DRAFT

SUPPLEMENTAL SITE INVESTIGATION REPORT
FORMER ORION PARK HOUSING AREA

Former Naval Air Station Moffett Field
Moffett Field, California

December 6, 2011

Prepared for:
U.S. Army Corps of Engineers
Sacramento District, California

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Prepared under:
U.S. Army Corps of Engineers, Sacramento District
Contract Number: W91238-06-D-0018
Task Order: 0004

SIGNATURE SHEET

Draft

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ACRONYMS AND ABBREVIATIONS

°C	Degrees Celsius
µg/L	Micrograms per liter
µV	Microvolt
AIS	American Integrated Services
Army	Department of the Army
bgs	Below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CPT	Cone penetrometer test
CSM	Conceptual site model
DCE	*cis*-1,2-Dichloroethene
DPT	Direct-push technology
EC	Electrical conductivity
ECD	Electron capture detector
EPA	U.S. Environmental Protection Agency
EVS	Environmental Visualization Software
FID	Flame ionization detector
FWENC	Foster Wheeler Environmental Corporation
GPS	Global positioning system
IDW	Investigation-derived waste
IT	International Technology Corporation
JMM	James M. Montgomery Consulting Engineers, Inc.
LOC	Location of concern
mg/L	Milligrams per liter
MIP	Membrane interface probe
Moffett	Naval Air Station Moffett Field
msl	Mean sea level
NAPL	Non-aqueous phase liquid
NASA	National Aeronautics and Space Administration
Navy	Department of the Navy
ND	Non-detect
NRC	National Research Council

OPHA	Orion Park Housing Area
PID	Photoionization detector
ppm	Parts per million
PQO	Project quality objective
PRC	PRC Environmental Management, Inc.
PVC	Polyvinyl chloride
QC	Quality control
SAIC	Science Applications International Corporation
SAP	Sampling and analysis plan
SBT	Soil behavior type
SC	Specific conductance
SCVWD	Santa Clara Valley Water District
SIG	The SI Group
SOP	Standard operating procedure
SSI	Supplemental site investigation
TCE	Trichloroethene
Tetra Tech	Tetra Tech EM Inc.
3D	3-dimensional
TPH	Total petroleum hydrocarbons
USACE	U.S. Army Corps of Engineers
USACHPPM	U.S. Army Center for Health Promotion and Preventative Medicine
USCS	Unified Soil Classification System
VOC	Volatile organic compound
Water Board	San Francisco Bay Regional Water Quality Control Board

EXECUTIVE SUMMARY

The Department of the Army (Army) conducted a supplemental site investigation (SSI) to identify potential on-site sources of trichloroethene (TCE)-contaminated groundwater at the former Orion Park Housing Area (OPHA) (Site) in Moffett Field, California. This SSI included a hydrogeologic study, soil and groundwater sampling, and contaminant-transport model of site geology, hydrogeology, and contaminant distribution.

The SSI was conducted pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act, and to the requirements of the National Oil and Hazardous Substances Pollution Contingency Plan, with oversight from the U.S. Environmental Protection Agency (EPA) Region 9 and support from the San Francisco Regional Water Quality Control Board (Water Board).

INVESTIGATION PURPOSE

During prior investigations, chlorinated solvents—primarily TCE at concentrations up to 1,200 micrograms per liter (µg/L)—were detected in groundwater samples collected from the Site. Although no historical records indicate TCE use at the Site, undocumented releases may have occurred. The SSI included additional characterization to investigate potential source areas of TCE identified by the oversight agencies as locations of concern (LOC). Nine LOCs were identified through review of historical groundwater sampling data, historical aerial photographs, and contractor's reports. The upper, unconfined A1 aquifer zone was targeted for investigation at LOCs 1, 2a, 2b, 3, and 4, and the lower A2 aquifer zone, which underlies the A1 aquifer zone, was targeted for investigation at LOCs 5a, 5b, 5c, and 6b.

A second purpose of the SSI was to investigate the LOC 4 area around boring FW41A, where field photoionization detector (PID) screening of vapors from soil cores in 2002 showed between 9.2 and 3,500 parts per million (ppm) by volume of volatile organic compounds (VOC) in the capillary fringe. Laboratory analysis to identify the compounds causing the elevated PID readings were not performed at that time; therefore, as part of the SSI, the Army collected and analyzed a soil sample at this location to identify those compounds.

FIELD ACTIVITIES

Under contract to U.S. Army Corps of Engineers (USACE), American Integrated Services (AIS) and its subcontractor Tetra Tech EM Inc. (Tetra Tech) performed five field activities as part of the SSI:

1. Obtained groundwater elevation measurements from on- and off-site wells to verify the potentiometric surfaces and groundwater flow directions of the A1 and A1 aquifer zones underlying the Site.
2. Collected groundwater samples from the 11 existing on-site wells for analysis for VOCs to verify historical VOC concentrations in groundwater.

3. Advanced 35 borings using a cone penetrometer test (CPT) rig equipped with a membrane interface probe (MIP) to identify potential on-site sources of contamination at nine LOCs, and to identify preferential pathways of contamination moving through the Site.
4. Advanced nine direct-push technology (DPT) borings and collected 11 groundwater grab samples to identify potential on-site sources of contamination and to confirm preferential pathways through the Site. One soil sample was collected to assess the presence of total petroleum hydrocarbons (TPH) and VOCs at FW41A.
5. Disposed of investigation-derived waste off site.

The Final Work Plan included a plan to drill and sample up to three groundwater monitoring wells if any of the LOCs was found to be a potential source area. However, the investigation did not confirm any potential source areas, so no wells were installed.

SUMMARY OF CONCLUSIONS

The results of the evaluation of data obtained during the SSI investigation and previous investigations indicate no on-site sources of TCE contamination at the nine LOCs investigated at the Site. The elevated VOCs detected on site within the plume appear to be associated with a late-stage plume that originates upgradient of the Site, crosses the Site from south to northwest (A1 aquifer zone) and south to north (A2 aquifer zone).

The Army therefore recommends no further action at the Site for on-site sources of TCE contamination. Because no sources of TCE were found on site, the Army plans to seek site closure.

LOC	Conclusion	Notes
1, 2a, 4, 5a, 5b, and 5c	No on-site source	MIP responses indicate contamination is part of larger chlorinated solvent plume. TPH and VOC soil results were nondetect at FW41A (LOC 4), indicating no TCE or TPH release had occurred at or near this location.
2b, 3, 6b	No on-site source	CPT/MIP and DPT data used in EVS-Pro modeling indicate contamination is part of larger chlorinated solvent plume.

1.0 INTRODUCTION

The Department of the Army (Army) conducted a supplemental site investigation (SSI) to identify potential on-site sources of trichloroethene (TCE)-contaminated groundwater at the former Orion Park Housing Area (OPHA) (Site) in Moffett Field, California (Figure 1). This SSI included a hydrogeologic study, soil and groundwater sampling, and development of a contaminant- transport model of site geology, hydrogeology, and contaminant distribution using the Environmental Visualization System (EVS)-Pro modeling software.

The SSI was conducted pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act, and to the requirements of the National Oil and Hazardous Substances Pollution Contingency Plan, with oversight from U.S. Environmental Protection Agency (EPA) Region 9 and support from the San Francisco Regional Water Quality Control Board (Water Board).

Under contract to U.S. Army Corps of Engineers (USACE), American Integrated Services (AIS) and its subcontractor, Tetra Tech EM Inc. (Tetra Tech), performed the following field activities in five phases as part of the SSI:

- Obtained groundwater elevation measurements from on- and off-site wells to verify the potentiometric surface and groundwater flow direction at the Site (Phase 1).

- Collected groundwater samples from the 11 existing on-site wells for analysis for volatile organic compounds (VOC) to verify recent VOC concentrations in groundwater (Figure 2) (Phase 1).

- Advanced 35 borings using a cone penetrometer test (CPT) rig equipped with a membrane interface probe (MIP) to identify potential on-site sources of contamination at nine locations of concern (LOC), and to identify the preferential pathways of contamination moving through the Site (Phase 2).

- Advanced nine direct-push technology (DPT) borings and collected 11 groundwater grab samples to identify potential on-site sources of contamination and confirm the preferential pathways through the Site. One soil sample was collected to assess the presence of total petroleum hydrocarbons (TPH) and VOCs at FW41A (Phase 3).

- Disposed of investigation-derived waste (IDW) off site (Phase 5).

The Final Work Plan included a plan to drill and sample up to three groundwater monitoring wells if any of the LOCs was found to have the characteristics of a source area (Phase 4). However, the investigation did not confirm any LOC as a potential source area, so no wells were installed.

