTERNATIVE 2B

FIGURE 6-1

APPENDIX A

CALCULATIONS

MADE BY: C. Pawlewski DATE: January 30, 2013
CHECKED BY: A. Monti DATE: January 31, 2013

PROJECT: West Side FS
SUBJECT: Oxidant Demand Calculations

---

1. **Background and Purpose**

This calculation has been prepared to estimate the quantity of oxidant (sodium permanganate) necessary to effectively treat the remaining PCE contaminant mass present in an area downgradient of the site source area.

2. **Design Criteria**

Design criteria used for calculating the amount of oxidant (sodium permanganate) required for remediation are discussed below.

a. Area of Remediation

The remediation is based on targeting four zones within the groundwater plume with PCE contamination. The area of each zone is defined by the number of injection wells and the assumed radius of influence for each injection well (i.e., 30 feet). The dimensions and estimated areas for each zone are presented below.

Zone	Width (ft)	Length (ft)	Area (ft^2)
Shallow	3,600	60	216,000
Intermediate > 100PPB	6,000	60	360,000
Intermediate > 1000PPB	1,440	60	86,400
Deep	2,160	60	129,600

b. Saturated Thickness

The estimated saturated thickness for each zone is presented below.

Zone	Saturated Thickness (ft)
Shallow	20
Intermediate 1	30
Intermediate 2	30
Deep	30

c. Soil Porosity

A porosity of 30% is used for the calculation based on the plume investigation report prepared by Malcolm Pirnie. Inc. (Malcolm Pirnie, 2009).

d. Contaminant Groundwater Concentrations

Recent groundwater data was used to estimate PCE concentrations in the groundwater plumes as summarized below.

Zone	Estimated Average PCE Concentration (µg/L)
Shallow	75
Intermediate > 100PPB	400
Intermediate > 1000PPB	2,000
Deep	200

e. Permanganate Natural Oxidant Demand (PNOD)

The PNOD is a measure of the oxidant demand of the soil regardless of contamination, i.e., the oxidant demand occurring naturally. It is also referred to as permanganate soil oxidant demand or PSOD. The PNOD is usually determined by analyzing one or more samples collected from the aquifer material for this parameter. Samples were not collected from this site; however, a value of 1 g$KMnO_4$/kg soil was used for the calculation of oxidant demand. This value was successfully used as the value for the OSER Ave. and Kliegman Brothers sites located in the same vicinity as this site, and will also be used for this calculation.

f. Effective PNOD

Based on Carus Corporation's experience in the field, they have developed the concept of effective PNOD. They have determined that laboratory results for PNOD are not reflective of permanganate demand in the field,

i.e., oxidant demand in the field is less than predicted by laboratory results. The discrepancy is due mainly to the following: 1.) laboratory results are based on well mixed soil that does not occur in the field when the oxidant is injected; and 2.) permanganate does not usually persist long enough in the field to oxidize all the PNOD present. The effective PNOD can vary; however, based on Carus' experience the effective PNOD is typically 10% of the measured PNOD. A value of 10% is used in this calculation

g. Average Stoichiometric Demand

Different compounds require different amounts of permanganate for oxidation that is based on stoichiometry. The stoichiometric relationships for the chlorinated alkenes are presented in Principles and Practices of In Situ Oxidation Using Permanganate by Siegrist, et al. These stoichiometric relationships are included in Attachment A. For PCE, the stoichiometric demand is 0.96 lb MnO_4^-/lb contaminant.

h. Confidence Factor

The confidence factor is a safety factor applied to the estimate based on the availability of data for the site and the unknowns and variables associated with the remediation. The confidence factor generally ranges from 1 (very confident) to 5 (not confident because data is minimal or site geology is highly variable). For this site, there is some subsurface characterization data available for the target remediation area, and the geology is somewhat variable but reasonably well known. However, the PNOD was not determined by analyzing samples from the site, reducing certainty in the calculation. In addition, the remediation will occur in a residential area, so it will be desirable to minimize the number of injections to minimize disturbance in the residential neighborhood. Therefore, it seems prudent to use a conservative confidence factor to reduce the probability of needing more injections after the calculated quantity is injected. On this basis, a confidence factor of 5 was used for the calculation of total oxidant demand.

3. Oxidant Required for Remediation

The oxidant required for remediation was calculated using the Carus spreadsheet with the input parameters discussed in Section 2 above. These calculations are included Attachment C. Attachment C includes calculations for RemOx S (potassium permanganate) and RemOx L (sodium permanganate); however, only sodium permanganate will be used for remediation as discussed in Section 4 below.

An example calculation for the shallow zone is presented below to show the basis for the spreadsheet calculations. The spreadsheet calculations are based on the following equation:

$T_R = [(C \times Q_w \times S) + (\text{Effective PNOD} \times Q_s)] \times C_F$

Where:

T_R = Total Oxidant Demand (lb)

C = Contaminant Concentration in Groundwater (mg/l) = 0.075 mg/l

Q_w = Quantity of Water (l)
Q_w = remediation area x saturated thickness x porosity
Q_w =216,000 ft^2 x 20 ft x 0.30 x 28.317 L/ft^3
Q_w = 36,698,832 L

S = Average Stoichiometric Demand (lb/lb) = 0.96 lb/lb

Effective PNOD = Effective Permanganate Oxidation Demand (g/kg)
Effective PNOD = 1.0 g/kg x 10%
Effective PNOD = 0.1 g/kg

Q_s = Quantity of Soil (lb) = Area (ft^2) x Saturated Thickness (ft) x Density of Soil (lb/ft^3)

The default value for soil density in the spreadsheet calculation is 1350 kg/CY of 110 lb/ft^3.

