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July 3, 2014

Penny Reddy
Groundwater Remediation Project Manager
Superfund Division SFD-7-3
EPA Region IX
75 Hawthorne Street
San Francisco, CA 94105

Subject: **Work Plan for In Situ Chemical Oxidation Pilot Study**
401 National Avenue, Former Fairchild Building 9
Middlefield-Ellis-Whisman Area
Mountain View, California

Dear Ms. Reddy:

Enclosed with this letter is a work plan for an *in situ* chemical oxidation (ISCO) pilot study at the former Fairchild Building 9, located at 401 National Avenue, Mountain View, California.

As indicated in the work plan, the ISCO pilot study is scheduled to take place following the demolition of Building 9, in conjunction with planned redevelopment activities at 401 National Avenue. Based on a general schedule provided verbally by the developer, it is anticipated that building demolition will be completed by the end of September 2014. We are therefore requesting approval of the work plan by 31 August 2014 to allow time for project set-up and contractor scheduling.

If you have any questions about the enclosed work plan, please feel free to contact me.

Very truly yours,

V. COCIANNI

Virgilio Cocianni
Remediation Manager

Attachment

CC: MEW Distribution List
Victor R. Fracaro, National Avenue Partners, LLC

Prepared for

Schlumberger Technology Corporation
105 Industrial Boulevard
Sugar Land, Texas 77478

WORK PLAN
FOR IN SITU CHEMICAL OXIDATION
PILOT STUDY

401 NATIONAL AVENUE
FORMER FAIRCHILD BUILDING 9
MIDDLEFIELD-ELLIS-WHISMAN AREA
MOUNTAIN VIEW, CALIFORNIA

Prepared by

Geosyntec consultants

engineers | scientists | innovators

1111 Broadway, 6th Floor
Oakland, California 94607

Project Number: WR1133B

3 July 2014

Work Plan
for In Situ Chemical Oxidation Pilot Study

401 National Avenue
Former Fairchild Building 9
Middlefield-Ellis-Whisman Area
Mountain View, California

Prepared by

Geosyntec Consultants, Inc.
1111 Broadway, 6th Floor
Oakland, California 94607

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Project Number: WR1133B
3 July 2014

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LIST OF ACRONYMS AND ABBREVIATIONS

AMEC	AMEC Environment and Infrastructure, Inc.
bgs	below ground surface
cDCE	cis-1,2-dichlorothene
cVOCs	chlorinated volatile organic compounds
DO	dissolved oxygen
ECD	electron capture detector
EPA	United States Environmental Protection Agency
ESD	Explanation of Significant Differences
Fairchild	Fairchild Semiconductor Corporation
FS	Feasibility Study
Geosyntec	Geosyntec Consultants, Inc.
gpm	gallons per minute
HASP	health and safety plan
HLA	Harding Lawson Associates
ISCO	in situ chemical oxidation
lbs	pounds
Locus	Locus Technologies
µg/L	micrograms per liter
MIP	membrane interface probe
MEW	Middlefield-Ellis-Whisman
MIP	membrane interface probe
MSL	mean sea level
ORP	oxidation-reduction potential
PID	photoionization detector

PPE	personal protective equipment
psi	pounds per square inch
PSOD	permanganate soil oxidant demand
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RI	Remedial Investigation
ROD	Record of Decision
ROI	radius of influence
SCRW	Source Control Recovery Well
SCVWD	Santa Clara Valley Water District
Site	former Building 9, 401 National Avenue, Mountain View, California
STC	Schlumberger Technology Corporation
SUMCO	SUMCO Phoenix Corporation
SVE	soil vapor extraction
TCE	trichloroethene
TDS	Total dissolved solids
USA	Underground Service Alert
VC	vinyl chloride
Vishay	Vishay GSI Inc.
Work Plan	Work Plan for In Situ Chemical Oxidation Pilot Study

1. INTRODUCTION

This Work Plan for In Situ Chemical Oxidation (ISCO) Pilot Study (Work Plan) presents a scope of work for an ISCO pilot study to address chlorinated volatile organic compounds (cVOCs) in groundwater at the former Fairchild Semiconductor Corporation (Fairchild) Building 9 facility located at 401 National Avenue[1] in Mountain View, California (Site, Figure 1 and Figure 2). Geosyntec Consultants, Inc. (Geosyntec) has developed this Work Plan on behalf of Schlumberger Technology Corporation (STC) based on data available from previous characterization and remediation activities conducted at the Site since the mid-1980s and a supplemental data collection field program conducted in September 2013 (Geosyntec, 2014b).

1.1 Purpose and Scope

In March 2013, the U.S. Environmental Protection Agency (EPA) directed the Middlefield-Ellis-Whisman (MEW) Study Area Parties to perform pilot studies at their sites to evaluate alternative technologies or approaches for increasing the rate of cVOC mass removal.[2] On behalf of STC, Geosyntec is planning this ISCO pilot study as a means of increasing the rate of cVOC mass removal at 401 National Avenue. The scope of work for the ISCO pilot study includes:

- Supplemental data collection to (1) assess site-specific oxidant demand and the efficacy of selected oxidant formulations, and (2) determine the injection footprint beneath the former Building 9 following planned demolition of the building;[3]
- Targeted ISCO injections in areas containing relatively high cVOC concentrations, to be implemented following building demolition;

[1] As part of a planned redevelopment, 401 National Avenue and the properties located to the immediate north (620 through 640 National Avenue) have been consolidated into a single address: 600 National Avenue (Figure 3). For consistency with historical project documents, the project site for the ISCO pilot study will be referred to as the Site, former Building 9, or 401 National Avenue throughout this Work Plan.
[2] P.W. Reddy, EPA, Email Communication, 11 March 2013.
[3] A work plan for the supplemental data collection activities has been submitted to the EPA under separate cover (Geosyntec, 2014c).

- Pilot study process and performance monitoring during and following the ISCO injection program; and
- Shutdown of the existing on-Site source control recovery wells (SCRWs), with the option of future resumption of groundwater recovery from some or all of the on-Site SCRWs based on the results of the pilot study performance monitoring.

The proposed pilot study is not associated with, or part of, the planned redevelopment activities at 401 National Avenue. However, the planned redevelopment provides access to portions of 401 National presently occupied by buildings (Section 2.1).

1.2 Report Organization

The remainder of this Work Plan is organized as follows:

- Section 2, *Background*, presents a description of the local hydrogeology and cVOC distribution at the Site, a description of previous remedial actions, and summary of remedy performance;
- Section 3, *Design Basis for Pilot Study*, summarizes the specific project objectives for the pilot study; evaluates current remedy performance; summarizes pilot study treatment area and depth interval selection based on recent data collected; and presents the proposed approach, layout, and performance monitoring network for the pilot study;
- Section 4, *Implementation Work Plan*, provides a work plan for implementing the pilot study scope of work;
- Section 5, *Criteria for Restarting Recovery Wells*, describes the evaluation that will be periodically conducted to assess whether groundwater extraction should resume from some or all of the on-Site SCRWs;
- Section 6, *Reporting and Schedule*, summarizes the reports that will be submitted to document the pilot study results and presents a schedule for implementing the pilot study; and
- Section 7, *References*, provides the references cited in this Work Plan.

Tables, figures, and appendices are provided at the end of this Work Plan.

2. BACKGROUND

The Site is located within the MEW Study Area in Mountain View, California. STC has been performing soil and groundwater remedies for cVOCs, primarily trichloroethene (TCE) and its breakdown products (cis-1,2-dichloroethene [cDCE] and vinyl chloride [VC]), at the former Building 9 facility since 1986. In conformance with the 1989 Record of Decision (ROD) and two subsequent Explanations of Significant Differences (ESDs) issued by the EPA for the MEW Study Area (EPA, 1989; 1990; 1996), the Building 9 groundwater remedy consists of groundwater extraction and treatment (pump-and-treat) by means of four recovery wells within an area bounded by a slurry wall constructed to a depth of approximately 40 feet below ground surface.

In March 2013, EPA directed the MEW Parties to perform pilot studies at their sites to evaluate alternative technologies or approaches for increasing the rate of cVOC mass removal. On behalf of STC, Geosyntec is planning this ISCO pilot study as a means of increasing the rate of cVOC mass removal at 401 National Avenue.

2.1 Site Description and History

Building 9 operated as a facility for receiving, mixing, and delivering chemicals for Fairchild from 1966 to 1987. During the Remedial Investigation/Feasibility Study (RI/FS) completed in 1988 for the MEW Study Area (HLA, 1987; Canonie, 1988a), two potential source areas (LS28 and LS29) were identified at the Site. LS28 was located on the north side of Building 9 and consisted of four solvent storage tanks and a spill collection sump. LS29 was a pH neutralization system located inside Building 9 that consisted of three treatment sumps.

A number of remedial actions have been conducted as part of the facility-specific remedy for the Site, including (in chronological order):

- 1986: installation of a soil-bentonite slurry wall in the A-zone to a depth of approximately 40 feet below ground surface (bgs) (Figure 2). The slurry wall is an approximately 34 inches thick[4], with an average permeability coefficient

[4] Test pits across the uppermost 5 feet of the slurry wall were excavated in September 2013 and the maximum thickness of soil-bentonite backfill was observed to be approximately 35 inches (Geosyntec,

(hydraulic conductivity) of 3.8×10^{-8} centimeters per second (cm/sec, 1.1×10^{-4} feet per day) based on post-construction quality control testing (Canonie, 1988b);

- Ongoing since 1986: groundwater extraction at SCRWs AE/RW-9-1, AE/RW-9-2, RW-20A, and RW-21A located within the Site slurry wall (Figure 2);

- Ongoing since 1996: groundwater extraction at SCRWs GSF-1A, GSF-1B1, and GSF-1B2 operated jointly for both 401 National Avenue and the adjacent 405 National Avenue site (AMEC, 2013) (Figure 2);

- 1995: 3,000 cubic yards of soil were excavated to a depth of 6 feet bgs and aerated at the Site (Smith, 1995; EPA, 2004); and

- 1996 through 1997: soil vapor extraction (SVE) in shallow soil at depths from 6 feet bgs to 18 inches above the water table (Locus, 1997; Smith, 1997a; and Smith, 1997b).

In 2013, the 401 National Avenue property was purchased by National Avenue Partners, LLC and in May 2014 redevelopment of 401 National was approved by the City of Mountain View in conjunction with three properties to the north. The approved redevelopment activities include the demolition of the former Building 9 and the construction of a two-story aboveground parking garage over most of the current 401 National Avenue property, as shown on Figure 3.

2.2 Local Hydrogeology

The MEW Study Area is located within the northern portion of the Santa Clara Valley Groundwater Sub-basin, the northernmost of three interconnected groundwater basins within Santa Clara County (Santa Clara Valley Water District [SCVWD], 2001). The groundwater flow direction is northerly, toward the San Francisco Bay, and generally sub-parallel to the ground slope. The hydrostratigraphy in this part of the sub-basin is divided into upper and lower water-bearing zones, separated by an extensive regional aquitard (SCVWD, 1989).

2014b) and post construction drawings indicate that the slurry wall is a minimum of 30 inches thick (Canonie, 1988b).

The upper water-bearing zone underlying the MEW Study Area is subdivided into two water-bearing zones: the A-zone (roughly between 14 and 40 feet bgs) and the B-zone (roughly between 45 and 160 feet bgs), which are separated by the A/B Aquitard. The B-zone is further subdivided into three zones (B1-, B2-, and B3-zones). The lower water-bearing zone occurs below a depth of about 200 feet bgs. The lower water bearing zone is subdivided into the C-zone (which extends to about 240 feet bgs) and the Deep zone. The aquitard separating the upper and lower water-bearing zones is represented as the B/C Aquitard and is the major confining layer beneath the Site.

Groundwater flow beneath the MEW Study Area is generally towards the north in the A- and B-zones under both non-pumping and pumping conditions. Groundwater hydraulic gradients are locally modified by the operation of groundwater recovery wells (both source control and regional recovery wells) and slurry walls, resulting in steeper gradients in the vicinity of pumping wells.

The A-zone is the primary groundwater unit monitored at the Site. Under pumping conditions, the potentiometric surface of the A-zone at the Site generally occurs under confined conditions. During the September 2013 semi-annual gauging event, groundwater at the Site was encountered at a depth of approximately 17 feet bgs, corresponding to groundwater elevations of approximately 26 feet above mean sea level (MSL) (Geosyntec, 2014a). An upward vertical gradient is observed within the slurry wall footprint from the deeper B1-zone into the A-zone during pumping conditions (Geosyntec, 2014a). Inward horizontal gradients are observed along most of the slurry wall during pumping, with the periodic exception of some locations along the northern, downgradient sections (Geosyntec, et al., 2008).

2.3 Nature and Extent of cVOCs

The primary cVOCs in Site groundwater are TCE and its reductive dechlorination daughter products cDCE and VC. TCE concentrations in groundwater from Site monitoring wells sampled in 2012/2013 are shown in Figure 4. Plots of TCE, cDCE, and VC versus time for select A-zone monitoring wells are included as Appendix A. Over the last 5 years (2008 to 2013), the maximum concentration of TCE detected in Site groundwater monitoring or SCRWs was 13,000 micrograms per liter (µg/L) in AE/RW-9-2 in 2013 (Geosyntec, 2014a). The TCE concentration measured in 2013 for Site well 123A, located upgradient (south) of the slurry wall, was 510 µg/L. TCE concentrations at Site wells 41A and 42A, located downgradient (north) of the slurry wall, were 580 and 470 μg/L, respectively (Figure 4).

2.4 Current Groundwater Remedy

As specified in the ROD for the MEW Study Area, the current, facility-specific groundwater remedy at the Site consists of slurry wall containment (A-zone) and groundwater extraction and treatment.

There are four A-zone SCRWs on-Site within the area bounded by the slurry wall that are primarily used to recover cVOC mass and maintain inward and upward groundwater gradients within the slurry wall, as stipulated by the ROD (Figure 2). The efficiency of mass recovery by the slurry wall SCRWs has declined over time (Geosyntec, et al., 2008), although mass recovery from the on-Site wells over the past 3 years has averaged 166 pounds of cVOCs per year. On-Site SCRWs are connected to the Fairchild System 1 treatment facility (Geosyntec, 2014a).

Outside of the slurry wall, there are currently three SCRWs (one in each of the A-, B1-, and B2-zones) and one additional planned A-zone SCRW associated with the Site. The existing off-Site SCRWs are located approximately 200 feet downgradient (north) of the Site and primarily provide Site containment. The location of the A-zone SCRW outside the slurry wall (well GSF-1A) is shown in Figure 5. The off-site SCRWs in the B1 and B2-zones (Wells GSF-1B1 and GSF-1B2) are immediately adjacent to GSF-1A. In addition, a new off-Site SCRW is planned to comply with EPA's directive for increased mass removal in the vicinity of monitoring well 116A, located approximate 70 feet downgradient of the Site. STC and Vishay GSI Inc. (Vishay)/SUMCO Phoenix Corporation (SUMCO) jointly operate wells GSF-1A, GSF-1B1 and GSF-1B2 by agreement as part of the source control measures for both 401 National Avenue and the adjacent 405 National Avenue site. These off-Site SCRWs are connected to the Vishay/SUMCO treatment facility that is currently located on the Site.[5] This off-Site remedy is referred to as the Shared Remedy. The anticipated extraction well in the vicinity of monitoring well 116A will also be operated as part of the Shared Remedy.

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[5] The Vishay/SUMCO treatment facility may be relocated on-Site to accommodate the planned redevelopment activities. The off-Site SCRWs would continue to be connected to the Vishay/SUMCO facility in the event it is relocated.

As shown in Figure 5, the Shared Remedy provides containment of groundwater for Site areas outside of and below the slurry wall.

3. DESIGN BASIS FOR PILOT STUDY

The design basis for the ISCO pilot study was developed based on recent investigations of the hydrogeology and extent of cVOCs within the Site slurry wall, a review of previous pilot studies conducted at other sites within the MEW Study Area, and the professional experience of the design engineers.

3.1 Pilot Study Objective

The pilot study described in this Work Plan has been designed to: (1) increase the short-term rate of mass removal at the Site to comply with EPA's directive for accelerating cVOC mass removal at each facility, and (2) to generate performance metrics for alternative technologies for use in a future groundwater feasibility study planned by EPA.

3.2 Mass Removal Rate of Current Remedy

As shown in the table below, annual mass removal rates for the Site SCRWs located inside the slurry wall ranged from 157 to 173 pounds per year between 2011 and 2013 (average of 166 pounds per year).

SCRW/Treatment System	cVOC Mass Removal (Pounds)		
	2011	2012	2013
AE/RW-9-1	26	37	38
AE/RW-9-2	101	69	66
RW-20A	29	25	40
RW-21A	17	26	25
Total Mass Removal for Site SCRWs Located Inside the Slurry Wall	**173**	**157**	**169**

Note: Individual well mass removal was calculated based on the estimated average annual groundwater extraction rate and the SCRW annual sampling results (sum of the cVOC concentrations) for the associated year from Table 1 and Table 17b[6], respectively, of the Annual Progress Report Former Fairchild Buildings 1-4, 9 and 18 (Geosyntec 2012, 2013a, 2014a).

[6] Table 10 in the 2011 Annual Report for Former Fairchild Building 9 (Geosyntec, 2012a).

If the current average cVOC mass removal rate of 166 pounds per year is extrapolated over the next 30 years, the mass removal for the current remedy would be approximately 5,000 pounds of cVOCs. Based on the historical mass removal rates by the current remedy, some decline in extracted cVOC concentrations over time is expected (see e.g., Geosyntec, 2008; Geosyntec, 2012b), resulting in an expected 30-year mass removal of less than 5,000 pounds.

For areas outside of and below the slurry wall, mass is currently being removed by off-Site SCRWs GSF-1A, GSF-1B1, and GSF-1B2, which are operated as part of the Shared Remedy. The mass removal of the Shared Remedy is expected to increase with the initiation of groundwater extraction at well 116A.

3.3 Treatment Area and Depth Interval

Between 28 August and 27 September 2013, field work was performed to collect data to support the pilot study design (Geosyntec, 2014b). The results of the data collection work were used to assess the Site hydrogeology and distribution of cVOCs prior to selecting pilot study treatment areas within the slurry wall. Relevant results from the supplemental data collection field work and treatment areas selected based on these results are discussed below.

A-zone Hydrostratigraphy

Cross-sections depicting the hydrogeology at the Site (Figure 6 and Figure 7) were developed using historical information and information generated during the September 2013 supplemental data collection field program. These cross-sections show that two relatively continuous layers of coarse-grained material are present within the planned pilot study area: the shallow coarse-grained layer is generally encountered between 17 and 23 feet bgs and the deep coarse-grained layer is generally encountered between 32 and 37 feet bgs.

Distribution of cVOCs

During the 2013 supplemental data collection activities, membrane interface probe (MIP) borings were advanced at several locations across the Site to provide qualitative information on the distribution of cVOCs (MIP-01 through MIP-12, Figure 4). The MIP results are discussed in detail in the Data Collection Summary Report (Geosyntec, 2014b). Electron capture detector (ECD) and photoionization detector (PID) profiles for the MIP borings are shown in cross-sectional view on Figures 6 and 7.

During the advancement of the MIP borings, the highest detector responses were observed at MIP-02 and MIP-09/MIP-12. At most locations, the highest detector responses were generally observed between 17 and 26 feet bgs.[7] High ECD responses were also observed between 32 and 36 feet bgs, with limited or no response for the other detectors. These zones of higher response generally correspond with the two coarse-grained layers identified in cross-sections A-A’ and B-B’ (Figure 6 and Figure 7). For the shallow coarse-grained layer (17 to 23 feet bgs), the highest detector response was observed just above and continuing, to a limited extent, into the underlying zone of fine-grained materials.

At selected MIP borings, grab groundwater samples were collected for comparison to the qualitative results from the MIP detectors. TCE concentrations in grab groundwater samples collected from temporary points set in the shallow and deep coarse-grained layers ranged from 100 to 560,000 µg/L (Figure 4, Table 1). Total cVOC concentrations detected in September 2013 ranged from approximately 2,500 to 630,000 µg/L and predominantly consisted of TCE and cDCE, with other detected cVOC concentrations one to two orders of magnitude lower in value (Table 1). TCE and total cVOC concentrations increased with depth in the shallow coarse-grained layer, with TCE concentrations measured at 16 to 22 feet bgs two orders of magnitude lower than TCE concentrations measured at 22 to 26 feet bgs at boring MIP-12 (Table 1 and Figure 6). TCE and total cVOC concentrations in groundwater collected from the deep coarse-grained layer were significantly lower than cVOC concentrations in the shallow coarse-grained layer, ranging from 100 to 1,200 µg/L and 3,200 to 5,600 µg/L, respectively.

Target Injection Zones

Target injection zones for the ISCO pilot study developed based on the September 2013 data collection activities are provided in plan view in Figure 8. ISCO pilot study

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[7] The ECD, which detects cVOCs, was the most responsive detector and reached its maximum value of 1.4×10^7 microvolts (uV) at most borings. In general, the PID, which detects chlorinated and non-chlorinated VOCs, and halogen-specific detector (XSD, detects cVOCs) responses were similar to each other but less responsive than the ECD, tending to respond only when the ECD response was sustained at the maximum value over a given depth interval.

injections will include three upper zones (U-1, U-2a, and U-2b) in the shallow coarse-grained layer totaling approximately 13,000 square feet (ft^2), and a single smaller lower zone (L-1) in the deep coarse-grained layer totaling approximately 8,000 ft^2. Injection zones in both the shallow and deep coarse-grained layers were selected to address the boring/well locations with the highest cVOC concentrations detected in groundwater or the largest PID response observed during the September 2013 MIP field program (e.g., MIP-2, MIP-9, and MIP-12).