1.1 SSI Report Organization

This SSI report is organized as follows:

- Section 1.0 provides an introduction and detailed site background; describes previous investigations of the Site, and geology and hydrogeology of the Site; presents the conceptual site model (CSM); summarizes the overall purpose and objectives for the project; and describes the SSI report organization.
- Section 2.0 describes the field investigation methods and any deviations from the SAP, and explains the EVS model parameters, inputs, and kriging methods.
- Section 3.0 discusses the results of each phase of the investigation and presents a refined contaminant-transport CSM.
- Section 4.0 lists the conclusions and offers recommendations resulting from the investigation.
- Section 5.0 lists documents used in preparing this SSI report.

Figures, tables, and appendices follow the text. All appendices are on CD only. Appendix A contains the Work Plan and SAP for this work. Appendix B presents the comparison of MIP response data with historical concentrations at co-located points. Appendix C presents the field data deliverables for each LOC. Appendix D presents validated data, the laboratory report, the data validation report, and a quality control (QC) data summary. Appendix E provides supporting figures and tables for a calculation of molar equivalents of chlorinated solvents at the upgradient site boundary and on site. Appendix F provides groundwater well sampling sheets, boring logs associated with the DPT borings, site logs, chain-of-custody forms, IDW waste manifests, and other field forms. Appendix G presents photographs from the field investigation, and Appendix H presents the Army's responses to agency comments on the field data summary package presented on April 5, 2011.

1.2 Site Background

The Site is part of the recently demolished Moffett Community Housing, and the former Naval Air Station Moffett Field (Moffett), Moffett Field, California (see Figure 3). The Department of the Navy (Navy) transferred the Community Housing to the Air Force in 1994. The Community Housing was subsequently transferred to the Army in July 2000. The Site encompasses approximately 77 acres. Pursuant to the Base Realignment and Closure 2005 recommendations, the Army Reserves demolished the existing housing units and associated structures over a 30-acre area in the northern part of the Site to construct a new Armed Forces Reserve Center and associated support facilities.

The Site was vacant or used for agriculture before construction of improvements including housing units and support facilities along with associated streets, parking areas, and green space. Housing was constructed between 1941 and 1982. The housing units included Moffett Homes built in 1941, Orion Park built in 1968, and Macon Terrace II and Macon Terrace III built in 1982 (Foster Wheeler Environmental Corporation [FWENC] 2002). Multi-family residences occupied most of the Site. The northern and southern rows of Moffett Homes were demolished in 1981 or 1982 to make room for Macon Terrace II and III. The remaining Moffett Homes units were demolished in 2001. The area that had been Moffett Homes is now open space.

Agricultural use continued on a portion of the Site until sometime after 1965 (FWENC 2002). Approximate locations of former farm buildings are shown on Figure 3. The former farm apparently had at least one potable water supply well. Santa Clara Valley Water District (SCVWD) well records indicate that well 06S02W15G01, approximately 160 feet deep, was decommissioned on March 24, 1993. The well was located immediately north of Housing Unit 842. The farmhouse had a septic tank and an associated drain field. Normal household usage would not suggest VOC contamination (Air Force Base Conversion Agency 2000); however, EPA information indicates solvents such as TCE may have been discharged to septic systems as a degreaser. The area around the septic tank was investigated in 2009 by the U.S. Army Center for Health Promotion and Preventative Medicine (USACHPPM) (USACHPPM 2009). No VOC contamination in soil samples was detected in the area around the abandoned septic tank, and the report concluded that the septic tank system was not a source of TCE contamination in the aquifer.

The area is relatively flat, ranging from 15 to 36 feet above mean sea level (msl). No wetlands or surface water is located within the Site. Stevens Creek runs along the west boundary of the Site.

1.2.1 Previous Investigations

Previous investigations of the Site and surrounding area were conducted to characterize the nature and extent of contaminated groundwater. The following information was reviewed before the Work Plan and Sampling and Analysis Plan (SAP) (Appendix A) for the SSI were prepared:

- National Aeronautics and Space Administration (NASA) – Report of TCE in groundwater at the downgradient boundary of the Site (Science Applications International Corporation [SAIC] 1999)
- Navy – Groundwater sampling based on the information provided by NASA in 1999 (International Technology Corporation [IT] 2000)
- Navy – Phase I and II site investigations to characterize the Site and to conduct a baseline risk assessment (FWENC 2003)
- Army – Investigation of groundwater south (upgradient) and west of the Site (The SI Group [SIG] 2003)
- EPA – Investigation of groundwater south (upgradient) of the Site (EPA 2005)
- Navy – Groundwater monitoring well installation and sampling (Tetra Tech EC 2007)
- USACHPPM – Geophysical survey, MIP investigation, and subsurface soil sampling of the former septic tank and drain field (USACHPPM 2009b)

Summaries of each of these investigations are found in Section 10.3 of the SAP, provided as Appendix A to the Work Plan (Appendix A). Sampling locations from previous investigations are shown in Figure 4.

1.2.2 Geology and Hydrogeology

This section describes the geologic and hydrogeologic conditions at the Site referencing the geologic and geochemical data gathered during previous investigations, as presented in the Work Plan and SAP (Appendix A). Information on the geology and hydrogeology at Moffett was obtained from the geology and hydrogeology technical memorandum (PRC Environmental Management, Inc. [PRC] and James M. Montgomery Consulting Engineers, Inc. [JMM] 1992), unless otherwise cited.

1.2.2.1 Regional Geologic Setting

The Site is located at the northern end of the Santa Clara Valley Basin, 1 mile south of San Francisco Bay. The land is relatively flat, ranging from 14 to 36 feet above msl. The northwesterly trending Santa Clara Valley Basin contains interbedded alluvial, fluvial, and estuarine deposits to a depth of as much as 1,500 feet (Iwamura 1980). Soils consist of varying combinations of clay, silt, sand, and gravel that represent the interfingering of estuarine and alluvial deposit environments during the late Pleistocene and Holocene epochs. The fluvial soils derived from the Santa Cruz highlands west of the basin, were deposited on an alluvial plain bounded by alluvial fan deposits to the west and the baylands bordering San Francisco Bay to the northeast (Iwamura 1980). In general, thicker intervals of sand and gravel and discontinuous intervals of clays and silt are found near the upper alluvial fan deposits located south, and upgradient, of the Site. The sand and gravel intervals are thin, and clay and silt intervals become thicker and laterally continuous close to the axis of the basin and farther from the fan deposits (as at the Site).

The upper 65 feet of sediments consist of fine-grained alluvium incised with coarse-grained deposits of gravel and sand (channel deposits), which appear to have distinct vertical and lateral boundaries. These gravel and sand deposits trend north-south and are surrounded by silt, sandy silt, and silty fine-grained sands (splay deposits) in thin blankets that extend laterally from the channel deposits. Splay deposits grade vertically and laterally into fine-grained floodplain deposits composed of silt and clay.

The streams did not meander laterally to the degree that is normally found in a fluvial environment because this area of the drainage basin was subsiding as these channel and splay deposits were being deposited. As a result, channel deposits at the Site have a “stringer-like” morphology, with individual channel deposits that are stacked upon, or incised into, each other. This vertical accretion of channel deposits may be the reason that the clay boundary between the A1 and A2 aquifer zones appears to be discontinuous in the area of the Site. Fewer channel deposits are apparent in the A2 aquifer zone than in the A1 aquifer zone. (The A-aquifer is divided into the A1 and A2 aquifer zones by a discontinuous, low-permeability horizon [A1/A2 aquitard] located approximately between 22 and 29 feet below ground surface (bgs), based on lithologic logs.)

The following lithologic descriptions are based on continuous soil cores collected during the 2007 groundwater monitoring well installation and from CPT data generated during previous investigations (Tetra Tech EC 2007).

Clay soils ranged from fines with high plasticity with minor amounts of fine sand, to fines with high plasticity with fine to coarse sand and gravel. Clay was most frequently encountered from near ground surface to approximately 10 feet bgs. The thickest continuous clay interval logged was 9 feet (monitoring well MCH-4LA at a depth interval of 9 to 18 feet bgs and MCH-10LA at a depth interval of 4 to 13 feet bgs). Groundwater was not observed in clay samples.

Silt was the most frequently logged soil type at the Site. Silt ranged from fines with low to medium plasticity with minor amounts of fine sand, to non-plastic fines with fine to coarse sand and gravel. The low to medium plasticity observed in some silt soils was an indication of clay content. The thickest continuous silt interval logged was approximately 38 feet at FW13B at a depth interval of 5 to 43 feet bgs. Groundwater was occasionally observed in sandy silt and silt with minor amounts of sand.

