REMEDIAL DESIGN WORK PLAN

WORK ASSIGNMENT D009803-14

WEST SIDE CORPORATION - OPERABLE UNIT NO. 2 (STATION 24)
SITE NO. 241026
JAMAICA, QUEENS COUNTY, NY

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

Basil Seggos, Commissioner

DIVISION OF ENVIRONMENTAL REMEDIATION

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FINAL

June 2020

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NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
DIVISION OF ENVIRONMENTAL REMEDIATION
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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

LIST OF ABBREVIATIONS/ACRONYMS

AECOM	AECOM USA, Inc.
bgs	below ground surface
DER	Division of Environmental Remediation
DO	dissolved oxygen
Drawings	Remedial Construction Contract Drawings
FFS	Focused Feasibility Study
g/kg	grams per kilogram
gpm	gallons per minute
ISCO	in situ chemical oxidation
NYSDEC	New York State Department of Environmental Conservation
OD	outside diameter
OM&M	Operation, Maintenance and Monitoring
ORP	oxidation reduction potential
OU	operable unit
PCE	perchloroethylene (tetrachloroethylene)
PNOD	permanganate natural oxidant demand
ppb	parts per billion
PVC	polyvinyl chloride
RDWP	Remedial Design Work Plan
ROD	Record of Decision
ROI	radius of influence
ROW	rights-of-way
SVI	soil vapor intrusion
UIC	Underground Injection Control
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

1.0 INTRODUCTION

This Remedial Design Work Plan (RDWP) presents the design rationale, criteria, computations, and analysis for a remedial design at Operable Unit Number 2 (OU2) of the West Side Corporation (West Side) Site (Site No. 241026) located in Jamaica, Queens, New York (Figure 1). This document presents the scope, site background, approach, and description of the remedial alternative selected for remediation of OU2 in accordance with the New York State Department of Environmental Conservation (NYSDEC) Amended Record of Decision (ROD) dated December 2013.

1.1 Previous Site Work and Investigations

AECOM USA, Inc. (AECOM) prepared this RDWP for the NYSDEC for OU2 of the Site as part of Work Assignment D009803-14 of the AECOM standby engineering services contract with the NYSDEC. Previous work performed by AECOM (formerly URS Corporation – New York) for OU2 prior to this RDWP included the following:

- 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.

- Developed a Focused Feasibility Study (FFS) to evaluate in situ chemical oxidation (ISCO) technology using sodium permanganate injection as an alternative to the existing groundwater extraction and treatment system. The FFS, issued by AECOM in March 2013, was based on information and data presented in the West Side Corporation Operable Unit No. 2 Final Offsite Plume Delineation and Investigation report prepared by Malcolm Pirnie, Inc., March 2009, and groundwater sampling data included in the West Side Corp. Site Operable Unit 2 Station 24 Treatment System Operations Report prepared by AECOM in December 2012.

- Assisted in the preparation of the Amended ROD issued by the NYSDEC in December 2013.

After the Amended ROD was issued, a pre-design investigation was performed by AECOM in 2014 that included the following:

- Collection of a synoptic round of depth to groundwater in existing monitoring wells.
- Groundwater sampling and analysis for volatile organic compounds (VOCs) in shallow and intermediate groundwater.
- Sampling and analysis for permanganate natural oxidant demand (PNOD) values in two soil samples from the shallow groundwater zone and two soil samples from the intermediate groundwater zone. Analytical results for PNOD are presented in Appendix A and discussed in Section 2.4.
- Performance of an injection pilot test in the shallow groundwater in OU2 to evaluate possible water table rise during injection. Field data forms are included as Appendix B. Results indicated that the proposed injection rate of 8 gallons per minute (gpm) for the aquifer was feasible and would not create groundwater mounding.

The design was never implemented. However, in December 2018, the Department requested that AECOM perform an additional groundwater sampling event as part of the Operation, Maintenance and Monitoring (OM&M) program for the Site. As a result, in March 2019 groundwater samples were collected at 32 monitoring wells in OU2 and analyzed for VOCs. Analytical results indicated that the contaminant plume extended in a southern direction beyond the existing monitoring well network. Consequently, NYSDEC decided that additional monitoring wells should be installed in areas south of the existing monitoring well network.

Between July 22 and August 12, 2019, groundwater screening borings were installed south of the then existing monitoring well network to determine future well locations and well construction details, such as well depth. A total of 41 groundwater samples and one soil sample were collected during the screening investigation. All samples were analyzed for VOCs. Based on the screening, shallow (S), intermediate (I), and deep (D) monitoring wells were installed as follows: W-16S, W-16I and W-16D; W-17S and W-17I; W-18I; W-19S, W-19I and W-19D; W-20S and W-20I; W-21S, W-21I and W-21D; and, W-22S and W-22I (see Figures 2 through 4 for well locations).

In September and October of 2019, groundwater samples were collected from 62 monitoring wells. All samples were analyzed for VOCs. In general, the sample results indicated that the concentrations of VOCs decreased significantly, and that the groundwater VOC plume migrated farther to the south and southwest. The results were used to estimate the area of remediation in OU2, which is discussed in Section 1.4.

1.2 Site History and Background

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 2). The West Side property was the location of a former distributor of perchloroethylene (PCE) for the dry-cleaning industry. Due to spills and/or poor housekeeping practices, PCE had been released to the environment. In July 2000, the NYSDEC signed a ROD, which selected a remedy to clean up soil and groundwater on the on-site property (OU1). In September 2002, an Explanation of Significant Differences was issued by the NYSDEC revising the OU1 remedy. By 2005, NYSDEC completed the remediation of the OU1 using electrical resistance heating, 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 had migrated from the Site to the south-southwest (OU2). OU2 is the subject of this work plan. (OU2 also pertains to soil gas at various locations within the groundwater plume; however, specifically addressing soil gas is not included in this design.)

An Amended ROD for OU2 was issued in December 2013 by the NYSDEC that was based on the FFS prepared by AECOM. The recommended alternative in the FFS included injection of permanganate in OU2 to address chlorinated VOC contamination within the 10 parts per billion (ppb) plume for the shallow groundwater zone and the 1,000 ppb plume in the intermediate groundwater zone.

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 investigations 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 has an undulating surface throughout the study area, increases southward from OU1 to OU2, ranging from 62 feet to 105 feet below ground surface (bgs). The average depth to the Gardiner's clay layer in OU2 is considered to be 90 feet bgs.

The horizontal groundwater gradient was estimated to be 0.0018 foot/foot along the plume's south-southwest heading in 2009. Given this gradient, an average hydraulic conductivity of 1,000 gallons per day/square foot and an average effective porosity of 30%, the rate of groundwater flow in the aquifer was estimated at 0.80 feet/day (2.8×10^{-4} centimeters/second).

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 foot, indicating no significant vertical gradient under non-pumping conditions. The most recent data, collected in September 2019, show water elevations in OU2 ranging from 7.12 to 21.12 feet bgs. Figures 2, 3 and 4 show the shallow, intermediate, and deep groundwater potentiometric surfaces, respectively, based on the September 2019 water level measurements. The data show that groundwater flow in the shallow, intermediate, and deep wells is to the south-southwest.

1.3 ROD and Amended ROD Approach

OU2 ROD and Remediation Area

Remedial goals identified for the OU2 in the ROD and Amended ROD were:

- 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 of organic vapors that could migrate from the water table into off-site residences.

2013 Amended ROD Approach

The components of the Recommended Remedy presented in the 2013 Amended ROD were as follows:

- Discontinue operation of the previously-installed groundwater extraction and treatment system.
- Install a network of injection wells within the 10 ppb PCE plume in the shallow groundwater zone along 174th, 175th, 176th, and 177th Streets.
- Install a network of injection wells within the 1,000 ppb PCE plume in the intermediate groundwater zone on Sayres Ave immediately east and west of Merrick Blvd.
- Space injection well locations approximately 60 feet apart (based on an effective radius of influence [ROI] of 30 feet). A total of 60 shallow and 24 intermediate injection wells were proposed in the Amended ROD.
- Based on estimates from the FFS, a 5% permanganate solution to be injected was estimated to be approximately 500,000 gallons for the shallow zone and 300,000 gallons for the intermediate zone.
- Distribute the required permanganate over two injection events for the shallow zone and three injection events would be used for the intermediate zone.
- Install two new monitoring well clusters 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.
- After each injection conduct performance monitoring for five 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 six 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 ongoing Soil Vapor Intrusion (SVI) mitigation program would continue.

1.4 Design Approach Based on 2019 Groundwater Data

The groundwater data collected in 2019 from OU2 varies significantly from that collected in 2012, which formed the basis for the approach to groundwater remediation presented in the 2013 FFS and outlined in the 2013 Amended ROD as summarized above. In general, the concentrations of chlorinated VOCs in the shallow and intermediate groundwater zones have decreased significantly. In addition, the extent of contamination has decreased significantly in the shallow zone although the extent is similar in the intermediate zone. In addition, the intermediate plume has migrated farther to the south compared to earlier results. Figures 5 and 6 show the shallow zone plume in 2012 and 2019, respectively while Figures 7 and 8 show the intermediate zone plume in 2012 and 2019, respectively.

The basic design parameters for groundwater remediation based on the 2019 data are as follows:

- Install injection wells in the shallow zone within the 10 ppb PCE plume (which includes a small plume of 100 ppb);
- Install injection wells in the intermediate zone within the 100 ppb PCE plume;
- Install injection wells downgradient of 100 ppb PCE plume in the intermediate zone:
- Space injection wells a distance of 100 feet apart;
- Inject a 6% solution of sodium permanganate.

This approach varies from the FFS because the character of groundwater contamination has changed significantly in the approximate time of seven years between groundwater sampling events. These variations are discussed below.

- Injection wells will be installed within the 10 ppb PCE plume within the shallow zone as proposed in the FFS; however, the area of the 10-ppb plume has decreased significantly and therefore fewer injection wells are needed.

- Injection wells were to be installed in the 1000 ppb PCE plume within the intermediate zone in the FFS. However, PCE contamination in the intermediate zone has decreased to levels below 1000 ppb based on the 2019 data. The currently identified 100 ppb PCE plume will be the target of remediation in the intermediate zone.

- Since results from 2019 indicate that contamination is continuing to migrate farther south in the intermediate zone, some additional injection wells will be installed downgradient of the 100 ppb PCE plume to reduce the migration of PCE away from the 100 ppb PCE in the intermediate zone.

- The proposed injection well spacing used in the FFS was 60 feet. The 2019 data shows that groundwater is attenuating, naturally. The extent and concentration of contamination has decreased significantly. The concentration of contamination in the intermediate zone has decreased significantly although contamination does continue to migrate to the south. The well spacing has been increased to 100 feet based on the data showing that attenuation of contamination is occurring naturally, and the textural nature of the formation is conducive for the proposed radius of influence.

- The current design has increased the concentration of sodium permanganate from 5% to 6% to decrease the time required for injections and the quantity of sodium permanganate needed to be shipped to the Site, thereby reducing cost.

1.5 Groundwater Remediation Area

The remediation plan for the shallow groundwater zone is shown in Figure 9. In keeping with the parameters presented in Section 1.4, injection wells are located within the 10 ppb plume. Well spacing will be approximately 100 feet. It should be noted that the PCE in W-21S located far downgradient of the Site will not be actively remediated. It is assumed that the PCE in this well will attenuate naturally in a short period of time. This area will be included in performance

groundwater monitoring events and the impact of injections on the extent and concentration of the PCE plume will be evaluated.

The remediation plan for the intermediate zone is shown in Figure 10. In keeping with the Section 1.4 parameters, well spacing will be approximately 100 feet. All injection wells will be located along roads or sidewalk areas accessible for drilling. In addition, as shown on Figure 10, some wells will be installed immediately downgradient of the 100 ppb plume to mitigate migration of PCE away from this area. Well spacing for these wells will also be approximately 100 feet.

2.0 IN SITU CHEMICAL OXIDATION (ISCO)

2.1 Description of Remediation

The design will incorporate ISCO within the remediation areas identified on Figures 9 and 10 for shallow and intermediate groundwater zones, respectively. Post-injection groundwater monitoring (performance monitoring) will evaluate the progress of remediation.

2.2 Injection Approach

Permanganate will be introduced during multiple injection events with performance monitoring conducted in between. The first injection event will provide implementation and treatment experience that can be used to direct the remediation contractor to modify subsequent injection events, as appropriate. This includes quantities injected and/or injection locations.