Based on groundwater cVOC concentrations and vertical profiles of PID response measured in the MIP borings, the target upper vertical injection zones in the shallow coarse-grained layer are approximately 17 to 23 feet bgs (Figure 9 and Figure 10).

Based on groundwater cVOC concentrations and vertical profiles of PID and ECD response measured in the MIP borings, the concentrations of cVOCs in the deep coarse-grained layer are generally lower than those observed in the shallow coarse-grained layer. The target vertical injection zone in the deep coarse-grained layer is approximately 33 to 36 feet bgs (Figure 9 and Figure 10).

Limited groundwater data are available within the footprint of the former Building 9. As a result, a supplemental data collection field program will be performed following the demolition of Building 9 to evaluate the distribution of cVOC concentrations in the saturated zone beneath the building, and to further refine the injection zone boundaries (Geosyntec, 2014c). If required, modifications to the target injection zones would be provided to EPA as an addendum to this Work Plan prior to implementation of the ISCO pilot study.

3.4 Oxidant Selection

Sodium permanganate ($NaMnO_4$) was selected as the chemical oxidant for use inside the slurry wall based on the following:

- Sodium permanganate is a well-studied chemical oxidant that has been demonstrated to effectively degrade TCE and other chlorinated ethenes (e.g., ITRC, 2005).
- It has been demonstrated that sodium permanganate can be successfully injected during pilot testing at two high concentration cVOC areas located along Evandale Avenue, west of the MEW Study Area. Natural soil oxidant demand

testing with soils collected on Evandale Avenue provided the design basis for dosing at the Site.

- Sodium permanganate has a higher aqueous solubility than potassium permanganate, making it a better choice for treatment of high cVOC concentrations.
- Sodium permanganate will be shipped to the Site as a liquid compound from which diluted solutions can be prepared onsite by mixing with groundwater or tap water. Other permanganate formulations (e.g., potassium permanganate) are solid, which can make mixing and handling more difficult.

Bench-scale testing will be performed by SiREM Laboratory of Guelph, Ontario, Canada to confirm the oxidant selection criteria described above. The bench-scale testing will consistent of two tasks:

- Permanganate soil oxidant demand (PSOD) bench-scale testing will be performed to provide information regarding the rate and extent of oxidant consumption by Site soil and groundwater when dosed with permanganate.
- A comparative oxidant performance test will be performed to compare the treatment of Site soil and groundwater when dosed with permanganate, iron activated persulfate, and a mixture of permanganate and persulfate.

Details on the bench-scale testing scope of work are provided in the Work Plan for ISCO Pilot Study Data Collection (Geosyntec, 2014c).

3.5 Oxidant Demand

The oxidant dosing is designed to account for the natural soil demand (i.e., oxidant use by naturally occurring organic matter) and cVOC demand (i.e., oxidant use by cVOCs) in the target treatment areas within the slurry wall. Site-specific bench-scale PSOD testing will be performed prior to implementation of the ISCO pilot study at Building 9; details of this bench-scale testing are being submitted concurrently under separate cover (Geosyntec, 2014c).

For the purpose of developing this preliminary ISCO design basis, PSOD testing results conducted as part of the ongoing ISCO pilot study along Evandale Avenue[8] have been used (Geosyntec, 2013b). The Evandale Avenue bench-scale PSOD testing was performed in April and May 2013 to evaluate the rate and extent of oxidant consumption by soil and groundwater[9] when treated with permanganate. The PSOD testing results report from the treatability laboratory is provided in the Final Pilot Study Design and Implementation Work Plan for Evandale Avenue Sources (Geosyntec, 2013b).

The cumulative soil oxidant demand measured during PSOD testing can be presented on a grams (g) of MnO_4^- per kilogram (kg) of soil basis. This provides an estimate of the soil oxidant demand (i.e., oxidant use by naturally occurring organic matter along with any cVOCs present in the tested soil and groundwater) and can be used to develop an oxidant dosing design basis. Both coarse-grained soil (i.e., sand and silty sand) and fine-grained soil (i.e., silt and clay) from along Evandale Avenue (consistent with the predominant soil types present at the former Building 9 area), were used for the PSOD testing. Bench-scale 10-day PSOD testing results for the Evandale Avenue soil ranged from 1.3 to 5.5 g MnO_4^-/kg soil, with a mean 10-day PSOD of 3.4 g MnO_4^-/kg soil ($n=5$; $\sigma=1.2$ g/kg). A mean 10-day PSOD of 3.4 g/kg is relatively low, with long-term permanganate natural oxidant demand values ranging from 0.8 to over 35 g MnO_4^-/kg soil reported in the literature (e.g., Strategic Environmental Research and Development Program [SERDP], 2007).

3.6 Oxidant Dosing

The oxidant dosing for the ISCO pilot study is dependent on two key design criteria: (1) the volume of the target treatment zone, and (2) the site-specific PSOD value determined during bench testing.

As described in Section 3.3, existing data were used to identify the lateral and vertical extent of several conceptual ISCO treatment zones. The table below lists design criteria for each conceptual treatment zone and provides the target permanganate dosing

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[8] The location of the Evandale Avenue ISCO pilot study is approximately 0.25 miles from 401 National Avenue and has similar hydrogologic conditions and cVOC concentrations.

[9] Soil and groundwater for PSOD testing were collected from borings located near the CPT-15 and CPT-21 Areas along Evandale Avenue (Geosyntec, 2013b).

required for each area to satisfy a PSOD of 3.4 g MnO_4^-/kg soil. For the ISCO pilot study, the design concentration of the sodium permanganate solution will be 35 grams as MnO_4^- per liter (g MnO_4^-/L) (Section 4.3.2).

Treatment Zone	Lithology	Area (ft^2)	Depth Interval (feet bgs)	Thickness (feet)	Volume Soil (ft^3)	Mass Soil (lbs)	Mass Permanganate lbs as MnO_4^-
U-1	shallow coarse-grained layer	8,900	18 to 23	5	44,500	4,450,000	15,100
U-2a		2,200	17 to 23	6	13,200	1,320,000	4,500
U-2b		1,900	16.5 to 23	6.5	12,350	1,235,000	4,200
L-1	deep coarse-grained layer	8,000	33 to 36	3	24,000	2,400,000	8,200
					Total Mass MnO_4^-		32,000
					Total Mass $NaMnO_4$		38,180

Note: Depth intervals may be adjusted based on conditions encountered in the field and interpreted lithology within each zone.

After completion of the scope of work described in the Work Plan for ISCO Pilot Study Data Collection (Geosyntec, 2014c), the extent of the proposed target treatment zones will be reviewed based on the results of sample collection from beneath the former Building 9 footprint, and the PSOD design assumption will be reviewed based on the results of the site-specific bench-scale testing. If required based on this review, modifications to the pilot study oxidant dosing would be provided to EPA as an addendum to this Work Plan prior to implementation of the ISCO pilot study.

3.7 Injection Rates and Radius of Influence

An injection test was performed during the September 2013 data collection field work to facilitate the development of depth-specific estimates for achievable injection rates and pressures within the pilot study area. The results of the injection test showed that flow rates of approximately 2 gallons per minute (gpm) can be achieved at low pressures (15 to 25 pounds per square inch [psi] above hydrostatic pressure) for most depth intervals.

Based on the above results, a nominal injection rate of 3.5 gpm was selected for each injection depth interval in the shallow and deep coarse-grained layers. While achieving this injection rate may require injecting at pressures in excess of 25 psi, engineering controls will be employed to limit injection pressures to less than 80 psi during implementation to reduce the potential for development of preferential flow pathways in the formation.

The design injection spacing in both the upper and lower zones is approximately 15 feet on center; the target radius of influence (ROI) for these injections is approximately 10 feet, allowing for some potential overlap between adjacent injection locations. A 10-foot ROI is considered reasonable based on experience with ISCO injections in similar geologic formations to those present at the Site.

During injection activities, one or more of the SCRWs located inside the slurry wall may be operated to limit increases in hydraulic head within the coarse-grained layers that could result from the injection of large volumes of oxidant solution within the slurry wall. Both during and following injection activities, SCRWs may also be utilized to enhance the distribution of oxidant by pumping until residual oxidant breakthrough is observed. Procedures for managing extracted groundwater during injection activities are presented in Section 4.3.1.

If design injection rates and volumes cannot be reasonably achieved in the field during initial injections, the actual injection rates and/or oxidant solution concentration will be modified. Modifications to the design injection rates or concentration, if necessary, would be determined in consultation with EPA. If injection rates and pressures observed during the beginning of the injection program are consistent with the design basis, the ISCO injection program would proceed as designed.

3.8 Evaluation of Potential Secondary Water Quality Impacts

As part of the ISCO pilot study design, an assessment of potential impacts to secondary water quality downgradient of the former Building 9 slurry wall was conducted. The assessment considered the following:

- The potential flow of groundwater from within the slurry wall to areas downgradient of the Site;
- The potential transport of MnO_4^- from within the pilot study area to downgradient receptor wells (the proposed SCRW at 116A, located north of the Site, and SCRW wells EX-1 through EX-4, located east of the Site); and
- The potential generation and transport of hexavalent chromium [Cr(VI)] from within the pilot study area to downgradient receptor wells.

Groundwater Flow

The on-Site SCRWs that will be shut down as part of the ISCO pilot study are located within the area surrounded by the former Building 9 slurry wall. Two A-zone SCRWs (one currently installed and one planned for future installation) immediately downgradient of the former Building 9 slurry wall are expected to remain operational for the duration of the pilot study (Section 2.4). These wells will continue to provide vertical and lateral containment of cVOCs from the Site for the duration of the pilot study, which is consistent with the criterion for installing and operating SCRWs as described in the Revised Final Design, Regional Groundwater Remediation Program (Smith, 1996).

Based on data collected in September 2013, groundwater elevations within the slurry wall when the on-Site SCRWs are not operating may be approximately 4 to 5 feet higher than elevations under pumping conditions (Geosyntec, 2014b). However, long-term data under non-pumping conditions inside the slurry wall are not available. Therefore, numerical modeling methods were used to assess hydraulic conditions that would occur during the ISCO pilot study following shutdown of the on-Site SCRWs.

The numerical model used to evaluate hydraulic conditions at the Site is based on the MEW Study Area regional groundwater flow model, with a refined model domain in order to obtain a higher resolution characterization of the subsurface and groundwater flow field around the slurry wall. Details regarding the modeling approach are included in Appendix B.

The results of the groundwater flow modeling indicate that a small amount of groundwater, on the order of approximately 0.7 gpm flows upwards and into the area surrounded by the slurry wall along the southern (upgradient) wall. The groundwater travels north through the aquifer material isolated by the slurry wall until it reaches the northern (downgradient) wall. Upon reaching the downgradient wall, a similarly small amount of groundwater (0.7 gpm) flows downward and out of the area surrounded by the slurry wall. The low rate of groundwater flux from within the slurry wall suggests that groundwater originating from within the slurry wall is not expected to be a significant component of groundwater extracted by nearby wells located outside of the slurry wall.

Permanganate Fate and Transport

A version of the MEW Study Area regional groundwater model with the capability of modeling solute transport was used to assess the fate of residual permanganate following ISCO implementation (Appendix B). The Evandale Avenue bench-scale PSOD testing results (Geosyntec, 2013b) were used to develop a kinetic model for reactive transport of permanganate. The model assumed a residual permanganate concentration in groundwater of 30 g MnO_4^-/L throughout the target treatment zones at the conclusion of the ISCO implementation, resulting in a residual permanganate mass loading that is approximately 50% greater than what is proposed for the pilot study.

Under these conservative conditions, the model results indicate that residual permanganate is expected to be consumed by natural organic matter present in the aquifer material prior to reaching the nearest SCRWs to the north (planned SCRW at 116A) and to the east (EX-1 through EX-4, operated as part of the groundwater remedy at 405 National Avenue, Figure 2).

Hexavalent Chromium Fate and Transport

Cr(VI) can be generated or introduced during ISCO implementation using permanganate solutions. However, the body of scientific literature on ISCO and Cr(VI) fate and transport (e.g., Siegrist et al., 2011; EPA, 2007) indicates the following:

- Generation of Cr(VI) is a transient process that occurs while residual permanganate is present in the system and once permanganate is depleted, additional Cr(VI) generation is not expected;
- Cr(VI) is expected to sorb to mineral surfaces, retarding its potential transport through the subsurface; and
- Due to the naturally occurring reduced subsurface environment, Cr(VI) generated during ISCO will be reduced to trivalent chromium [Cr(III)] over distance and time following implementation.

Data collected during previous ISCO injections conducted at the MEW Study Area indicate that the above attenuation processes can be expected at the Site. For example, concentrations of Cr(VI) were reportedly below the analytical method detection limit (0.010 milligrams per liter [mg/L]) within 4.5 months following the ISCO injections at the SMI Holding, Inc. site located at 501/505 East Middlefield Road (PES

Environmental, 2001). In addition, Cr(VI) has not been observed above background levels in samples collected from performance monitoring wells located downgradient of the ISCO injections ongoing along Evandale Avenue.

3.9 Pilot Study Process and Performance Monitoring

Pilot study process monitoring will be conducted to assess the progress of the ISCO injection program by assessing the distribution and consumption of permanganate and verifying that permanganate injection is controlled. Process monitoring will be conducted near preferential pathways, if identified, to limit the potential for extraction of residual oxidant during operation of the SCRWs while injections are ongoing. In addition, process monitoring will be conducted to assess potential changes in secondary water quality outside of the slurry wall due to the injection program.

Performance monitoring will be conducted to assess the progress of the pilot study with respect to achieving the pilot study objectives (Section 3.1) and monitoring for potential secondary water quality impacts within the slurry wall. Pilot study effectiveness will be indicated if cVOC degradation is observed following implementation of the pilot study ISCO injections, with cVOCs considered to be degrading if concentrations of TCE are reduced from the baseline sample concentrations. Chloride production will be used as a second line of evidence of cVOC destruction. However, the observed cVOC concentrations may be low while oxidant is present in the subsurface with a “rebound” in the cVOC concentrations as residual oxidant is depleted and geochemical conditions return to near baseline (ITRC, 2005). Therefore, evaluation of overall cVOC concentration reduction at the Site will be based on observed cVOC and chloride concentrations once the oxidant has been depleted from the system.

3.10 Estimated ISCO cVOC Mass Removal

As described in Section 3.6, a total of approximately 32,000 pounds of permanganate ion (MnO_4^-) will be injected during the pilot study, corresponding to a minimum oxidant dosing of 3.4 grams of MnO_4^- per kilogram of soil (g MnO_4^-/kg soil). The stoichiometric equation for oxidation of TCE (C_2HCl_3) by MnO_4^- is:

$$C_2HCl_3 + 2MnO_4^- \rightarrow 2MnO_2 + 2CO_2 + 3Cl^- + H^+$$

Based on the above equation and the molar mass of TCE and MnO_4^-, one pound of MnO_4^- is expected to degrade 0.55 pound of TCE. If 32,000 pounds of MnO_4^- are potentially available for degradation of target cVOCs, the resulting TCE mass removal could be as high as 17,600 pounds. As described in Section 3.2, the average cVOC mass removal via the on-Site SCRWs was 166 pounds per year over the last three years. The ISCO process could therefore accelerate mass removal at the Site by as much as 105 years compared to the current remedy.

However, between 50% and 90% of the applied oxidant may be consumed by non-target reactions with organic matter or other reduced species under field applications. Therefore, the ISCO pilot study injections will more likely remove between 1,760 and 8,800 pounds of TCE. As a result, ISCO process will likely accelerate mass removal over ten times as compared to the current remedy and be equivalent to between 10 and 50 years of groundwater extraction and treatment, assuming that concentrations of cVOC do not continue to decline as has been the case since the current remedy became operational.

4. IMPLEMENTATION WORK PLAN

Details regarding the methods and procedures that will be used for implementation of the ISCO injection program and associated monitoring are provided in the sections below.

4.1 Pre-Field Activities

4.1.1 Health and Safety Planning

The existing site-specific health and safety plan (HASP) will be updated to include all field activities associated with the ISCO pilot study implementation. The HASP will contain procedures for hazard identification and mitigation, emergency response including a map of the nearest hospital and emergency contact information, incident reporting, use of appropriate personal protective equipment (PPE), and air monitoring procedures.

Prior to the start of field activities each day, a safety tailgate meeting will be conducted that will include a discussion of the field activities to be performed, safe work practices, identification of potential hazards, use of PPE, decontamination procedures, and emergency response protocols. Health and safety protocols related to permanganate handling are discussed in Section 4.3.6.

4.1.2 Notifications, Access, and Permitting

Prior to the start of field activities, the following will be performed:

- Coordinate with National Avenue Partners for access to the Site;
- Coordinate and subcontract with the drilling contractor, oxidant vendor, and analytical laboratory; and,
- Obtain drilling permits from the SCVWD.

The EPA, SCVWD, City of Mountain View, and National Avenue Partners will be notified of the planned work schedule prior to the start of field activities.

4.1.3 Utility Clearance

Boring locations will be marked with white paint and Underground Service Alert (USA) North will be contacted a minimum of 48 hours prior to commencement of intrusive subsurface activities. Additionally, Site reconnaissance will be conducted to locate utilities using available as-built drawings and a private utility locator will perform a geophysical survey in the vicinity of each proposed boring location area to identify potential utilities, pipelines, or other subsurface obstructions prior to drilling.

4.2 Performance Monitoring Network Installation

Three temporary pilot study monitoring wells will be installed within the pilot study treatment zones (Figure 11). Two of these monitoring wells are expected to be installed to a total depth of 23 feet bgs, with screen intervals located from approximately 16 to 23 feet bgs. The third monitoring well is expected to be installed to a total depth of 37 feet bgs, with screen intervals located from approximately 32 to 37 feet bgs. Actual total depths and screen intervals for the individual monitoring wells may be adjusted in the field based on the subsurface conditions encountered.

The monitoring wells will be installed by a C-57 licensed drilling subcontractor using hollow stem auger drilling methods. Geologic logging of the hollow stem auger soil cuttings will be conducted by Geosyntec field staff under the direction of a California Professional Geologist using the Unified Soil Classification System. The soil will be field-screened for volatile organic compounds using a PID and the readings recorded on the boring logs. All downhole equipment will be decontaminated prior to use and between boring locations.

Once the target depth is reached at each boring, the monitoring well will be constructed through the hollow stem auger casing. The monitoring wells will be constructed of 2-inch diameter, flush-threaded, Schedule 40 polyvinyl chloride (PVC) casing, with 0.020-inch factory-slotted well screen, and a flush-threaded bottom cap. A graded silica sand pack will be tremie filled into the annular space across the screened interval of each monitoring well, extending approximately 1 foot above the top of the screen. Approximately 2 feet of bentonite pellets or chips will be placed on top of the sand pack and hydrated to provide a seal above the filter pack. The remainder of the borehole will be tremie filled with neat cement grout (maximum 6 gallons of water per 94 pound bag of cement) to one foot below the ground surface. A waterproof locking cap will be installed over each monitoring well within an appropriately-sized flush-mounted well box.

Once installed, the grout seal will be allowed to set for at least 48 hours prior to development. Well development will be performed by a subcontractor under supervision of Geosyntec field staff. Development will consist of a combination of bailing, surging, and pumping as described in the MEW quality assurance project plan (QAPP) (Canonie, 1991) and will serve to stabilize the filter pack and remove fines from the filter pack and well screen. Groundwater quality parameters (temperature, pH, specific conductance, and turbidity) will be measured during well development. Groundwater generated during development will be temporarily stored onsite prior to disposal at one of the MEW Study Area groundwater treatment systems.

The north side of each well box and PVC well casing will be surveyed for elevation and location by a California-licensed surveyor.

4.3 <u>ISCO Injections</u>

4.3.1 Groundwater Recovery System

On-Site SCRWs located within the slurry wall will be turned off prior to the ISCO injections to limit the potential for the injected oxidant to interact with the treatment system. One or more of the four on-Site SCRWs may be pumped periodically during injections to promote oxidant distribution and reduce hydraulic mounding. Groundwater extracted from the on-Site SCRWs will be pumped to a temporary onsite holding tank and used to supplement the potable water used for ISCO injections. The oxidant concentration entering the tank will be measured at least once per day using a field spectrophotometer. Operation of individual SCRWs may be altered to limit the extraction of residual oxidant and/or reduce groundwater mounding if oxidant is not observed at a SCRW.

4.3.2 Materials Handling and Mixing

Sodium permanganate handling will be in compliance with City of Mountain View Fire Department requirements and the *National Fire Protection Association (NFPA) 430: Code for the Storage of Liquid and Solid Oxidizers* (NFPA, 2004). The project HASP will include a list of emergency response materials that will be present onsite such as containment materials, adsorbent, neutralizing solution (e.g., sodium thiosulfate, $Na_2S_2O_3$, or equivalent), and personal protective equipment.

The project team will receive onsite training in permanganate handling and emergency response prior to beginning oxidant injections. Emergency response supplies and equipment will be staged near the work area in the event of a release and verified daily.

The following activities will be conducted as part of the mixing equipment set up:

- Establishment of site control areas (i.e., exclusion zone, decontamination zone, etc.); and
- Receipt of sodium permanganate and staging in a temporary secondary containment system.