C_f = Confidence Factor = 5

For RemOx S (potassium permanganate),

T_R = [(0.075 mg/l x 36,698,832 L x lb/454,000mg x 0.96lb/lb) + (0.1g/kg x (216,000 ft^2 x 20 ft x CY/27 ft^3) CY x 1350kg/CY x lb/454g)] x 5

T_R = 237,915 lbs

For RemOx L (40% sodium permanganate solution), the oxidant demand is derived from the RemOx S demand as follows:

$T_{RemOx\ L}$ = T_R x (mol. wt. $NaMnO_4$/mol. wt. $KMnO_4$) / (0.4 lb $NaMnO_4$ per lb of solution)

$T_{RemOx\ L}$= (237,915 lb x (142g/mole/158g/mole))/ 0.4

$T_{RemOx\ L}$= (237,915 lb x 0.898)/0.4

$T_{RemOx\ L}$ = 534,119 lbs

4. Oxidant Type

Permanganate is available in two forms, namely, potassium and sodium permanganate. Sodium permanganate will be used for remediation at this site based on the following: 1.) The quantity of permanganate solution injected for each injection event would be reduced since potassium permanganate is generally injected at about 2% by weight solution and sodium permanganate is injected at about 5 to 10% by weight solution. This reduction in the volume injected reduces the complexities associated with mixing and transportation of

permanganate and reduces the time required for the injection. This is a distinct advantage in the highly urban remediation area; and 2.) use of sodium permanganate eliminates concerns associated with Homeland Security requirements. In addition, injection of a 5% solution of sodium permanganate significantly reduces health and safety concerns associated with potential human or environmental exposure associated with higher concentrations of sodium permanganate. Carus specifies that spills of sodium permanganate must be diluted to 6% or below to safely neutralize the spill and thereby protect human health and the environment. In general, sodium permanganate solutions are very stable at concentrations of 6% or less and are much safer to work with.

5. Injection Volume

The calculations presented in Attachment B for all four zones are summarized below.

Zone	Amount of RemOx L (lb)	Amount of RemOx L (gal of 40% solution)	Amount of RemOx L (gal of 5% solution)
Shallow	533,477	46,673	489,020
Intermediate > 100PPB	1,334,402	116,746	1,223,198
Intermediate > 1000PPB	321,093	28,092	294,335
Deep	480,228	42,015	440,208

ATTACHMENT A

Appendix B
Ref. 2

Principles and Practices of

In Situ Chemical Oxidation Using Permanganate

Robert L. Siegrist
Michael A. Urynowicz
Olivia R. West
Michelle L. Crimi
Kathryn S. Lowe

TABLE 2-1. Properties and characteristics of potassium permanganate (CAIROX).[1]

Property	Value and/or comments
Chemical formula	$KMnO_4$
Purity (% by weight)	Technical Grade = 98%, Free Flowing Grade = 97%, USP Grade = 99%
Molecular weight	158.03 g/mol
Form and features	Dark purple solid with metallic luster, sweetest astringent taste, odorless, granular crystalline, oxidizer
Specific gravity—solid	2.703 g/cm^3
Specific gravity—6% sol.	1.039 g/cm^3
Bulk density	90 to 100 lb/ft^3
Solubility in distilled water:	
0C	27.8 g/L
20C	65.0 g/L
40C	125.2 g/L
60C	230.0 g/L
Heat of solution	10.2 Kcal/mole
Packaging	25 kg pail, 50 kg drum, 150 kg drum, plus special packaging
Hazardous class (ID no.)	Oxidizer (UN1490)
Stability	Stable indefinitely if held in cool dry area in sealed containers
Incompatibilities	Avoid contact with acids, peroxides, and all combustible organics or readily oxidizable materials
Materials compatibility	In neutral or alkaline conditions $KMnO_4$ is not corrosive to iron, mild steel or stainless steel. However chloride corrosion may be accelerated. Plastics such as polypropylene, PVC, epoxy resins, Lucite, Viton A, and Hypalon are suitable but Teflon FEP and TFE, and Telzel ETFE are best. Natural rubbers and fibers are often incompatible

[1]Refer to Appendix A for additional manufacturer's information.

available. Sodium permanganate ($NaMnO_4$) is supplied by Carus as a concentrated liquid (min. 40 wt.% as $NaMnO_4$, Table 2-2). In this form, MnO_4^- ion is provided without the potassium (for sites where ^{40}K is a concern) and without dusting hazards associated with dry $KMnO_4$ solids.