2.3 Description of Oxidant

2.3.1 Chemistry

Permanganate is a common oxidant and has demonstrated significant effectiveness in oxidizing chlorinated solvents such as PCE. Permanganate is more chemically stable than other ISCO reagents and does not reduce to manganese dioxide (MnO_2) until it encounters oxidizable material. Therefore, permanganate has the potential to be effective for longer periods of time following injection and/or to move farther from the point of injection. Permanganate destroys contaminants through an ionic reaction versus the hydroxyl radical production associated with other ISCO reagents. No heat or gas is produced in the permanganate oxidation reaction, as shown in the half reaction provided in Equation 1, where MnO_4^- is the permanganate ion, H_2O is water, e^- is an electron, $MnO_{2(s)}$ is manganese dioxide solid, and OH^- is the hydroxyl ion.

$$MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_{2(s)} + 4OH^- \qquad \text{Equation 1}$$

PCE is oxidized according to the following half reaction:

$$\frac{1}{4}\, C_2Cl_2 + H_2O \rightarrow \frac{1}{2}\, CO_2 + Cl^- + 2H^+ + e^- \qquad \text{Equation 2}$$

Combining the two half reactions, the overall reaction follows:

$$3C_2Cl_4 + 4MnO_4^- + 4H_2O \rightarrow 6CO_2 + 4MnO_{2(s)} + 12Cl^- + 8H^+ \qquad \text{Equation 3}$$

2.3.2 Selection of Sodium Form of Permanganate

Sodium permanganate ($NaMnO_4$), available as a liquid, will be used rather than potassium permanganate ($KMnO_4$), which is available as a powder that must be dissolved into water. Sodium permanganate as a liquid generally reduces the complexities associated with storage, mixing and transportation of the material. In addition, $NaMnO_4$ is not subject to the Homeland Security regulations that apply to $KMnO_4$, further reducing the complexities associated with storage and transportation of the material.

A 6% by weight $NaMnO_4$ solution will be used for remediation at the OU2. This solution formula is based on the manufacturer's specification because spills of $NaMnO_4$ at greater concentrations must be reduced to 6% or less before they can be neutralized. Design calculations for the quantities of $NaMnO_4$ injection were updated based on the current PCE plume concentrations and size, and site-specific PNOD values. These are presented in Appendix C and are discussed below in Section 2.4.

2.4 Chemical Oxidant Dosage

The oxidant dosage for applications of 6% by weight $NaMnO_4$ was estimated based on stoichiometry and the volume of the aquifer to be treated. The basis and assumptions for each of these criteria are presented below.

2.4.1 Stoichiometry

The amount of permanganate needed for a given mass or volume of aquifer is driven by the oxidant demand of the aquifer. The oxidant demand is governed by:

- The stoichiometric amount of permanganate needed to oxidize PCE;
- The natural oxidant demand of the soil in the aquifer as measured by the PNOD parameter;

- The percentage of the PNOD that is reachable by the injected permanganate; and
- A factor of safety.

For this design, the following values of these parameters were used:

Permanganate stoichiometry: Based on the reaction presented above in Equation 3, 4/3 mole of permanganate is needed for each mole of PCE oxidized (i.e., approximately 1.1 grams of $NaMnO_4$ per gram of PCE).

Natural Oxidant Demand: Results of PNOD sampling and analysis conducted in 2014 indicated that the PNOD in the two shallow overburden samples was 0.02 and 0.08 gram per kilogram (g/kg) with an overall average of 0.05 g/kg. Since these values are very low and because there is concern about soil gas entering buildings from shallow groundwater contamination, a conservative value of 0.1 g/kg, or slightly over the maximum value, has been selected to use in the oxidant calculations for the shallow overburden. Results of PNOD sampling and analysis in the two intermediate overburden samples was 0.5 and 0.7 g/kg with an overall average of 0.56 g/kg. The average PNOD value of 0.56 g/kg has been selected to use in the oxidant calculations for the intermediate overburden. It is noted that these measured values were lower than the 1 g/kg assumed in the FFS.

Percentage Reachable: Typically, the reachable amount of natural oxidant demand is less than what is measured in the laboratory as the well-mixed conditions in the laboratory are not matched in the field. A typical value of 10% is used as the percent of the natural oxidant demand that is reachable. It is assumed that all the demand from the dissolved contaminants is reachable.

Factor of Safety: To account for uncertainties in these parameters, an uncertainty factor of up to 10 is typically applied to the estimate of permanganate demand. Since there is significant groundwater data over a long period of time available for the Site and there is PNOD data available, a lower uncertainty factor of 3 has been used to estimate the quantities for injection.

2.4.2 Volume of Aquifer Treated

The volume of aquifer treated is calculated as the product of the depth interval to which the injection is applied, and the area addressed by the injections. The thickness of the shallow plume

is defined as 20 feet, corresponding to roughly 10 to 30 feet bgs, and thickness of the intermediate plume is 30 feet corresponding to roughly 30 to 60 feet bgs, although this varies with distance from the source.

Figures 9 and 10 show where permanganate will be injected. Injection wells will be installed along the sidewalks as this is where there is access. However, the plume also extends under the buildings between the streets.

There are two ways to calculate the treatment area addressed by the injections. The first method is to take into account the ROI of each well. Using this method, the area is calculated as the product of 7,850 ft^2 (corresponding to a 50-foot ROI) and the number of injection wells of each corresponding type.

The second method is to use the area of the plume as defined by the 10 ppb contour for the shallow component of the plume and the 100 ppb contour for the intermediate plume, and then calculate the amount of permanganate required to treat the entire plume area. This corresponds to a larger area and presumes that unreacted permanganate migrates with natural groundwater flow beyond the radius of influence.

For the shallow plume, the first method was used to calculate the required amount of sodium permanganate for remediation based on a network of wells within the plume as shown on Figure 9.

For the 100 ppb intermediate plume, there is not a network of injection wells because access is limited and only available along Sayre Ave. Realistically, the permanganate will not migrate throughout the entire area defined by the 100 ppb contour line shown on Figure 10. For permanganate estimating purposes, it is assumed that the injected permanganate reacts with a plume that is essentially 100 feet wide.

In addition, injection wells will be installed downgradient of the 100 ppb intermediate plume to prevent additional migration of PCE beyond its current extent. This measure is included because wells within the 100 ppb plume will not likely distribute permanganate throughout the entire plume because areas within the plume where wells can be installed is limited as discussed above. It would be expected that the dissolved PCE concentrations and extent will decrease over time. For the downgradient wells, the first method for calculating the area remediated was used

(i.e., based on the ROI of the wells). The preliminary plan for injection well locations downgradient of the 100 ppb plume is presented in Figure 10.

2.4.3 Calculated Permanganate Injection Volumes.

The parameter values listed above were used in the design calculations to estimate permanganate injection volumes. A spreadsheet supplied by a permanganate manufacturer, Carus Remediation Technologies, was used to perform the calculations. Design calculations are provided in Appendix C.

Approximately 19,360 gallons of 6% by weight $NaMnO_4$ solution will be required for the shallow groundwater remediation area and will be injected over two injection events. Assuming the solution will be applied evenly over the two events, approximately 440 gallons of the 6% by weight solution will be injected into each of the 22 proposed injection wells for a total of 9,680 gallons during each of the injection events.

Approximately 118,560 gallons of 6% by weight $NaMnO_4$ solution will be required for the intermediate groundwater remediation area within the 100 ppb plume and will be injected over three injection events. Assuming the solution will be applied evenly over the three events, approximately 2,470 gallons of the 6% by weight solution will be injected into each of the 16 proposed injection wells for a total of 39,520 gallons during each of the injection events.

Approximately 74,100 gallons of 6% by weight $NaMnO_4$ solution will be required for the intermediate groundwater remediation area downgradient of the 100 ppb plume and will be injected over three injection events. Assuming the solution will be applied evenly over the three events, approximately 2,470 gallons of the 6% by weight solution will be injected into each of the ten proposed injection wells for a total of 24,700 gallons during each of the injection events.

2.5 Remedial Components

The remedial components required to implement the remedial activities within the OU2 downgradient area include installation of injection wells, permanganate delivery, and oxidant containment and safety measures. Remedial components may also include a temporary aboveground manifold for the new injection wells. Table 1 includes a summary of delivery well

information for the injection events. Table 2 includes a summary of the performance monitoring program.

2.5.1 Delivery Well Installation

A total of 22 injection wells (e.g., IWS-01 through IWS-22) [where IWS refers to injection well shallow] will be located within the 10 ppb PCE plume in the shallow groundwater remediation area, all planned to be located within public rights-of-way (ROW). New York City Department of Transportation (NYCDOT) Street Opening Permits will be required. Shallow groundwater contamination is present from the water table, at a depth of approximately 10 feet bgs to approximately 30 feet bgs. Each injection location will consist of a single injection well with a 10-foot screened interval beginning 5 feet below the water table (i.e., screened interval at an approximate depth of 15 to 25 feet bgs). The Remedial Construction Contract Drawings (Drawings) will present a Well Schedule which is based on the available depth-specific information used to select the depth intervals. An injection well detail will be presented on the Drawings.

A total of 16 injection wells (e.g., IWI-101 through IWI-116) [where IWI refers to injection well intermediate] are proposed for within the 100 ppb PCE plume and ten injections wells (e.g., IWI-117 through IWI-126) are proposed immediately downgradient of the plume in the intermediate groundwater remediation area, all planned to be located within public ROWs. NYCDOT Street Opening Permits will be required. Intermediate groundwater contamination is present from approximately 30 feet bgs to approximately 60 feet bgs. Each injection location will consist of a single injection well with a 20-foot screened interval beginning 25 feet below the water table (i.e., screened interval at an approximate depth of 35 to 55 feet bgs). The Drawings will present a Well Schedule which is based on the available depth-specific information used to select the depth intervals. An injection well detail will be presented on the Drawings.

Injection wells will be located outside of roadway intersection areas and not on private property. Injection wells will be located preferably in the sidewalks along the roadways, or in the grassy median adjacent to the roadways. If either of these options is not feasible, injection wells may be located within the roadway(s). In these instances, NYCDOT Street Opening Permits will be required. The actual location of the injection wells will be finalized in the field and then surveyed. In addition to aboveground and underground constraints (e.g., trees, utilities), there are

also overhead constraints in the form of tree limbs and power/communication lines. The remediation contractor will be required to work around and protect these features. This may require the use of short-mast drill rigs and power line protection cuffs and/or other similar measures.

The stratigraphy in the area consists of primarily sand and the injection well depths are relatively shallow, especially for the shallow injection wells. Because stratigraphic information is available from prior investigations, the boreholes will not be logged continuously but will be logged as drilling approaches the water table in order to set the well screens at an appropriate depth and to identify localized geologic conditions. The injection wells will be constructed of 2-inch outer diameter (OD) Schedule 40 polyvinyl chloride (PVC) pipe with a threaded bottom cap, continuous wrap 10-slot well screen, and solid PVC riser to the ground surface. The annulus of each well will be filled with #1 sand. The sand pack will extend from the bottom of the borehole to approximately 2 feet above the top of the screen. Bentonite seal and then bentonite grout will complete the remaining borehole backfill. The flush mount surface completion for each delivery well will be constructed to tolerate moderate to heavy vehicle traffic. The wells will be fitted with locking well caps to deter tampering.

All drill cuttings and water generated during the course of injection well installations will be drummed and picked up daily by the disposal contractor. No on-site storage of waste materials will be allowed.

2.5.2 Delivery System

Precise components of the delivery system will be considered means and methods to be proposed by the remediation contractor and will be subject to review and approval by NYSDEC and the Engineer. However, components of the delivery system are expected to generally include the items described in the following paragraph and in Section 2.5.3, Permanganate Delivery.

There will be oxidant solution transfer from the oxidant transport container (e.g., tanker truck, large volume poly container on flatbed trailer, and/or poly cube tote) to injection wells through flexible hoses. Secondary containment will be implemented around containers and other points of potential discharge. Hoses will be covered with traffic ramps to allow residential traffic access (e.g., primarily driveway access) as necessary. Flow meters will be used to measure the volume of permanganate injected. Injection pressures will be measured with pressure gauges.