Sodium permanganate will be mixed with water to achieve the target injection solution concentration of 35 g MnO_4^-/L. The oxidant batch mixing will be performed numerous times during the injection activities and will include the following activities:

- Checking safety supplies and donning personal protective equipment;
- Connecting the mix tanks to the water supply and begin filling of the mix tanks. Mix tanks will be staged within temporary secondary containment with a capacity of at least 125% of the working volume of the largest individual tank. Mix tanks will be equipped with electric mechanical mixer(s), a recirculation pump, and lines to the distribution system [filter, pump(s) and manifold(s)].
  - One or more of the on-Site SCRWs may be temporarily connected to the mix system. Batch extraction of groundwater from these wells may periodically be conducted while personnel are on-Site to enhance distribution of oxidant and reduce the mounding associated with the ISCO injections.
  - Potable water will be used to prepare the majority of ISCO injection volume due to the limited capacity of the individual SCRWs (between 1 and 7 gpm depending on the well) as compared to the planned daily injection rate of approximately 20 to 28 gpm.
- Transfer of oxidant to the mix tanks. Oxidant will be stored in a chemical storage area with secondary containment and a controlled work zone. The

storage configuration will be consistent with the California Code of Regulations and approved by the City of Mountain View Fire Department prior to delivery of permanganate to the jobsite.

- Mixing the mix tank contents with an electric high-flow mixer; and
- Periodically sampling the solution to confirm the oxidant concentration. Permanganate ion content will be measured using a field spectrophotometer.

These steps may be modified if the proposed oxidant formulation is modified to include sodium persulfate or another additive. Potential modification of the oxidant formulation would be determined on the basis of the bench-scale testing proposed in the Work Plan for ISCO Pilot Study Data Collection (Geosyntec, 2014c). As discussed in Section 6.1, an addendum to this Work Plan would be submitted to EPA if bench-scale testing supports modification of the proposed oxidant formulation.

4.3.3 Injection Program Sequencing

Temporary borings for oxidant injections will be advanced by a C-57 licensed drilling contractor using direct-push drilling. All down-hole equipment will be decontaminated prior to use. At each location, hollow steel direct-push rods will be advanced to the target injection interval and injection solution will be emplaced. Injections will occur at up to eight locations concurrently. As detailed in Section 3.3, the injections will take place in four target injection zones (U-1, U-2a and U-2b, and L-1) (Figure 8). Cross-sections showing target vertical injection intervals for each zone are shown in Figure 9 and Figure 10. The sequencing of injection events in each target injection zone will be as follows:

First: L-1 Injection Zone

The first round of injections will be performed in the L-1 (lower) injection zone to provide targeted treatment of high cVOC concentrations in this zone and establish an oxidizing zone below the elevation of subsequent injections in the shallow coarse-grained layer. Creating a reactive zone in L-1, in conjunction with pumping of one or more SCRWs to limit mounding during ISCO injections is intended to limit the potential for downward migration of residual cVOC contamination during the injection program. Each injection within the L-1 zone will consist of one depth interval (3 feet thick) between 31 and 36 feet bgs. The exact depth of treatment will be dependent on interpreted lithology within each portion of the L-1 zone (Figure 9 and Figure 10).

The volume of permanganate solution that will be injected in L-1 has been developed based on the estimated target dosing described in Section 3.6 and the proposed injection location spacing and target vertical depth interval described above. At each of the 40 planned injection locations, the injections will be performed as follows:

- The target volume of sodium permanganate solution for a single injection event will be approximately 700 gallons applied in a single 3-foot interval at each injection location. The target injection volume may be increased from 700 to 900 gallons per location based on observed conditions during implementation;
- Concentration of sodium permanganate in the injection solution will be approximately 35 g MnO_4^-/L;
- Total nominal injection volume for L-1 will be 27,800 gallons, corresponding to the injection of at least 8,200 pounds (lbs) MnO_4^-; and
- The target sodium permanganate dose applied in the L-1 injection zone is approximately 3.4 g MnO_4^-/kg soil for a single injection event.

The number of injection locations, injection volume, and permanganate dosing will be re-evaluated based on the process monitoring and performance monitoring data collected during the initial injections within the L-1 injection zone.

If permanganate surfacing, preferential pathways, or other potentially negative impacts are observed during L-1 injections and cannot be remedied by altering the ISCO pilot study design or implementing engineering controls at the Site, the EPA will be notified and additional ISCO pilot study injections will not be implemented in L-1.

Second: U-2 Injection Zones

The second round of injections will be performed in the U-2a and U-2b injection zones. Each injection within the U-2 zones will consist of two depth intervals (2 to 5 feet thick) between 16 and 24 feet bgs.[10] The total thickness of the two injection intervals will be 6

[10] The injection depth intervals may be extended slightly into the fine-grained layer underlying the shallow coarse-grained layer to promote oxidant injection into relatively lower permeability materials containing high cVOC concentrations.

to 6.5 feet. The exact depth of treatment will be dependent on interpreted lithology within each portion of the U-2 zones (Figure 9 and Figure 10).

The volume of permanganate solution that will be injected in U-2a has been developed based on the estimated target dosing described in Section 3.6, the lateral extent of the injection zone, and a target vertical depth interval of 6.5 feet. At each of the planned 16 injection locations, the injections will be performed as follows:

- The target volume of sodium permanganate solution for the first injection event will be a total of approximately 960 gallons distributed between two vertical injection intervals (each 2 to 5 feet in length) at each injection location. The target injection volume may be increased from 960 to 1,170 gallons per location based on observed conditions during implementation;
- Concentration of sodium permanganate in the injection solution will be approximately 35 g MnO_4^-/L;
- Total nominal injection volume for U-2a will be 15,360 gallons per injection event, corresponding to the injection of at least 4,500 lbs MnO_4^-; and
- The target sodium permanganate dose applied in the U-2a injection zone is approximately 3.4 g MnO_4^-/kg soil.

The volume of permanganate solution that will be injected in U-2b has been developed based on the estimated target dosing described in Section 3.6, the lateral extent of the injection zone, and a target vertical depth interval of 6 feet. At each of the planned 14 injection locations, the injections will be performed as follows:

- The target volume of sodium permanganate solution for the first injection event will be a total of approximately 1,035 gallons distributed between two injection intervals (each 2 to 5 feet in length) at each injection location. The target injection volume may be increased from 1,035 to 1,265 gallons per location based on observed conditions during implementation;
- Concentration of sodium permanganate in the injection solution will be approximately 35 g MnO_4^-/L;
- Total nominal injection volume for U-2b will be 14,500 gallons per injection event, corresponding to the injection of at least 4,200 lbs MnO_4^-; and

- The target sodium permanganate dose applied in the U-2b injection zones is approximately 3.4 g MnO_4^-/kg soil.

The number of injection locations, injection volume, and permanganate dosing will be re-evaluated based on the process monitoring and performance monitoring data collected during the initial injections within the U-2 injection zone.

If permanganate surfacing, preferential pathways, or other potentially negative impacts are observed during the U-2a and/or U-2b injections and cannot be remedied by altering the ISCO pilot study design or implementing engineering controls at the Site, the EPA will be notified and additional ISCO pilot study injections will not be implemented in U-2a and/or U-2b.

Third: U-1 Injection Zone

The volume of permanganate solution that will be injected in U-1 has been developed based on the estimated target dosing described in Section 3.6, the lateral extent of the injection zone, and a target vertical depth interval of 6 feet. At each of the 50 planned injection locations, the injections will be performed as follows:

- The target volume of sodium permanganate solution for a single injection event will be a total of approximately 1,030 gallons distributed between two injection intervals (each 1 to 4 feet in length) at each injection location. The target injection volume may be increased from 1,030 to 1,330 gallons per location based on observed conditions during implementation;
- Concentration of sodium permanganate in the injection solution will be approximately 35 g MnO_4^-/L;
- Total nominal injection volume for U-1 will be 51,500 gallons, corresponding to the injection of at least 15,100 lbs MnO_4^-; and
- Target sodium permanganate dose applied in the U-1 injection zone is approximately 3.4 g MnO_4^-/kg soil.

The planned injection locations, injection volume, and permanganate dosing will be re-evaluated based on the process monitoring and performance monitoring data collected during the initial injections within the U-1 injection zone.

If permanganate surfacing, preferential pathways, or other potentially negative impacts are observed during U-1 injections and cannot be remedied by altering the ISCO pilot study design or implementing engineering controls at the Site, the EPA will be notified and additional ISCO pilot study injections will not be implemented in U-1.

Fourth: U-2 Injection Zones (Second Round)

A second round of injections in target injection zones U-2a and U-2b will be considered based on the results of the Site-specific PSOD testing and process monitoring observations from the initial round of injections in these zones. Based on existing PSOD data from Evandale Avenue and the known extent of cVOC impacts in the U-2 zones, the following scope has been developed for a second round of injections. During the second round, each injection within the U-2 zones will consist of two depth intervals (2 to 5 feet thick) oriented between 16 and 24 feet bgs. The total thickness of the two injection intervals will be 6 to 6.5 feet. The exact depth of treatment will be dependent on interpreted lithology within each portion of the U-2 zones (Figure 9 and Figure 10).

The volume of permanganate solution that will be injected in U-2a during the second event is 50% of the volume injected during the first round of injections and will be applied over a target vertical depth interval of 6.5 feet. At each of the planned 16 injection locations, the injections will be performed as follows:

- The target volume of sodium permanganate solution for the first injection event will be a total of approximately 480 gallons distributed between two injection intervals (each 2 to 5 feet in length) at each injection location. The target injection volume may be increased from 480 to 1,170 gallons per location based on observed conditions during implementation;
- Concentration of sodium permanganate in the injection solution will be approximately 35 g MnO_4^-/L;
- Total nominal injection volume for U-2a will be 7,720 gallons per injection event, corresponding to the injection of at least 2,250 lbs MnO_4^-; and
- The target sodium permanganate dose applied in the U-2a injection zones is approximately 1.7 g MnO_4^-/kg soil (not including the previous 3.4 g MnO_4^-/kg soil dose from the first injection event).

The volume of permanganate solution that will be injected in U-2b is 50% of the volume injected during the first round of injections and will be applied over a target vertical depth interval of 6 feet. At each of the 14 planned injection locations, the injections will be performed as follows:

- The target volume of sodium permanganate solution for the first injection event will be a total of approximately 520 gallons distributed between two injection intervals (each 2 to 5 feet in length) at each injection location. The target injection volume may be increased from 520 to 1,265 gallons per location based on observed conditions during implementation;
- Concentration of sodium permanganate in the injection solution will be approximately 35 g MnO_4^-/L;
- Total nominal injection volume for U-2b will be 7,200 gallons per injection event, corresponding to the injection of at least 2,100 lbs MnO_4^-; and
- The target sodium permanganate dose applied in the U-2b injection zones is approximately 1.7 g MnO_4^-/kg soil (not including the previous 3.4 g MnO_4^-/kg soil dose from the first injection event).

The planned injection locations, injection volume, and permanganate dosing will be re-evaluated based on the process monitoring and performance monitoring data collected during the first injection event in the U-2 injection zones.

If permanganate surfacing, preferential pathways, or other potentially negative impacts are observed during the U-2a and/or U-2b injections and cannot be remedied by altering the ISCO pilot study design or implementing engineering controls at the Site, the EPA will be notified and additional ISCO pilot study injections will not be implemented in U-2a and/or U-2b.

Oxidant Injection Approach

The oxidant solution will be injected from the aboveground storage tank through an injection line connected to the hollow steel direct push rods. Prior to starting injections, the injection line will be inspected for signs of damage or leaks, and connections will be checked. The injection line will be equipped with a mechanical flow totalizer, flow meter, pressure gauge, and flow control valve to monitor the injection volume, rate, and pressure. The maximum operational pressure will be 80 psi. In order to limit the number of boreholes advanced in the pilot study areas and minimize the potential for preferential flow upward through abandoned boreholes, the injection tooling will be left in place while injections are ongoing.

Within each of the injection zones defined in Section 3.3 (e.g., L-1, U-1, U-2a, U-2b), injections will begin at the edges of the target injection zone and proceed toward the center of the injection zone, to mitigate potential displacement of contaminated groundwater outside of the injection zone. The active injection points will be staggered (i.e., adjacent points will not be injected into simultaneously) to reduce potential groundwater mounding.

Design injection volumes and rates are described above and in Section 3.7. If possible based on achievable injection rates and pressures, the design volume of oxidant solution will be injected during each injection event. At the start of each injection, the rate and pressure will be slowly increased from conservatively low values to the design injection rate. The oxidant delivery rate and target injection volume may be adjusted during implementation based on observed field conditions.[11] If the oxidant cannot be delivered under pressures less than the maximum allowable injection pressure at a given injection interval, the oxidant volume that cannot be injected will be re-allocated to adjacent boreholes.

The total duration of the injection program will depend on the selected numbers of injection locations and achievable injection rates. The primary injection line will be equipped with a mechanical flow totalizer, flow meter, pressure gauge, and flow control valve to monitor the injection volume, rate, and pressure. Each injection point will be monitored with a flow meter, flow regulator, and pressure gauge.

Once injections at a given boring location are complete, the boring will be tremie grouted from total depth of the boring to ground surface using a concrete-bentonite grout in accordance with Santa Clara County requirements.

[11] EPA will be notified if there is a need to revise the oxidant delivery rate or target injection volume.

4.3.4 Water Level Monitoring During Injection

Pressure transducers will be temporarily installed in up to three A-zone wells located inside the slurry wall prior to the start of injection. Pressure transducers will be downloaded daily during the injection program to collect real-time data on groundwater elevation changes inside the slurry wall. In addition, groundwater level measurements will be collected from Site wells located inside the slurry wall and adjacent to the injection areas before injections begin and periodically each day during the injection program.

If water levels rise to less than 5 feet bgs during the field work, injection flow rates will be reduced and/or injections may be temporarily suspended, with a goal of achieving the minimum injection volumes described in this Work Plan.

4.3.5 Surfacing and Preferential Pathway Monitoring

As oxidant solution is injected into the subsurface, it will move away from the injection point and can be influenced by natural heterogeneities in the subsurface, bedding and backfill materials associated with buried utilities, and compromised buried utility conduits (i.e., leaking storm sewers). Prior to the start of injections, features where oxidant solution could surface (i.e., manholes, storm drains, etc.) will be identified and then monitored prior to and during injections. In addition, available as-built drawings will be reviewed and Site reconnaissance will be conducted to locate subsurface features that may potentially cross the Building 9 slurry wall in the vicinity of the treatment areas.

During injection activities, potential preferential pathways in close proximity to the injection points will be visually monitored for the presence of the oxidant. Locations of storm sewer manholes and catch basins that could be preferential pathways and are present following building demolition will be marked as part of pilot study data collection activities. These Site features will be monitored during injection activities. If oxidant indicators (e.g., purple liquid if a permanganate-containing oxidant formulation is injected) are observed in a potential preferential pathway, the injections will be temporarily stopped while an approach for mitigating the preferential pathway is investigated. In the event that the presence of excess permanganate solution requires neutralization emergency response, procedures will be implemented as discussed in the following section.

4.3.6 Emergency Response Procedures

In the event that the presence of excess oxidant solution requires neutralization or process chemical are spilled during Site operations and require neutralization, emergency response procedures will be implemented. Activities involved include the following:

- Stopping the oxidant injections;
- Notifying the Project Manager and Site Safety Officer in accordance with the HASP;
- Notifying the EPA and City of Mountain View if the spill exceeds the reportable quantity (100 pounds in the case of permanganate);
- Containment of oxidant solutions;
- Managing any surface seepage of oxidant solutions; and
- Neutralize spilled oxidant using <15% sodium thiosulfate or 3% hydrogen peroxide/household vinegar/water solution.

Prior to injection activities, STC will work with EPA and the City of Mountain View to develop a list of contacts that will be notified in the event of an oxidant spill or release. The contact list will be included in the HASP that will be onsite while field work is underway.

4.4 Sampling and Analysis Plan

The follow section describes the baseline, process, and performance monitoring that will be conducted to evaluate the progress of the pilot study.

4.4.1 Baseline Sampling

A minimum of 72 hours after the completion of well development, baseline groundwater samples will be collected from the five wells in the performance monitoring well network (Figure 11) to establish baseline cVOC and geochemical conditions prior to the implementation of oxidant injections.

During baseline sampling, the performance monitoring wells will be purged three to five casing volumes prior to collection of groundwater samples. The wells will be purged using a submersible pump equipped with new disposable tubing. Water will be pumped through a closed flow-through cell fitted with a multi-parameter groundwater meter. Temperature, pH, electrical conductivity, turbidity, dissolved oxygen (DO), and oxidation reduction potential (ORP) will be measured during purging. Groundwater will be purged until the temperature, pH, and electrical conductivity values stabilize. Groundwater levels will be monitored during purging to confirm that drawdown stabilizes prior to sampling.

Following stabilization of field parameters, groundwater samples will be collected. Samples will be analyzed for the following compounds:

- cVOCs by EPA Method 8260B (8010 analyte list);
- Total dissolved solids (TDS) by Method SM 2540C;
- Chloride by EPA Method 300.0;
- Dissolved manganese, iron, and chromium by EPA Method 6010B; and
- Dissolved Cr(VI) by EPA Method 7196.

Groundwater samples will be collected in laboratory-supplied sample containers and labeled with project identification, sample location, analytical method, time and date of sampling, and any preservative added to the sample. Samples will be stored in an ice-cooled chest, maintained at approximately 4º C, for transport under chain-of-custody procedures to a State of California-certified laboratory for analysis.

Quality assurance/quality control (QA/QC) samples will be collected for cVOC samples. In accordance with the MEW QAPP (Canonie, 1991), one duplicate, one field blank and one equipment blank will be collected for every 20 groundwater samples collected for cVOC analysis. In addition a laboratory provided trip blank will be included with each cooler containing groundwater samples for cVOC analysis that is sent to the laboratory.

4.4.2 Process Monitoring

Daily process monitoring will include sampling for permanganate concentration and periodically checking groundwater elevations in monitoring wells and monitoring electrical conductivity in selected monitoring wells located adjacent to (outside of) the former Building 9 slurry wall. The five performance monitoring wells will be checked once in the morning and once at the end of the work day for the presence of permanganate. If permanganate is observed, a sample will be collected and analyzed for permanganate using a field spectrophotometer. Water elevations will be monitored periodically during each day to assess the observed water levels against the maximum water level rise criteria for the injection program (minimum measured depth to water of 5 feet bgs during injections). In addition, a field meter will be deployed daily into wells 31A, 39A, 41A, and 138A (Figure 2) to measure electrical conductivity in groundwater. An increase in electrical conductivity above baseline conditions may indicate changes to geochemical conditions outside of the slurry wall due to the injection program. If increased electrical conductivity is observed at the wells and cannot be remedied by altering the ISCO pilot study design, the EPA will be notified and the pilot study injection program may be stopped.

Groundwater samples will also be periodically collected from the five performance monitoring wells (Figure 11) to evaluate the progress of the ISCO injections during implementation. After two weeks of injections, and every two weeks thereafter, the five monitoring wells will be purged and sampled to provide process monitoring data. The performance monitoring wells will be purged three to five casing volumes prior to collection of groundwater samples. The wells will be purged using a submersible pump equipped with new disposable tubing. Water will be pumped through an enclosed flow-through cell fitted with a multi-parameter groundwater meter. Temperature, pH, electrical conductivity, turbidity, DO, and ORP will be measured during purging. Groundwater will be purged until the field parameter values stabilize. Groundwater levels will be monitored during purging to confirm that drawdown stabilizes prior to sampling. Following stabilization of field parameters, groundwater samples will be collected and analyzed for the following compounds:

- Quenched cVOCs by EPA Method 8260B (8010 analyte list); and
- Permanganate ion using a field spectrophotometer or a commercially available field test kit if other oxidants are used.

In order to ensure that residual permanganate in the groundwater (if present) does not further oxidize the cVOCs between sample collection and laboratory analysis, cVOC samples will be quenched in the field immediately following sample collection. The sample preparation for quenched cVOCs involves the addition of approximately 2 to 3 grams of anhydrous manganese sulfate ($MnSO_4$) to a groundwater sample in the field. The groundwater sample is allowed to react with the $MnSO_4$ for approximately ten minutes, after which the sample is decanted into a VOA vial containing hydrochloric acid for transport to the analytical laboratory.

Process monitoring samples will be collected in laboratory-supplied sample containers and labeled with project identification, sample location, analytical method, time and date of sampling, and any preservative added to the sample. Samples will be stored in an ice-cooled chest, maintained at approximately 4º C, for transport under chain-of-custody procedures to a State of California-certified laboratory for analysis.

QA/QC samples will be collected for cVOC samples. In accordance with the MEW QAPP (Canonie, 1991), one duplicate, one field blank and one equipment blank will be collected for every 20 groundwater samples collected for cVOC analysis. In addition a laboratory provided trip blank will be included with each cooler containing groundwater samples for cVOC analysis that is sent to the laboratory.

4.4.3 Performance Monitoring

Pilot study performance monitoring samples will be collected annually from the five wells in the performance monitoring network beginning two months after the completion of the ISCO injection program. An annual monitoring frequency has been selected for the pilot study because it will provide sufficient temporal and spatial monitoring information to evaluate the progress of the pilot study with respect to meeting the objectives described in Section 3.1.