The composition of potassium permanganate has two facets that are relevant to water quality effects but that are unrelated to in situ o[illegible]

TABLE 2-2. Properties and characteristics of sodium permanganate (LIQUOX).[1]

Property	Value and/or comments
Chemical formula	$NaMnO_4$
Purity	40.0 % by weight minimum as $NaMnO_4$
Molecular weight	141.93 g/mol
Form and features	Dark purple liquid with metallic luster, sweetest astringent taste, odorless, granular crystalline, oxidizer
Specific gravity	1.36 to 1.39 g/cm^3 for a 40% solution
Solubility in water	Miscible with water in all proportions
Insolubles	100 to 1900 ppm
Potassium	1000 to 2200 ppm
pH	6.0 to 7.0
Packaging	18.9L Jerrican, 18.9L steel drum, 208L steel drum
Hazard class (ID no.)	Oxidizer (UN3214)
Stability	Stable for >18 mon
Incompatibilities	Avoid contact with acids, peroxides, and all combustible organics or readily oxidizable materials
Materials compatibility	In neutral or alkaline conditions $NaMnO_4$ is not corrosive to carbon and 316 stainless steel. However chloride corrosion may be accelerated. Plastics such as Teflon, polypropylene, HDPE, and EDPM are compatible, but Teflon FEP and TFE, and Telzel ETFE are best

[1]Refer to Appendix A for additional manufacturer's information.

The stoichiometric reactions for the complete destruction of several common chlorinated organic solvents in an aqueous system are given in eqn. 2.11.

Tetrachloroethene (PCE)

$$4KMnO_4 + 3C_2Cl_4 + 4H_2O \rightarrow 6CO_2 + 4MnO_2 + 4K^+ + 8H^+ + 12Cl^- \quad (2.8)$$

Trichloroethene (TCE)

$$2KMnO_4 + C_2HCl_3 \rightarrow 2CO_2 + 2MnO_2 + 2K^+ + H^+ + 3Cl^- \quad (2.9)$$

Dichloroethene (DCE)

$$8KMnO_4 + 3C_2H_2Cl_2 \rightarrow 6CO_2 + 8MnO_2 + 8K^+ + 6Cl^- + 2OH^- + 2H_2O \quad 2.10)$$

Vinyl chloride (VC)

$$10KMnO_4 + 3C_2H_3Cl \rightarrow 6CO_2 + 10MnO_2 + 10K^+ + 3Cl^- + 7OH^- + H_2O \quad (2.11)$$

Based on the above stoichiometry, the oxidant demand and product formation for chemical oxidation of the four chlorinated ethenes are given in Table 2-4. Note that the reactions are comparable in permanganate demand whether it is supplied in the potassium form or sodium form. As shown in Table 2-4, on a unit mass basis, halocarbons with higher chlorine substitution (e.g., PCE vs. DCE) consume less oxidant (per the stoichiometric requirement) and produce less MnO_2 solids.

Reaction Pathways

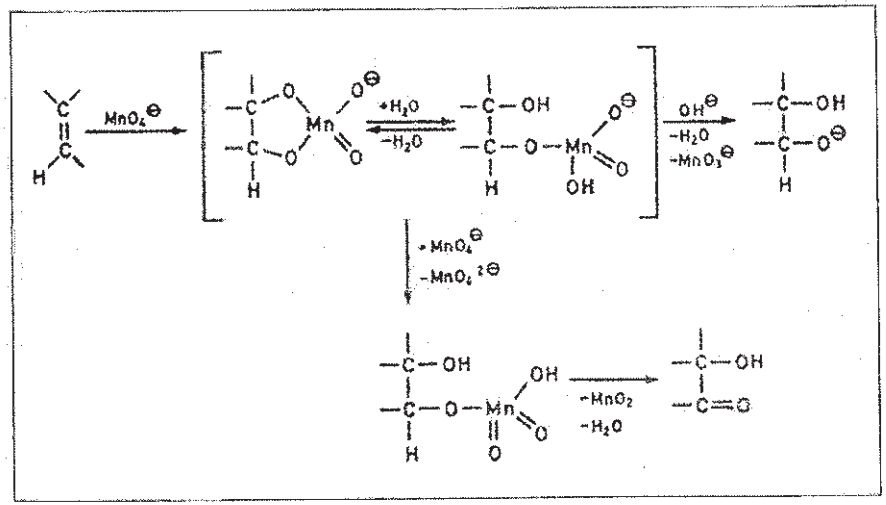
The hydroxylation of olefins by MnO_4^- has been known for many years (Wagner 1895). It is generally accepted that under neutral to acidic pHs, MnO_4^- initially reacts with the carbon-carbon double bond to form a five-member cyclic hypomanganate ester (Figure 2-1). That reaction consumes 1 mole of permanganate for each mole of olefin, and that cycloaddition has been reported to be the rate-determining step in degradation (Wiberg and Saegebarth 1957, Stewart 1965, Freeman 1976). Yan and Schwartz (1998, 1999) recently proposed a similar reaction scheme for the chemical oxidation of TCE in which the cyclic ester can then undergo decomposition to carbon dioxide along several oxidative or hydrolysis pathways depending on pH. Several carboxylic acid intermediates including formic, oxalic, glyoxylic and glycolic acids were also identified. In highly alkaline solutions, hydroxyl radicals, which can contribute to oxidative destruction, also may be formed. The degradation

TABLE 2-4. Stoichiometric requirements for mineralization of organic compounds by permanganate.[1]

Target compound	Compound molecular weight (g/mol)	Oxidant demand (g MnO_4^- / g of target)	MnO_2 produced (g MnO_2 / g target oxidized)
Tetrachloroethene	165.6	0.96	0.70
Trichloroethene	131.2	1.81	1.32
Dichloroethene	96.8	3.28	2.39
Vinyl chloride	62.4	6.35	4.64
Phenol	94.1	11.8	8.62
Naphthalene	128.2	14.8	10.8
Phenanthrene	178.2	14.7	10.7
Pyrene	202.3	14.5	10.6

[1]Molecular weight of MnO_4^- = 118.9 g, MnO_2 = 86.9 g, $KMnO_4$ = 158 g, and $NaMnO_4$ = 141.9 g.