(Based on the results of the injection pilot test, injection pressures are anticipated to be less than 2 pounds per square inch gauge. Aboveground manifolds may be used to allow delivery of oxidant solution at several injection wells at one time, while monitoring flow rates and injections pressures to each well.

2.5.3 Permanganate Delivery

Because of the location of the injection wells along public sidewalks, no permanent above-grade components will be allowed. Injections will be made from a mobile delivery unit. Materials used for aboveground hoses used for transfer of oxidant, pumps used for transfer or injection, and storage containers will be compatible with sodium permanganate. The manufacturer's recommendations for decontamination and/or maintenance will be followed to prevent corrosion of hoses, pumps, and/or any equipment exposed to the sodium permanganate.

Sodium permanganate will be delivered to the Site as a 6% by weight solution. An alternate 40% by weight solution provided by the manufacturer can be mixed with water at an off-site location but shall be delivered to the Site as a 6% by weight solution. Since little, if any, space is available on-site for mixing operations, on-site mixing will not be allowed.

2.6 Storage, Containment and Safety Measures

Permanganate solutions are hazardous substances and strong oxidizers. Sodium permanganate is a Class 2 oxidizer. For the purposes of this Design, it has been assumed that the $NaMnO_4$ will be delivered to the Site as a 6% by weight solution after being mixed off-site. The solution may not be stored on-site, so it will be shipped in smaller (daily use) quantities for immediate use for injection. This method is required since there is no available on-site storage area.

The New York State Fire Code and the NYSDEC bulk storage requirements (6NYCRR Parts 595-599) regulate the storage of oxidizers. Among other requirements included in the regulations, Chapter 40 of the Fire Code requires outdoor storage of Class 2 oxidizers to be stored a minimum of 35 feet from buildings, lot lines, streets, alleys, and means of egress.

Secondary containment is required by and must comply with the NYSDEC bulk storage regulations. Secondary containment is required for oxidant transfer, storage, mixing and manifold operations. At connection points (e.g., hose and/or piping connections) secondary containment measures will be implemented.

Any spilled permanganate solution will be contained and, if possible, reused. If reuse is not possible, permanganate solution will be neutralized using either a solution of dilute peroxide and acetic acid (e.g., vinegar) or dissolved sodium thiosulfate. Permanganate should be diluted and decomposed using sodium metabisulfite or sodium sulfite. Decontamination of equipment, storage, personal protection, and other related safety concerns should be in accordance with the Safety Data Sheets and vendor recommendations. Oxidant safety materials are presented in Appendix D.

2.7 Injection Schedule

Two application events of $NaMnO_4$ solution injections are scheduled for the shallow zone and three application events for the intermediate zone. Groundwater performance monitoring will be conducted between application events. Performance monitoring is discussed further in Section 2.8. Modifications to the injection program may be made following a review of the performance monitoring results, including the quantity and/or injection locations.

Each $NaMnO_4$ application is anticipated to require approximately 0.9 hours at each shallow injection well and 5.1 hours at each intermediate injection well. This does not include mobilization, demobilization or travel time between injection wells. The injection pilot test indicated that the aquifer readily accepted 8 gpm. Site conditions and lithology at individual wells may allow for increased or require decreased flow rates over the average anticipated injection rate of 8 gpm. Injection may be conducted at several injection wells at one time, and/or through the use of manifolds. Both of these options would decrease the overall time frame required for remediation.

2.8 Performance Monitoring

Performance monitoring will include approximately 70 monitoring wells. Performance monitoring will include bi-monthly (twice a month) measurement of field parameters (ORP, DO, specific conductivity, temperature and color) from the injection and monitoring wells following

each injection event for a period of two months. Additional monitoring may be conducted in month three, as necessary. Performance monitoring will also include water depth measurements and groundwater sampling from the monitoring wells and laboratory analysis for VOCs, metals, and alkalinity prior to the next injection event and post-remediation.

2.9 Utility Requirements for Injection

Since sodium permanganate will be shipped to the Site in a 6% by weight solution, mixing will not be required, and utilities (electric and water) to accommodate mixing will not be required. Minimal power will be required for injection pumps that can be supplied by running a portable generator supplied by the remediation call out contractor. Water will need to be on hand to address spills, if they occur. Water could be obtained from hydrants or it could be trucked in. Permits will be obtained, if needed.

2.10 Access Requirements

Work on private property will be avoided. Remediation activities will be confined to public sidewalks and ROW. The remediation contractor will be required to obtain a street-opening permit(s) to install injection wells in any public areas. The areas impacted by well construction will be restored to city requirements at the completion of remediation.

The trailer at OU1 could be accessible during remediation and may be utilized for the storage of sampling equipment pending appropriate access agreement(s). No oxidant material or waste material (drill cuttings/decontamination water drums) will be stored at OU1. The disposal contractor will perform daily pick up of drummed waste materials.

3.0 PERMITS AND APPROVALS

Injection wells used for aquifer remediation and experimental technologies are distinguished from hazardous waste injection wells and are designated as Class V under the United States Environmental Protection Agency (USEPA) Underground Injection Control (UIC) Program. Class V wells covered by the Federal UIC Program are authorized by rule and do not require a separate UIC permit. However, an Inventory of Injection Wells Form must be submitted to the USEPA as required by the USEPA UIC Program to document well installation.

The planned injections will comply with the NYSDEC Division of Environmental Remediation (DER) "*Guidance on Injections for Remediation*," dated April 21, 2014.

To install the wells in the public ROW, NYCDOT Street Opening Permits will be required. Because parts of the road will be required to set up the drilling rigs, lane closure permits could be required. The remediation call out contractor will be required to submit a Maintenance and Protection of Traffic Plan that addresses lane closure and other traffic issues prior to commencing work. Operations will have to comply with New York City noise monitoring and mitigation requirements and the remediation call out contractor will need to comply with this plan.

In addition, when the work is initialed, the call out contractor shall submit a Job Hazard Analysis (JHA) that will specifically deal with COVID-19.

4.0 OXIDANT PURCHASE AND CONSTRUCTION SEQUENCING

Permanganate products are available from several vendors within the United States including the following:

Carus Chemical Company
315 Fifth Street
P.O. Box 599
Peru, Illinois 61354-0599
Telephone: 815.224.6852
Fax: 815.224.6896
Contact: Kelly Frasco
Email: Kelly.frasco@caruschem.com
Company Web Page: http://www.caruscorporation.com/

Hepure Technologies
40 Route 31
Speedway Plaza - #75
Flemington, NJ 08822
Phone: 866.727.4776 ext. 3
Fax: 888.975.9840
Contact: Santo Auriemma
Email: santo@hepure.com
Company Web Page: http://www.hepure.com/

Wintersun Chemical
1250 E Belmont St.
Ontario, California 91761
Phone: 909.930.1688 ext. 228
Fax: 909.947.1788
Contact: Michael Shen
Email: mshen@wintersungroup.com
Company Web Page: http://www.wintersunchem.com/

This section presents a description of remediation sequencing. The remediation contractor will determine the actual sequence and duration of work segments within the time frame specified in the Contract Documents. The major remediation work elements presented in the expected sequence of implementation are described below.

1. Mobilization of Equipment, Manpower, and Temporary Facilities: It is expected that any temporary facilities required will be located in OU1 at the existing trailer on New York City Department of Environmental Protection property.

2. Baseline Monitoring: The round of groundwater samples collected in 2019 is considered to be the baseline groundwater concentration monitoring event.

3. Injection and Monitoring Well Installation: Twenty-two injection wells will be installed in the shallow groundwater zone and 26 injection wells will be installed in the intermediate groundwater zone.

4. Oxidant Injection: $NaMnO_4$ solution will be injected during two events in the shallow overburden and during three events in the intermediate overburden. Groundwater will be monitored in between each injection to evaluate the effectiveness of oxidation. Adjustments to the oxidant dose will be implemented as appropriate based on the monitoring results.

5. Drummed Waste Materials: No drummed waste materials will be stored on-site. All drums will be picked up on a daily basis.

6. Performance Monitoring: Performance monitoring will be in accordance with Table 2. Post-remediation monitoring will be conducted as directed by the NYSDEC.

7. Demobilization: All temporary facilities at OU1 will be removed from the Site, temporary utilities discontinued, and disturbed areas restored to the original condition.

8. Well Decommissioning: Injection wells installed for this work will be decommissioned after monitoring is complete and accepted as directed by the NYSDEC.

The selected remediation contractor will submit a detailed construction schedule to NYSDEC and update the schedule as needed.

TABLES

Table 1
Delivery Well and Oxidant Injection Quantities
West Side Corp. Site

PCE Plume Area	**Shallow Overburden**			**Intermediate in 100 ppb Plume**			**Intermediate Downgradient**		
	1st event	2nd event	3rd event	1st event	2nd event	3rd event	1st event	2nd event	3rd event
Number of Injection Locations	22	22	0	16	16	16	10	10	10
Total Volume 6% $NaMnO_4$ Solution (gal)	19,360			118,560			74,100		
Total Volume 6% $NaMn0_4$ Solution Per Injection Event (gal)	9,680	9,680	0	39,520	39,520	39,520	24,700	24,700	24,700
Volume 6% $NaMnO_4$ Solution (gal) per Injection Well	440	440	0	2,470	2,470	2,470	2,470	2,470	2,470
At Potential Injection Rate - 8 gpm Duration of Injection per Well per Event (hrs)	0.9	0.9	0.0	5.1	5.1	5.1	5.1	5.1	5.1

Table 2
Performance Monitoring Details
West Side Corp. Site

Activity	Field Analysis					Sample Collection and Laboratory Analysis for Evaluation	
Frequency	Following 1st, 2nd and 3rd Injection Events					Prior to 2nd and 3rd Injection Event	Post - Remediation
	Month 1		Month 2		Month 3 (if necessary)		Following 3rd Injection Event
	Week 2	Week 4	Week 6	Week 8	Week 12	Once	Annual
Groundwater MWs							
VOCs						x	x
Dissolved Metals						x	x
Hexavalent Chromium						x	x
Alkalinity						x	x
Injection Wells							
Color	x	x	x	x	x		
Groundwater MWs							
Color	x	x	x	x	x		
Field parameters:							
pH, Conductivity, DO, ORP	x	x	x	x	x		

Monitoring Wells for Laboratory Sampling and Analysis (Total of 70)