Sand intervals ranged from fine sand with silt, to medium- and coarse-grained, subrounded to subangular sand, with fine, subangular gravel. The thickest continuous sand interval was 14 feet at MCH-2LA at a depth interval of 30 to 44 feet bgs. Sand layers were thicker and more prevalent in the A1 aquifer zone than in the A2 aquifer zone. Many estimates of sand thickness from lithologic boreholes may be overestimated because of heaving sand conditions.

1.2.2.2 Local Hydrogeology

The shallow aquifer (approximately the upper 250 feet) is subdivided into the A-, B-, and C-aquifers. A laterally extensive clay aquitard (B/C aquitard) effectively isolates the C-aquifer (approximately 160 to 250 feet bgs) from the upper aquifers. The A/B aquitard, which separates the A- and B-aquifers, may be locally continuous, because the B-aquifer (approximately 70 to 120 feet bgs) at Moffett, located east of the Site, is largely free of the solvent contamination found in the A-aquifer.

The A-aquifer extends to an estimated depth of 65 feet bgs at the Site. Stringer-like alluvial channel deposits composed of sand and gravel constitute the permeable portion of the A-aquifer. The channels are generally oriented in the north-south direction. These channel deposits provide complex and tortuous pathways for contaminant transport. The A-aquifer is divided into the A1 and A2 aquifer zones by a discontinuous, low-permeability horizon (A1/A2 aquitard) located approximately between 22 and 29 feet bgs, based on lithologic logs.

As in most aquifers with alluvial channel deposits, these channel deposits provide preferential flow paths through the aquifer, and most groundwater that flows through the A aquifer at the Site likely passes through these deposits. The low permeability of the splay deposits and clay alluvium limits groundwater flow through these units.

Groundwater occurs at a depth of 8 to 12 feet bgs across the Site, occurring at progressively shallower depths to the north, toward the San Francisco Bay. Low-permeability material (clay and silt) has been observed from ground surface to approximately 10 to 12 feet bgs at most borehole locations. First-observed groundwater was encountered below this relatively impermeable layer. DPT and temporary well sample locations FW19A and FW20A were the only locations where the groundwater was first observed within, rather than right at the upper contact of, permeable sand and gravel deposits.

Water levels in the A1 and A2 aquifer zones were measured quarterly from August 2005 to June 2006. Water levels increased 2 to 3 feet at wells in both the A1 and A2 aquifer zones from December 2005 to March 2006, and then decreased almost back to December levels in June 2006. This pattern suggests seasonal recharge during the rainy season from December to March. Increases were greatest at wells located in the eastern and southern portions of the Site, in other words, at wells farthest from Stevens Creek. Thus, infiltration through the ground surface, or discharge through leaky storm sewers, are likely to be more important recharge mechanisms than discharge from a "losing" Stevens Creek.

Groundwater gradients estimated from the potentiometric map of the A1 aquifer zone in August 2005 range from 0.006 foot/foot at the southern and eastern portions of the Site, to 0.01 foot/foot in the west-central portion of the Site (near well MCH-9UA). The inferred flow direction is north-northwest in the southern part of the Site, bending sharply to the northwest near well MCH-9UA.

Groundwater gradients estimated from the potentiometric map of the A2 aquifer zone in August 2005 range from 0.007 foot/foot at the southern and eastern portions of the Site, slightly steepening to 0.008 foot/foot at the southwestern portion of the Site. Inferred flow directions in the A2 aquifer zone were similar to those in the A1 aquifer zone.

Hydraulic gradient calculations with and without MCH-9UA indicate a steepening of the gradient and a westerly deflection in the inferred flow direction along the western side of the Site. The flow direction suggests a strong sink for A1 and A2 aquifer zone groundwater beyond the west boundary of the Site. According to SCVWD, Stevens Creek is a gaining stream during the summer; however, this could not be verified by the investigation (acquisition of data regarding groundwater/surface water interaction was beyond the scope of this investigation).

1.2.3 Preliminary Conceptual Site Model

The following sections present the preliminary CSM for the Site as understood during the planning of this investigation. The CSM specifies movement of groundwater, identifies potential on-site and off-site sources of contaminants, and indicates fate and transport of the contamination. The CSM for the Site was refined after collection and evaluation of data; Section 3.3.6 presents the refined CSM.

1.2.3.1 Groundwater Flow

Section 1.2.2 describes the groundwater flow at the Site. Figure 2 show the potentiometric surfaces in the A1 and A2 aquifer zones as measured in November 2010. A comparison of these figures shows that the potentiometric surface elevation is approximately equal in both aquifers, except for one well in the A2 zone (MCH-8LA) that indicates an anomalously low water elevation. The groundwater flow at the Site is to the north-northwest, and the gradients are somewhat consistent across the Site.

Figure 5 also shows a potentiometric surface map based on measurements in August 2005. A comparison of the potentiometric surface maps from August 2005 and November 2010 indicates that the direction of groundwater flow is generally consistent except within the area around well MCH-10LA in the A2 aquifer zone.

1.2.3.2 Distribution of Contamination

Groundwater at the Site is primarily contaminated with TCE and its breakdown product, *cis*-1,2-dichloroethene (DCE). TCE concentrations are generally higher in the lower aquifer zone (A2) than in the upper aquifer zone (A1). Concentrations of TCE in the A1 aquifer zone are relatively consistent from the south to the north across the Site (see Figure 6). Past investigations found that TCE concentrations in the A2 aquifer zone generally increase from the southwest to the northeast across the central area of the Site (see Figure 7).

Although the distribution patterns for TCE and DCE in the A1 aquifer zone indicate similar concentrations from the southern to the northern boundaries of the Site, TCE concentrations at some sample locations are anomalously high relative to concentrations at upgradient sample locations; however, this doesn't necessarily indicate a source area.

The distribution patterns for TCE and DCE in the A2 aquifer zone are consistent with those found in the A1 aquifer zone (Tetra Tech EC 2007). As within the A1 aquifer zone, concentrations at some sample locations are anomalously high relative to concentrations at upgradient sample locations.

Results from groundwater grab samples collected in February 2011 for this SSI confirmed previous findings regarding movement of TCE and DCE through the Site. The CSM describing contaminant transport and distribution was refined using data collected during this SSI, and is presented in Section 3.3.6.

1.2.3.3 Preliminary Identification of Potential Sources of On-Site Releases

As described in Section 1.1, the Site was used for agriculture before military housing was built. During the 1940s, the military began to construct housing on the Site, and shared the property with the farm owner until 1965. After 1965, the property was used for military housing until 2001. The military began to raze housing units in 2001, and the last of the military housing was demolished in 2009.

The potential sources of on-site releases at the Site are agricultural workers (until 1965), residential backyard mechanics living in the military housing area (early 1940s through 2001), construction workers during construction of the Moffett Boulevard and Highway 101 interchange (circa 1963), and commercial workers during construction of the various phases of military housing. Table 1 and Figures 8 and 9 describe and show the potential source-release scenarios for on-site contamination.

1.2.3.3.1 Agricultural Workers

The potential sources of TCE or other related solvents from an agricultural worker are limited to cleaning farm equipment or septic tanks (Figure 8). The volume and frequency of solvent used to clean farm equipment are likely to be low and infrequent. Furthermore, the solvent of choice to clean equipment parts would most likely be gasoline or diesel fuel, which a farmer is likely to already own. Farmers are unlikely to waste large volumes of TCE by disposing of it down the drain or on the ground surface. Therefore, the potential release volume to ground surface from cleaning farm equipment is likely to be small.

The farm at the Site included a septic tank, which could have been degreased with a chlorinated solvent. However, the area of the abandoned septic tank was investigated, and the results of the investigation concluded the septic tank area is not a source of on-site contamination (USACHPPM 2009).

1.2.3.3.2 Backyard Mechanic

The backyard mechanic is a potential release source of small volumes of chlorinated solvents (Table 1 and Figure 8). Because of the nature of the organization and operation of military personnel; however, it is highly unlikely that a single source area would exist for a long time period. Military personnel customarily move every 4 years, so rarely is one person in a residence for longer than this period. As a result, repeated releases by a backyard mechanic in the housing area would be ephemeral. In addition, backyard mechanics work with small volume of chemicals and any releases would be infrequent or periodic (for example, a half-gallon of TCE released every Saturday for 3 weeks, or once every 3 months). The pathway of contamination of these types of releases is either directly onto the ground or through a storm drain or sanitary sewer. Figure 10 shows the historical storm drains and sewers at the Site.