FIGURE 2-1. Pathway for oxidation of olefins such as TCE.



ATTACHMENT B

SHALLOW	Estimates	Units	
Treatment Area Volume			
Length	60	ft	
Width	3600	ft	
Area	216000	sq ft	
Thickness	20	ft	
Total Volume	160000	cu yd	
Soil Characteristics/Analysis			
Porosity	30	%	
Total Plume Pore Volume	9694752	gal	
Avg Contaminant Conc	0.075	ppm	
Mass of Contaminant	6.07	lb	
PNOD	1	g/kg	
Effective PNOD	10	%	
Effective PNOD Calculated	0.1		
PNOD Oxidant Demand	47520	lb	
Avg Stoichiometric Demand	0.96	lb/lb	
Contaminant Oxidant Demand	5.83	lb	
Theoretical Oxidant Demand	47525.83	lb	
Confidence Factor	5		
Calculated Oxidant Demand	237629.1263		
Injection Volumes for RemOx S			
RemOx S Injection Concentration	5.0%	%	
Total Volume of Injection Fluid	569,513	gal	
Pore Volume Replaced	0.06	%	
Amount of RemOx S ISCO Reagent Estimated			**237,629 pounds**
Injection Volumes for RemOx L			
RemOx L Injection Concentration	5.0%	%	
Calculated Specific Gravity	1.0458115	g/ml	
Total Volume of Injection Fluid	489,020	gal	
Pore Volume Replaced	0.05	%	
Amount of RemOx L ISCO Reagent Estimated			**533,477 pounds**
			46,673 gallons

INTERMEDIATE>100PPB	Estimates	Units	
Treatment Area Volume			
Length	60	ft	
Width	6000	ft	
Area	360000	sq ft	
Thickness	30	ft	
Total Volume	400000	cu yd	
Soil Characteristics/Analysis			
Porosity	30	%	
Total Plume Pore Volume	24236880	gal	
Avg Contaminant Conc	0.4	ppm	
Mass of Contaminant	80.91	lb	
PNOD	1	g/kg	
Effective PNOD	10	%	
Effective PNOD Calculated	0.1		
PNOD Oxidant Demand	118800	lb	
Avg Stoichiometric Demand	0.96	lb/lb	
Contaminant Oxidant Demand	77.67	lb	
Theoretical Oxidant Demand	118877.67	lb	
Confidence Factor	5		
Calculated Oxidant Demand	594388.3507		
Injection Volumes for RemOx S			
RemOx S Injection Concentration	5.0%	%	
Total Volume of Injection Fluid	1,424,538	gal	
Pore Volume Replaced	0.06	%	
Amount of RemOx S ISCO Reagent Estimated			**594,388 pounds**
Injection Volumes for RemOx L			
RemOx L Injection Concentration	5.0%	%	
Calculated Specific Gravity	1.0458115	g/ml	
Total Volume of Injection Fluid	1,223,198	gal	
Pore Volume Replaced	0.05	%	
Amount of RemOx L ISCO Reagent Estimated			**1,334,402 pounds**
			116,746 gallons

INTERMEDIATE>1000PPB	Estimates	Units	
Treatment Area Volume			
Length	60	ft	
Width	1440	ft	
Area	86400	sq ft	
Thickness	30	ft	
Total Volume	96000	cu yd	
Soil Characteristics/Analysis			
Porosity	30	%	
Total Plume Pore Volume	5816851	gal	
Avg Contaminant Conc	2	ppm	
Mass of Contaminant	97.09	lb	
PNOD	1	g/kg	
Effective PNOD	10	%	
Effective PNOD Calculated	0.1		
PNOD Oxidant Demand	28512	lb	
Avg Stoichiometric Demand	0.96	lb/lb	
Contaminant Oxidant Demand	93.20	lb	
Theoretical Oxidant Demand	28605.20	lb	
Confidence Factor	5		
Calculated Oxidant Demand	143026.0208		
Injection Volumes for RemOx S			
RemOx S Injection Concentration	5.0%	%	
Total Volume of Injection Fluid	342,783	gal	
Pore Volume Replaced	0.06	%	
Amount of RemOx S ISCO Reagent Estimated			**143,026 pounds**
Injection Volumes for RemOx L			
RemOx L Injection Concentration	5.0%	%	
Calculated Specific Gravity	1.0458115	g/ml	
Total Volume of Injection Fluid	294,335	gal	
Pore Volume Replaced	0.05	%	
Amount of RemOx L ISCO Reagent Estimated			**321,093 pounds**
			28,092 gallons