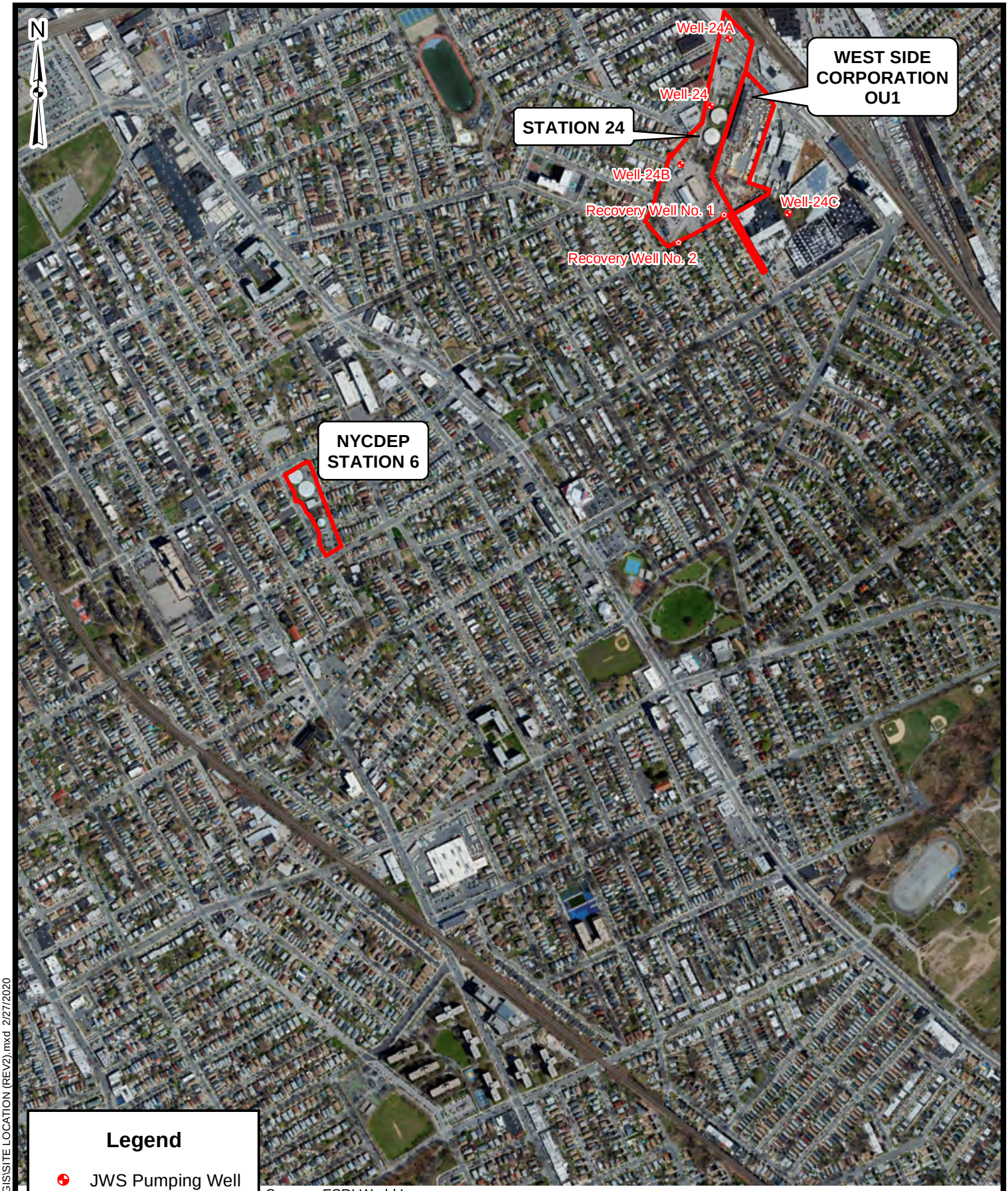
W-01S/1I/1D
W-02S/2I/2D
W-03S/3I/3D
W-04S/4I/4D
W-05
W-06S/6I/6D
W-07S/7I/7D
W-08S/8I/8D
W-09S/9I/9D
W-10S/10I/10D
W-11S/11I/11D
W-12S/12I/12D
W-13S/13I/13D
W-14S/14I/14D
W-15S/15I/15D
W-16S/16I/16D
W-17S/17I/17D
W-18S/18I/18D
W-19S/19I/19D
W-20S/20I/20D
W-21S/21I/21D
MW-24-4S/4I/4D
MW-24-5S/5I/5D
MW-24-6S/6I/6D

Injection Wells for Field Analysis (Total of 48)

IWS-1 through IWS-22

IWI-101 through IWI-126

FIGURES



J:\Projects\11173144.00000\DB\GIS\SITE LOCATION (REV2).mxd 2/27/2020

AECOM

WEST SIDE CORPORATION
JAMAICA, NEW YORK
SITE LOCATION

FIGURE 1

J:\Projects\11173144.00000\DB\GIS\GROUNDWATER ELEVATION SHALLOW (SEPTEMBER 2019).mxd 11/13/2019

WEST SIDE CORPORATION

W-01S, 17.91
W-09S, 17.30
W-05S, 17.64
W-03S, 16.88
W-02S, 16.66
W-04S, 16.12
MW-24-5S, 15.62
MW-24-4S, 15.46
W-07S, NM
W-08S, 12.89
W-06S, 13.92
MW-24-6S, 15.25
W-11S, 14.18
W-12S, 14.00
W-14S, 13.48
W-10S, 13.19
W-13S, 12.78
W-15S, 13.11
W-16S, 11.24
W-19S, 10.33
W-22S, 10.90
W-21S, 9.40
W-20S, 9.48
W-17S, 8.12

17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5

Legend

- Monitoring Well
- Groundwater Flow Direction
- Groundwater Elevation Contour (14.0)
- W-17S, 8.12 — Location ID / Groundwater Elevation

NOTE:
NM = Not Measured

500 0 500 Feet

AECOM

WEST SIDE CORPORATION - JAMAICA, NEW YORK
GROUNDWATER ELEVATION CONTOURS IN SHALLOW MONITORING WELLS
SEPTEMBER 2019

FIGURE 2

J:\Projects\11173144.00000\DB\GIS\GROUNDWATER ELEVATION INTERMEDIATE (SEPTEMBER 2019).mxd 11/13/2019

WEST SIDE CORPORATION

W-01I, 17.92
W-09I, NM
W-03I, NM
W-02I, 16.70
W-04I, 16.04
MW-24-5I, 15.63
MW-24-4I, 15.49
W-07I, NM
W-08I, 13.60
W-06I, 13.93
MW-24-6I, 15.29
W-11I, 14.21
W-12I, NM
W-10I, 13.27
W-14I, 13.46
W-13I, 12.76
W-15I, 13.09
W-18I, 11.51
W-16I, 11.24
W-19I, 10.49
W-22I, 10.89
W-21I, 9.59
W-20I, 9.45
W-17I, 8.12

17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5

Legend

- Monitoring Well
- Groundwater Flow Direction
- 14.0 Groundwater Elevation Contour

W-17I, 8.12
Location ID — Groundwater Elevation

NOTE:
NM = Not Measured

500 0 500 Feet

AECOM

WEST SIDE CORPORATION - JAMAICA, NEW YORK
GROUNDWATER ELEVATION CONTOURS IN INTERMEDAITE MONITORING WELLS
SEPTEMBER 2019

FIGURE 3

J:\Projects\11173144.00000\DB\GIS\GROUNDWATER ELEVATION DEEP (SEPTEMBER 2019).mxd 11/13/2019

WEST SIDE CORPORATION

W-01D, 17.96
W-09D, 17:31
W-03D, NM
W-02D, 16.71
W-04D, 16:05
MW-24-5D, 15.64
MW-24-4D, 15.52
W-07D, NM
W-08D, 14.17
W-06D, 14.20
MW-24-6D, 15.30
W-11D, 14.09
W-12D, 12.91
W-14D, 13.41
W-10D, 13.26
W-13D, 12.79
W-15D, 13.18
W-16D, 11.25
W-19D, 10.52
W-21D, 9.61

17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
13.0
12.5
12.0
11.5
11.0
10.5
10.0

Legend

- Monitoring Well
- Groundwater Flow Direction
- Groundwater Elevation Contour (14.0)
- W-21D, 9.61 (Location ID, Groundwater Elevation)

NOTE:
NM = Not Measured

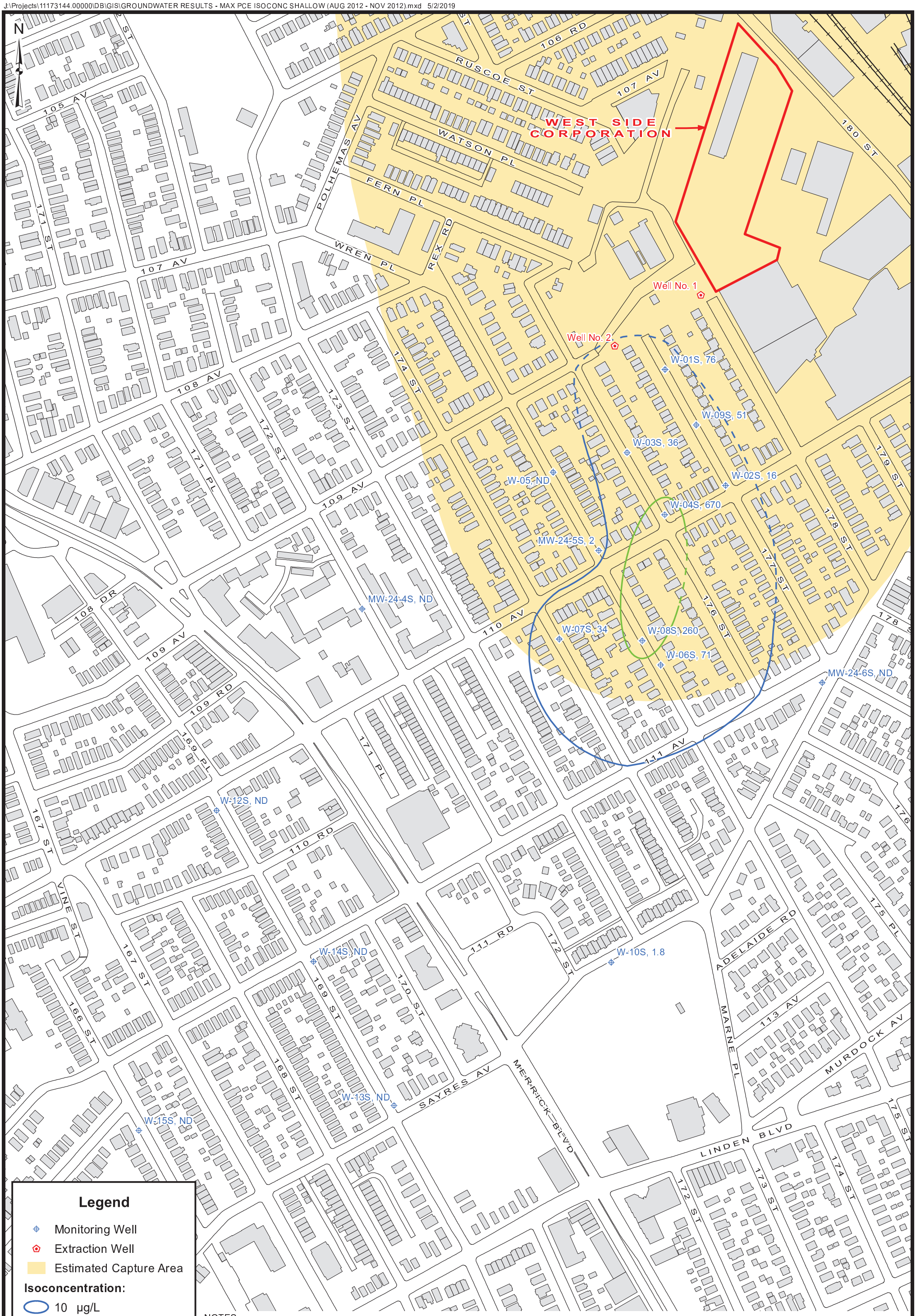
500 0 500 Feet

AECOM

WEST SIDE CORPORATION - JAMAICA, NEW YORK
GROUNDWATER ELEVATION CONTOURS IN DEEP MONITORING WELLS
SEPTEMBER 2019

FIGURE 4

J:\Projects\11173144.00000\DB\GIS\GROUNDWATER RESULTS - MAX PCE ISOCONC SHALLOW (AUG 2012 - NOV 2012).mxd 5/2/2019



AECOM

WEST SIDE CORPORATION - JAMAICA, NEW YORK
GROUNDWATER SAMPLING RESULTS FOR MAXIMUM PCE CONCENTRATION
BETWEEN AUGUST 2012 AND NOVEMBER 2012 IN SHALLOW MONITORING WELLS

FIGURE 5

J:\Projects\11173144.00000\DB\GIS\GROUNDWATER RESULTS - PCE ISOCONC SHALLOW (SEP 2019).mxd 11/19/2019

N

WEST SIDE CORPORATION

Well No. 1

Well No. 2

W-01S, 4.1

W-09S, 5.5

W-03S, 3.4

W-05S, ND

W-02S, 14

W-04S, 15

MW-24-5S, 3

MW-24-4S, ND

W-08S, 200

W-06S, 21

MW-24-6S, 0.37

W-11S, ND

W-12S, 0.39

W-14S, ND

W-10S, ND

W-13S, ND

W-15S, ND

W-16S, ND

W-19S, 4.3

W-22S, ND

W-21S, 20

W-17S, ND

Legend

- Monitoring Well
- Extraction Well

Isoconcentration:

- 10 ppb
- 100 ppb

NOTES:
Dashed line is inferred isoconcentration;
ND - Not Detected

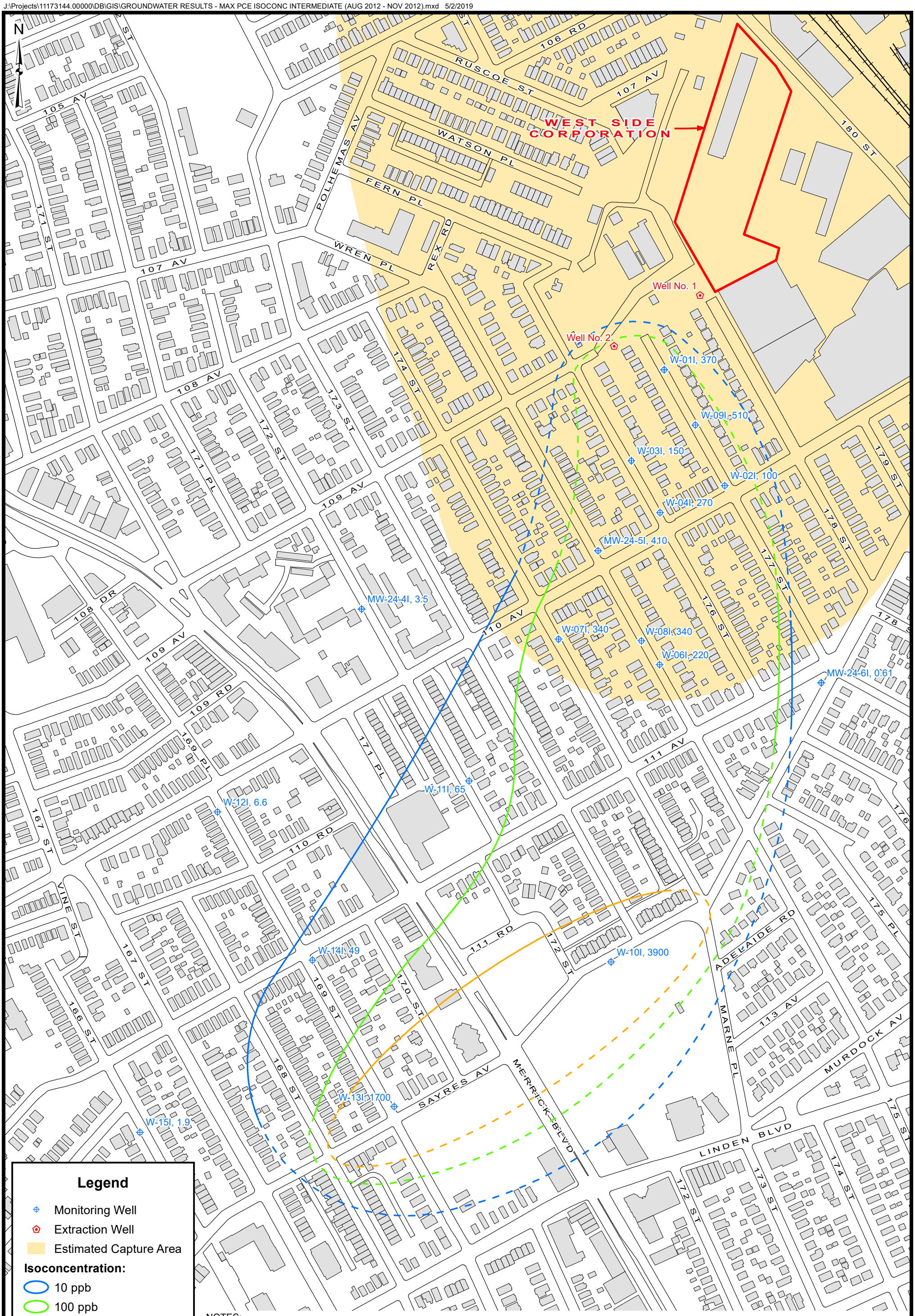
500 0 500 Feet

AECOM

WEST SIDE CORPORATION - JAMAICA, NEW YORK
GROUNDWATER SAMPLING RESULTS FOR PCE IN SHALLOW MONITORING WELLS
SEPTEMBER - OCTOBER 2019

FIGURE 6

J:\Projects\11173144.00000\DB\GIS\GROUNDWATER RESULTS - MAX PCE ISOCONC INTERMEDIATE (AUG 2012 - NOV 2012).mxd 5/2/2019



Legend

- Monitoring Well
- Extraction Well
- Estimated Capture Area

Isoconcentration:

- 10 ppb
- 100 ppb
- 1000 ppb

NOTES:
Dashed line is inferred isoconcentration;
ND - Not Detected

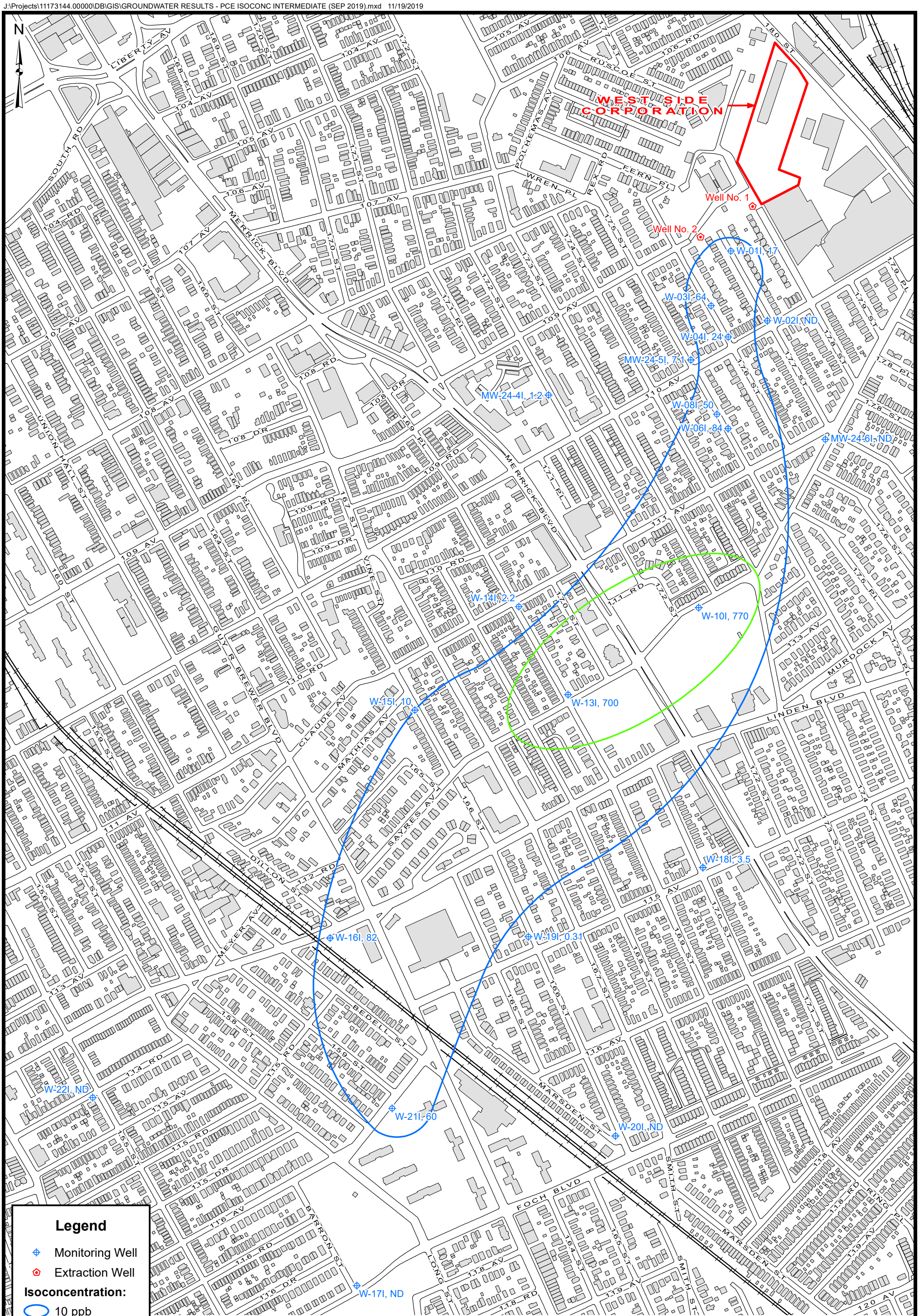
300 0 300 Feet

AECOM

WEST SIDE CORPORATION - JAMAICA, NEW YORK
GROUNDWATER SAMPLING RESULTS FOR MAXIMUM PCE CONCENTRATION
BETWEEN AUGUST 2012 AND NOVEMBER 2012 IN INTERMEDIATE MONITORING WELLS

FIGURE 7

J:\Projects\11173144.00000\DB\GIS\GROUNDWATER RESULTS - PCE ISOCONC INTERMEDIATE (SEP 2019).mxd 11/19/2019



AECOM

WEST SIDE CORPORATION - JAMAICA, NEW YORK
GROUNDWATER SAMPLING RESULTS FOR PCE IN INTERMEDIATE MONITORING WELLS
SEPTEMBER - OCTOBER 2019

FIGURE 8

J:\Projects\11173144.00000\DB\GIS\PRELIMINARY IW PLAN - SHALLOW GW.mxd 1/13/2020

N

WEST SIDE CORPORATION

Well No. 1

Well No. 2

W-01S, 4.1

W-09S, 5.5

W-03S, 3.4

W-05S, ND

W-02S, 14

W-04S, 15

MW-24-5S, 3

MW-24-4S, ND

W-08S, 200

W-06S, 21

MW-24-6S, 0.37

W-11S, ND

W-12S, 0.39

W-14S, ND

W-10S, ND

W-13S, ND

W-15S, ND

W-16S, ND

W-19S, 4.3

W-22S, ND

W-21S, 20

W-17S, ND

SOUTH RD

LIBERTY AV

MERRICK BLVD

POLHEMAS AV

RUSCOE ST

FERN PL

WREN PL

REX RD

MARNE PL

LINDEN BLVD

MURDOCK AV

CLAUDE AV

MATHIAS AV

PHROANE AV

SAYRES AV

DILLON ST

MEYER AV

BEDELL ST

MARSDEN ST

FOCH BLVD

SMITH ST

BARRON ST

LONG ST

QUY R BREWER BLVD

UNION HALL ST

Legend

- Proposed Injection Well
- Monitoring Well
- Extraction Well

Isoconcentration:

- 10 ppb
- 100 ppb

NOTES:
Dashed line is inferred isoconcentration;
ND - Not Detected

500 0 500 Feet

AECOM

WEST SIDE CORPORATION - JAMAICA, NEW YORK
PRELIMINARY INJECTION WELL PLAN
(SHALLOW GROUNDWATER)

FIGURE 9

J:\Projects\11173144.00000\DB\GIS\PRELIMINARY IW PLAN - INTERMEDIATE GW.mxd 1/16/2020

WEST SIDE CORPORATION

Well No. 1

Well No. 2

W-01I, 17

W-03I, 64

W-02I, ND

W-04I, 24

MW-24-5I, 7.1

MW-24-4I, 1.2

W-08I, 50

W-06I, 84

MW-24-6I, ND

W-14I, 2.2

W-10I, 770

W-13I, 700

W-15I, 10

W-18I, 3.5

W-16I, 82

W-19I, 0.31

W-22I, ND

W-21I, 60

W-20I, ND

W-17I, ND

Legend

- Proposed Injection Well
- Monitoring Well
- Extraction Well

Isoconcentration:

- 10 ppb
- 100 ppb

NOTES:
Dashed line is inferred isoconcentration;
ND - Not Detected

500 0 500 Feet

AECOM

WEST SIDE CORPORATION - JAMAICA, NEW YORK
PRELIMINARY INJECTION WELL PLAN
(INTERMEDIATE GROUNDWATER)

FIGURE 10

APPENDIX A

PNOD ANALYTICAL RESULTS

Carus Remediation Technologies
Remediation Report

5 September 2014

Customer: TestAmerica Buffalo
10 Hazelwood Drive
Amherst, NY 14228-2298

Cc: T. Lizer

Attention: Judy Stone

From: L. Mueller

TECH # 14-145

Subject: RemOx® S ISCO Reagent Permanganate Natural Oxidant Demand

Summary
The overall average RemOx® S ISCO reagent permanganate natural oxidant demand (PNOD) at 48 hours for the two soil samples was determined to be 0.05 g/kg. The average demands ranged from 0.02 g/kg to 0.08 g/kg. These values are calculated on a weight as potassium permanganate ($KMnO_4$) per dry weight of soil.

Background
Two soil samples were received from TestAmerica Buffalo from West Side Corp #241026 (JAMAICA) project on August 29, 2014. The soil sample designations were PZ-2 (10-13') (480-66210-2) and PZ-3 (10-13') (480-66210-1). The samples were analyzed for permanganate natural oxidant demand. The measurement of the permanganate natural oxidant demand is used to estimate the concentration of permanganate that will be consumed by the natural reducing agents during a given time period of 48 hours.