1.2.3.3.3 Construction Worker

Releases by a construction worker (Table 1 and Figure 9) would have a short overall duration because the work is temporary. Historical aerial photographs show a potential staging area for construction of the Moffett Boulevard and Highway 101 interchange, which took place in the southern portion of the site around well MCH-1UA (FWENC 2002) (Figure 12). Releases from construction activities also could have occurred during the construction of the houses and related facilities. Construction of the interchange likely lasted no more than 1 to 2 years. Spills may have occurred at this site as a part of minor maintenance of construction equipment, such as degreasing surfaces of equipment for servicing and cleaning mechanical parts during mechanical repair, resulting in 1 to 5 gallons per release spilled onto the ground surface. Major repairs would most likely not be completed at the site; instead, the equipment would be removed and replaced if major repairs were required. Potential sources of chlorinated solvents from construction would be incidental release of TCE from a storage area (for example, leakage from buckets) or disposal of spent TCE to the ground surface. There would not be a subsurface release point of contamination because there were no on-site storm sewers in the area (the structure of the storm drain system is linked directly with construction of Macon Terrace II, built after the interchange, see Figure 10). Therefore, the volumes of chlorinated solvent released from a construction worker at a staging area would have been irregular and a low to moderate volume and are unlikely to significantly contribute to contamination at the Site.

1.2.3.3.4 Commercial Workers

Potential releases under the commercial worker scenario (Table 1 and Figure 9) at the Site specifically involve the paint storage locker located near the central part of the site (Figure 12). Since the building was identified as a storage locker, regular activities that would result in a release would not likely occur at the Site. Instead, incidental spills or leaks would be the most likely release mechanism. The volume could range from 1 gallon to 55 gallons, and the initial release point would most likely be to the ground surface via transport through the foundation of the storage locker floor, or through a floor drain in a storage unit if it existed (possible secondary release point). The Army is unaware of any drawings on record for this building besides a drawing from the Yards and Docks collection (Navy 1956). The releases on Site from the paint storage locker would have been irregular and of low to moderate volumes.

1.2.3.4 Potential Sources of Off-Site Releases

Identification of specific potential off-site sources of upgradient contamination is beyond the scope of this investigation. A large number of chlorinated solvent plumes have been identified throughout the urban and industrial portions of Santa Clara County, some of which stretch for many miles. There are numerous commercial and industrial sources potentially contributing to the TCE plume underlying the Site. The commercial- and industrial-scale sources are the most likely source points for larger volumes of TCE and for frequent and regular releases over longer periods. Contamination could have occurred because industry commonly used chlorinated solvents in production (for example, private computer chip manufacturers), or maintenance (for example, electric utility maintenance yard). Volumes and durations of off-site releases are likely much greater than volumes of potential on-site source releases.

1.2.3.5 Preliminary Fate and Transport of Contamination Model

In the A1 aquifer zone, three mechanisms could alter contaminant concentrations in the shallow aquifer (Figure 11):

- Leaking storm drain pipes could discharge storm water to the unsaturated zone, which could percolate to the water table and leach chemicals to the saturated zone. Conversely, large volumes of storm water could dilute existing contaminant when recharging the A1 aquifer zone.
- Rain or lawn irrigation could infiltrate through unpaved areas to recharge the water table (especially in low areas where rainwater pools).
- In unlined portions of Stevens Creek, surface water may discharge to the groundwater table through the creek bottom sediments or creek banks, particularly during high stages in the winter. Water may flow laterally away from the creek in areas where permeable soils intersect the creek (both on site and in upgradient, off-site source areas).

In the A2 aquifer zone, the mechanisms that could alter contaminant concentrations are less influenced by recharge to the water table than from mechanisms discussed above. The primary mechanism for transferring additional contaminant mass from a source in the unsaturated zone is infiltration of precipitation and storm water during the rainy season (a seasonal pulsed release).

The volumes released by the four potential on-site sources (agricultural worker, backyard mechanic, construction worker, and commercial worker) are unlikely to generate sufficient entry pressures to displace groundwater and penetrate the capillary fringe as a mobile non-aqueous phase liquid (NAPL). In a more likely scenario, the solvent material would be dispersed laterally as it encounters increasingly water-saturated soil conditions, until it spreads out as an immobile residual phase in the lower vadose zone and upper capillary fringe. Some portion of the contaminant mass would be dissolved and flushed into and through the capillary fringe by pulses of infiltrating water. This process would result in gradual contamination of the aquifer via seasonal "pulses," and would leave a long-term, yet diminishing source within the capillary fringe.

Agricultural releases, if any, ceased after 1965, and potential residential releases from the backyard mechanic may have occurred until 2001, when the housing area closed. Even if the contamination breached the capillary fringe, the volumes released would have been unlikely to penetrate 20 to 30 feet of the saturated zone to reach the A2 aquifer zone. The primary leaching mechanism for solvent in unsaturated zone from an on-site source is limited to infiltrating precipitation during the rainy season (a seasonal pulsed release).

1.3 INVESTIGATION PURPOSE

During prior investigations, chlorinated solvents—primarily TCE at concentrations up to 1,200 micrograms per liter (µg/L)—have been detected in groundwater samples collected from the Site. Although no historical records indicate TCE use at the Site, undocumented releases may have occurred. The SSI included additional characterization to investigate potential source areas of TCE identified by the oversight agencies as LOCs. Nine LOCs were identified through review of historical groundwater sampling data, historical aerial photographs, and previous contractors' reports (Figure 12). The upper, unconfined A1 aquifer zone was targeted for investigation at LOCs 1, 2a, 2b, 3, and 4, and the lower A2 aquifer zone, which underlies the A1 aquifer zone, was targeted for investigation at LOCs 5a, 5b, 5c, and 6b.

A second purpose of the SSI was to investigate the LOC 4 area around boring FW41A, where field photoionization detector (PID) screening of vapors from soil cores in 2002 showed between 9.2 and 3,500 parts per million (ppm) by volume of volatile organic compounds (VOC) in the capillary fringe. Soil samples were not collected in 2002 at the corresponding depth interval to determine the source of the high PID screening result; therefore, as part of the SSI, the Army collected and analyzed a soil sample at this location to identify those compounds.

1.4 ASSUMPTIONS AND LIMITATIONS

The main limitations of this investigation were the large size of the Site and the absence of known point sources at which to focus the investigation. A decision logic process was tailored to address the "indefinite" sources—specifying a spatial pattern of sampling locations, a set of criteria for decision making, and a logical sequence of questions to pose in assessing the data gathered from the sampling locations.

The resulting plan and its implementation were dynamic, as the decision logic process was conducted in real-time while the field team was mobilized. Thus, the investigation is considered to have achieved its goals regarding the nine LOCs.

2.0 METHODS

The field investigation proceeded in accordance with the SAP (Appendix A), except where noted below in Section 2.1.5. The SAP was prepared with input from the EPA and Water Board during meetings on August 10, August 16, and September 2, 2010; both oversight agencies indicated concurrence on the SAP on November 8, 2010. This section describes the field methods employed at the Site from November 18, 2010, through February 16, 2011.

2.1 FIELD INVESTIGATION METHODS

The field investigation was conducted in phases that included groundwater elevation measurement, groundwater monitoring, CPT/MIP, DPT, and data evaluation using EVS. Field and evaluation methods are described in the following sections.

2.1.1 Groundwater Monitoring and Elevation Measurement

Water levels were measured at on-site wells by the Navy during the regional groundwater elevation monitoring event (termed "Black Thursday") on November 18, 2010. On the same day, AIS/Tetra Tech measured water levels at the off-site wells south of the Site at the former vector control yard currently owned by the City of Mountain View, and previously operated by Santa Clara County. The field team recorded all water levels to the nearest 0.1 inch in field logbooks and on groundwater sampling sheets (see field forms in Appendix F). All water levels were measured with a water level indicator. The Navy also measured water levels in wells located to the east of the Site, and NASA measured water levels in its wells, located to the north of the Site. AIS/Tetra Tech coordinated with Navy and NASA personnel to share all water level data.

Groundwater elevation measurements obtained during the Black Thursday event were used to create a potentiometric surface map in order to determine groundwater contours and flow direction at the Site for both the A1 and A2 aquifer zones (Figure 2). The proposed CPT and MIP boring locations for LOC 6b were adjusted based on the potentiometric surface contour map of the A2 aquifer zone.

Groundwater samples were collected on January 3 through 5, 2011, from the 11 existing on-site wells (Figure 2) by use of peristaltic or non-dedicated submersible bladder pumps as described in the SAP (Appendix A). Groundwater sampling sheets are presented in Appendix F (Field Forms).