DEEP	Estimates	Units	
Treatment Area Volume			
Length	60	ft	
Width	2160	ft	
Area	129600	sq ft	
Thickness	30	ft	
Total Volume	144000	cu yd	
Soil Characteristics/Analysis			
Porosity	30	%	
Total Plume Pore Volume	8725277	gal	
Avg Contaminant Conc	0.2	ppm	
Mass of Contaminant	14.56	lb	
PNOD	1	g/kg	
Effective PNOD	10	%	
Effective PNOD Calculated	0.1		
PNOD Oxidant Demand	42768	lb	
Avg Stoichiometric Demand	0.96	lb/lb	
Contaminant Oxidant Demand	13.98	lb	
Theoretical Oxidant Demand	42781.98	lb	
Confidence Factor	5		
Calculated Oxidant Demand	213909.9031		
Injection Volumes for RemOx S			
RemOx S Injection Concentration	5.0%	%	
Total Volume of Injection Fluid	512,666	gal	
Pore Volume Replaced	0.06	%	
Amount of RemOx S ISCO Reagent Estimated			**213,910 pounds**
Injection Volumes for RemOx L			
RemOx L Injection Concentration	5.0%	%	
Calculated Specific Gravity	1.0458115	g/ml	
Total Volume of Injection Fluid	440,208	gal	
Pore Volume Replaced	0.05	%	
Amount of RemOx L ISCO Reagent Estimated			**480,228 pounds**
			42,015 gallons

APPENDIX B

COST ESTIMATES

West Side Corp OU2 FFS
Permanganate Injection

Construction Cost Estimate

Bases

(1) Performance Monitoring - After each of 2 injection events for Alt 2A and 3 injection events for Alts 2B and 2C, perform 5 rounds of monitoring, one round per each of 5 months then a round of VOCs, metals and alkalinity.

(2) Baseline Monitoring - Baseline monitoring shall be done to supplement the program completed in Fall 2012.

(3) Injection Events - Two (2) injection events to be performed for Alt 2A, 3 events for Alts 2B and 2C

(4) Permanganate - Inject at 5% solution (Oser OU2 was 20% solution).

(5) Assume Alt 2B and 2C are essentially "same"in terms of number of wells and performance monitoring effort, given the assumptions noted and level of accuracy noted within the individual unit pricing and costs derived herein.

(6) Thus the main differences between all Alts are permanganate volumes for each Alt; and the performance monitoring for Alt 2A versus 2B/2C.

(7) Well depth per Table 4-1 (attached):
Shallow = 30 ft bgs
Intermediate = 60 ft bgs
Deep = 90 ft bgs

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

	By: RJP	Cked By: AMM	
	Date: 2/19/2013	Date: 2/21/2013	

Bid Item	**Description of Bid Item**	**Unit of Measure**
UC-1	Site Services	Day

Limited to 5% of bid amount per Measurement and Payment spec

Total of cost items exclusive of

	UC-1	Site Services
and	LS-1	Mob/Demob & Site Prep

which are the two "limited to 5% of bid amount items"

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

By:	RJP	Cked By:	AMM
Date:	2/19/2013	Date:	2/21/2013

Bid Item	**Description of Bid Item**	**Unit of Measure**
UC-2a	Injection Well Installation - Nest of Two	LF

The basis for this item is Item UC-4 Monitoring Well Installation (Singles), 2-in diam, which will be installed via HSA method at 6-inch diameter. Injection wells will be installed via sonic method and will be two 1-inch risers installed into an 8-inch diameter borehole.

Cross section area A:
6-inch diam = (pi)(3 in.)^2 = 28.3 sq. in.
8-inch diam = (pi)(4 in.)^2 = 50.2 sq. in. or approx. double the 6-in. dia.

Thus the net adds for sonic drilling are as follows:

(a) (8-inch sonic drilling) minus (6-inch HSA drilling) = ($40/LF) - ($20/LF) = $20/LF
See attached unit pricing from driller for these unit prices.

(b) PVC well labor and materials: Assume it is 1.5 (x $18) that of single well = $ 27/LF

(c) Cuttings are minimized to negligible due to using sonic method so cuttings volume is actually decreased compared to that of 6-inch HSA boring. Ignore cost reduction of cuttings to be conservative.

(d) Total add-on $ 47/LF
(e) Monitoring Well unit price plus $ 200/LF

TOTAL $ 247/LF

say $250/LF

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

	By: RJP	Cked By: AMM
	Date: 2/19/2013	Date: 2/21/2013

Bid Item	Description of Bid Item	Unit of Measure
UC-2b	Injection Well Installation - Nest of Three	LF

Use UC-2a Injection Well Installation - Nest of Two, as cost basis.
Nest of three will also be constructed in 8-inch diameter bore hole via sonic method.

Thus, use Nest of Two and add $18/LF to account for additional riser:

Nest of Two unit cost	$250/LF
Add for add'l riser	$18/LF
SUB-TOTAL 1	$268/LF

To account for management of traffic (MOT) add $30,000

$30,000/(80 wells x 40 LF) = $9/LF SUB-TOTAL 2

TOTAL = $277/LF

say $280/LF

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

	By: RJP	Cked By: AMM	
	Date: 2/19/2013	Date: 2/21/2013	

Bid Item	Description of Bid Item	Unit of Measure
UC-2c	Injection Well Installation - Single	LF

See Cost Summary and unit price derivation for Injection Wells Doubles and Triples. There is minor difference between unit price for doubles and triples. Doubles are about 10% lower unit price than triple.

Double and triples are assumed to both be installed in 8-inch diameter borehole so most of cost is in the drilling aspect. Singles may be able to be installed in smaller diameter bore hole but, for this level estimate, assume singles are also installed in 8-inch diameter bore hole.