Experimental
The samples were analyzed for permanganate natural oxidant demand following ASTM D7262-07 Test Method A. A brief summary is as follows:

To determine the PNOD, the soil was baked at 105°C for 24 hours then allowed to cool to room temperature. The soil was then blended and passed through a U.S. 10 sieve (2 mm). Reactors were loaded with 50 grams of soil and 100 mL of 20 g/L $KMnO_4$ for an initial dose of 40 g/kg $KMnO_4$ on a dry soil weight basis at a 1:2 soil to aqueous reagent ratio. Each soil dose was performed in triplicate. The reaction vessels were inverted once to mix the reagents. Residual permanganate (MnO_4^-) was determined at 48 hours. The demands were calculated on a dry weight basis.

Results
The permanganate demand is the amount of permanganate consumed in a given amount of time. It should be noted that in a soil or groundwater sample, the oxidation of any compound by permanganate is dependent on the initial dose of permanganate and the reaction time available. As the permanganate dose is increased, the reaction rate and oxidant consumption may also

increase. Some compounds that are not typically oxidized by permanganate under low doses can become reactive with permanganate at higher concentrations.
The 48-hour PNOD results can be seen in Table 1 (on a dry soil basis).

Table 1: 48-Hour PNOD *

Soil Sample Identification	Average and Standard Deviation (g/kg)	Replicate 1 (g/kg)	Replicate 2 (g/kg)	Replicate 3 (g/kg)
PZ-2 (10-13') (480-66210-2)	0.02 ± 0.03	0.05	0.00	0.00
PZ-3 (10-13') (480-66210-1)	0.08 ± 0.08	0.15	0.10	0.00
Overall Average	0.05			

*Demands were calculated on a weight $KMnO_4$/dry soil weight basis from an initial dose of 40.0 g/kg $KMnO_4$ initial dose at a 1:2 soil to aqueous solution ratio

Conclusions
For this application the amount of permanganate needed will be dependent on the reaction time allowed. On average, the soil samples had a 48-hour permanganate demand value of 0.05 g/kg. The average demands ranged from 0.02 g/kg to 0.08 g/kg. Generally, remediation sites with a soil demand of less than 20.0 g/kg at the time of interest are favorable for *in situ* chemical oxidation with permanganate (see Table 2 for additional information).

Table 2: Correlation of Permanganate Natural Oxidant Demand Results*

PNOD (g/kg)	**Rank**	Comment
<10	Low	ISCO with MnO_4^- is recommended. Soil contribution to MnO_4^- demand is low.
10-20	Moderate	ISCO with MnO_4^- is recommended. Soil contribution to MnO_4^- demand is moderate. Economics should be considered.
>20	High	ISCO with MnO_4^- is technically feasible. Other technologies may provide lower cost alternatives.

*Dry Weight Basis

Carus Remediation Technologies
Remediation Report

28 August 2014

Customer: TestAmerica Buffalo
10 Hazelwood Drive
Amherst, NY 14228-2298

Cc: T. Lizer

Attention: Judy Stone

From: L. Mueller

TECH # 14-141

Subject: RemOx® S ISCO Reagent Permanganate Natural Oxidant Demand

Summary
The overall average RemOx® S ISCO reagent permanganate natural oxidant demand (PNOD) at 48 hours for the two soil samples was determined to be 0.56 g/kg. The average demands ranged from 0.5 g/kg to 0.7 g/kg. These values are calculated on a weight as potassium permanganate ($KMnO_4$) per dry weight of soil.

Background
Two soil samples were received from TestAmerica Buffalo from West Side Corp #241026 (JAMAICA) project on August 17, 2014. The soil sample designations were SB-1 (35-40') (480-65596-1) and SB-2 (35-40') (480-65596-2). The samples were analyzed for permanganate natural oxidant demand. The measurement of the permanganate natural oxidant demand is used to estimate the concentration of permanganate that will be consumed by the natural reducing agents during a given time period of 48 hours.

Experimental
The samples were analyzed for permanganate natural oxidant demand following ASTM D7262-07 Test Method A. A brief summary is as follows:

To determine the PNOD, the soil was baked at 105°C for 24 hours then allowed to cool to room temperature. The soil was then blended and passed through a U.S. 10 sieve (2 mm). Reactors were loaded with 50 grams of soil and 100 mL of 20 g/L $KMnO_4$ for an initial dose of 40 g/kg $KMnO_4$ on a dry soil weight basis at a 1:2 soil to aqueous reagent ratio. Each soil dose was performed in triplicate. The reaction vessels were inverted once to mix the reagents. Residual permanganate (MnO_4^-) was determined at 48 hours. The demands were calculated on a dry weight basis.

Results
The permanganate demand is the amount of permanganate consumed in a given amount of time. It should be noted that in a soil or groundwater sample, the oxidation of any compound by permanganate is dependent on the initial dose of permanganate and the reaction time available. As the permanganate dose is increased, the reaction rate and oxidant consumption may also

increase. Some compounds that are not typically oxidized by permanganate under low doses can become reactive with permanganate at higher concentrations.
The 48-hour PNOD results can be seen in Table 1 (on a dry soil basis).

Table 1: 48-Hour PNOD *

Soil Sample Identification	Average and Standard Deviation (g/kg)	Replicate 1 (g/kg)	Replicate 2 (g/kg)	Replicate 3 (g/kg)
SB-1 (35-40') (480-65596-1)	0.5 ± 0.07	0.4	0.5	0.5
SB-2 (35-40') (480-65596-2)	0.7 ± 0.22	0.9	0.6	0.5
Overall Average	0.56			

*Demands were calculated on a weight $KMnO_4$/dry soil weight basis from an initial dose of 40.0 g/kg $KMnO_4$ initial dose at a 1:2 soil to aqueous solution ratio

Conclusions
For this application the amount of permanganate needed will be dependent on the reaction time allowed. On average, the soil samples had a 48-hour permanganate demand value of 0.56 g/kg. The average demands ranged from 0.5 g/kg to 0.7 g/kg. Generally, remediation sites with a soil demand of less than 20.0 g/kg at the time of interest are favorable for *in situ* chemical oxidation with permanganate (see Table 2 for additional information).

Table 2: Correlation of Permanganate Natural Oxidant Demand Results*

PNOD (g/kg)	**Rank**	Comment
<10	Low	ISCO with MnO_4^- is recommended. Soil contribution to MnO_4^- demand is low.
10-20	Moderate	ISCO with MnO_4^- is recommended. Soil contribution to MnO_4^- demand is moderate. Economics should be considered.
>20	High	ISCO with MnO_4^- is technically feasible. Other technologies may provide lower cost alternatives.

*Dry Weight Basis

Buffalo
10 Hazelwood Drive

Amherst, NY 14228
phone 716.504.9852 fax 716.691.7991

Chain of Custody Record

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

TestAmerica Laboratories, Inc.

Client Contact	Project Manager: ~~Paul Lundin~~ (MB) Mike Naegerle	Site Contact: K. Bradley	Date: 8/11/14	COC No:
GES for NYSDEC	Tel/Fax: ext. 3859	Lab Contact:	Carrier:	1 of 1 COCs
16 Mt. Ebo Road South, Suite 21	Analysis Turnaround Time			Job No. 1101638-05-201
Brewster, NY 10509	Calendar (C) or Work Days (W) Normal			
(866) 839-5195 Phone	TAT if different from Below _____			
(845) 878-8077 FAX	■ 2 weeks			SDG No.
Project Name: NYSDEC - Jamaica	☐ 1 week			
Site: 107-10 180th St., Jamaica, NY	☐ 2 days			
P O # Callout ID #120521	☐ 1 day			

Sample Identification	Sample Date	Sample Time	Sample Type	Matrix	# of Cont.	Filtered Sample	Permanganate Natural Oxidant Deman
SB-1 (35-40')	8/11/14	10:00	GOM	SO	2		x
SB-2 (35-40')	8/11/14	9:05	GOM	SO	2		x
			(MS)	~~SO~~	~~2~~		~~x~~
				~~SO~~	~~2~~		~~x~~

480-65596 Chain of Custody

Sample Specific Notes:

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other 2

Possible Hazard Identification
☒ *Non-Hazard* ☐ *Flammable* ☒ *Skin Irritant* *Poison B* ☐ *Unknown* ☐

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☒ *Disposal By Lab* ☐ *Archive For _____ Months*

Special Instructions/QC Requirements & Comments:
Please Email Report to: ~~Mrocotti@gesonline.com~~ kbradley@gesonline.com
Please Email EQuIS EDD to: ges@equisonline.com
EQuIS File Name: NYSDEC - West Side Corporation -"Lab Report Number".14672.EQEDD.zip

Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
	GES	8/11/14 1:15	GES	Fridge	8/11/14 1:15
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
				TAS	8-13-14 0845
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:

#2 4.0

Buffalo
10 Hazelwood Drive

Amherst, NY 14228
phone 716.504.9852 fax 716.691.7991

Chain of Custody Record

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

TestAmerica Laboratories, Inc.

Client Contact	Project Manager: Michael Maegerle	Site Contact: K. Bradley	Date: 8/25/14	COC No:
GES for NYSDEC	Tel/Fax: ext. 3859	Lab Contact:	Carrier:	1 of 1 COCs
16 Mt. Ebo Road South, Suite 21	**Analysis Turnaround Time**			Job No. 1101638-05-201
Brewster, NY 10509	Calendar (C) or Work Days (W) _____			
(866) 839-5195 Phone	TAT if different from Below _____			
(845) 878-8077 FAX	■ 2 weeks			
Project Name: NYSDEC - Jamaica	☐ 1 week			
Site: 107-10 180th St., Jamaica, NY	☐ 2 days			
P O # Callout ID #120521	☐ 1 day			

480-66210 Chain of Custody

Sample Identification	Sample Date	Sample Time	Sample Type	Matrix	# of Cont.	Filtered Sample	TCLP Volatiles and Semi-Volatiles	RCRA Metals	PCB's	Sample Specific Notes:
PZ-3 (10-13')	8/25/14	11:06	Composite	SO	1	N	X	X	X	
PZ-2 (10-13')	8/25/14	11:45	Comp.	SO	1				X	

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other 2

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☒ Skin Irritant Poison B ☐ Unknown ☐

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return To Client ☒ Disposal By Lab ☐ Archive For _____ Months

Special Instructions/QC Requirements & Comments:
Please Email Report to: kbradley@gesonline.com
Please Email EQuIS EDD to: ges@equisonline.com
EQuIS File Name: NYSDEC - West Side Corporation -"Lab Report Number".14672.EQEDD.zip

Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
	GES	8/25/14 4:00	GES Fridge		8/25/14 4:00 pm
M Roseth	GES	8/26/14 16:30		TA Buff	8/27/14 0900
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:

Form No. CA-C-WI-002, dated 04/07/2011

3 4.6

TestAmerica Buffalo
10 Hazelwood Drive
Amherst, NY 14228-2298
Phone (716) 691-2600 Fax (716) 691-7991

Chain of Custody Record

#14-145

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Client Information (Sub Contract Lab)	Sampler:	Lab PM: Stone, Judy L	Carrier Tracking No(s):	COC No: 480-18933.1
Client Contact: Shipping/Receiving	Phone:	E-Mail: judy.stone@testamericainc.com		Page: Page 1 of 1
Company: Carus Corporation		Analysis Requested		Job #: 480-66210-1

Address: 1500 Eighth Street, Bldg 45, Customer Service Lab	Due Date Requested: 9/9/2014
City: LaSalle	TAT Requested (days):
State, Zip: IL, 61301	
Phone:	PO #:
Email:	WO #:
Project Name: West Side Corp #241026 (JAMAICA)	Project #: 48004009
Site:	SSOW#:

Preservation Codes:

A - HCL	M - Hexane
B - NaOH	N - None
C - Zn Acetate	O - AsNaO2
D - Nitric Acid	P - Na2O4S
E - NaHSO4	Q - Na2SO3
F - MeOH	R - Na2S2SO3
G - Amchlor	S - H2SO4
H - Ascorbic Acid	T - TSP Dodecahydrate
I - Ice	U - Acetone
J - DI Water	V - MCAA
K - EDTA	W - ph 4-5
L - EDA	Z - other (specify)