During each performance monitoring event, the performance monitoring wells will be purged three to five casing volumes prior to collection of groundwater samples. The wells will be purged using a submersible pump equipped with new disposable tubing. Water will be pumped through an enclosed flow-through cell fitted with a multi-parameter groundwater meter. Temperature, pH, electrical conductivity, turbidity, DO, and ORP will be measured during purging. Groundwater will be purged until the field parameter values stabilize. Groundwater levels will be monitored during purging to confirm that drawdown stabilizes prior to sampling. Following stabilization of field parameters, groundwater samples will be collected and analyzed for the following compounds:

- Quenched cVOCs by EPA Method 8260B (8010 analyte list);
- Permanganate ion using a field spectrophotometer or a commercially available field test kit if other oxidants are used;

- TDS by Method SM 2540C;
- Chloride by EPA Method 300.0;
- Dissolved total manganese, iron, and chromium by EPA Method 6010B; and
- Dissolved Cr(VI) by EPA Method 7196. This analysis is subject to interference in the presence of permanganate. If permanganate is used in the oxidant formulation and groundwater is pink or purple during sampling, samples will not be analyzed for this compound.

In order to ensure that residual permanganate in the groundwater (if present) does not further oxidize the cVOCs between sample collection and laboratory analysis, cVOC samples will be quenched in the field immediately following sample collection. The sample preparation for quenched cVOCs involves the addition of approximately 2 to 3 grams of anhydrous $MnSO_4$ to a groundwater sample in the field. The groundwater sample is allowed to react with the $MnSO_4$ for approximately ten minutes, after which the sample is decanted into a VOA vial containing hydrochloric acid for transport to the analytical laboratory.

Performance monitoring samples will be collected in laboratory-supplied sample containers and labeled with project identification, sample location, analytical method, time and date of sampling, and any preservative added to the sample. Samples will be stored in an ice-cooled chest, maintained at approximately 4° C, for transport under chain-of-custody procedures to a State of California-certified laboratory for analysis.

QA/QC samples will be collected for cVOC samples. In accordance with the MEW QAPP (Canonie, 1991), one duplicate, one field blank and one equipment blank will be collected for every 20 groundwater samples collected for cVOC analysis. In addition a laboratory provided trip blank will be included with each cooler containing groundwater samples for cVOC analysis that is sent to the laboratory.

4.5 Temporary Performance Monitoring Well Destruction Plan

At the conclusion of the pilot study, the three temporary performance monitoring wells will be destroyed. The temporary performance monitoring wells will be pressure grouted by a C-57 licensed drilling contractor in accordance with County, State and Federal requirements.

4.6 Investigation Derived Waste Management

Water generated during the pilot study implementation activities will be neutralized if residual oxidant is present, and then treated and discharged through one of the MEW Study Area groundwater treatment systems. Soil cuttings will be temporarily stored on-Site in 55-gallon drums or roll off bins pending analysis. Following waste profiling, soil cuttings will be disposed of in accordance with Federal and State requirements at an appropriate offsite facility.

5. CRITERIA FOR RESTARTING RECOVERY WELLS

At the conclusion of the pilot study, resumption of groundwater extraction and treatment within the slurry wall may be required to satisfy the conditions of the MEW ROD. Data developed during annual performance monitoring will be used to assess whether resumption of groundwater extraction from one or more of the SCRWs within the slurry wall is necessary. In general, groundwater extraction may be resumed if performance monitoring data indicate that all of the following conditions are met at all performance monitoring wells:

- The injected oxidant solution has been depleted and oxidant is not detected in the performance monitoring wells above the analytical method detection limit;
- Following depletion of the oxidant solution, TCE concentrations in groundwater are higher than observed concentrations in upgradient monitoring wells (approximately 500 µg/L); and
- Cr(VI) and TDS are not detected at concentrations that could result in potential secondary water quality concerns for discharge from System 1.
  - SCRWs would not be restarted if hexavalent chromium is detected above 6 µg/L (equivalent to 50% of the National Pollutant Discharge Elimination System [NPDES] trigger level).
  - SCRWs would not be restarted if TDS is above 1,000 mg/L which is consistent with the freshwater designation of Stevens Creek (the receiving water for System 1 effluent).

Prior to restart of the SCRWs, a short-duration extraction test will be conducted to evaluate whether the above conditions are maintained during groundwater extraction. During the extraction test, the SCRWs would be plumbed to one or more large-capacity (~20,000 gallon) holding tanks. The wells would be operated as follows:

- Each SCRW would be operated individually at its maximum achievable flow rate for a minimum period of four hours; and
- All SCRWs passing the above criteria after four hours of operations will then be operated simultaneously at the maximum achievable flow rate per well for a minimum period of four hours.

During operation of the wells, samples would be collected at least once per hour from the SCRW sampling ports for analysis of:

- cVOCs by EPA Method 8260B (8010 analyte list);
- Permanganate ion using a field spectrophotometer or a commercially available field test kit if other oxidants are used;
- TDS by Method SM 2540C; and,
- Dissolved Cr(VI) by EPA Method 7196. This analysis is subject to interference in the presence of permanganate. If permanganate is used in the oxidant formulation and groundwater is pink or purple during sampling, samples will not be analyzed for this compound and SCRW will not be re-started.

If the analytical results collected during the short-term extraction test confirm that the conditions required for extraction restart are met, operation of one or more SCRW would resume. If conditions are not met during the extraction test, it would indicate that oxidizing conditions may remain present within the slurry wall and groundwater extraction would not resume, pending the results of the next year's annual performance monitoring.

Water generated during the extraction test would be neutralized if residual oxidant is present, and then either treated and discharged through one of the MEW Study Area groundwater treatment systems or disposed of offsite in accordance with Federal and State requirements at an appropriate facility.

6. REPORTING AND SCHEDULE

This section summarizes the pilot study reporting and presents a schedule for implementing the pilot study.

6.1 Pilot Study Reporting

Work Plan Addendum, If Necessary

As described in the ISCO Pilot Study Data Collection Work Plan (Geosyntec, 2014c), the results of the proposed data collection activities will be reviewed to assess the need for modifications to the pilot study design basis (Section 3) or implementation work plan (Section 4). If necessary based on the data review, Geosyntec will submit an addendum to this Work Plan to EPA summarizing the findings of the ISCO pilot study data collection program and proposing adjustments to the ISCO pilot study scope of work (e.g., modifications to the treatment area dimensions, oxidant selection, or design oxidant dosing). If modifications to this Work Plan are not required, Geosyntec will notify EPA of STC's intent to proceed with the proposed pilot study scope of work.

Implementation Report

A Pilot Study Implementation Report will be prepared and submitted to EPA following implementation of the ISCO injection program. The Pilot Study Implementation Report will include the following:

- A complete write-up of the pilot study data collection activities (Geosyntec, 2014c);
- A description of activities related to temporary performance monitoring well installation and development, including boring logs and well construction diagrams;
- A summary of the results of the baseline sampling, including data tabulation;
- A summary of the oxidant injection program, including the volume and concentration of oxidant injected, the observed injection rates and pressures, and the results of surfacing and preferential pathways monitoring; and
- The results of process monitoring sampling, including data tabulation and creation of data summary figures.

Progress Reporting

The progress of the pilot study will be documented in Annual Progress Reports submitted to EPA as part of the Annual Monitoring Reports for former Fairchild Buildings 1-4, 9, and 18. The Annual Progress Reports will include the following:

- A summary of the performance monitoring sampling, including data tabulation and the creation of data summary figures;
- A discussion of the performance monitoring results; and
- Recommendations for follow-on work. Follow-on work could potentially include continued annual performance monitoring of the pilot study area to assess long-term oxidant depletion and cVOC concentration trends or resumption of groundwater extraction from within the former Building 9 slurry wall if the criteria for well restart described in Section 5 are met.

6.2 Schedule

A summary of the proposed schedule is presented below. The proposed schedule was developed in consideration of the planned redevelopment activities at 401 National Avenue and may be adjusted to accommodate changes to the development schedule. In addition, the schedule may be adjusted as needed following EPA review and approval of the work plan due to delays in obtaining required access or permits or due to conditions encountered during field implementation. EPA will be notified if there is a need to adjust the pilot study implementation schedule.

- 31 July 2014 – EPA approval of ISCO Pilot Study Data Collection Work Plan (Geosyntec, 2014c).
- 31 August 2014 – EPA Approval of ISCO Pilot Study Work Plan.
- September through October 2014 – Data collection activities.
- October 2014 – Submittal of Work Plan Addendum (if necessary) for EPA concurrence.
- October 2014 – Permitting, installation, development, and baseline sampling of temporary performance monitoring wells.
- November through December 2014 – ISCO injection program and associated process monitoring.

- February 2015 – Submit Pilot Study Implementation Report.
- February 2015 – First annual pilot study performance monitoring event.
- April 2015 – Submit pilot study Annual Progress Report as part of the Annual Monitoring Reports for former Fairchild Buildings 1-4, 9, and 18.

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TABLE

Table 1
Groundwater Analytical Results: Detected cVOCs
401 National Avenue
Mountain View, California

Sample Location	Sample Date	Sample Depth (ft bgs)[1]	Concentration in µg/L by EPA method 8260B									
			PCE	TCE	cis-1,2-DCE	trans-1,2- DCE	Vinyl Chloride	1,1,1-TCA	1,1-DCA	1,1-DCE	Freon 113	Total VOCs[2]
Wells Inside Slurry Wall												
35A	9/25/2012	12-37	<0.50	220	130	1.7	1.1	<0.50	3.6	2.5	2.1	400
36A	9/18/2012	35-40	<0.50	110	270	2.1	0.7	<0.50	3.3	2.7	0.64	400
37A	10/23/2013	15-30	<0.50	72	370	3.7	49	7.6	36	8.6	1.1	500
122A	9/26/2012	28-38	<0.50/<0.50	210/230	100/100	1.6/1.6	<0.50/<0.50	<0.50/<0.50	3.0/3.0	2.1/2.1	1.0/0.97	300
137A	10/23/2013	34-36	<5.0	6,400	4,300	41	<5.0	<5.0	<5.0	11	16	10,800
AE/RW-9-1	10/17/2013	8-33	1.5	810	710	7.7	13	45	53	12	3.9	1,700
AE/RW-9-2	10/17/2013	8-37	4.6	13,000	8,800	78	260	49	84	38	190	22,500
RW-20A	10/17/2013	26.5-36.5	1.7	1,100	940	7.0	4.1	9.1	12	9.3	7.2	2,100
RW-21A	10/17/2013	21-36	4.6	410	350	5.8	1.8	1.6	5.0	5.0	9.0	800
Grab Samples Inside Slurry Wall												
MIP-02	9/9/2013	21-25	<1,000	560,000	59,000	<1,000	3,000	<1,000	<1,000	<1,000	7,100	630,000
MIP-02	9/9/2013	33-36	<25	100	5,300	71	86	<25	<25	<25	<25	5,600
MIP-03	9/10/2013	18-22	<50	6,600	15,000	200	56	<50	<50	<50	<50	21,900
MIP-04	9/9/2013	16-20	<50	360	11,000	79	180	<50	<50	<50	<50	11,600
MIP-04	9/9/2013	33-36	<25/<25	1,200/1,200	2,700/2,700	<25/<25	25/25	<25/<25	<25/<25	<25/<25	<25/<25	3,900
MIP-08	9/10/2013	18-22	<50	2,100	1,200	<50	<50	<50	<50	<50	64	3,400
MIP-09	9/10/2013	20-23	<50	76,000	45,000	480	570	50	210	140	410	120,000
MIP-12	9/10/2013	18-22	<25	2,300	180	<25	<25	<25	<25	<25	36	2,500
MIP-12	9/10/2013	22-26	59	120,000	55,000	280	520	<50	310	160	1,200	180,000
MIP-12	9/10/2013	33-35	<50	770	2,400	<50	<50	<50	<50	<50	<50	3,200
Well Upgradient of Slurry Wall												
123A	10/23/2013	28-38	<5.0	510	260	<5.0	<5.0	<5.0	<5.0	<5.0	6.2	800
Wells Downgradient of Slurry Wall												
41A	10/23/2013	13-25	<5.0	580	220	<5.0	<5.0	<5.0	<5.0	<5.0	7.0	800
42A	10/23/2013	10-35	1.9/1.7	480/470	87/85	1.4/1.3	1.1/1.0	1.8/1.7	1.4/1.4	2.2/2.1	6.8/6.5	600
Wells Transgradient of Slurry Wall												
40A	10/23/2013	11.5-27	1.2	560	180	2.0	1.6	3.8	3.6	4.8	10	800
43A	10/23/2013	15-27	1.5	420	96	1.2	1.5	1.4	1.3	1.8	3.5	500
44A	10/23/2013	13.5-28	1.8	330	51	0.79	<0.50	1.0	0.7	1.2	2.4	400
126A	9/25/2012	23-38	<0.50	130	110	1.0	0.59	<0.50	4.0	2.8	1.7	300
138A	10/23/2013	34-37	<0.50	340	920	6.4	16	<0.50	3.2	3.6	<50	1,300

<u>Notes:</u>

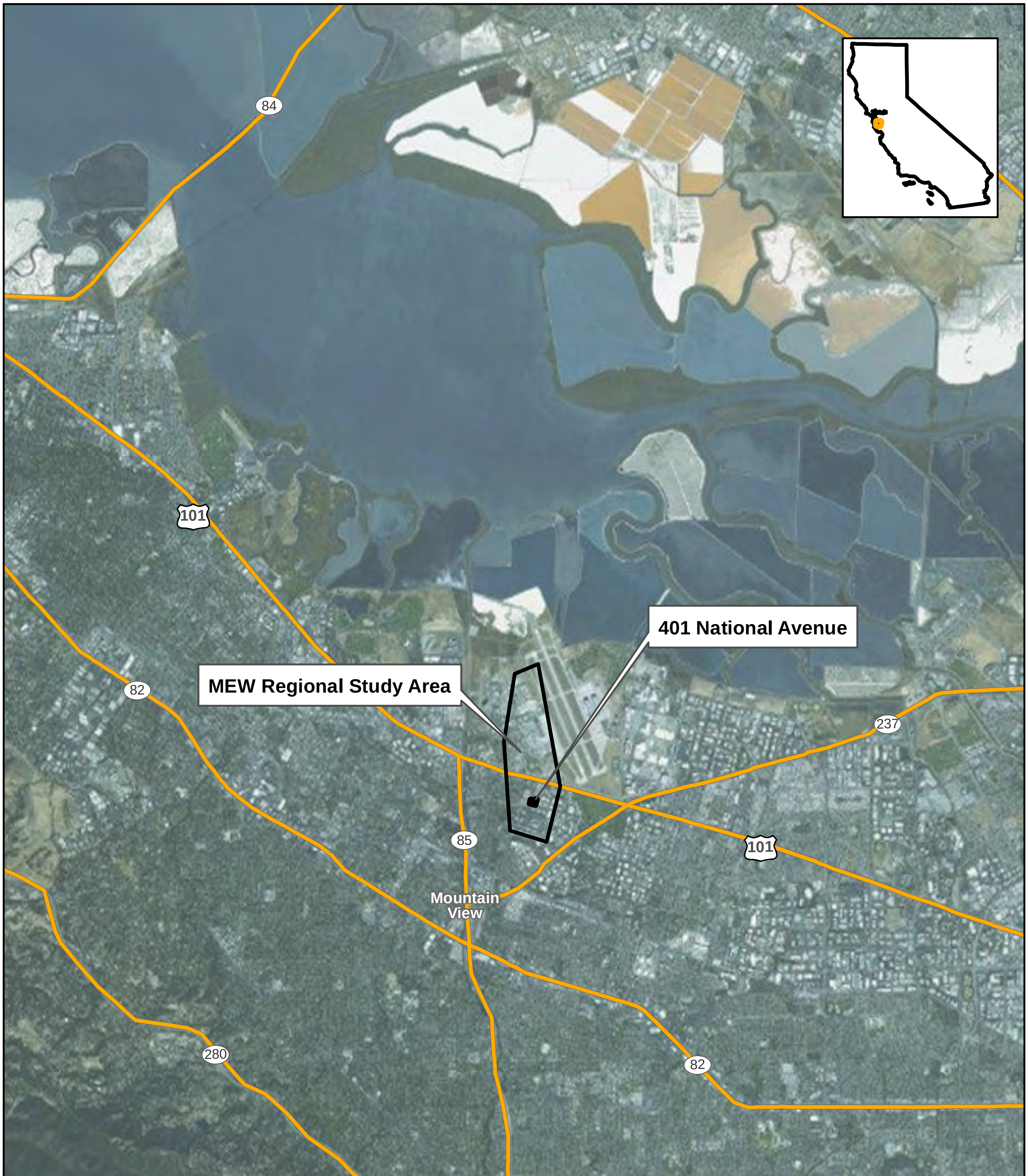
1. Sample depth represents screen intervals for monitoring wells or grab sample depths
2. The Total VOCs values were rounded

ft bgs = feet below ground surface
µg/L = micrograms per liter
EPA = Environmental Protection Agency
1,200/1,200 indicates primary and duplicate sample results
< indicates analyte not detected above the reported detection limit

PCE = Tetrachloroethene
TCE = Trichloroethene
cis-1,2-DCE = cis-1,2-Dichloroethene
trans-1,2-DCE = trans-1,2-Dichloroethene
1,1,1-TCA = 1,1,1-Trichloroethane
1,1-DCA = 1,1-Dichloroethane
1,1-DCE = 1,1-Dichloroethene

Freon 113 = Trichlorotrifluoroethane
VOC = volatile organic compounds
cVOCs = chlorinated volatile organic compounds

FIGURES



N

0 5 Miles

Basemap Sources: USGS, ESRI, TANA, AND, DeLorme, NPS

Site Location Map

401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland | July 2014

Figure **1**

P:\GIS\MEW\Project\Fairchild\Building9\2014_ISCOWorkplan\Fig01_SiteLocation.mxd

Legend

- Recovery Well
- Recovery Well (Inactive)
- Monitoring Well
- 401 National Avenue
- ==== Slurry Wall †

N

Notes:
† The slurry wall location in the north eastern portion of the site was revised based on information collected during 2013 utility location activities.
Aerial Source: USGS April 2011

50 25 0 50 Feet

Site Plan Under Current Configuration

401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland | July 2014

Figure **2**

P:\GIS\MEW\Project\Fairchild\Building9\2014_ISCOWorkplan\Fig02_SitePlanUnderCurrentConfiguration.mxd

Legend

- Recovery Well
- Recovery Well (Inactive)
- Monitoring Well
- Proposed Four Story Office Building
- Proposed One Level Aboveground Parking Structure
- Slurry Wall †
- 401 National Avenue

N

Notes:
† The slurry wall location in the north eastern portion of the site was revised based on information collected during 2013 utility location activities.
Aerial Source: USGS April 2011

50 25 0 50 Feet

Proposed Redevelopment Plans

401 National Avenue
Mountain View, California

Geosyntec consultants

Figure **3**

Oakland | July 2014

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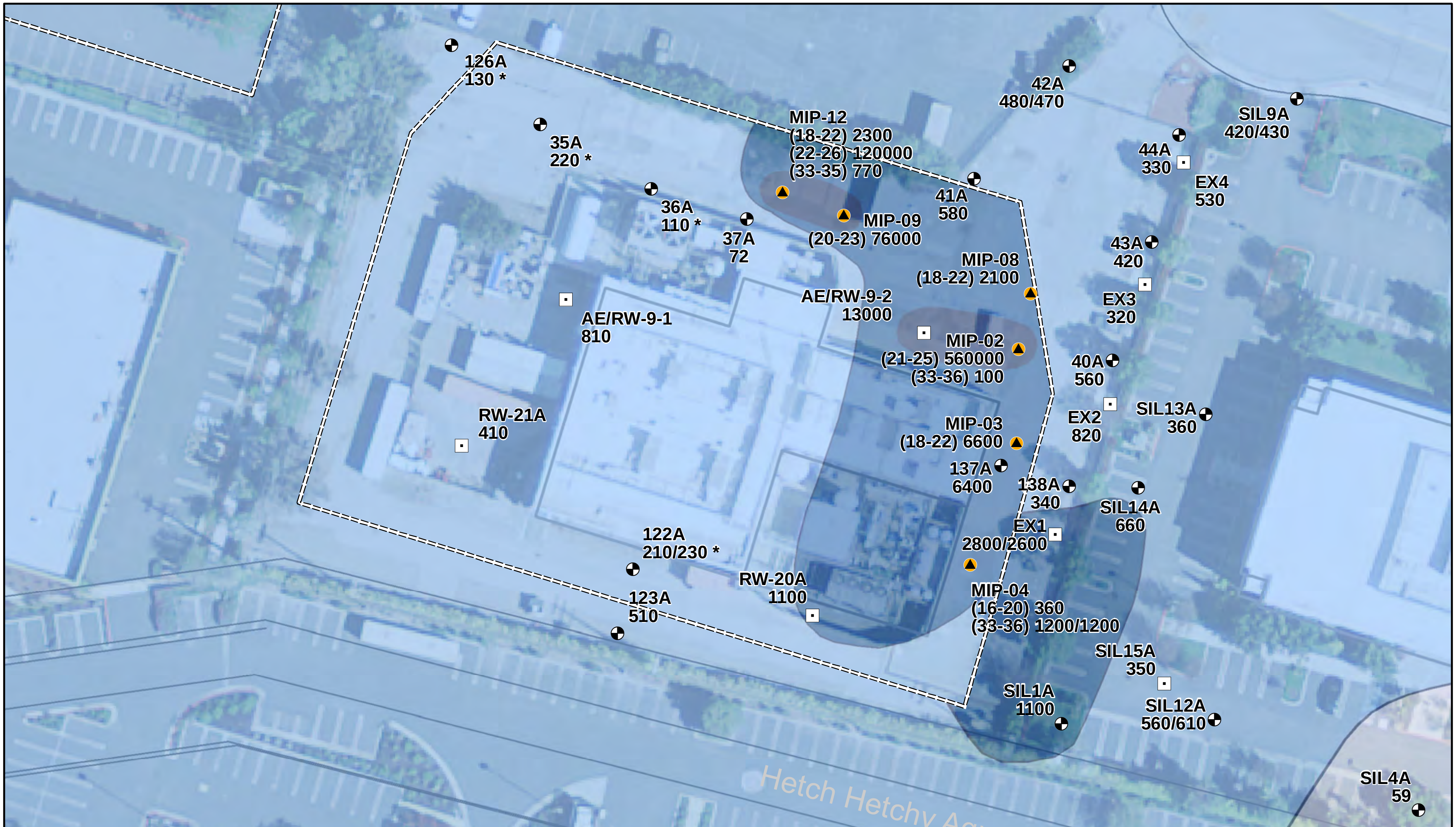

Legend

- MIP/SCP Boring Location
- Recovery Well
- Monitoring Well
- **MIP-12** MIP ID
- **(18-22) 2300** (Sample Depth in ft bgs) TCE Concentration

TCE Concentration

- 5 - 100 ug/L
- 100 - 1,000 ug/L
- 1,000 - 10,000 ug/L
- Greater than 10,000 ug/L

==== Slurry Wall †

N

30 15 0 30 Feet

Notes:
TCE = Trichloroethene
ug/L = micrograms per liter
MIP = Membrane Interface Probe
ft bgs = Feet below ground surface
SCP = Soil Conductivity Probe
* Only wells sampled in 2012 or 2013 shown in Figure. Star indicates well last sampled in 2012.
† The slurry wall location in the northeastern portion of the site was revised based on information collected during 2013 utility location activities.