Say, single unit price is 10% less than double unit price:

Single = (0.90) x ($250/LF) = $ 225 per LF

compare to OSER bids this is too high; look at OSER bids and use avg

say $170/LF

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

By:	RJP	Cked By:	AMM
Date:	2/19/2013	Date:	2/21/2013

Bid Item	Description of Bid Item	Unit of Measure
UC-3	Sodium Permanganate Injection	Gallon

Kliegman estimate was approx $4.50/gallon for 5% sodium permanganate solution injected.

Recent Carus estimate for permanganate delivered reported at		$3.50	per gallon
Add for injection	this site	$2.00	per gallon
	TOTAL	$5.50	per gallon

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

	By: RJP	Cked By: AMM	
	Date: 2/19/2013	Date: 2/13/2013	

Bid Item	Description of Bid Item	Unit of Measure
UC-4	Monitoring Well Installation (Singles)	LF

Stuart Olver-Holtz

Ref Stuart Olver-Holtz (DEC) site with similar construction and approx 30-ft deep = $161/LF

Oser OU2

Oser OU2 mon wells per dwg C-005

SPMW-01	64 LF
SPMW-02	45 LF
SPMW-03	46 LF
SPMW-04	23 LF
SPMW-05	31 LF
SPMW-06	9 LF

avg 36 LF

West Side: Assume Two monitoring well "clusters" at 3 individual wells each.
That is, drill 6 individual wells.
Well depth about 90 feet bgs:

(6 wells) x (90 ft) = 540 LF

Assume 25% premium to drill to 90 ft bgs. Drillers usually quote pricing for 0 to 50 ft then 50 to 100 ft bgs, etc.

Use $161/LF plus 50% = $ 201

say $200/LF

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

		By: RJP	Cked By: AMM
		Date: 2/19/2013	Date: 2/21/2013

Bid Item	**Description of Bid Item**	**Unit of Measure**
UC-5	Health and Safety	Day

Ref. vendor quote (attached)

$250/day

Oser OU2 basis was for 300 days to address well construction plus injection events.

Alt 2A will have about same number of wells (60) but one less injection event
(2 events instead of 3). So use about 300 days for West Side Alternative 2A

Alt 2B will have more wells (84) and the same (3) injection events
So use about 450 days for West Side Alternative 2B

Alt 2C will have more wells (196) and the same (3) injection events
So use about 750 days for West Side Alternative 2C
(Note that multiple crews are included for Alternative 2C)

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

	By:	Cked By:
	Date:	Date:

Bid Item	Description of Bid Item	Unit of Measure
UC-6	NOT USED	LF

NOT USED

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

	By:	Cked By:
	Date:	Date:

Bid Item	Description of Bid Item	Unit of Measure
UC-7a	NOT USED	LF

NOT USED

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

	By:	Cked By:
	Date:	Date:

Bid Item	Description of Bid Item	Unit of Measure
UC-7b	NOT USED	LF

NOT USED

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

		By: RJP	Cked By: AMM
		Date: 2/19/2013	Date: 2/21/2013

Bid Item	Description of Bid Item	Unit of Measure
LS-1	Mob/Demob & Site Prep	Lump Sum

Limited to 5% of bid amount per Measurement and Payment spec

Total of cost items exclusive of

	UC-1	Site Services
and	LS-1	Mob/Demob & Site Prep

which are the two "limited to 5% of bid amount items"

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

		By: RJP	Cked By: AMM
		Date: 2/19/2013	Date: 2/21/2013

Bid Item	Description of Bid Item	Unit of Measure
LS-2	Site Survey	Lump Sum

Oser OU2 Take-Off:

Refer to attached price quote from Naik Group

Services include the following:

1. Establish survey control
2. Pre-stakeout of 60/84/196 proposed injection wells, 6 new monitoring wells
3. Surficial features locating
4. Public right-of-ways
5. Locate as-built x-y-z of constructed wells
6. Base map preparation
7. "Normal" constr. Coord. with Prime Contractor, Engineer, and Municipalities
8. Typical construction submittals such as electronic files and field notes

Cost Quote = $57,900

West Side:

West Side preliminary design consists of about 60/84/196 proposed injection wells plus 6 new monitoring wells, (compared to 60 for Oser OU2).
All other tasks for West Side should be similar to Oser OU2 so use Oser OU2 estimate for West Side.

Say	$60,000	2A, 2B
	$75,000	2C

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

By:	RJP	Cked By:	AMM
Date:	2/19/2013	Date:	2/21/2013

Bid Item	Description of Bid Item	Unit of Measure
LS-3a	Baseline Monitoring	Lump Sum

Oser OU2 Basis:

Average bid was $64,000 and entire project low bidder was $79,000.

This involved: 55 lab samples from 45 locations (mon wells, surface water, sed.)
plus 35 field test locations

West Side OU2:

West Side involves 54 samples from 19 locations.

This plan is very similar to Oser OU2 so can expect $65k to $80K.

say $80,000

	By: RJP	Cked By: AMM
	Date: 2/19/2013	Date: 2/21/2013

Bid Item	Description of Bid Item	Unit of Measure
LS-3b	Performance Monitoring	Lump Sum

Oser OU2 Basis:

Average bid was $272,000 and entire project low bidder was $227,000.
This involved 20 trips and 73 wells @ various depths for total of 125 sample intervals per trip.