Groundwater samples were sent to EMAX laboratories in Torrance, California using chain-of-custody protocol, and analyzed for VOCs. Purge water was handled as discussed in Section 3.5.

2.1.2 CPT/MIP Methods

During January 17 through 28, 2011, a CPT/MIP was pushed using a DPT rig to investigate the subsurface and yield an overall profile of the lithology and VOC distribution. A dynamic sampling strategy following the decision logic diagram in the SAP was implemented to delineate areas with high VOC concentrations (Figures 13 and 14). The dynamic strategy allowed for addition of new CPT/MIP locations at each LOC based on real-time data. A total of 36 borings were advanced: 15 to investigate the A1 aquifer zone, 15 (including 1 refusal) to investigate the A2 aquifer zone, and six to investigate on-site upgradient conditions and to assess preferential pathways through the Site.

CPT provides detailed hydrogeologic logging by pushing an instrumented cone into the ground at a controlled rate. The CPT cone has two pressure sensors: one mounted on its tip that measures the tip resistance — the pressure at the tip of the instrument as the cone penetrates the formation — and one mounted on its side that measures the sleeve friction, or the frictional resistance to the cone as it passes through the formation. The data are recorded at small intervals (15 readings per foot of penetration), providing a near-continuous record of soil characteristics. The tip resistance and sleeve friction are used to calculate the in situ soil behavior type (SBT), which is considered predictive of the Unified Soil Classification System (USCS) soil classification that would result from conducting geotechnical soil tests on an ex situ soil sample (Robertson 2009).

The MIP is a sampling tool that produces a nearly continuous profile of VOC concentrations at 0.5- to 1-foot intervals. The MIP tool heats adjacent media to 120 degrees Celsius (°C) as it penetrates the subsurface. The heat volatilizes VOCs in the immediate area; the MIP then draws the constituents through a gas-permeable membrane and into a carrier gas that is circulated to the surface and analyzed with three different detectors: a PID, which measures VOCs in ppm, a flame ionization detector (FID), which measures VOCs using a flame and gas chromatography in microvolts (µV), and an electron capture device (ECD), which measures VOCs via electron capture ionization in µV. A separate log is plotted for the responses measured by each detector used. Logs are presented within the field data deliverables for each LOC in Appendix C (LOC CPT/MIP Field Data Deliverables). MIP results are not matrix-specific; constituents may volatilize from soil, soil gas, or the free phase liquid above the water table, and from soil, groundwater, or the free phase liquid below the water table. This tool effectively sums VOC concentrations that have partitioned into different media, and detects VOC concentrations in the vadose zone, capillary fringe, and saturated zone.

For this investigation, penetration was paused at 1-foot intervals at all pushes to reach 120 °C. Between 5 and 15 feet bgs at some locations, the probe was paused at 0.5-foot intervals to obtain a more continuous profile through the capillary fringe. The concentration of VOCs indicated by the use of the MIP's detectors represents a sum of all VOC concentrations that respond to the detector, thus, the MIP does not provide analyte-specific results.

The MIP ECD logs provided in Appendix B (Comparison of MIP Response to Historical Data at Co-Located Points) also include the electrical conductivity (EC) plots. The EC response can be used to evaluate the extents of permeable deposits because the EC log deflects to the left when sandy deposits are encountered and deflects to the right when clays are encountered.

CPT/MIP sampling was implemented to identify hot-spot areas as potential on-site sources of TCE. CPT/MIP locations are shown on Figure 12. Field decisions were based on the decision logic depicted on Figures 13 and 14. Section 3.2 documents decisions during the investigation of each LOC and explains the rationale supporting the selection of locations for advancing borings.

CPT/MIP sampling was compared with, and followed by, discrete interval groundwater grab sampling using DPT. After all field work had been completed, drill rigs and equipment were demobilized from the Site. All IDW was handled as discussed in Section 3.5.

2.1.3 Comparison of MIP Response to Co-Located Groundwater Results

Comparison of MIP's ECD response to groundwater results is achieved through response testing with known standard liquids and sample concentrations, and qualitative comparisons with groundwater concentrations measured in monitoring wells and DPT borings.

2.1.3.1 Standard Liquids

QC for the ECD is achieved through response testing with known standard liquids. The ECD is immersed in a series of aqueous TCE solutions with standard TCE concentrations (100 parts per billion [ppb], 1 ppm, and 10 ppm), and the response in µV is measured and recorded. An example response test graph is provided as Figure B-1 in Appendix B (Comparison of MIP Response to Historical Data at Co-Located Points).

If the response is not within the predetermined acceptable range, the operator must diagnose and correct the reason for an inaccurate reading--such as a blocked sample port, a trunk line improperly heating, or a problem with the electronics—and then re-test the instrument. Response tests were conducted before and after every push during this investigation. All of the response tests confirmed the instrument was operating properly before being used.

2.1.3.2 Sample Concentrations

Another way to assess instrument performance is by comparing the MIP response to known sample concentrations. This; however, is not as straightforward as it may seem, and a linear relationship between ECD responses and TCE concentrations is generally not achievable because of temporal differences, spatial variability, matrix effects, and probe membrane wear.

Prior to the investigation, an ECD response of approximately $3x10^5$ to $5x10^5$ µV was expected to correspond to a range of concentrations from the detection limit to approximately 10 µg/L; an ECD response of approximately $5x10^5$ to $9x10^5$ µV was expected to represent a range of concentrations from 10 to 100 µg/L; and an ECD response in the range of $1x10^6$ to $5x10^6$ µV was expected to correspond to a range of TCE concentrations of 100 to 1,000 µg/L. These were approximate guidelines, based on past experience with MIP at other sites. Past experience also suggested that a MIP response of $1x10^7$ µV or greater would indicate TCE in the NAPL phase.

Appendix B (Comparison of MIP Response to Historical Data at Co-Located Points) shows the relationship between ECD responses and TCE concentrations in groundwater samples from monitoring wells and from DPT samples. The initial point of investigation (MIP #0) at each LOC was co-located with either a monitoring well or a grab groundwater sampling location to evaluate the correspondence between the ECD responses and analytical results from the groundwater samples. MIP #0 was co-located with monitoring wells at LOCs 1, 2a, 2b, 5a, and 6b; and with DPT groundwater grab sampling locations at LOCs 5b, 5c, 3, and 4.

DPT groundwater grab samples were collected in 2002, and because the samples were 8 years old at the time of this SSI, a comparison with a DPT result was to be referenced only to suggest whether an ECD detection would be above or below background. Nonetheless, most results did fall within the expected ranges. The two highest ECD responses (within the DPT sample intervals) of approximately $1x10^6$ µV at the MIP #0 locations for LOCs 5b and 3 corresponded to TCE concentrations of 190 µg/L at an interval of 16 to 17 feet bgs at FW17B, and 210 µg/L at an interval of 16 to 17 feet bgs at FW15B.

2.1.3.3 Qualitative Comparisons with Groundwater in Monitoring Wells

Qualitative comparisons with concentrations of TCE in monitoring wells were made using sample results from wells that were sampled a few weeks before the MIP investigation began, thus minimizing temporal differences. However, the long (10-foot) screens of most monitoring wells span many geologic layers, thus mixing water from different layers that may have sharply different TCE concentrations, making comparisons with point values extracted from the ECD log difficult.

The comparisons were generally better in the A1 aquifer zone where the MIP #0 peak responses at LOCs 1, 2a and 2b were in a range of $7.2x10^5$ to $1.3x10^6$ µV, corresponding to a range of TCE concentrations from 180 to 400 µg/L. Although the ECD responses were muted in some parts of the A2 aquifer zone, they did deflect from the baseline signal wherever TCE contamination was expected, based on TCE concentrations in monitoring wells and groundwater grab samples. It is also important to note that the highest ECD responses generally occur on the upper and lower contacts of sand deposits, rather than in the most permeable portions.

The highest ECD response was usually in the silty sand deposits that bound the main channel deposits, above and below the most permeable material (these layers are indicated by EC responses between the two extremes discussed above). The elevated ECD response in the silty sand layers may indicate that the ECD response is affected by higher groundwater flow within the most permeable portion of the channel, thereby diluting the higher TCE concentrations in the lower-permeability materials at the upper and lower contacts of the channel deposit.

2.1.3.5 Qualitative Comparisons with Groundwater in DPT Borings

Finally, the best comparison could be made where a DPT groundwater grab sample was co-located with a MIP push during the Phase 3 investigation. This comparison was the most valid because the point value of the ECD response was compared to the analytical result from a sample collected within a small interval, rather than a long screen interval, and the sample was collected within one month after the MIP was pushed, precluding the issue of variability in time.