Other:

Sample Identification - Client ID (Lab ID)	Sample Date	Sample Time	Sample Type (C=Comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	SUB (Permanganate Natural Oxidant Demand (PNOD))	Total Number of containers	Special Instructions/Note:
			Preservation Code:						
PZ-3 (10-13') (480-66210-1)	8/25/14	11:06 Eastern		Solid			X	1	
PZ-2 (10-13') (480-66210-2)	8/25/14	11:45 Eastern		Solid			X	1	

Possible Hazard Identification
Unconfirmed

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For_____ Months*

Deliverable Requested: I, II, III, IV, Other (specify)

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:

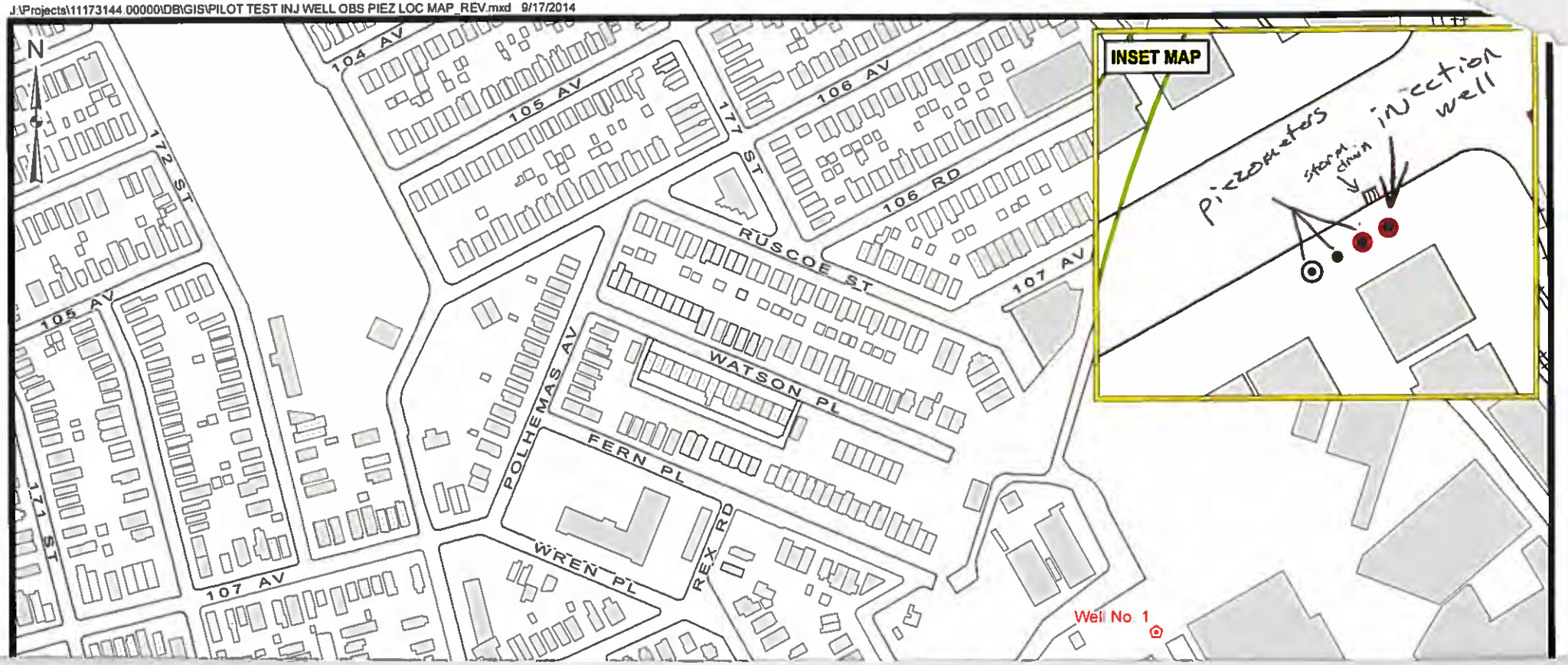
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Carmeron Wallace	8-27-14 1700	TAB			
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time: 8-29	Company Carus

Custody Seals Intact: Δ Yes Δ No | Custody Seal No.: | Cooler Temperature(s) °C and Other Remarks:

APPENDIX B

INJECTION PILOT TEST RESULTS

J:\Projects\11173144.00000\DB\GIS\PILOT TEST INJ WELL OBS PIEZ LOC MAP_REV.mxd 9/17/2014



Location West side Date 10/21/14

Project / Client Jamaica, NY

0630 - depart Hotel for site
Wx: 60°F, partly cloudy, calm
0715 - Fred Deleo (water truck) onsite. Set up piping + fittings, pump, flow meter.
0745 - begin injection of potable water
0930 - try to increase pump rate, but pump/air compressor are maxed out. Injection rate steady @ 8 gmp + 0-2 psi on inlet hose. Air compressor @ 60 psi.
1010 - measure to bottom at nearest storm drain 7' away - 3' to bottom
1030 - end injection.

Location Date

Project / Client

INJECTION PILOT TEST FIELD DATA LOG

DATE: 10/21/14

				10'	20'	30'	
	INJECTION WELL			PZ-1	PZ-2	PZ-3	
TIME	Depth to Water (BTOR)	Injection Rate (gpm)	Injection Pressure (gpm)	Depth to Water (BTOR)	Depth to Water (BTOR)	Depth to Water (BTOR)	COMMENTS
0730	8.62	–	–	8.96	9.35	9.47	initial DTW
0745	–	4.0	0-6	–	–	–	start injection
0800	–	4.0	0-6	8.93	9.34	9.47	~~142 gal total~~ 65 gal total
0815	–	6.5	0-6	8.88	9.30	9.45	~~252 gal total~~ 142 gal total
0830	–	8.0	0-6	8.88	9.30	9.44	252 gal total
0845	–	8.0	0-2	8.88	9.30	9.44	387 gal total
0900	–	8.0	0-2	8.88	9.30	9.44	500 gal total
09:15	–	8.0	0-2	8.88	9.30	9.44	616 gal total
09:30	–	8.0	0-2	8.88	9.30	9.44	755 gal total
0945	–	8.0	0-2	8.88	9.30	9.44	860 gal total
1000	–	8.0	0-2	8.88	9.30	9.44	965 gal total
1015	–	8.0	0-2	8.88	9.30	9.44	1097 gal total
1030	~~8.62~~	8.0	0	8.88	9.30	9.44	1200 gal total
	8.62						
	27.95			13.00	13.05	12.71	Depth to bottom

APPENDIX C

OXIDANT CALCULATIONS

	Estimates	Units	
Treatment Area Volume			
Number of Wells	22	each	
Area per Well	7850	sq ft	
Area	172700	sq ft	
Thickness	20	ft	shallow
Total Volume	127926	cu yd	
Soil Characteristics/Analysis			
Porosity	30	%	
Total Plume Pore Volume	7751313	gal	
Avg Contaminant Conc	0.01	ppm	
Mass of Contaminant	0.65	lb	
PNOD	0.1	g/kg	
Effective PNOD	10	%	
Effective PNOD Calculated	0.01		
PNOD Oxidant Demand	3799.4	lb	
Avg Stoichiometric Demand	1.1	lb/lb	
Contaminant Oxidant Demand	0.71	lb	
Theoretical Oxidant Demand	3800.11	lb	
Confidence Factor	3		
Calculated Oxidant Demand	11400.33469		
Injection Volumes for RemOx S			
RemOx S Injection Concentration	6.0%	%	
Total Volume of Injection Fluid	22,769	gal	
Pore Volume Replaced	0.00	%	
Amount of RemOx S ISCO Reagent Estimated			**11,400 pounds**
Injection Volumes for RemOx L			
RemOx L Injection Concentration	6.0%	%	
Calculated Specific Gravity	1.0549738	g/ml	
Total Volume of Injection Fluid	19,381	gal	
Pore Volume Replaced	0.00	%	
Amount of RemOx L ISCO Reagent Estimated			**25,594 pounds**
		at 40%	**2,239 gallons**

	Estimates	Units	
Treatment Area Volume			
Number of Wells	16	each	
Area per Well	7850	sq ft	
Area	125600	sq ft	
Thickness	30	ft	intermediate
Total Volume	139556	cu yd	
Soil Characteristics/Analysis			
Porosity	30	%	
Total Plume Pore Volume	8455978	gal	
Avg Contaminant Conc	0.1	ppm	
Mass of Contaminant	7.06	lb	
PNOD	0.56	g/kg	
Effective PNOD	10	%	
Effective PNOD Calculated	0.056		
PNOD Oxidant Demand	23210.88	lb	
Avg Stoichiometric Demand	1.1	lb/lb	
Contaminant Oxidant Demand	7.76	lb	
Theoretical Oxidant Demand	23218.64	lb	
Confidence Factor	3		
Calculated Oxidant Demand	69655.92756		
Injection Volumes for RemOx S			
RemOx S Injection Concentration	6.0%	%	
Total Volume of Injection Fluid	139,117	gal	
Pore Volume Replaced	0.02	%	
Amount of RemOx S ISCO Reagent Estimated			**69,656 pounds**
Injection Volumes for RemOx L			
RemOx L Injection Concentration	6.0%	%	
Calculated Specific Gravity	1.0549738	g/ml	
Total Volume of Injection Fluid	118,417	gal	
Pore Volume Replaced	0.01	%	
Amount of RemOx L ISCO Reagent Estimated			**156,378 pounds**
		at 40%	**13,681 gallons**

	Estimates	Units	
Treatment Area Volume			
Number of Wells	10	each	
Area pe Well	7850	sq ft	
Area	78500	sq ft	
Thickness	30	ft	intermediate
Total Volume	87222	cu yd	
Soil Characteristics/Analysis			
Porosity	30	%	
Total Plume Pore Volume	5284986	gal	
Avg Contaminant Conc	0.1	ppm	
Mass of Contaminant	4.41	lb	
PNOD	0.56	g/kg	
Effective PNOD	10	%	
Effective PNOD Calculated	0.056		
PNOD Oxidant Demand	14506.8	lb	
Avg Stoichiometric Demand	1.1	lb/lb	
Contaminant Oxidant Demand	4.85	lb	
Theoretical Oxidant Demand	14511.65	lb	
Confidence Factor	3		
Calculated Oxidant Demand	43534.95472		
Injection Volumes for RemOx S			
RemOx S Injection Concentration	6.0%	%	
Total Volume of Injection Fluid	86,948	gal	
Pore Volume Replaced	0.02	%	
Amount of RemOx S ISCO Reagent Estimated			**43,535 pounds**
Injection Volumes for RemOx L			
RemOx L Injection Concentration	6.0%	%	
Calculated Specific Gravity	1.0549738	g/ml	
Total Volume of Injection Fluid	74,011	gal	
Pore Volume Replaced	0.01	%	
Amount of RemOx L ISCO Reagent Estimated			**97,736 pounds**
		at 40%	**8,551 gallons**

APPENDIX D

SAFETY DATA SHEETS

SAFETY DATA SHEET

Version 3.6
Revision Date 07/03/2014
Print Date 11/04/2014

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product identifiers

Product name : Sodium permanganate solution

Product Number : 519073
Brand : Aldrich

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

1.4 Emergency telephone number

Emergency Phone # : (314) 776-6555

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Oxidizing liquids (Category 2), H272
Acute toxicity, Oral (Category 4), H302
Skin corrosion (Category 1B), H314
Serious eye damage (Category 1), H318
Acute aquatic toxicity (Category 1), H400
Chronic aquatic toxicity (Category 1), H410

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word Danger

Hazard statement(s)
H272 May intensify fire; oxidiser.
H302 Harmful if swallowed.
H314 Causes severe skin burns and eye damage.
H410 Very toxic to aquatic life with long lasting effects.

Precautionary statement(s)
P210 Keep away from heat.
P220 Keep/Store away from clothing/ combustible materials.
P221 Take any precaution to avoid mixing with combustibles.
P264 Wash skin thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.