West Side OU2:

West Side planned to consist of 12 trips and 60 - 80 wells @ various depths for total of 100 to 140 sample intervals per trip for Alts 2A and 2B

Since West Side # wells and # samples is about same as Oser OU2, we can assume that West Side is about same as Oser OU2 in this regard for Alts 2A and 2B
However, West Side # trips is about 2/3 that of Oser OU2 for Alt 2A

Thus, assume West Side cost = (2/3) x ($250,000) =	$ 165,000	Alt 2A
	$250,000	Alt 2B
(Alt 2C is about triple this effort in terms of manhours, per back-up; and double in terms of # samples per backup. Thus, say Alt 2C cost is triple of that shown above.	$750,000	Alt 2C

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

	By:	Cked By:
	Date:	Date:

Bid Item	Description of Bid Item	Unit of Measure
LS-3c	NOT USED	Lump Sum

NOT USED

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing

	By:	Cked By:
	Date:	Date:

Bid Item	Description of Bid Item	Unit of Measure
LS-4	NOT USED	Lump Sum

NOT USED

DRAFT

Table 5-1

Alternatives 2A, 2B, 2C Cost Estimates

ITEM NO.	DESCRIPTION	UNIT	UNIT PRICES: UNIT PRICE FROM ATTACHED BACK-UP	UNIT PRICES: AVG UNIT PRICE FROM OSER OU2 BIDS	UNIT PRICES: UNIT PRICE FROM OSER OU2 LOW BIDDER	ALT 2A: EST QTY	ALT 2A: TOTAL PRICE ($)	ALT 2B: EST QTY	ALT 2B: TOTAL PRICE ($)	ALT 2C: EST QTY	ALT 2C: TOTAL PRICE ($)
UC-1	Site Services	Day	NA	$ 286	$ 150	1	**$ 179,552**	1	**$ 281,714**	1	**$ 758,127**
UC-2a	Injection Well Installation - Nest of Two	LF	250	$ 171	$ 115		$ -				
UC-2b	Injection Well Installation - Nest of Three	LF	280	$ 170	$ 120		$ -		$ -		$ -
UC-2c	Injection Well Installation - Single	LF	230	$ 170	NA	1,800	**$ 305,233**	3,240	**$ 549,419**	11,040	**$ 1,872,095**
UC-3	Sodium Permanganate Injection	Gallon	$5.50	$ 12	$ 11	500,000	**$ 2,750,000**	800,000	**$ 4,400,000**	2,175,000	**$ 11,962,500**
UC-4	Monitoring Well Installation (Singles)	LF	200	$ 190	$ 135	540	**$ 102,708**	540	**$ 102,708**	540	**$ 102,708**
UC-5	Health and Safety	Day	250	$ 427	$ 283	300	**$ 128,098**	450	**$ 192,148**	750	**$ 320,246**
UC-6	NOT USED	LF	0	$ -	$ -		$ -		$ -		$ -
UC-7a	NOT USED	LF	0	$ -	$ -		$ -		$ -		$ -
UC-7b	NOT USED	LF	0	$ -	$ -		$ -		$ -		$ -
LS-1	Mob/Demob & Site Prep	Lump Sum	179,552	$ 179,936	$ 271,803	1	**$ 179,552**	1	**$ 281,714**	1	**$ 758,127**
LS-2	Site Survey	Lump Sum	60,000	$ 23,438	$ 37,114	1	**$ 60,000**	1	**$ 60,000**	1	**$ 75,000**
LS-3a	Baseline Monitoring	Lump Sum	80,000	$ 64,000	$ 79,000	1	**$ 80,000**	1	**$ 80,000**	1	**$ 80,000**
LS-3b	Performance Monitoring	Lump Sum	250,000	$ 272,000	$ 226,000	1	**$ 165,000**	1	**$ 250,000**	1	**$ 750,000**
LS-3c	NOT USED	Lump Sum	0	$ -	$ -	0	$ -		$ -		$ -
LS-4	NOT USED	Lump Sum	-	$ -	$ -	0	$ -		$ -		$ -
		SUBTOTAL					**$ 3,950,143**		**$ 6,197,702**		**$ 16,678,803**
		CONTINGENCY (15% of Subtotal)					**$ 592,521**		**$ 929,655**		**$ 2,501,821**
		GRAND TOTAL					**$ 4,542,664**		**$ 7,127,357**		**$ 19,180,624**

Highlighted item = 5% of total of all non-hilighted items

Highlighted item = selected unit price for this estimate

Highlighted item only shown for illustration and not necessarily for direct comparison as scope of such items may be different for different projects

West Side Corp OU2 FFS
Permanganate Injection
Unit Pricing Back-Up

By: GK
Date: 8/10/2011

Average cost for:

TCL VOC by SW846-8260B	=	$ 67
TAL Metals by SW846-6010B/7470A/7471A	=	$ 96
Alkalinity by EPA 310	=	$ 13
Total		$176

Lab Color by SM 2120B …… $11

(Add sample frequency of 5% for Baseline testing for MS/MSD's … i.e., 5% mark-up)

Average Turnaround Time premium

24 hour = 89%
48 hour = 62%
72 hour = 40%
1 week = 18%
2 week = 7%

Averages based on 9 bid responses for NYSDEC Standby Contract D007622, May 2011, rounded up to the nearest dollar. Prices for soil and water are the same.
NYSDEC ASP Category B deliverables