Four DPT groundwater grab sample locations were co-located with MIP locations; all were in the A1 aquifer zone. Sample LOC6b-DP-05 was collected within the 12- to 13-foot bgs interval adjacent to MIP LOC6b-0-LA, where the ECD response was close to background ($3.6x10^5$ µV). The TCE concentration was 0.36 µg/L, so this sample exhibited very good correlation with a near-background ECD response. Similarly, the TCE concentration of 0.76 µg/L within the 15- to 16-foot bgs interval at LOC3-DP-03 compared favorably with a low ECD result ($4.5x10^5$ µV at

LOC3-P4-UA). Those sample pairs are very important because they demonstrate good agreement at the low end of the detection range at the uppermost portion of the A1 aquifer zone at and just below the capillary fringe. The other two co-located samples were collected at LOC3-DP-01 adjacent to MIP LOC3-0-UA within the 15- to 16-foot bgs and within the 17- to 18-foot bgs intervals. The TCE concentrations were 94 and 110 µg/L, which compared favorably to the relatively high ECD responses of $0.5x10^6$ µV and $1.7x10^6$ µV LOC3-0-UA.

2.1.4 DPT Methods

During the DPT investigation on February 14 through 16, 2011, 11 groundwater grab samples were collected and analyzed for VOCs, and one soil sample was collected and analyzed for VOCs and TPH as gasoline, motor oil, and diesel fuel.

Samples were collected using a DPT rig and temporary wells. Temporary wells were installed with the intention to leave them and return once the water had filled the casing, as the soil type at the target depth interval in most of the borings was clay. A 2-inch-diameter outer rod equipped with a shoe and a 1-inch-diameter inner rod equipped with a tip were advanced to the target sample depth. The outer rod was then pulled back 1 foot to expose the sample interval, and the inner rod was removed. A 3/4-inch polyvinyl chloride (PVC) pipe with a 5-foot screened section (0.010-inch slots) was then inserted to replace the inner rod, and was pushed to the bottom of the hole. In all cases, the formation in the exposed interval remained open while the pipe was installed.

New PVC pipe was utilized, and a new disposable bailer was used to collect a sample at each location. When quick recharge occurred, samples were collected immediately. All groundwater grab samples were placed in vials, labeled, and kept in an ice-filled cooler until they were analyzed for VOCs at a fixed laboratory.

One subsurface soil sample was collected using DPT to assess a potential hotspot at FW41A in LOC 4. The soil sample was obtained from an acetate sleeve placed inside the core barrel. An EnCore™ sampler was used to collect the soil sample from the acetate sleeve for analyses for VOCs and TPH as gasoline. The remainder of the acetate sleeve was capped and submitted to the laboratory for analysis for TPH as diesel and motor oil.

The DPT core barrel was decontaminated just before sample collection at each location so that compounds in the upper soil column would not contaminate the sample interval. Soil generated from borings was placed in a labeled drum at the drill site, and characterized and disposed of as described in Section 3.5.

After the samples from each boring had been collected, the subcontractor completely sealed each borehole with a bentonite and cement grout. The grout was emplaced through the drill pipe starting from the bottom of the hole and brought to the surface. All borings were then staked, and the locations were surveyed using global positioning system (GPS) technology. After all field work had been completed, drill rigs and equipment were demobilized from the Site.

2.1.5 Deviations from the SAP

The sampling method for the groundwater grab samples was slightly altered due to concerns that the clay-like soil type would inhibit the groundwater from entering the Hydropunch casing. Modifications in the field included leaving the temporary well casing in the ground for up to 30 minutes (instead of collecting the sample immediately) to allow time for the groundwater to enter the casing.

At some locations, field personnel elected to collect a measurement every 0.5 vertical foot (instead of every 1.0 vertical foot) at the depths where the capillary fringe was expected to occur, in order to obtain a better VOC profile through the capillary fringe.

Additionally, per Step 2 of the project quality objectives (PQOs) (Worksheet #11 in the SAP [Appendix A]) groundwater wells were not installed and an additional round of groundwater sampling was not conducted because no on-site sources were identified.

2.2 EVS Model

EVS is a modeling software program that creates 3-dimensional (3D) visualizations from subsurface geologic, hydrologeologic, water table surface, and chemical concentration data. EVS combines data to create geologic cross sections and 3D models that can be used to refine the CSM iteratively.

EVS was used to conduct the following tasks:

- Before Investigation: Combine groundwater and lithology data from previous investigations, and incorporate these data into EVS to assess: (1) the most likely locations of potential sources; and (2) locations of elevated TCE concentrations in groundwater related to these sources.
- During Investigation: Incorporate CPT and MIP data into EVS and evaluate the resulting model in EVS to guide placements of additional CPT/MIPs during Phase 2, and to determine locations for DPT groundwater grab samples during Phase 3.
- After Investigation: Develop a model of the site geology, and depiction of the TCE plume as follows:
  - Merge geologic data from CPT logs and lithologic logs into a common data set to characterize the distribution of soil types across the Site in 3D. The resulting soil-type characterization was depicted as a solid model of geology, and displayed as individual borehole logs (Figure 16).
  - Discretize and krige MIP responses in EVS (described in the following section) to develop a solid model of ECD responses representing the distribution of VOCs in soil and groundwater throughout the Site (Figures 17 through 21).

- Combine the solid model of geology with VOC distribution and groundwater potentiometric surfaces (from water level measurements) to assess preferential flow paths of TCE plumes within the Site (Figures 22 through 25 and 29).

The data inputs used to construct the EVS model, the geostatistical analysis performed by the EVS model, the output figures from the EVS model, and the assumptions and associated uncertainty with the EVS model are described in more detail in the following sections.

2.2.1 Input Data

Geologic, hydrologic, and two types of chemical data were input into the EVS modeling system. Chemical data obtained with the MIP were pre-processed and aggregated into a single input file for the entire Site (the MIP log files had been provided to AIS/Tetra Tech as ASCII files, with each row of data corresponding to a depth-specific suite of sensor measurements).

Similarly, a single input file for Site lithology was built as an aggregate of SBT values from the CPT boreholes combined with lithologic determinations at boreholes logged by field geologists. The procedures used to create these files, as well as the files containing discrete groundwater sample concentrations and water level measurements at monitoring wells, are discussed below.

2.2.1.1 Geologic Data

The geologic data input to the model were lithologic descriptions obtained from geologic borehole logs and from CPT logs.

Lithologic borelogs are prepared by geologists who have directly observed soil cores and recorded their characteristics using the USCS. Thus, these borelogs represent direct observations of the physical characteristics of the soil, particularly the grain-size distribution of granular soils.

CPT logs provide a continuous profile of the soil column, and interpretation is consistent from borehole to borehole. Because the measurements are conducted *in-situ*, the sampled medium is relatively undisturbed. The CPT measures the various pressures exerted on the cone as it penetrates the soil to assess the soil "behavior" and relates this behavior to USCS lithologies through empirical relationships.

To maximize usefulness of a solid model of the Site's hydrogeology, both types of data were combined into a single data set in the EVS model. Table 2 presents the unified classification scheme used to merge the two data sets. The two right-hand columns list the SBT soil classifications, using the integer scale developed by Robertson (Robertson and others 1986).

The integer scale assigns soils one of 12 SBTs based primarily on their tip resistance and sleeve friction, with soft, cohesive soils (low tip resistance, high frictional resistance) at the low end of the scale and hard, granular soils (high tip resistance, low frictional resistance) at the high end of the scale. The two exceptions are the "sensitive fine-grained" soils (assigned a value of 1) that have low tip resistance and low friction resistance, and over-consolidated soils (such as caliche) that have high tip resistance and frictional resistance (assigned values of 11 to 12). Most SBT categories are not identified as a single soil type, but rather as a range such as "clayey silt to silty clay," which is assigned a value of 5.

To modify the system to accommodate the USCS lithologies identified in lithologic borelogs, each USCS soil type was assigned a number that positioned it with respect to the SBT ranges. Because the SBT scale consists of integers, many USCS soil types would have values between the integers—for instance, silty sand is positioned on the boundary between SBT classification 7 (silty sand to sandy silt) and 8 (sand to silty sand). Thus, silty sand was assigned a value of 7.5.