P273	Avoid release to the environment.
P280	Wear protective gloves/ protective clothing/ eye protection/ face protection.
P301 + P312	IF SWALLOWED: Call a POISON CENTER or doctor/ physician if you feel unwell.
P301 + P330 + P331	IF SWALLOWED: rinse mouth. Do NOT induce vomiting.
P303 + P361 + P353	IF ON SKIN (or hair): Remove/ Take off immediately all contaminated clothing. Rinse skin with water/ shower.
P304 + P340	IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P305 + P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310	Immediately call a POISON CENTER or doctor/ physician.
P321	Specific treatment (see supplemental first aid instructions on this label).
P363	Wash contaminated clothing before reuse.
P370 + P378	In case of fire: Use dry sand, dry chemical or alcohol-resistant foam for extinction.
P391	Collect spillage.
P405	Store locked up.
P501	Dispose of contents/ container to an approved waste disposal plant.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.2 Mixtures

Formula : $MnNaO_4$

Molecular Weight : 141.93 g/mol

Hazardous components

Component		Classification	Concentration
Sodium permanganate			
CAS-No. EC-No.	10101-50-5 233-251-1	Ox. Sol. 2; Acute Tox. 4; Skin Corr. 1B; Eye Dam. 1; Aquatic Acute 1; Aquatic Chronic 1; H272, H302, H314, H410	30 - 50 %

For the full text of the H-Statements mentioned in this Section, see Section 16.

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Take off contaminated clothing and shoes immediately. Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.Continue rinsing eyes during transport to hospital.

If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
no data available

5. FIREFIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
Sodium oxides, Manganese/manganese oxides

5.3 Advice for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

5.4 Further information
Use water spray to cool unopened containers.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures
Use personal protective equipment. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas.
For personal protection see section 8.

6.2 Environmental precautions
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

6.3 Methods and materials for containment and cleaning up
Contain spillage, and then collect with an electrically protected vacuum cleaner or by wet-brushing and place in container for disposal according to local regulations (see section 13).

6.4 Reference to other sections
For disposal see section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling
Avoid contact with skin and eyes. Avoid inhalation of vapour or mist.
Keep away from sources of ignition - No smoking.Keep away from heat and sources of ignition.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters

Component	CAS-No.	Value	Control parameters	Basis
Sodium permanganate	10101-50-5	C	5 mg/m3	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
	Remarks	Ceiling limit is to be determined from breathing-zone air samples.		
		TWA	0.2 mg/m3	USA. ACGIH Threshold Limit Values (TLV)
		Central Nervous System impairment Adopted values or notations enclosed are those for which changes are proposed in the NIC See Notice of Intended Changes (NIC) varies		

		C	5 mg/m3	USA. OSHA - TABLE Z-1 Limits for Air Contaminants - 1910.1000
		TWA	1 mg/m3	USA. NIOSH Recommended Exposure Limits
		ST	3 mg/m3	USA. NIOSH Recommended Exposure Limits

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection
Tightly fitting safety goggles. Faceshield (8-inch minimum). Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body Protection
Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type ABEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: liquid
b)	Odour	no data available
c)	Odour Threshold	no data available
d)	pH	no data available
e)	Melting point/freezing point	no data available
f)	Initial boiling point and boiling range	100 °C (212 °F)
g)	Flash point	no data available
h)	Evapouration rate	no data available
i)	Flammability (solid, gas)	no data available
j)	Upper/lower flammability or explosive limits	no data available
k)	Vapour pressure	no data available
l)	Vapour density	no data available
m)	Relative density	1.391 g/cm3

n)	Water solubility	no data available
o)	Partition coefficient: n-octanol/water	no data available
p)	Auto-ignition temperature	no data available
q)	Decomposition temperature	no data available
r)	Viscosity	no data available
s)	Explosive properties	no data available
t)	Oxidizing properties	no data available

9.2 Other safety information
no data available

10. STABILITY AND REACTIVITY

10.1 Reactivity
no data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
no data available

10.4 Conditions to avoid
no data available

10.5 Incompatible materials
Powdered metals, Strong oxidizing agents, Strong acids, Organic materials, Strong reducing agents

10.6 Hazardous decomposition products
Other decomposition products - no data available
In the event of fire: see section 5

11. TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity
no data available

Inhalation: no data available

Dermal: no data available

no data available

Skin corrosion/irritation
no data available

Serious eye damage/eye irritation
no data available

Respiratory or skin sensitisation
no data available

Germ cell mutagenicity
no data available

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity
no data available
no data available

Specific target organ toxicity - single exposure
no data available

Specific target organ toxicity - repeated exposure
no data available

Aspiration hazard
no data available

Additional Information
RTECS: Not available

Men exposed to manganese dusts showed a decrease in fertility. Chronic manganese poisoning primarily involves the central nervous system. Early symptoms include languor, sleepiness and weakness in the legs. A stolid mask-like appearance of the face, emotional disturbances such as uncontrollable laughter and a spastic gait with tendency to fall in walking are findings in more advanced cases. High incidence of pneumonia has been found in workers exposed to the dust or fume of some manganese compounds., Material is extremely destructive to tissue of the mucous membranes and upper respiratory tract, eyes, and skin., spasm, inflammation and edema of the larynx, spasm, inflammation and edema of the bronchi, pneumonitis, pulmonary edema, burning sensation, Cough, wheezing, laryngitis, Shortness of breath, Headache

Stomach - Irregularities - Based on Human Evidence
Stomach - Irregularities - Based on Human Evidence (Sodium permanganate)

12. ECOLOGICAL INFORMATION

12.1 Toxicity
no data available

12.2 Persistence and degradability
no data available

12.3 Bioaccumulative potential
no data available

12.4 Mobility in soil
no data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects
An environmental hazard cannot be excluded in the event of unprofessional handling or disposal.
Very toxic to aquatic life with long lasting effects.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Burn in a chemical incinerator equipped with an afterburner and scrubber but exert extra care in igniting as this material is highly flammable. Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material. Dissolve or mix the material with a combustible solvent and burn in a chemical incinerator equipped with an afterburner and scrubber.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
UN number: 3214 Class: 5.1 Packing group: II
Proper shipping name: Permanganates, inorganic, aqueous solution, n.o.s. (Sodium permanganate)
Reportable Quantity (RQ):
Marine pollutant: No
Poison Inhalation Hazard: No

IMDG
UN number: 3214 Class: 5.1 Packing group: II EMS-No: F-H, S-Q
Proper shipping name: PERMANGANATES, INORGANIC, AQUEOUS SOLUTION, N.O.S. (Sodium permanganate)
Marine pollutant: No

IATA
UN number: 3214 Class: 5.1 Packing group: II
Proper shipping name: Permanganates, inorganic, aqueous solution, n.o.s. (Sodium permanganate)

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
The following components are subject to reporting levels established by SARA Title III, Section 313:

	CAS-No.	Revision Date
Sodium permanganate	10101-50-5	2007-07-01

SARA 311/312 Hazards
Reactivity Hazard, Acute Health Hazard, Chronic Health Hazard

Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Water	7732-18-5	
Sodium permanganate	10101-50-5	2007-07-01

New Jersey Right To Know Components

	CAS-No.	Revision Date
Water	7732-18-5	
Sodium permanganate	10101-50-5	2007-07-01

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Full text of H-Statements referred to under sections 2 and 3.

Acute Tox.	Acute toxicity
Aquatic Acute	Acute aquatic toxicity
Aquatic Chronic	Chronic aquatic toxicity
Eye Dam.	Serious eye damage
H272	May intensify fire; oxidiser.
H302	Harmful if swallowed.
H314	Causes severe skin burns and eye damage.
H318	Causes serious eye damage.

H400	Very toxic to aquatic life.
H410	Very toxic to aquatic life with long lasting effects.
Ox. Sol.	Oxidizing solids
Skin Corr.	Skin corrosion

HMIS Rating

Health hazard:	3
Chronic Health Hazard:	*
Flammability:	0
Physical Hazard	2

NFPA Rating

Health hazard:	3
Fire Hazard:	0
Reactivity Hazard:	2
Special hazard.I:	OX

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 3.6 Revision Date: 07/03/2014 Print Date: 11/04/2014

SAFETY DATA SHEET

Version 4.6
Revision Date 07/23/2014
Print Date 11/04/2014

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product identifiers

Product name : Sodium thiosulfate

Product Number : S7026
Brand : Sigma

CAS-No. : 7772-98-7

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

1.4 Emergency telephone number

Emergency Phone # : (314) 776-6555

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

Not a hazardous substance or mixture.

2.2 GHS Label elements, including precautionary statements

Not a hazardous substance or mixture.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.1 Substances

Synonyms : Sodium thiosulphate

Formula : $Na_2O_3S_2$
Molecular Weight : 158.11 g/mol
CAS-No. : 7772-98-7
EC-No. : 231-867-5

No ingredients are hazardous according to OSHA criteria.
No components need to be disclosed according to the applicable regulations.

4. FIRST AID MEASURES

4.1 Description of first aid measures

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration.

In case of skin contact
Wash off with soap and plenty of water.

In case of eye contact
Flush eyes with water as a precaution.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
no data available

5. FIREFIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
no data available

5.3 Advice for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

5.4 Further information
no data available

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures
Avoid dust formation. Avoid breathing vapours, mist or gas.
For personal protection see section 8.

6.2 Environmental precautions
Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up
Sweep up and shovel. Keep in suitable, closed containers for disposal.

6.4 Reference to other sections
For disposal see section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling
Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs.
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Keep container tightly closed in a dry and well-ventilated place.
Do not store near acids.

Keep in a dry place. Keep in a dry place.

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
Contains no substances with occupational exposure limit values.

8.2 Exposure controls

Appropriate engineering controls
General industrial hygiene practice.

Personal protective equipment

Eye/face protection
Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Choose body protection in relation to its type, to the concentration and amount of dangerous substances, and to the specific work-place., The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Respiratory protection is not required. Where protection from nuisance levels of dusts are desired, use type N95 (US) or type P1 (EN 143) dust masks. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Do not let product enter drains.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: powder Colour: white
b)	Odour	no data available
c)	Odour Threshold	no data available
d)	pH	6.0 - 8.5 at 50 g/l at 20 °C (68 °F)
e)	Melting point/freezing point	52 °C (126 °F) - Decomposes on heating.
f)	Initial boiling point and boiling range	no data available
g)	Flash point	no data available
h)	Evapouration rate	no data available

i)	Flammability (solid, gas)	no data available
j)	Upper/lower flammability or explosive limits	no data available
k)	Vapour pressure	no data available
l)	Vapour density	no data available
m)	Relative density	1.667 g/cm3 at 20 °C (68 °F)
n)	Water solubility	210 g/l at 20 °C (68 °F)
o)	Partition coefficient: n-octanol/water	no data available
p)	Auto-ignition temperature	no data available
q)	Decomposition temperature	no data available
r)	Viscosity	no data available
s)	Explosive properties	no data available
t)	Oxidizing properties	no data available

9.2 Other safety information
no data available

10. STABILITY AND REACTIVITY

10.1 Reactivity
no data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
no data available

10.4 Conditions to avoid
no data available

10.5 Incompatible materials
Strong acids, Strong oxidizing agents

10.6 Hazardous decomposition products
Other decomposition products - no data available
In the event of fire: see section 5

11. TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity
LD50 Oral - rat - > 8,000 mg/kg

Inhalation: no data available

Dermal: no data available

LD50 Intraperitoneal - mouse - 5,200 mg/kg

Skin corrosion/irritation
no data available

Serious eye damage/eye irritation
no data available

Respiratory or skin sensitisation
no data available

Germ cell mutagenicity
no data available

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity
no data available

no data available

Specific target organ toxicity - single exposure
no data available

Specific target organ toxicity - repeated exposure
no data available

Aspiration hazard
no data available

Additional Information
RTECS: XN6476000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

Toxicity to fish	LC50 - Gambusia affinis (Mosquito fish) - 24,000 mg/l - 96 h

12.2 Persistence and degradability
no data available

12.3 Bioaccumulative potential
no data available

12.4 Mobility in soil
no data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects

no data available

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods

IMDG
Not dangerous goods

IATA
Not dangerous goods

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
No SARA Hazards

Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Sodium thiosulphate	7772-98-7	

New Jersey Right To Know Components

	CAS-No.	Revision Date
Sodium thiosulphate	7772-98-7	

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

HMIS Rating

Health hazard:	0
Chronic Health Hazard:	
Flammability:	0
Physical Hazard	0

NFPA Rating

Health hazard:	0
Fire Hazard:	0
Reactivity Hazard:	0

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

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