West Side Corp OU2 FFS
Permanganate Injection

Performance Monitoring

> Mon/Sampling Table
> Man-Hour Estimate

				ALT 2A			ALT 2B			ALT 2C		
				#	Depth (ft)	Length (LF)	#	Depth (ft)	Length (LF)	#	Depth (ft)	Length (LF)
Injection wells at 60-foot intervals												
	Shallow	Intermediate	Deep									
Along 177th St												
109th - 110th (600 ft)	11	11		11	30	330	11	30	330	22	30/60	990
110th - 111th (600 ft)	5	5		5	30	150	5	30	150	10	30/60	450
									0			
Along 176th St									0			
109th - 110th (600 ft)	11	11		11	30	330	11	30	330	22	30/60	990
110th - 111th (600 ft)	11	11		11	30	330	11	30	330	22	30/60	990
									0			
Along 175th St									0			
110th - 111th (600 ft)	11	11		11	30	330	11	30	330	22	30/60	990
110th - 111th (420 ft)			8						0	8	90	720
									0			
Along 174th St									0			
110th - 111th (600 ft)	11	11		11	30	330	11	30	330	22	30/60	990
110th - 111th (300 ft)			5						0	5	90	450
111th - 112th (600 ft)		10	10							20	60/90	1500
									0			
Along 111th (300 ft)									0			
172nd - 173rd		6							0	6	60	360
									0			
Along Sayres (W to E)	East of Merrick Blvd								0			
250 ft		5	5				5	60	300	10	60/90	750
200 ft		4	4				4	60	240	8	60/90	600
200 ft		4	4				4	60	240	8	60/90	600
									0			
Along Sayres (W to E)	West of Merrick Blvd								0			
200 ft		4					4	60	240	4	60	240
200 ft		4					4	60	240	4	60	240
150 ft		3					3	60	180	3	60	180
				60		1800	84		3240	196		11040
	Shallow	**Intermediate**	**Deep**									
TOTALS	**60**	**100**	**36**									

Note: Spacing at 60-foot intervals refers to a 30-foot radius of influence

Well Screen Depths: Shallow: 12 - 22 feet bgs Intermediate: 35 - 45 feet bgs Deep: 70 - 80 feet bgs
Groundwater zones: Shallow: 10 - 30 feet bgs Intermediate: 30 - 60 feet bgs Deep: 60 - 90 feet bgs

ALTERNATIVE 2A - 60 SHALLOW INJECTION WELLS
ALTERNATIVE 2B - 60 SHALLOW AND 24 INTERMEDIATE INJECTION WELLS ALONG SAYRES AVE
ALTERNATIVE 2C- 60 SHALLOW AND 100 INTERMEDIATE AND 36 DEEP INJECTION WELLS

Alternative 2A						
	# of Injection Wells	Gallons 5% Permanganate Solution	@ 8 gpm required injection hrs per well	Productivity Reduction	# of Injection Events	Manhours per Injection Event (assume 2 person crew)
Shallow	60	500,000	18	0.75	2	1,440
Intermediate						
Deep						

Alternative 2B						
	# of Injection Wells	Gallons 5% Permanganate Solution	@ 8 gpm required injection hrs per well	Productivity Reduction		Manhours per Injection Event (assume 2 person crew)
Shallow	60	500,000	18	0.75	2	1,440
Intermediate	24	300,000	27	0.75	3	576
Deep						

Alternative 2C						
	# of Injection Wells	Gallons 5% Permanganate Solution	@ 8 gpm required injection hrs per well	Productivity Reduction	# of Injection Events	Manhours per Injection Event (assume 2 person crew)
Shallow	60	500,000	18	0.75	2	1,440
Intermediate	100	1,225,000	26	0.75	3	2,312
Deep	36	450000	27	0.75	3	864

Frequency of Groundwater Sample Collection	Baseline Monitoring Prior to 1st Injection Event						Prior to 2nd Injection Event						Prior to Subsequent Injection Events
Parameters		Month 1	Month 2	Month 3	Month 4	Month 5	Month 6 (approx)	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6 (approx)
VOCs, Metals, Alkalinity	x						x						x
Color		x	x	x	x	x	x	x	x	x	x	x	x
Field Parameters (pH, DO, ORP, Specific Conductivity)	x	x	x	x	x	x	x	x	x	x	x	x	x

Baseline Monitoring	Shallow	Intermediate	Deep
W-01	S	I	D
W-02	S	I	D
W-03	S	I	D
W-04	S	I	D
W-05	S		
W-06	S	I	D
W-07	S	I	D
W-08	S	I	D
W-09	S	I	D
W-10	S	I	D
W-11		I	D
W-12	S	I	D
W-13	S	I	D
W-14	S	I	D
W-15	S	I	D
MW-24-5	S	I	D
MW-24-6	S	I	D
New Monitoring Well P1	S	I	D
New Monitoring Well P2	S	I	D
Totals	18	18	18
Total # of Groundwater Samples			**54**
Total # of Sampling Locations			**19**

Prior to Injection Events	Shallow	Intermediate	Deep	Total # of Samples	Total # of Sample Locations
Baseline Monitoring Wells	18	18	18	54	19
Alternative 2A	60			114	79
Alternative 2B	60	24		138	103
Alternative 2C	60	100	36	250	132