A-Zone TCE Concentrations

401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland	July 2014	Figure 4

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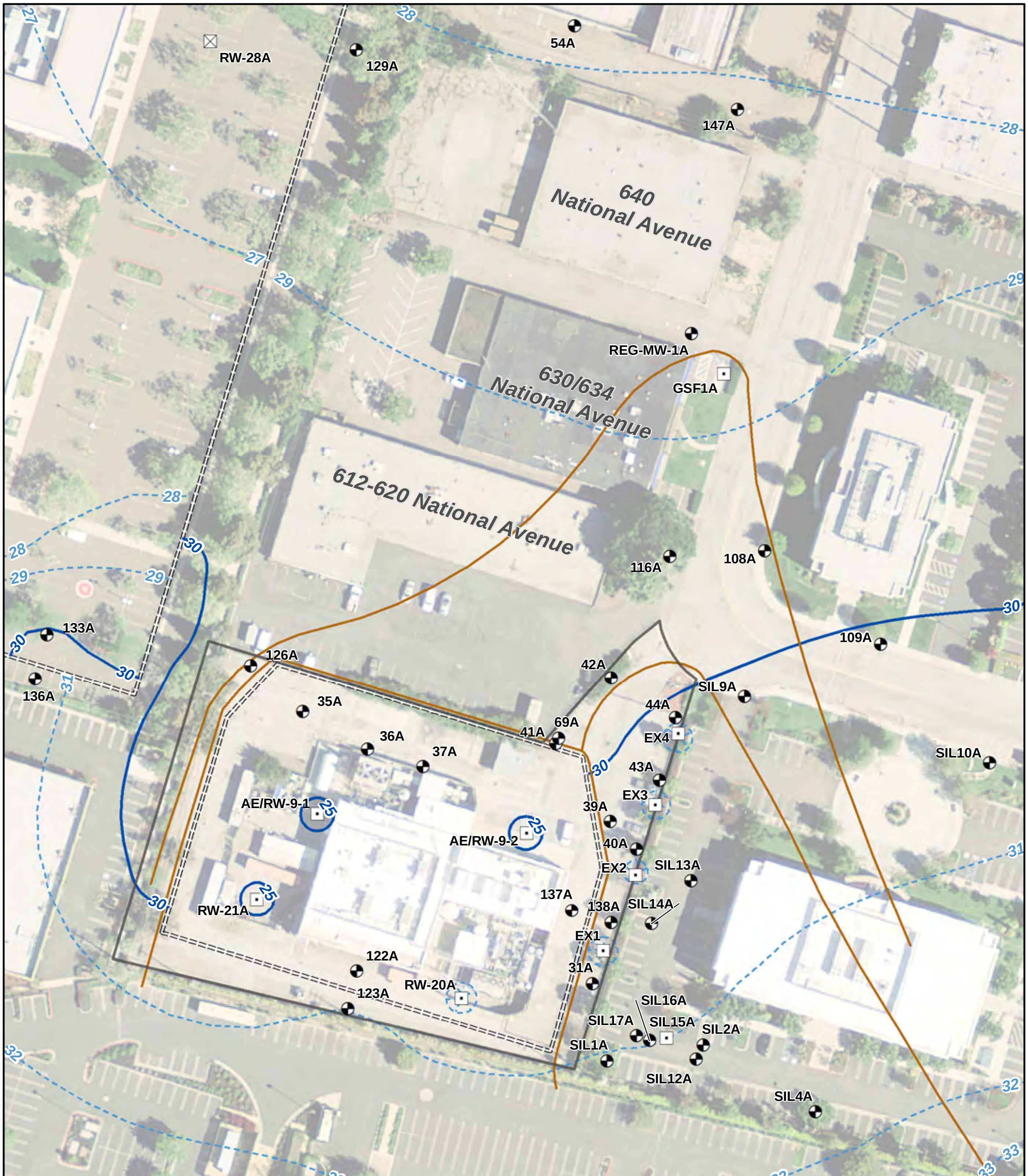


Legend

- Recovery Well
- Recovery Well (Inactive)
- Monitoring Well
- 401 National Avenue

Groundwater Elevation Contours (September 2013)

- 1 foot interval
- 5 foot interval
- Estimated Capture Zone
- Slurry Wall †

N

50 25 0 50 Feet

Notes:
SCRW - Source Control Recovery Well
Source: Geosyntec, 2014. Annual Progress Report for Regional Groundwater Remediation Program, April 15.
† The slurry wall location in the north eastern portion of the site was revised based on information collected during 2013 utility location activities.
Aerial Source: USGS April 2011

Local A-Zone Groundwater SCRWs and Capture Zones

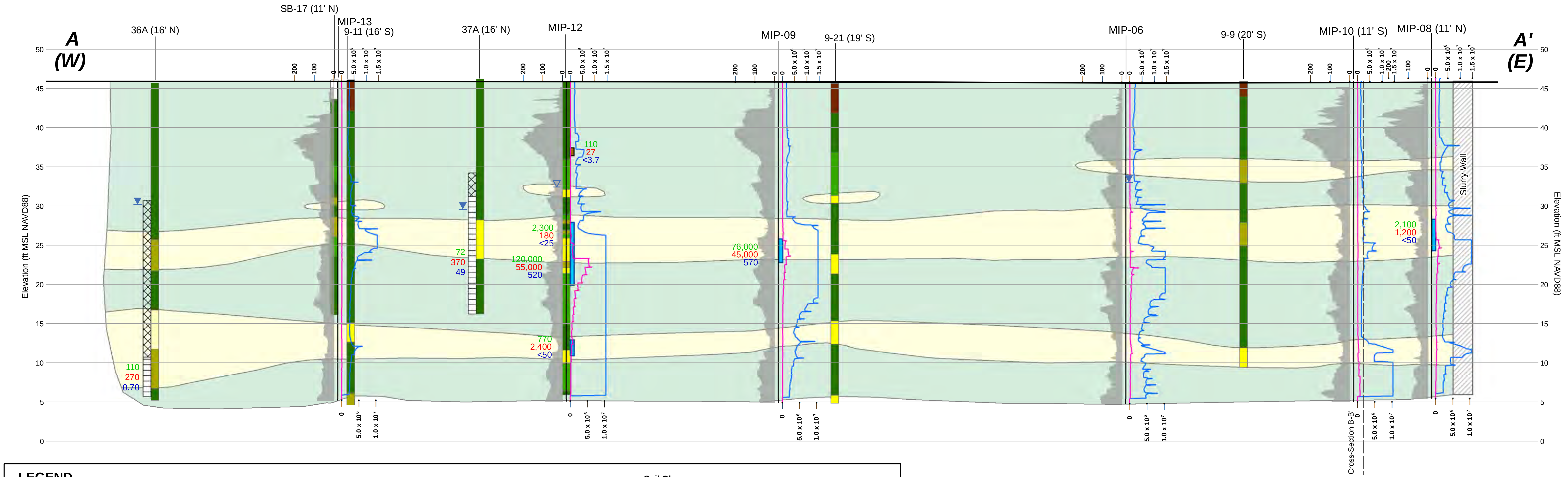
401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland | July 2014

Figure 5

P:\GIS\MEW\Project\Fairchild\Building9\2014_ISCOWorkplan\Fig05_LocalGroundwaterExtractionWellsAndCaptureZones.mxd



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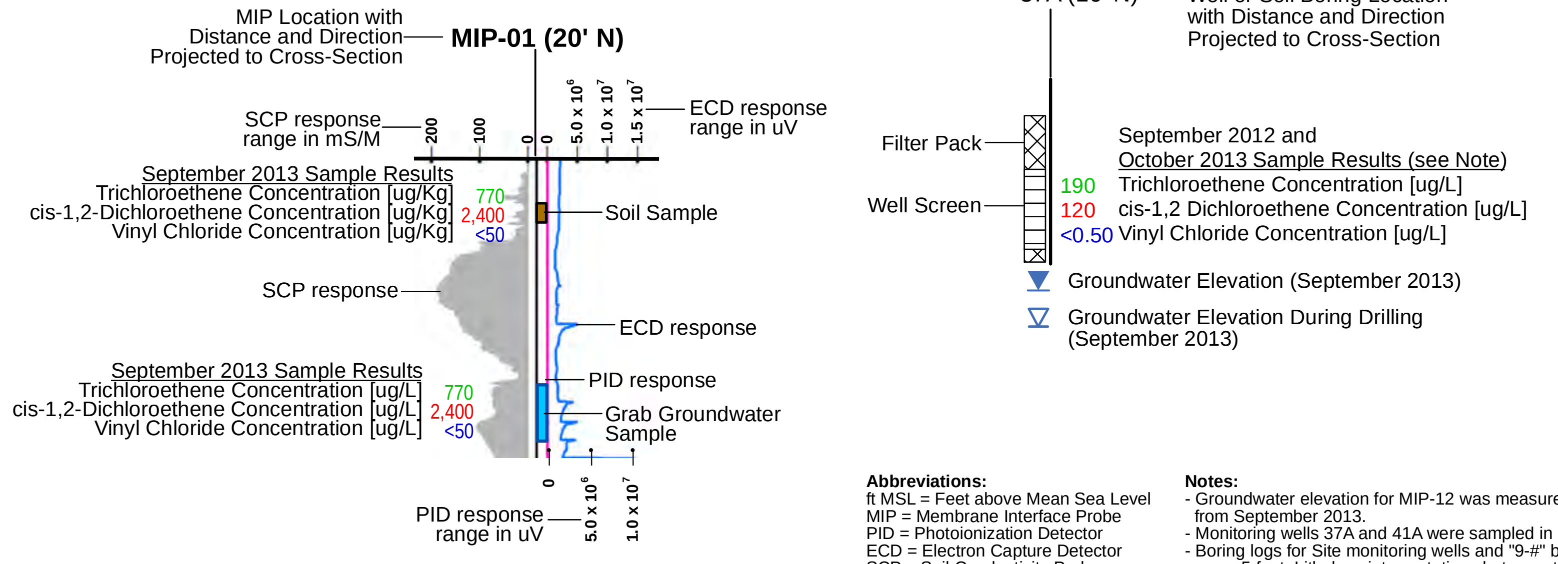


Soil Class

- No Recovery
- Asphalt; Fill
- Sand and Gravel Fill Material
- Topsoil
- CL Clay
- ML Silt
- SC-SM Clayey Sand to Silty Sand
- SP-SW Poorly Graded Sand to Well Graded Sand
- SW-GW Well Graded Gravelly Sand to Well Graded Gravel

Lithology

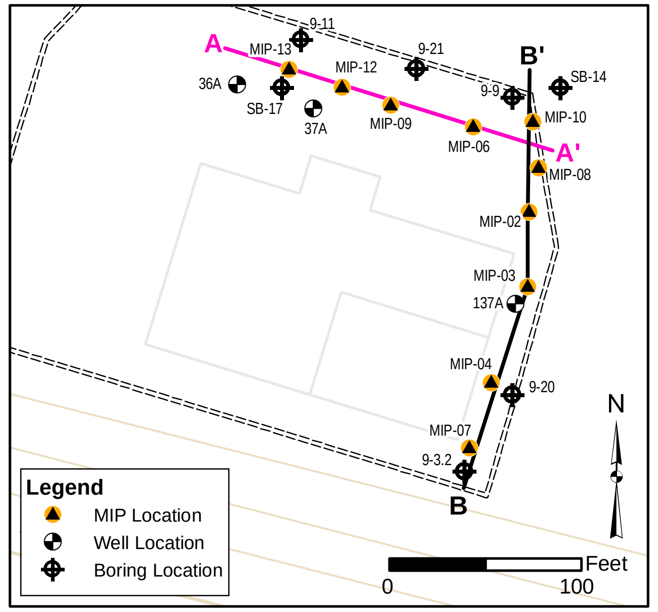
- Generalized Fine-Grained Layer
- Generalized Coarse-Grained Layer

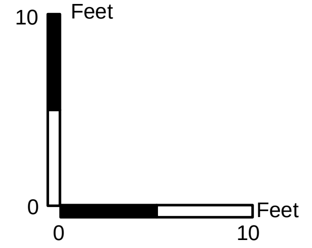
Abbreviations:

ft MSL = Feet above Mean Sea Level
MIP = Membrane Interface Probe
PID = Photoionization Detector
ECD = Electron Capture Detector
SCP = Soil Conductivity Probe
mS/M = milliSiemens per meter
uV = microvolts
ug/Kg = micrograms per kilogram
ug/L = micrograms per liter

Notes:

- Groundwater elevation for MIP-12 was measured on 6 September 2013, monitoring well groundwater measurements are from September 2013.
- Monitoring wells 37A and 41A were sampled in October 2013. Monitoring well 36A was sampled in September 2013.
- Boring logs for Site monitoring wells and "9-#" borings were logged using ~12-inch soil samples collected approximately every 5 feet. Lithology interpretations between these samples were estimated on historical boring logs. "MIP" soil borings and SCP borings advanced in 2013 were logged continuously and are expected to be more representative of subsurface conditions.
- Slurry wall location adjusted 5 feet east on cross-section to include log for MIP-8 inside slurry wall.
- Ground surface from topographic survey found in construction drawings provided by Kenneth Rodrigues and Partners, Inc., December, 2013.



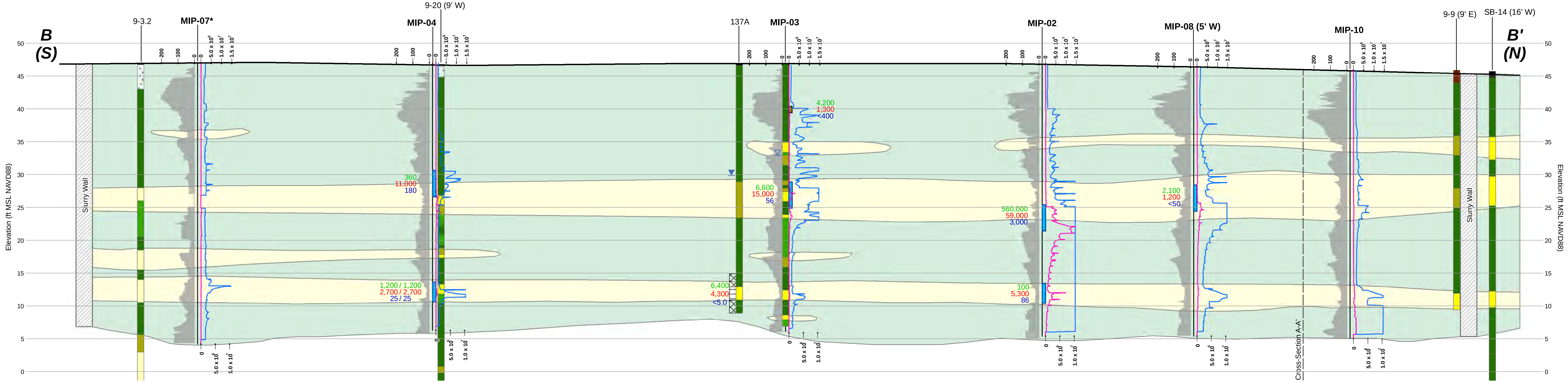


Cross-Section A-A'
401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland | July 2014

Figure 6



LEGEND

MIP Location with Distance and Direction Projected to Cross-Section — MIP-X

SCP response range in mS/M — 200, 100, 0

ECD response range in uV — 0, 5.0 x 10^6, 1.0 x 10^7, 1.5 x 10^7

September 2013 Sample Results
- Trichloroethene Concentration [ug/Kg] 770
- cis-1,2-Dichloroethene Concentration [ug/Kg] 2,400
- Vinyl Chloride Concentration [ug/Kg] <50

Soil Sample

SCP response

ECD response

PID response

Grab Groundwater Sample

September 2013 Sample Results
- Trichloroethene Concentration [ug/L] 770
- cis-1,2 Dichloroethene Concentration [ug/L] 2,400
- Vinyl Chloride Concentration [ug/L] <50

PID response range in uV — 0, 5.0 x 10^6, 1.0 x 10^7

37A (16' N) — Well or Soil Boring Location with Distance and Direction Projected to Cross-Section

Filter Pack

Well Screen

September 2013 Sample Results
- 190 Trichloroethene Concentration [ug/L]
- 120 cis-1,2 Dichloroethene Concentration [ug/L]
- <0.50 Vinyl Chloride Concentration [ug/L]

Groundwater Elevation (September 2013)

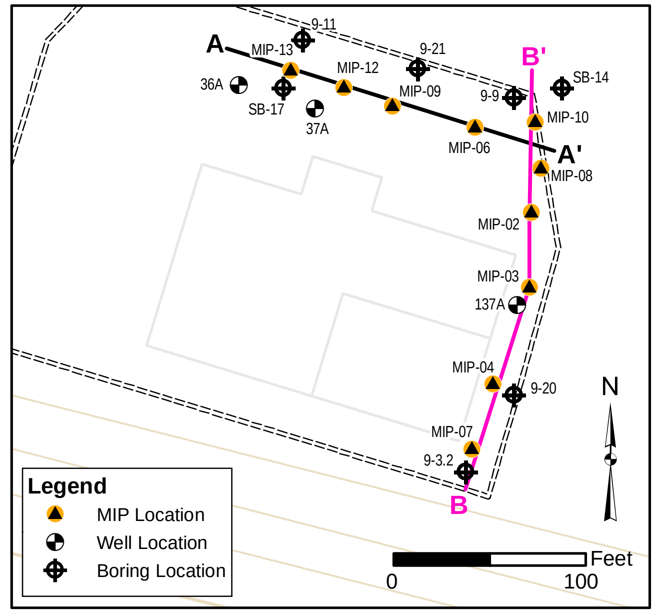
Groundwater Elevation During Drilling (September 2013)

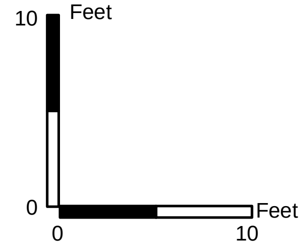
Soil Class
- No Recovery
- Asphalt; Fill
- Sand and Gravel Fill Material
- Topsoil
- CL Clay
- ML Silt
- SC-SM Clayey Sand to Silty Sand
- SP-SW Poorly Graded Sand to Well Graded Sand
- SW-GW Well Graded Gravelly Sand to Well Graded Gravel

Lithology
- Generalized Fine-Grained Layer
- Generalized Coarse-Grained Layer

Abbreviations:
"/" Indicates duplicate sample
ft MSL = Feet above Mean Sea Level
MIP = Membrane Interface Probe
PID = Photoionization Detector
ECD = Electron Capture Detector
SCP = Soil Conductivity Probe
mS/M = milliSiemens per meter
uV = microvolts
ug/Kg = micrograms per kilogram
ug/L = micrograms per liter

Notes:
- Groundwater elevation for MIP-3 was measured on 3 September 2013, monitoring well groundwater measurements are from September 2013.
- Boring logs for Site monitoring wells and "9-#" borings were logged using ~12-inch soil samples collected approximately every 5 feet. Lithology interpretations between these samples were estimated on historical boring logs. "MIP" soil borings and SCP borings advanced in 2013 were logged continuously and are expected to be more representative of subsurface conditions.
- Slurry wall depth is approximate.
- Ground surface from topographic survey found in construction drawings provided by Kenneth Rodrigues and Partners, Inc., December, 2013.
- Slurry wall location adjusted 5 feet east on cross-section to include log for MIP-8 inside slurry wall.
* Data for MIP-07 is approximate due to a computer failure at 20 feet bgs. It is likely that no data was collected between 20 and 22 feet bgs.