The CPT logs were pre-processed to reduce the aggregate input file to a manageable size and to match the data frequency (number of values per foot of CPT boring) to that occurring at lithologic boreholes (most geologists record lithologic data at minimum intervals of 0.5 foot). This was accomplished by extracting one line of data every 0.5 feet, rather than averaging all the data obtained through a 0.5-foot interval. This approach was taken to avoid mischaracterizing the distinct soil layers that would likely be observed (such as a sand or clay layer) by averaging them all to silt. Although this approach arguably has limitations in representing the bulk characteristics of the soil, it represents the heterogeneity of the sampled soils.

As mentioned above, data obtained at lithologic boreholes is generally recorded at 0.5-foot intervals. Thus, all borehole logs from boreholes that were continuously logged were evaluated using Table 2, and the corresponding index value was entered into the aggregate data file at 0.5-foot intervals.

2.2.1.2 Hydrologic Data

The hydrologic data set consisted of depth-to-water measurements from monitoring wells in and around the Site that had been converted to water elevations, above msl, referenced to the North American Vertical Datum of 1988 (NAVD88). Water level measurements were obtained at wells screened in both the A1 and A2 aquifer zones. Input data files were created for two different measurement events—November 2010 and January 2011. The November 2010 data set was used in the EVS visualizations because it is a larger data set, including wells located on the Site and wells within surrounding portions of NASA and Moffett Field (Figure 12).

2.2.1.3 Chemical Data

Two types of chemical data were included in EVS input files: (1) discrete chemical sample results from monitoring wells and DPT grab samples, and (2) ECD response values measured in µV. The discrete results are from the SSI investigation, as well as earlier investigations dating to 2002. The input files consisted of groundwater sample results for TCE and its daughter products. Discrete sample results displaying concentrations in µg/L were not used in the kriging process. The concentration is displayed as a number at the depth the sample was collected adjacent to a boring or monitoring well. All color-coded chemical data were generated based on the ECD response in µV.

MIP data were provided in ASCII files, one measurement per row with the individual parameters (depth, temperature, PID, FID, and ECD responses) per column. MIP data, similar to CPT data, are obtained at closely spaced intervals, except that the only valid MIP results are obtained when the penetration is paused long enough for the probe to heat the formation to at least 120 °C. Thus, the MIP ACSII files required pre-processing to reduce the input file to a manageable size, and to remove invalid data. To accomplish this, the data were sorted by temperature, and the rows with temperature values below 120 °C were culled from the file. The remaining data were preserved in the input file. The resulting data frequency is one measurement per foot of MIP boring at most locations, with measurements at half-foot intervals in the capillary fringe of MIP borings at the suspected or indefinite sources (generally those MIP borings labeled LOC#0). The PID, FID, and ECD data were included in separate columns in the input file. However, because the ECD data are the most representative of TCE concentrations, only the ECD data were geostatistically processed, as discussed in following sections.

2.2.2 EVS Geostatistical Analysis

The EVS used a three-dimensional kriging algorithm to estimate the ECD responses. Kriging is an interpolation method that assumes the parameter values vary continuously from one location to the next, and that points close together have some degree of spatial correlation, while widely separated points are statistically independent (Davis 1986). Unlike other linear least-squares algorithms, such as the widely used "inverse-distance weighted" method, kriging fits a geostatistical model that allows three-dimensional variation of the weights attributed to the data.

Geostatistical analysis is a two-part process. First, a "variogram" is fitted to the data. The variogram models the correlation of the variable to its location in three-dimensional space. In the second step, the data are "kriged," meaning values are estimated at each node of the estimation grid based on the variogram model developed in the first step. In EVS, the variogram model is fitted automatically; while the user specifies a number of parameters that guide the kriging procedure. Specified parameters guide how the estimation grid algorithm is developed, and how the data are processed, searched, and weighted. The user-specific parameters are discussed below.

2.2.2.1 Estimation Grid Algorithm

The type of estimation grid algorithm selected was "adaptive gridding." Adaptive gridding alters the grid so as to position each known data point at a grid node. This ensures that the kriging algorithm will honor each known point.

The first step in developing an adaptive grid is to specify the boundaries of the grid and the gridding algorithm. In EVS, the user can either create a grid that is slightly larger than a three-dimensional shape (referred to as a "convex hull") that encloses all the data points or bound a grid with geologic surfaces created by the user. The geologic surfaces option uses the contoured ground surface at the top and a surface defined by the deepest borings at the bottom to provide for a smoothed model, which avoids wavy upper and lower surfaces in areas where data density may be less, such as between the LOCs. A 5-foot depth was subtracted from the upper surface so that the model would not use the MIP data generated in the first 5 feet, which were not valid because these data had derived from the hand-augered (disturbed) portion of each CPT/MIP boring.

2.2.2.2 Data Processing

The data were processed using the "log 10" option, which takes the base 10 logarithm of each data value before the data are kriged. Chemical concentration data, and by extension, ECD responses caused by chemical concentrations, are usually best modeled using a log transformation of the data.

2.2.2.3 Data Searching

The data were searched using the "octant search" option in the EVS model. Search parameters guide the kriging algorithm's selection of data analyzed at each point. The "octant search" option, which divides the search neighborhood into eight equal wedges (octants) that are centered on the grid node, was used because it forces the algorithm to select at least 20 points within each octant surrounding a node. Within each octant, a maximum number of points (up to one-fourth of the total points) is selected. Then points are taken sequentially from each octant up to the maximum number of total points or until all the octant's points have been used. This procedure "declusters" the data when the samples are grouped together rather than evenly distributed across the model domain.

2.2.2.4 Data Weighting

The geologic data were weighted in horizontal and vertical directions away from a given model node to reflect horizontal/vertical anisotropy ratios used in the kriging algorithm. In most cases, geologic materials are deposited with platy clay minerals oriented horizontally, and thus flow of water in both the saturated and unsaturated zones can be slower in the vertical direction than in the horizontal direction. Consequently, contaminant distributions also tend to be oriented or concentrated more in the horizontal, rather than vertical, direction. The horizontal/vertical anisotropy ratio basically tells the kriging algorithm what multiplication factor should be used to apply biased weighting on data points in horizontal and vertical directions away from a given model node. The default value for the kriging algorithm is 10, which allows data points in a horizontal direction away from a model node to influence the kriged value at that node 10 times more than data points an equal distance away in a vertical direction.

A higher value of 100 for the kriging algorithm was selected for this exercise because the MIP data in this project derived from sampling closely spaced along vertical borings. The MIP data were estimated at 0.5-foot intervals at each boring, creating a "stack" of data points. However, most of the MIP borings were separated by 10 to 100 feet or more, even within a LOC. Thus, without a high anisotropy, the estimated value at any model node close to a MIP boring would use only the data from that single boring to fulfill its data requirement for the octant within which the boring lies. This would result in a distorted model with contaminant hot spots that would be strongly vertical, similar to a series of stovepipes.

2.2.3 Guide to Interpreting EVS Model Figures

The results of the EVS modeling conducted after the field investigation used to depict the TCE plume are presented in this report as a series of figures. The following discussion presents guidance for interpreting these figures.

The EVS-generated figures were created by interpolation of closely sampled (one reading every vertical foot) ECD responses at the 36 MIP borings and TCE concentrations from 11 groundwater grab samples from the recent investigation, coupled with lithologic data generated from two earlier investigations. The input of lithologic and MIP data provides a robust model of VOC contamination at the Site. The EVS-generated figures show all of the discrete data points used to develop the plume model. The data points are shown to help reviewers understand and evaluate the relationship between data density and the accuracy of the model at any one location. The figures produced from the EVS model are three-dimensional and incorporate multiple data inputs, as described above in Section 2.2.

Three types of EVS-generated figures are used in this report to present investigation results:

- One figure depicts the sand and gravelly sand distribution as a solid model of geology (Figure 16)
- Five figures show the kriged distribution of MIP response across the Site as a solid model representing the distribution of VOCs in soil and groundwater throughout the Site (Figures 17 through 21), and
- Four cross sections (Figures 23, 24, 25, and 29) and one fence diagram (Figure 30) present the distribution of ECD response (as slices of the solid model) with depictions of lithology at the boreholes that make up the cross section, as well as TCE concentrations detected in groundwater grab samples (Figures 23, 24, and 25).

All figures depict the estimated location of the A1/A2 aquitard surface, which was contoured using lithologic and CPT data generated from this and prior investigations. Low-permeability units that constitute the A1/A2 aquitard are generally found between depths of 22 and 29 feet bgs across the Site, with most between depths of 24 and 27 feet bgs. On the figures, the A1/A2 aquitard surface is included at about 50 percent transparency to depict the relationship of the A1/A2 aquitard to the features depicted by the solid models or the cross sections.