Cross-Section B-B'
401 National Avenue
Mountain View, California

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Figure 7

Oakland | July 2014

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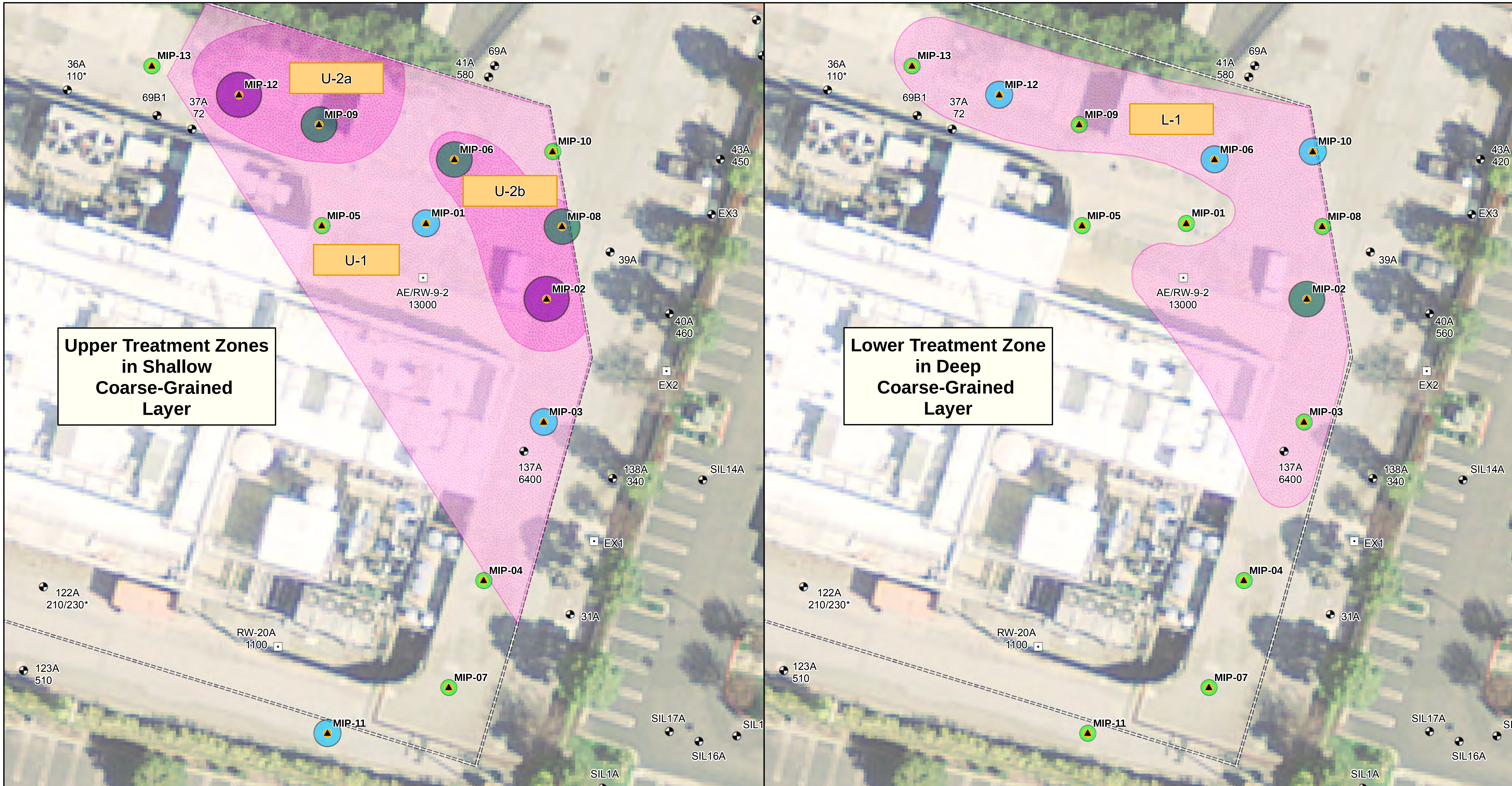

Legend

- Recovery Well
- Monitoring Well
- 36A / 110* — Well ID / TCE Concentration
- MIP Location (September 2013)
- ====== Slurry Wall†
- Conceptual Treatment Zones

Sum of PID Responses

- 0.0 - 0.5E+08 µV
- 0.5E+08 - 1.0E+08 µV
- 1.0E+08 - 3.0E+08 µV
- >3E+08 µV

Notes:
- Colored halos represent the sum of PID response measurements from 14-31 ft bgs (left panel) and 31-40 ft bgs (right panel). PID responses are measured every 0.05 ft bgs during MIP advancement.
* Figure shows results for only those wells sampled in 2012 and 2013 for 401 National Avenue. Star indictes wells that were last sampled in 2012.

† The slurry wall location in the north eastern portion of the site was revised based on information collected during 2013 utility location activities.
- Data for MIP-07 is approximate due to a computer failure at 20 ft bgs. It is likely that no data was collected between 20 and 22 ft bgs.

µV - microvolts
ug/L - micrograms per liter
ft bgs - feet below ground surface
MIP - membrane interface probe
PID - photoionization detector

N

30 15 0 30 Feet

Conceptual Treatment Zones
Plan View

401 National Avenue
Mountain View, California

Geosyntec consultants

Figure 8

Oakland | July 2014

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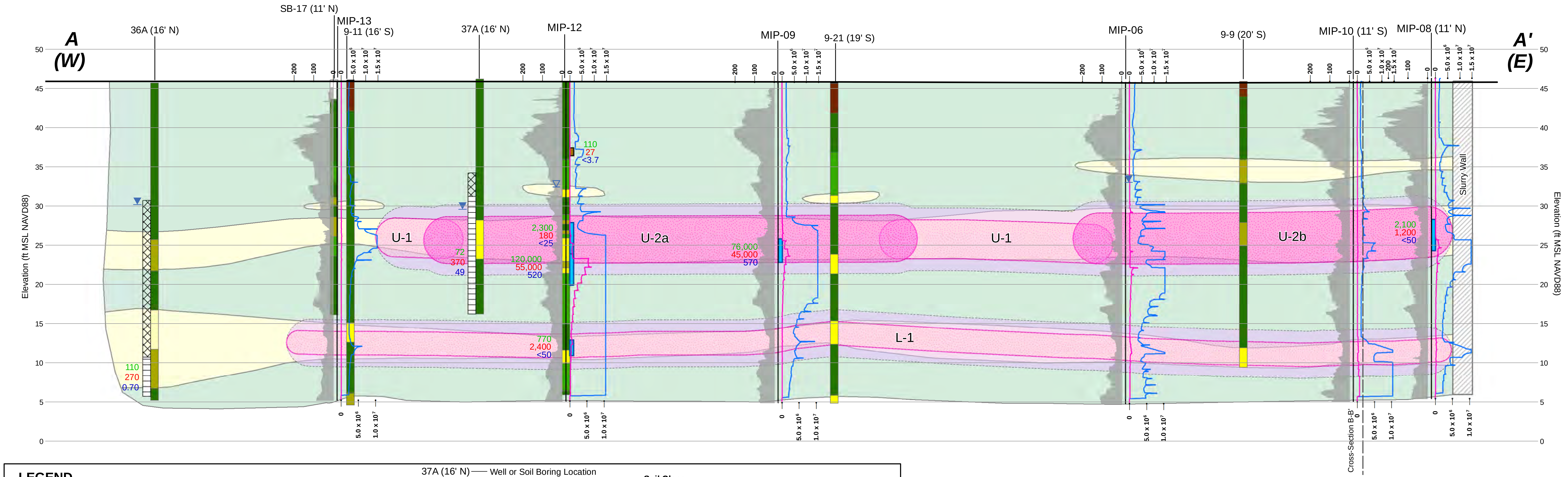


LEGEND

MIP Location with Distance and Direction Projected to Cross-Section — MIP-01 (20' N)

SCP response range in mS/M

ECD response range in uV

September 2013 Sample Results
Trichloroethene Concentration [ug/Kg] 770
cis-1,2-Dichloroethene Concentration [ug/Kg] 2,400
Vinyl Chloride Concentration [ug/Kg] <50

Soil Sample

SCP response

ECD response

September 2013 Sample Results
Trichloroethene Concentration [ug/L] 770
cis-1,2-Dichloroethene Concentration [ug/L] 2,400
Vinyl Chloride Concentration [ug/L] <50

PID response

Grab Groundwater Sample

PID response range in uV

37A (16' N) — Well or Soil Boring Location with Distance and Direction Projected to Cross-Section

Filter Pack

Well Screen

September 2012 and October 2013 Sample Results (see Note)
190 Trichloroethene Concentration [ug/L]
120 cis-1,2 Dichloroethene Concentration [ug/L]
<0.50 Vinyl Chloride Concentration [ug/L]

Groundwater Elevation (September 2013)

Groundwater Elevation During Drilling (September 2013)

Target Injection Zone

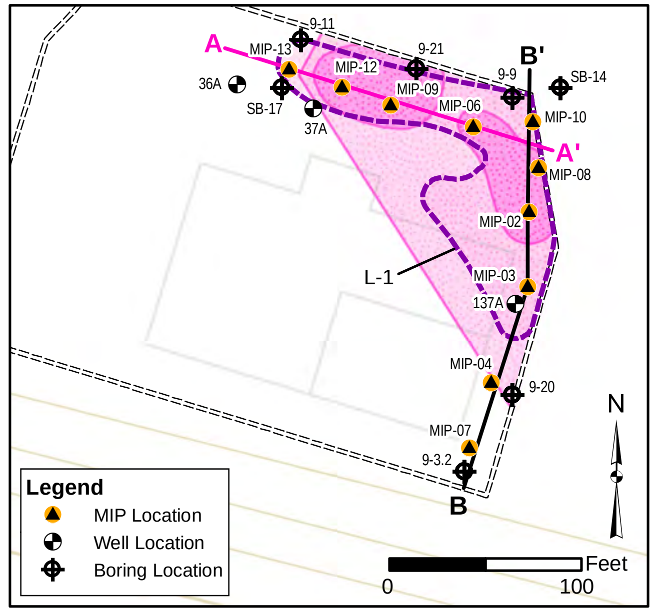
Potential Zone of Oxidant Influence

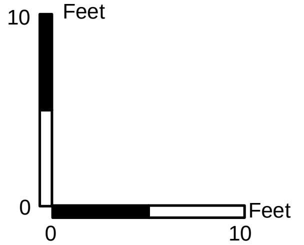
Soil Class
- No Recovery
- Asphalt; Fill
- Sand and Gravel Fill Material
- Topsoil
- CL Clay
- ML Silt
- SC-SM Clayey Sand to Silty Sand
- SP-SW Poorly Graded Sand to Well Graded Sand
- SW-GW Well Graded Gravelly Sand to Well Graded Gravel

Lithology
- Generalized Fine-Grained Layer
- Generalized Coarse-Grained Layer

Abbreviations:
ft MSL = Feet above Mean Sea Level
MIP = Membrane Interface Probe
PID = Photoionization Detector
ECD = Electron Capture Detector
SCP = Soil Conductivity Probe
mS/M = milliSiemens per meter
uV = microvolts
ug/Kg = micrograms per kilogram
ug/L = micrograms per liter

Notes:
- Groundwater elevation for MIP-12 was measured on 6 September 2013, monitoring well groundwater measurements are from September 2013.
- Monitoring wells 37A and 41A were sampled in October 2013. Monitoring well 36A was sampled in September 2013.
- Boring logs for Site monitoring wells and "9-#" borings were logged using ~12-inch soil samples collected approximately every 5 feet. Lithology interpretations between these samples were estimated on historical boring logs. "MIP" soil borings and SCP borings advanced in 2013 were logged continuously and are expected to be more representative of subsurface conditions.
- Slurry wall location adjusted 5 feet east on cross-section to include log for MIP-8 inside slurry wall.
- Ground surface from topographic survey found in construction drawings provided by Kenneth Rodrigues and Partners, Inc., December, 2013.





Conceptual Treatment Zones - Cross-Section A-A'
401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland | July 2014

Figure 9

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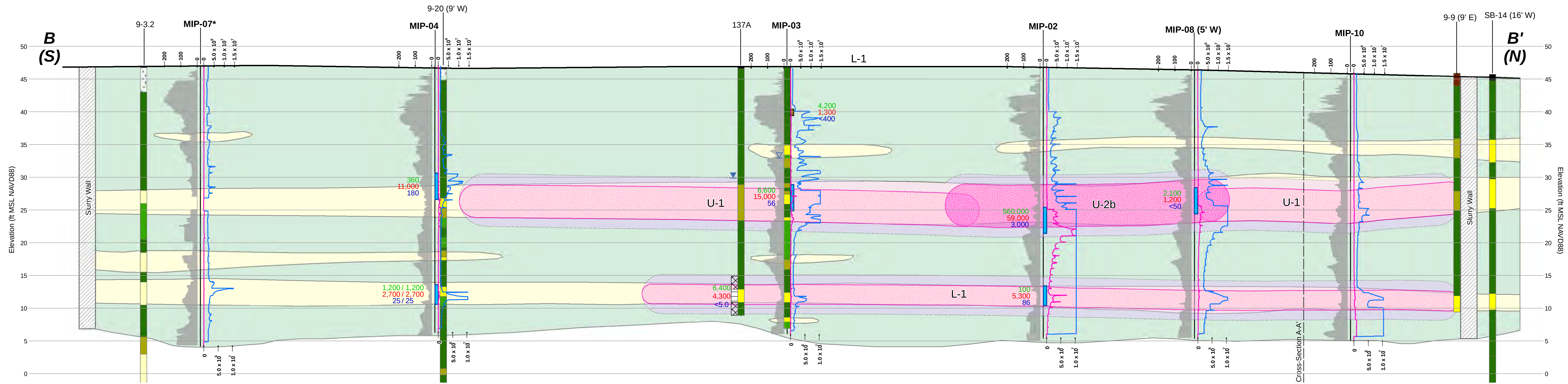

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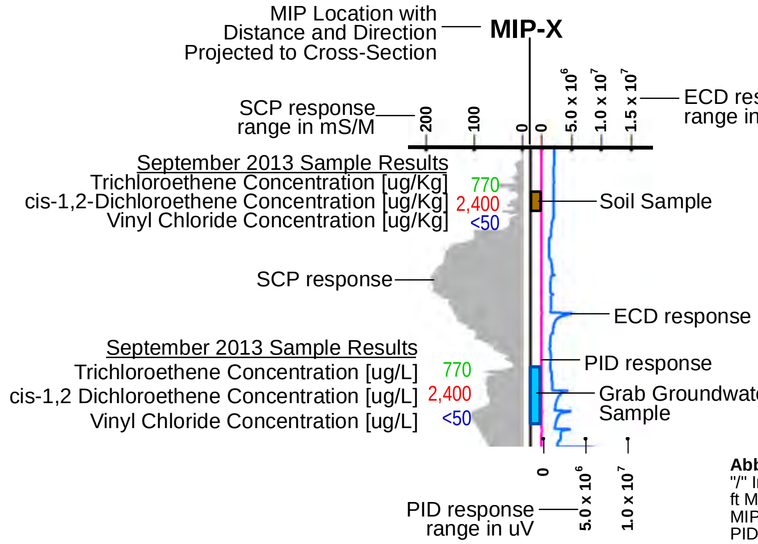


37A (16' N) — Well or Soil Boring Location with Distance and Direction Projected to Cross-Section

Filter Pack

Well Screen

September 2013 Sample Results
- 190 Trichloroethene Concentration [ug/L]
- 120 cis-1,2 Dichloroethene Concentration [ug/L]
- <0.50 Vinyl Chloride Concentration [ug/L]

Groundwater Elevation (September 2013)

Groundwater Elevation During Drilling (September 2013)

Target Injection Zone

Potential Zone of Oxidant Influence

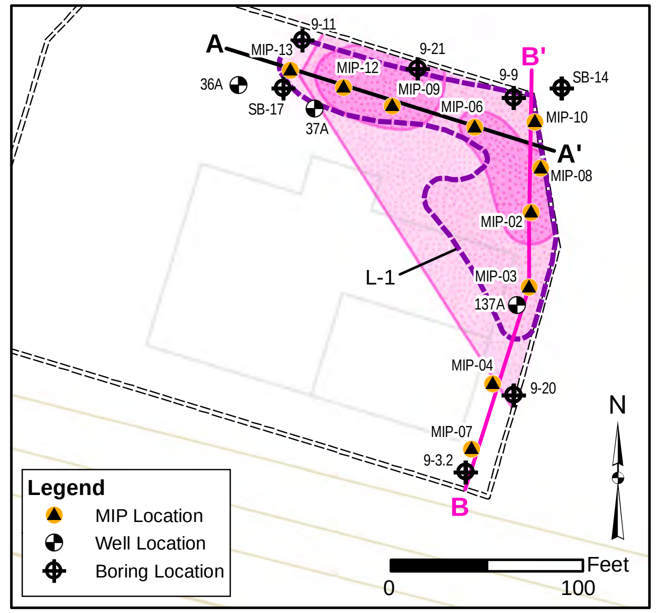
Soil Class
- No Recovery
- Asphalt; Fill
- Sand and Gravel Fill Material
- Topsoil
- CL Clay
- ML Silt
- SC-SM Clayey Sand to Silty Sand
- SP-SW Poorly Graded Sand to Well Graded Sand
- SW-GW Well Graded Gravelly Sand to Well Graded Gravel

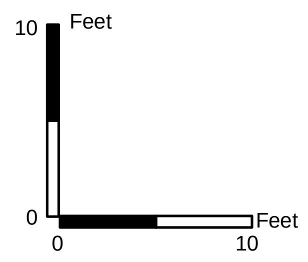
Lithology
- Generalized Fine-Grained Layer
- Generalized Coarse-Grained Layer

Abbreviations:
"/" Indicates duplicate sample
ft MSL = Feet above Mean Sea Level
MIP = Membrane Interface Probe
PID = Photoionization Detector
ECD = Electron Capture Detector
SCP = Soil Conductivity Probe
mS/M = milliSiemens per meter
uV = microvolts
ug/Kg = micrograms per kilogram
ug/L = micrograms per liter

Notes:
- Groundwater elevation for MIP-3 was measured on 3 September 2013, monitoring well groundwater measurements are from September 2013.
- Boring logs for Site monitoring wells and "9-#" borings were logged using ~12-inch soil samples collected approximately every 5 feet. Lithology interpretations between these samples were estimated on historical boring logs. "MIP" soil borings and SCP borings advanced in 2013 were logged continuously and are expected to be more representative of subsurface conditions.
- Slurry wall depth is approximate.
- Ground surface from topographic survey found in construction drawings provided by Kenneth Rodrigues and Partners, Inc., December, 2013.
- Slurry wall location adjusted 5 feet east on cross-section to include log for MIP-8 inside slurry wall.

* Data for MIP-07 is approximate due to a computer failure at 20 feet bgs. It is likely that no data was collected between 20 and 22 feet bgs.





Conceptual Treatment Zones - Cross-Section B-B'

401 National Avenue
Mountain View, California

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Figure 10

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Legend

- Proposed Temporary Pilot Study Monitoring Well
- Recovery Well
- Monitoring Well
- ====== Slurry Wall†
- Conceptual Treatment Zones

Notes:
† The slurry wall location in the northeastern portion of the site was revised based on information collected during 2013 utility location activities.

N

30 15 0 30 Feet

Performance Monitoring Points

401 National Avenue
Mountain View, California

Geosyntec consultants

Figure **11**

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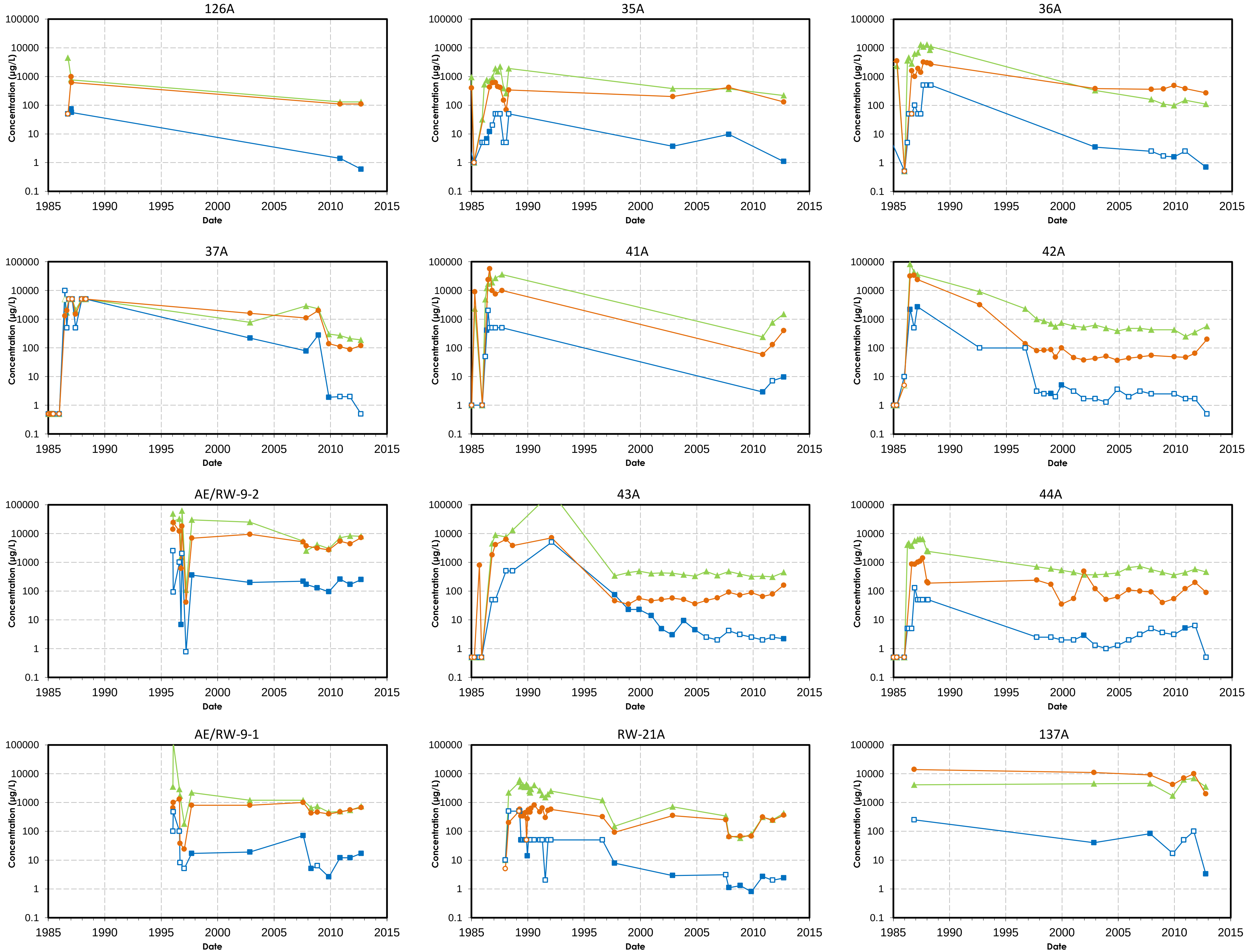
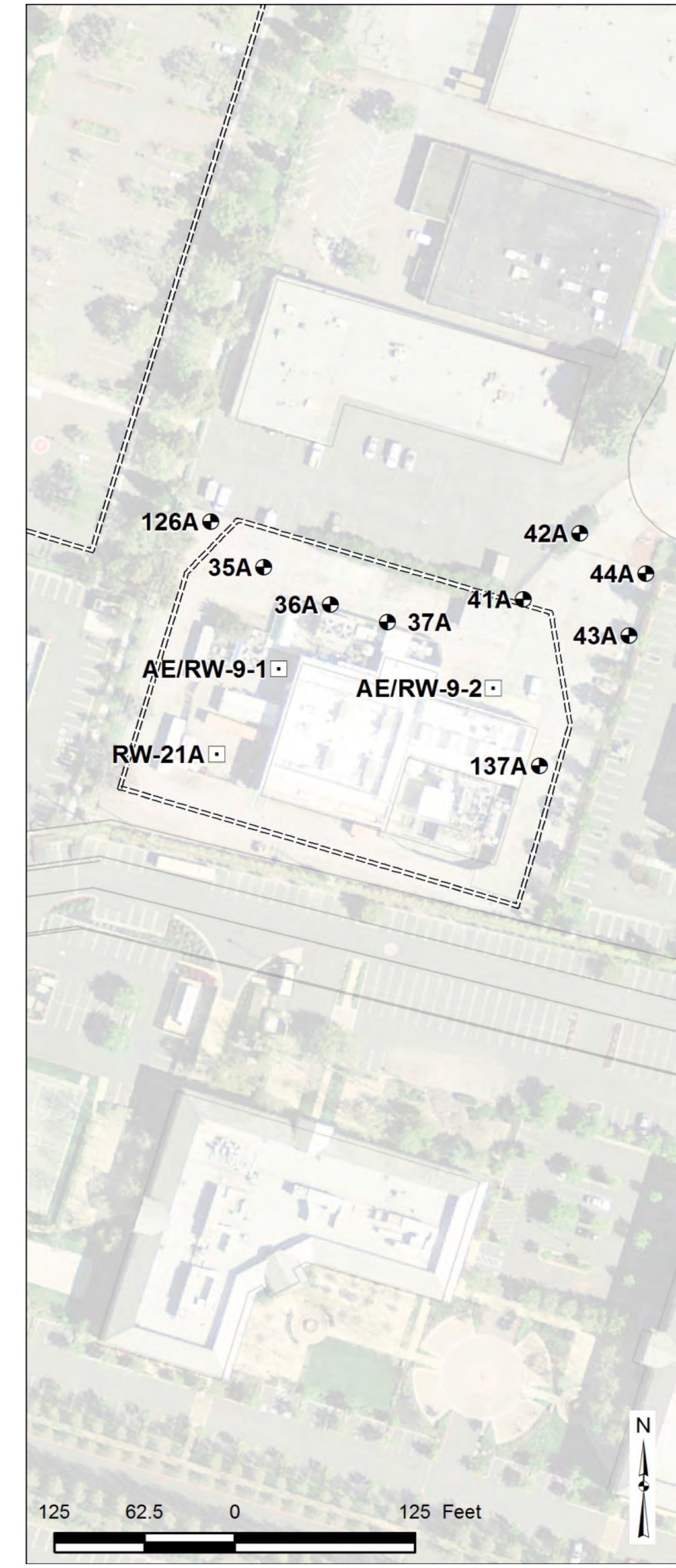
APPENDIX A
VOCs vs. Time Graphs



35A Monitoring Well
RW-21A Extraction Well (On)

- Trichloroethene
- cis-1,2-Dichloroethene
- Vinyl Chloride

Note:
Open symbols are non-detects, presented at limit of quantification



VOCs vs. Time Graphs

401 National Avenue
Mountain View, California

Geosyntec consultants

Figure **A-1**

Oakland | July 2014

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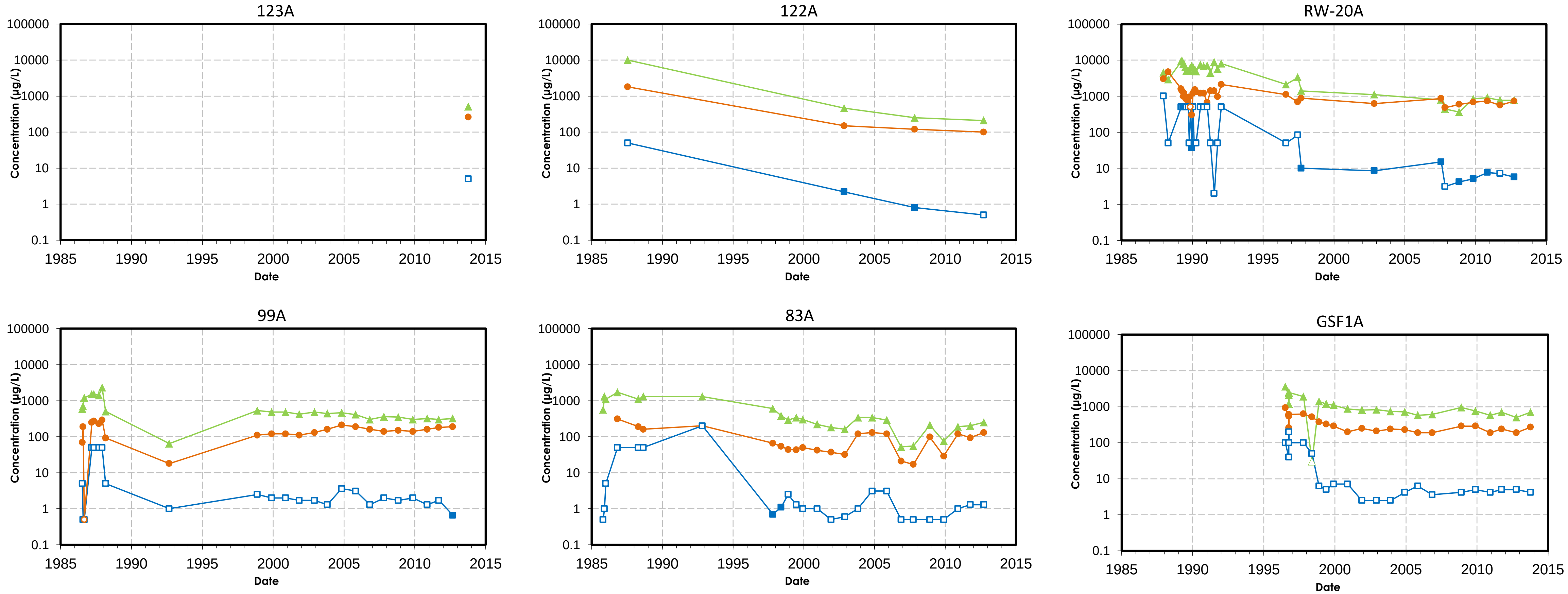

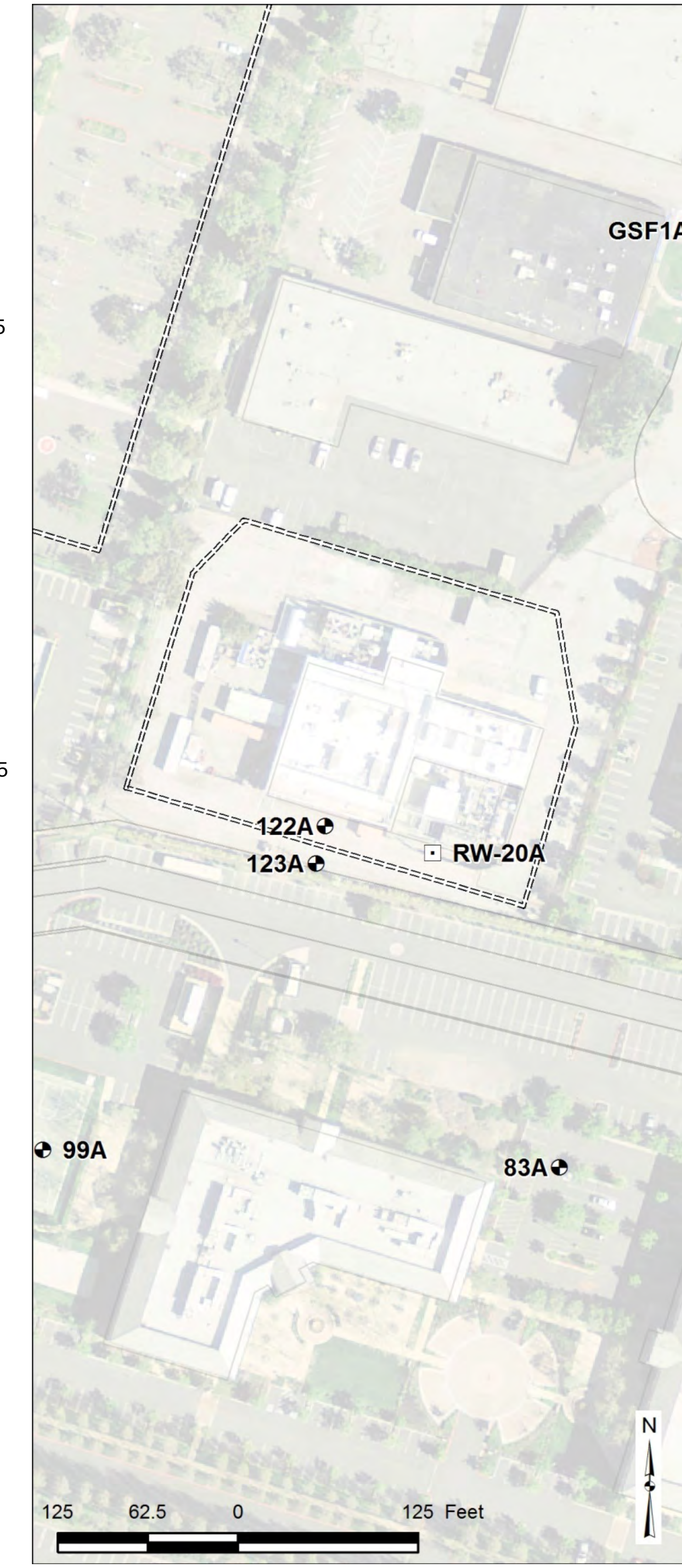

Trichloroethene
cis-1,2-Dichloroethene
Vinyl Chloride

Note:
Open symbols are non-detects, presented at limit of quantification

35A Monitoring Well
RW-21A Extraction Well (On)

VOCs vs. Time Graphs

401 National Avenue
Mountain View, California

Geosyntec consultants

Figure **A-2**

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APPENDIX B
Numerical Model Supporting Information

APPENDIX B – Numerical Flow and Transport Model

The scope of work described in the Work Plan for In Situ Chemical Oxidation (ISCO) Pilot Study (Work Plan) includes injection of permanganate and shutdown of the on-site recovery wells located within the former Building 9 slurry wall (the Site). Because there are recovery wells operating adjacent to the Site, numerical modeling was performed to assess the potential for permanganate to reach the off-site recovery wells following implementation of the Pilot Study.

This assessment was performed by: (i) developing a numerical groundwater flow model of the Site; (ii) assessing the groundwater flow field after shutdown of the on-site recovery wells within the former Building 9 slurry wall; and (iii) assessing potential fate and transport of residual permanganate following injections.

1. NUMERICAL GROUNDWATER FLOW MODEL

1.1 Numerical Model Domain, Grid, and Layers

The three-dimensional model for flow and transport was developed using MODFLOW and RT3D (for chemical transport analysis), industry standard finite-difference codes. Groundwater flow in the model was assumed to be steady-state.

The domain of the numerical model used at the Site is based on the Middlefield-Ellis-Whisman (MEW) regional groundwater flow model (Geosyntec, 2008). The model domain and the Site location are shown in Figure B-1.

The numerical model is similar to the revised regional groundwater flow model for MEW (Geosyntec, 2014). The details of the model development are given below.

The layering is not based on the A-, B1-, and B2-zone stratigraphy at MEW. Rather, each model layer is of uniform thickness and the distribution of soil types from site borings are used to interpolate the variation in material properties within each layer.

The model domain was divided into 13 layers as follows. The top seven layers were defined to match the stratigraphy observed at the Site. The layers below were chosen to best group materials of similar soil type, and remained the same as for the regional model.

- Layer 1 = 0 – 15 feet below ground surface (bgs); the top layer (Layer 1) is mostly dry and was therefore not active in the model simulations.

- Layer 2 = 15 – 20 feet bgs
- Layer 3 = 20 – 25 feet bgs
- Layer 4 = 25 – 32 feet bgs
- Layer 5 = 32 – 37 feet bgs
- Layer 6 = 37 – 45 feet bgs
- Layer 7 = 45 – 50 feet bgs
- Layer 8 = 50 – 60 feet bgs
- Layer 9 = 60 – 70 feet bgs
- Layer 10 = 70 – 80 feet bgs
- Layer 11 = 80 – 100 feet bgs
- Layer 12 = 100 feet bgs – top of the B3 aquifer (determined based on the top of the sandy layer observed in boring logs below 100 feet bgs)
- Layer 13 = B3 aquifer.

The top of the model domain was interpolated from a Digital Elevation Model (DEM) file obtained from USGS database.

The grid cells are 50 feet x 50 feet in most of the model domain and are refined to 2.5 feet x 2.5 feet in the vicinity of the Site.

1.2 Model Stratigraphy

The model stratigraphy was defined following the same approach as for the revised regional groundwater flow model, with interpolated sand fraction maps created for the Layers 2 through 7 based on available boring and membrane interface probe (MIP) logs for the Site. The model stratigraphy below 50 feet bgs was not changed from the revised regional model.

1.3 Groundwater Flow Model

1.3.1 Observation Data – Head

The groundwater flow model has been calibrated to water level measurements collected between 2010 and 2012 from monitoring wells located inside the model domain.

1.3.2 Model Boundaries and Stresses

The model boundaries are unchanged from the regional flow model. Constant head boundaries were applied to the northern and southern edges of the model and no-flow boundaries were applied to the eastern and western sides of the model domain.

Recharge from direct precipitation was defined over the entire domain with a rate of 1 inch per year. Evapotranspiration was defined in the northern part of the domain, corresponding to the non-residential area of the model domain.

In the vicinity of the Site, the main stresses are the extraction wells and the presence of the slurry wall. The slurry wall was modeled with the horizontal flow barrier (HFB) package in MODFLOW. The HFB representing the slurry wall was defined down to 50 feet bgs (Layer 7). The HFB hydraulic parameter was defined assuming a constant slurry wall thickness of 3 feet and a hydraulic conductivity of 0.001 foot/day, which are consistent with information presented in the Slurry Cutoff Walls Record of Construction (Canonie, 1988).

The extraction wells were defined based on the screen interval. Average pumping rates from 2010-2012 were applied in all extraction wells for model calibration. Well construction and groundwater pumping rate information are included in the Annual Progress Report for the Site (Geosyntec, 2013a).

The locations of the Building 9 slurry wall and extraction and monitoring wells in the vicinity of the Site are shown in Figure B-2.

1.3.3 Material Properties

Aquifer hydraulic conductivity was defined using the same approach as for the regional model. A relationship between hydraulic conductivity and sand fraction was used to calculate hydraulic conductivity field in the refined model layers. The relationship between horizontal hydraulic conductivity (K_H in feet/day) and sand fraction (SF in %) is:

$$K_H = \begin{cases} 300 \cdot SF^3 & if\ SF \leq 50\% \\ 75 \cdot SF & if\ SF \geq 50\% \end{cases}$$

The ratio between horizontal and vertical hydraulic conductivity was set equal to 10.

The vertical hydraulic conductivity value of the low conductivity layer present at the bottom of the slurry wall was estimated to be 0.1 to 0.2 foot/day based on observed drawdown inside the slurry wall under pumping conditions. The median vertical hydraulic conductivity value of layer 6 (located from 37 to 45 feet bgs) in the slurry wall footprint is 0.14 foot/day based on the hydraulic conductivity relationship described above.

1.4 Solute Transport Model

1.4.1 Model Boundaries and Stresses

A uniform initial sodium permanganate concentration is assumed to be present throughout the target treatment zones for the ISCO pilot study (Figure 8 in Work Plan). The target treatment zones correspond to layer 3 (upper treatment zone) and layer 5 (lower treatment zone) in the model. The initial permanganate concentration is assumed to be 30 grams per liter (g/L), which is comparable to the oxidant solution concentration proposed for the pilot study, and results in a residual permanganate mass loading in the model that is approximately 50% greater than what is proposed for the pilot study.

1.4.2 Geochemical Model

Oxidant – Sodium Permanganate

In order to model permanganate fate and transport, several additional model input parameters were incorporated using the Reactive Multi-Species Transport in 3-Dimensional Groundwater model (RT3D, Clement, 1997). The RT3D model allows consideration of parameters and reaction kinetics relevant to ISCO, including permanganate consumption by naturally-occurring organic compounds in aquifer material (i.e., natural oxidant demand [NOD]).

After injections, permanganate is consumed by at least three processes:

- Fast-reacting NOD (NOD-fast);
- Slow-reacting NOD (NOD-slow); and,
- Reaction with the target chlorinated solvents.

For this analysis the permanganate consumption by chlorinated solvents was not included, which is a conservative assumption when assessing the potential fate and transport of the oxidant after injections.

The kinetic model for permangante consumption by NOD is based on the results of bench-scale testing to evaluate NOD that was conducted on soil and groundwater collected along Evandale Avenue (Geosyntec, 2013b).

- Based on these bench-scale testing data, a first-order rate constant was calculated for NOD-fast (0.2 day^{-1}). The calculated first-order rate constant yields an initial permanganate consumption by fast-reacting NOD of 6,000 milligrams per liter per day (mg/L-day) for an initial permenganate concentration of 30 g/L.
- The average zero-order NOD-slow oxidation rate was estimated to be 37 mg/L-day based on the bench-scale testing data.

The amount of fast-reacting NOD depends on the concentration of the injected oxidant and the duration of the fast reaction. Based on the bench-scale testing results, the amount of NOD-fast was estimated to be approximately 4,700 mg/L for an initial permanganate concentration of 30 g/L.

The bench testing results also indicated that the amount of slow-reacting NOD consumed was similar for different starting concentrations of permangenate. The model assumed that the amount of NOD-slow is approximately twice the amount of NOD-fast. Recent studies have reported that the fast-reacting NOD represents between 16 and 60 % of the total NOD (Thomson et al., 2009). In this analysis the fast-reacting NOD represents 33% of the total NOD, which is consistent with recent studies.

Based on the above conditions, the initial NOD-fast and NOD-slow concentrations were assumed to be 4,700 and 10,000 mg/L, respectively. As a simplifying assumption, the initial values of NOD-fast and NOD-slow were applied to the entire model domain. The final kinetic expressions for the reactive transport of NOD-fast, NOD-slow and permanganate are presented in Equations 1 through 3.

The kinetic expressions developed for decay of NOD-fast, in the presence of permanganate:

Equation (1) $\frac{d[NOD-fast]}{dt} = -0.2 * [MnO_4^-]$

The kinetic expression developed for decay of NOD-slow, in the presence of permanganate:

Equation (2) $\frac{d[NOD-slow]}{dt} = -37$

The kinetic expression developed for consumption of permanganate by NOD-fast and NOD-slow:

Equation (3) $\frac{d[MnO_4^-]}{dt} = -0.2 * [MnO_4^-] - 37$

Where:

$[MnO_4^-]$ = concentration of permanganate (mg/L)

[NOD-fast] = concentration of fast-reacting NOD in subsurface (mg/L)

[NOD-slow] = concentration of slow-reacting NOD in subsurface (mg/L)

The above equations were incorporated into the reactive transort model and used to simulate the fate of injected permanganate.

1.4.3 Other Fate and Transport Properties

The longitudinal dispersivity was estimated based on a recent review article prepared by Schulze-Makush (2005), where longitudinal dispersivity from 156 sites with unconsolidated media was compiled. From this study, the longitudinal dispersivity (α_L) can be estimated by:

$$\alpha_L \text{ (feet)} = 0.106 \times L^{0.81}$$

where L is the scale of interest (feet). The objective of the fate and transport modeling at the Site is to assess solute transport from the injection interval within the slurry wall to closest extraction wells, with the nearest downgradient extraction well located approximately 400 feet away. The corresponding longitudinal dispersivity is 14 feet. The transverse horizontal and vertical dispersivities are assumed to be equal to 1/10 of the longitudinal dispersivity or 1.4 feet.

In the model, the effective porosity is assumed to be 0.25, which is within the range reported in literature for sand/silty sand (e.g., Morris and Johnson, 1967; McWhorter and Sunata, 1977).

1.5 Model Calibration

The flow model was calibrated to fit the average observed head at the monitoring wells between 2010 and 2012. At the regional scale (including all observation data), the root mean square error (RMSE) was 3.8 feet, corresponding to 5.3% of the range of the observed water levels.

The observed and simulated heads at the monitoring wells in the vicinity of the Site are summarized below. The locations of the monitoring wells are shown in Figure B-2.

Monitoring Wells	Observed Head (feet msl)[1]	Simulated Head (feet msl)	Residual (feet)[2]
116A	29.97	28.28	1.69
122A	28.31	28.38	-0.07
123A	32.22	32.40	-0.18
126A	30.08	29.72	0.36
137A	28.03	27.46	0.57
138A	31.48	30.36	1.12
36A	28.07	29.44	-1.37
39A	30.84	28.46	2.38
69A	30.19	28.54	1.65
108A	30.14	28.40	1.74
31A	31.39	30.81	0.58
35A	28.07	28.22	-0.15
37A	27.8	27.64	0.16
40A	31.03	28.63	2.40

Monitoring Wells	Observed Head (feet msl)[1]	Simulated Head (feet msl)	Residual (feet)[2]
41A	30.22	28.49	1.73
42A	30.37	28.43	1.94
43A	30.84	28.20	2.64
44A	30.76	28.22	2.54
SIL12A	31.80	31.97	-0.17
SIL2A	31.92	31.84	0.08
SIL13A	31.22	29.66	1.56
SIL14A	31.26	29.97	1.29
SIL1A	32.15	32.09	0.06
SIL4A	32.39	32.82	-0.43
SIL9A	30.67	28.78	1.89
104B1	28.58	29.69	-1.11
109B1	28.62	29.52	-0.90
69B1	30.98	30.30	0.68
122A	29.11	28.37	0.74
123A	32.53	32.50	0.03
126A	30.29	30.21	0.08
137A	28.84	29.05	-0.21
35A	28.86	28.36	0.50
36A	28.85	28.97	-0.12
37A	28.54	28.48	0.06
41A	30.43	30.63	-0.20
69A	30.4	30.63	-0.23
69B1	31.12	30.90	0.22
RMSE[3]			**1.40**

1. Average observed head between 2010 and 2012
2. Residual = Observed Head – Simulated Head
3. RMSE = Root Mean Square Error

2. SIMULATED FLOW FIELD UPON SHUTDOWN OF EXTRACTION WELLS

Pumping rates were set to 0 at the four on-site extraction wells to simulate groundwater flow conditions in the absence of pumping. Pumping rates at the off-site recovery wells were set to the average 2013 pumping rates. Pumping rate at the planned extraction well near monitoring well 116A was set equal to the average 2013 pumping rate at GSF-1A (2.1 gallons per minute). The other boundary conditions remained unchanged.

2.1 Simulated Flow Field

The simulated hydraulic heads inside and in the vicinity of the slurry wall are shown in Figure B-3.Upward flow is simulated in the upgradient (southern) portion of the slurry wall, while downward flow is simulated in the downgradient (northern) portion of the wall. The rate of downward flow from the injection depth intervals (located above 37 feet bgs) is estimated to be 0.7 gallons per minute (gpm).

3. SIMULATED OXIDANT CONCENTRATION

For the oxidant fate and transport modeling, the points of compliance considered were the groundwater extraction wells located closest to Site (planned extraction well near monitoring well 116A to the north, and extraction wells EX-1 to EX-4 to the east). Simulated permanganate concentration contours are shown in Figure B-4. The upper panels illustrate the simulated permanganate concentrations in the upper treatment zone described in the Work Plan. The lower panels illustrate the simulated permanganate concentrations in the lower treatment zone described in the Work Plan. The shown concentration contours of 300 milligrams per liter (mg/L), 30 mg/L, and 3 mg/L are equivalent to attenuation of 99%, 99.9%, and 99.99% of the residual permanganate concentration of 30 g/L, respectively. The simulated permanganate front does not reach the deeper zone (50 to 60 feet bgs) outside of the slurry wall. Based on the model simulations as shown in Figure B-4, even at a conservatively high residual value of 30 g/L and higher permanganate mass than proposed in the pilot study, sodium permanganate is expected to be consumed by natural organic matter present in the aquifer material prior to being transported outside of the slurry wall and reaching the extraction wells located in the vicinity of the site.

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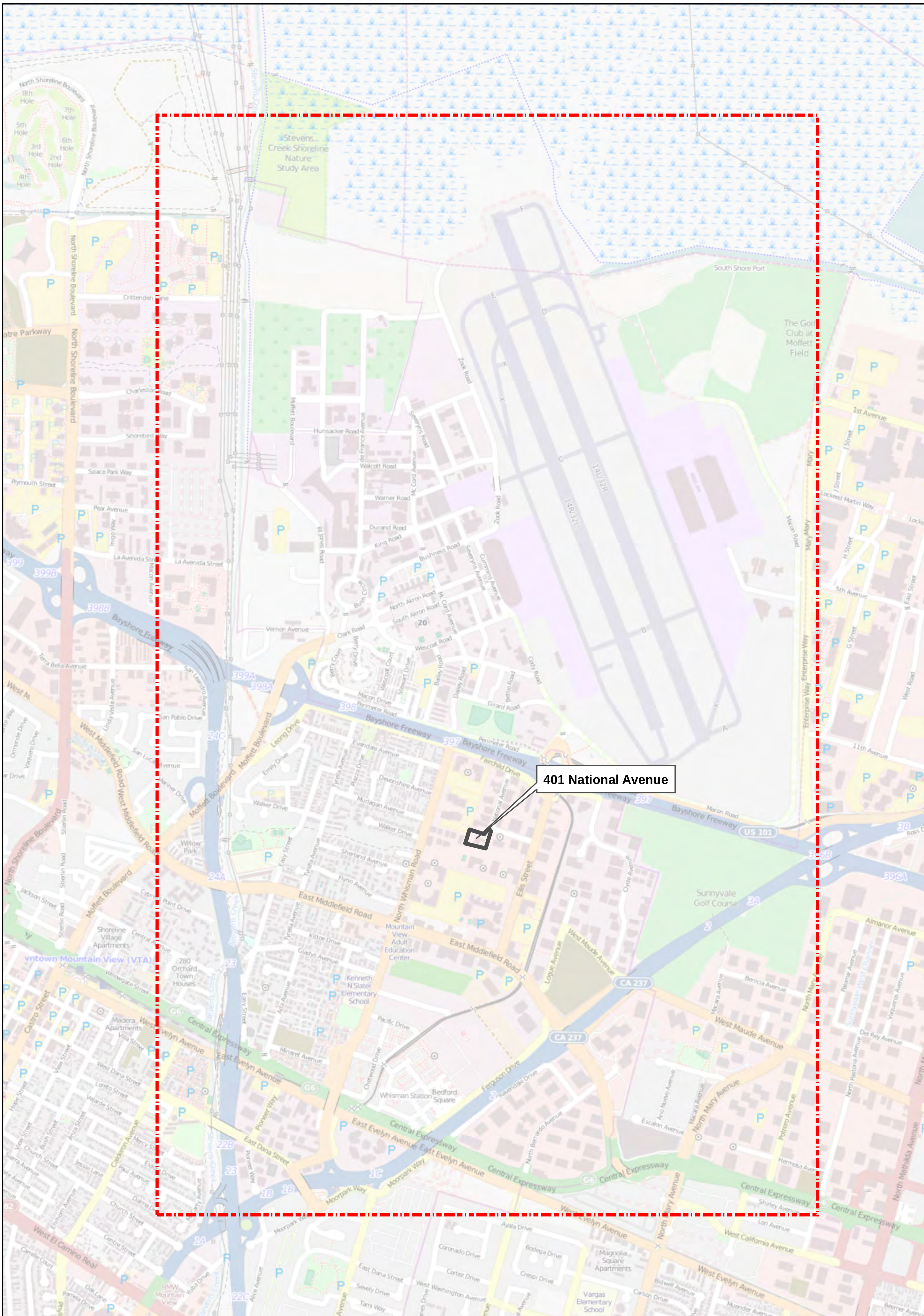

Legend

Model Domain

401 National Avenue

N

1,500 750 0 1,500 Feet

Notes:
Basemap Source: OpenStreetMap, July 2014

Model Domain

401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland	July 2014	Figure **B-1**

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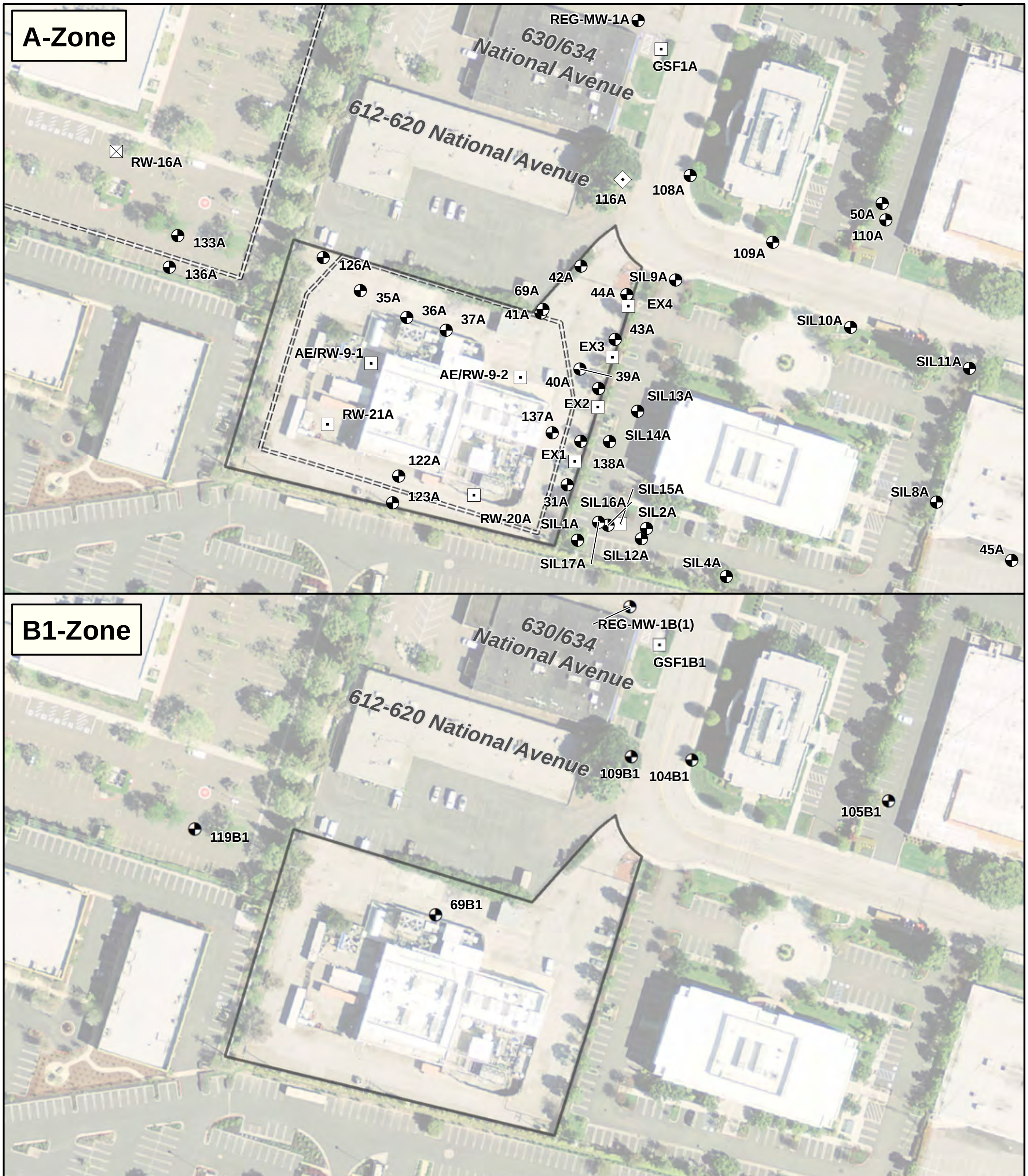

Legend

- Recovery Well
- Proposed Recovery Well
- Monitoring Well
- 401 National Avenue
- === Slurry Wall

N

70 35 0 70 Feet

Notes:
SCRW - Source Control Recovery Well
Aerial Source: USGS April 2011

Local A- and B1-Zone Groundwater SCRWs and Monitoring Wells

401 National Avenue
Mountain View, California

Geosyntec consultants

Oakland | July 2014

Figure **B-2**

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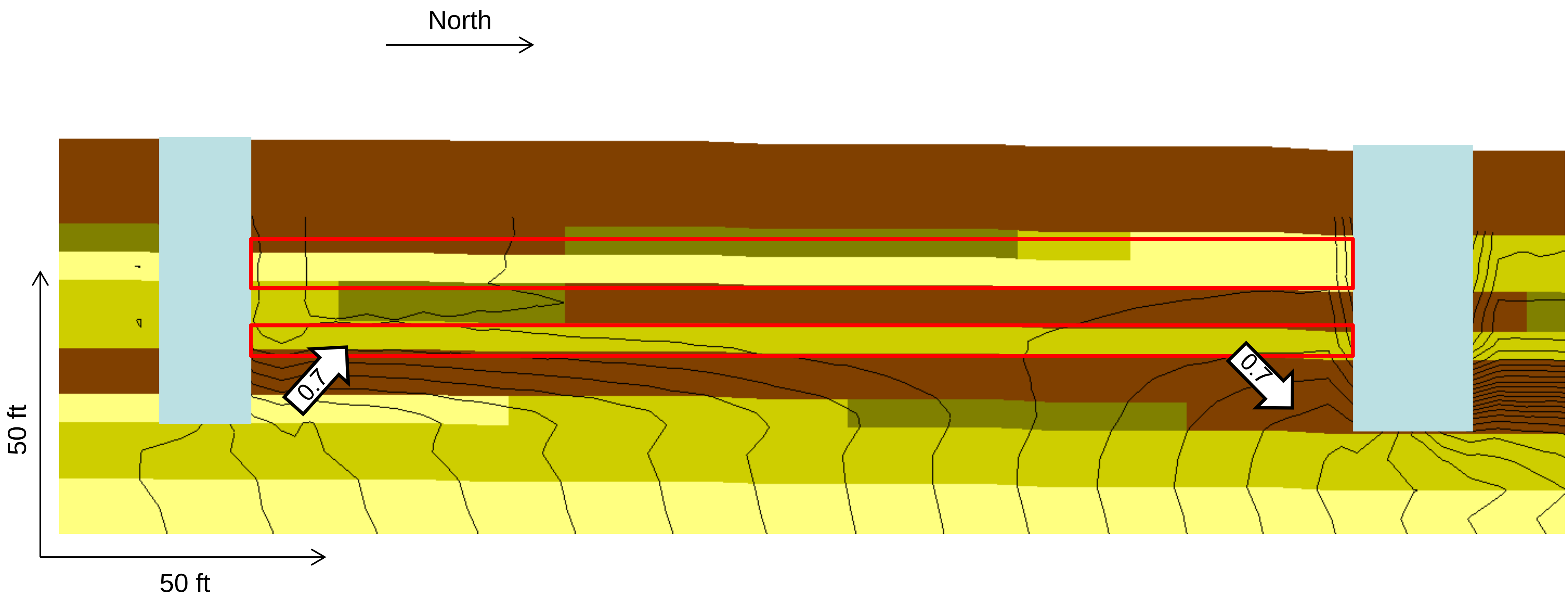

Horizontal Hydraulic Conductivity (feet/day)

- 0 - 5
- 5 - 10
- 10 - 25
- 25 - 70

Hydraulic Head Contours (0.1 ft)

Slurry Wall (horizontal thickness exaggerated)

Proposed oxidant injection depths

0.7 Groundwater flow direction and estimated flow rate in gallons per minute (see Section 2.1)

Simulated Hydraulic Head in Slurry Wall

401 National Avenue
Mountain View, California

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Figure B-3

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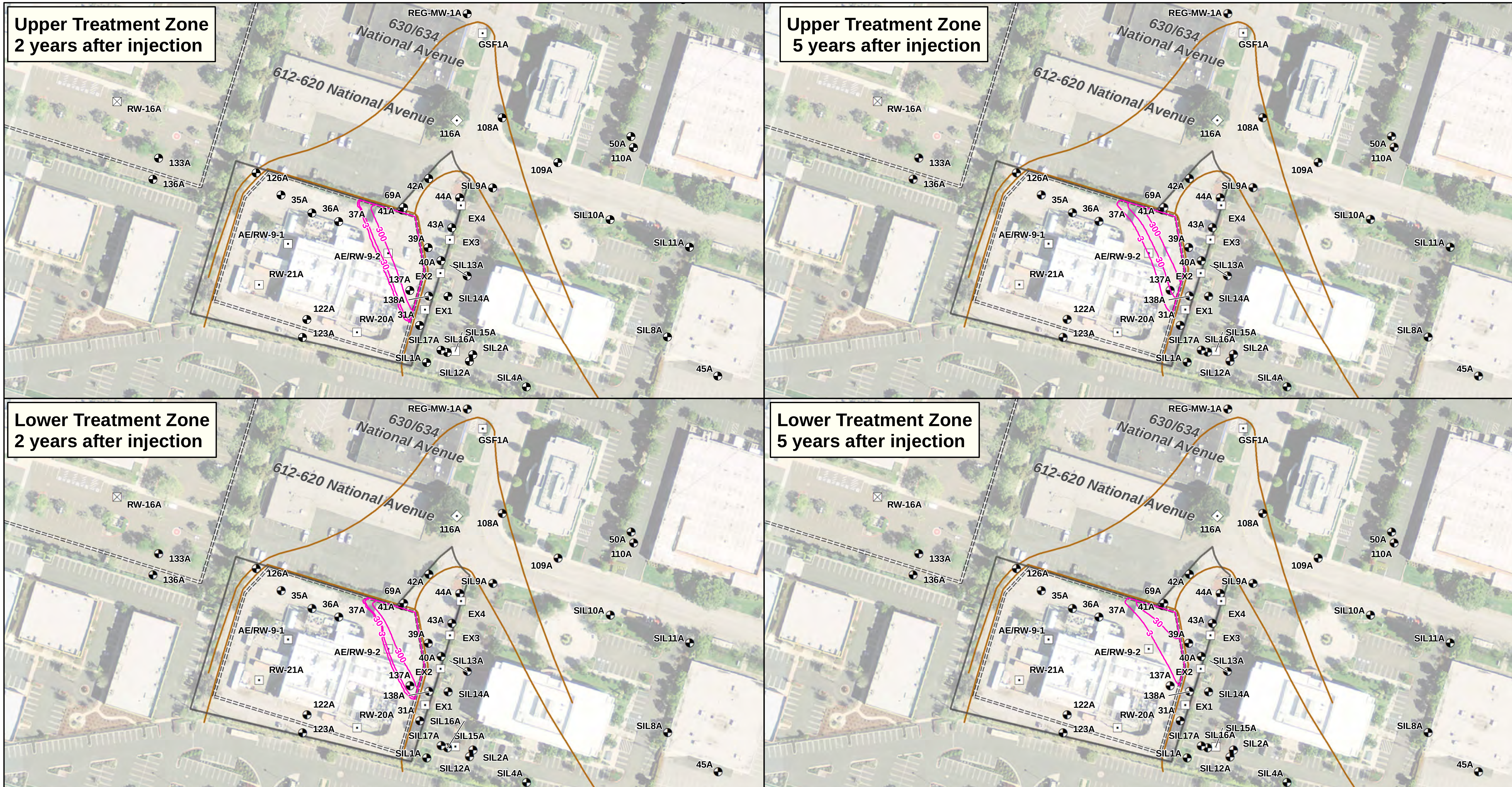

Legend

- Recovery Well
- Proposed Recovery Well
- Monitoring Well
- 401 National Avenue
- Simulated Permanganate Concentration (mg/L)
- Estimated Capture Zone
- Slurry Wall

Notes:
mg/L = Milligrams per Liter
Estimated Capture Zone Source: Geosyntec, 2014. Annual Progress Report for Regional Groundwater Remediation Program, April 15.
Modeled Results Assume A-Zone Extraction Wells Located Inside 401 National Avenue Slurry Wall Will Not Operate Following Oxidant Injections.
Aerial Source: USGS April 2011

N

70 35 0 70 Feet

Simulated Permanganate Concentrations

401 National Avenue
Mountain View, California

Geosyntec consultants

Figure B-4

Oakland | July 2014

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