Figure 16 and Figures 18 through 21 show site features as viewed by an observer located northeast of the Site, at an angle of 25 degrees from horizontal. The surrounding roads and outlines of the LOC areas are also shown to help orient the reader. The 3D model viewed from this 25-degree angle is optimal for displaying the geologic, hydrologic, and chemical variables in a clear and unobstructed manner.

Figure 17 shows the same data as Figure 18, but from a top view; Figure 17 was included to orient the reader to the LOC areas in the ECD response figures.

Figure 16 – Solid Model of Geology

Figure 16 shows the interpolated EVS model of the sand and gravel channels within the A1 and A2 aquifer zones throughout the Site. The EVS model portrays lithologic variation across the Site through the kriged distribution of these data and shows the discrete results of the CPT and lithologic logging, which are depicted as color-coded intervals at the boreholes themselves. The SBT categories estimated by the CPT (Section 2.2.1), and their lithologic log equivalents, were kriged, providing a three-dimensional solid model of geology. The finer-grained layers (SBT less than 7) were then subset (peeled away) in the next step, revealing the portions of the Site where silty sand, sand, and gravelly sand dominate. Although the "solid model" of sand distribution is shown only on Figure 16, the color-coded lithology corresponding with depth is also shown on Figures 23, 24, and 25.

Figures 17 through 21 – Solid Model of ECD Response and A1 Potentiometric Surface

Figures 17 through 21 depict the solid model created by kriging the ECD response data (Section 2.2.1) at various levels of response. The A1 potentiometric surface contours, developed from the November 2010 water level data set, are superimposed on the model. The locations of the CPT/MIP borings are highlighted in blue, while the other borings from previous investigations are highlighted in gray. The CPT/MIP borings are the locations of the data that were used to develop both the solid model of geology (Figure 16) and this solid model of ECD response.

The sequence of visualizations represented by these figures presents ever-higher ECD response levels from $5x10^5$ µV (Figure 18) to $2.5x10^6$ µV (Figure 21). Sequentially peeling away the lower ECD response (and presumably lower TCE concentration) layers one by one reveals the core of the plume at the southern boundary of the Site (Figure 21).

Figures 17 (top-view) and 18 depict ECD responses of $5x10^5$ µV and above. The $5x10^5$ level is considered an ECD response typical of low-level TCE concentrations detectable above the background response. Figures 19 through 21 show the distribution of mid- and high-level MIP responses throughout the Site.

Figures 22 through 25 and Figure 29 – Cross Sections (Which Depict Preferential Flow Paths of TCE Plumes Within the Site)

Figures 22 through 25 and Figure 29 show cross sections of the MIP responses along transects (locations are shown on Figure 22) selected to show the preferential flow paths of the TCE plumes within the site. These cross sections show the movement of the TCE plume, as characterized by the ECD response, through the A1 and A2 aquifer zones. Figure 29 shows a pair of plume cross sections viewed at an angle of 65 degrees from horizontal and from the west-northwest direction.

On each figure, the distribution of the MIP response is contoured on the sections themselves, and lithologies from CPT and DPT data are depicted at the boreholes. At boreholes, TCE concentration values from groundwater grab samples are presented adjacent to the depth of the sample interval.

Preferential pathways are indicated where permeable lithologies at boreholes (yellow and orange soil classifications) line up at similar elevations. The ECD data collected with the MIP have been contoured on the cross sections themselves, with reddish hues indicating high response (representing high VOC concentrations) and greenish hues representing low response. The coarse lithologies and high responses closely correspond in the deeper and more southern portions of the cross sections, less so in the more shallow and northern and northwestern portions of the cross sections. This effect is discussed in Section 3.3.6.2.

2.2.4 Assumptions and Associated Uncertainty

The figures reveal some inconsistencies between the model and point data that are expected in highly heterogeneous alluvial settings because of three factors:

(1) Temporal variations in TCE concentrations from previous investigations

(2) Projection of borings on to the cross section that do not lie directly on the path of the cross section, but rather in front or behind the plane of the cross section

(3) Heterogeneity of lithologic units (sands and gravels) that may trend locally across the Site and not be in the same plane as two adjacent MIP points on the cross section.

These factors may lead to the observed disconnect between the ECD response and the TCE concentrations at a borehole.

2.3 MOLAR CALCULATION

A decreasing trend in TCE concentrations from the upgradient boundary to downgradient sampling locations suggest that the Site has no on-site source. As chlorine ions constitute a substantial part of the total mass of TCE (81 percent) and DCE (73 percent), observing a decrease in the total mass concentration of these constituents may reflect a loss of a chlorine atom from TCE in its degradation process of transformation to DCE. Therefore, observed trends in contaminant mass from upgradient to downgradient locations were further assessed through conversion of chlorinated ethane concentrations from mass per unit volume to molarity. Molarity values were calculated for the direct-push groundwater grab results for total TCE and DCE molarity to take into account the presence of degradation products and are presented in Appendix E (Molar Calculation). The molarity calculation was made using the following formula:

$$c_i = n_i / V$$

where:

c_i equals the moles of the solute (n_i) divided by the volume of the solution (V).

The mass concentration reported by the laboratory was converted from milligrams per liter (mg/L) to moles per liter by dividing the mass concentration by the molar mass (grams per mole) of each constituent and by 1,000. The molar mass is a physical property that can be referenced for each constituent.

3.0 RESULTS AND EVALUATION OF THE SSI

This section describes the results of the SSI, as indicated by data obtained during the field investigation.

3.1 PHASE 1 – GROUNDWATER MONITORING AND GROUNDWATER ELEVATION MONITORING

As described in Section 2.1.1, elevation measurements were obtained during the November 18, 2010, Black Thursday regional monitoring event from on-site wells, off-site wells south of the Site at the former vector control yard, and off-site wells located to the east and north of the Site. The data were used to update the groundwater elevation (potentiometric surface) map for the A1 and A2 aquifer zones (Figure 2).

As indicated on the potentiometric surface maps, groundwater flow directions in the vicinity of each LOC were compared to data from previous studies. Groundwater flow directions were similar except within the A2 aquifer zone around LOC 6b, where groundwater flows to the northeast rather than to the northwest. Sampling locations proposed for Phase 2 were reviewed and adjusted following Phase 1 of the field investigation, based on changes in the groundwater elevation contours. The orientation of the LOC 6b investigation area was adjusted to reflect November 2010 groundwater flow conditions (see Section 1.2.3.1). The adjustment was made because the decision logic for deciding if an LOC was a source depended on sampling upgradient of the indefinite source area; thus, if the local gradient is revised based on new data, the sampling locations should be revised as well. However, because of the uncertainty in groundwater flow gradient, and the possibility that it may be seasonally variable in this area, both upgradient areas were investigated (see Section 3.3.1).

Additionally, groundwater samples were collected from the 11 existing on-site monitoring wells from January 3 to 5, 2011, in order to obtain knowledge about current conditions of groundwater, because the previous samples had been collected between August 2005 and June 2006, and concentrations may have changed over time. All groundwater samples were reviewed and validated. The indicated trend is slight degradation of TCE concentrations over time; however, concentrations of TCE in January 2011 may have been diluted by rain, as the sampling was performed during the rainy season. Groundwater concentrations of TCE are reported in Table 3, and the full analytical results are presented in Table D-1. Groundwater sampling sheets are presented in Appendix F (Field Forms) and photographs from the field investigation are provided in Appendix G (Field Investigation Photographs).

3.2 PHASE 2 – CONE PENETROMETER BORINGS WITH MEMBRANE INTERFACE PROBE TOOL

A dynamic direct-push sampling strategy following the decision logic diagram in the SAP (Figures 13 through 15) was implemented to evaluate potential source areas and delineate areas with high VOC concentrations. The dynamic strategy allowed for addition of new CPT/MIP locations at each LOC based on real-time data. The CPT/MIP investigation occurred from January 14 to 28, 2011. In total, 35 borings were advanced to a maximum depth of 75 feet bgs. At one location, LOC5c-P1-LA (a second boring) was advanced because refusal was encountered at 14 feet bgs; the second boring also hit refusal as a result of unknown subsurface obstructions at 16 feet bgs. In general, the depths of the borings targeting the A1 aquifer zone were extended through the A1/A2 aquitard to a depth of 35 feet within the A2 aquifer zone, while most of the borings targeting the A2 aquifer zone were extended to a depth of 65 feet, the estimated base of the A2 aquifer zone. Fifteen borings were advanced to investigate the upper aquifer, 15 borings were advanced to investigate the lower aquifer, and six borings were advanced to investigate preferential pathways through the Site. Table 4 lists the MIP/CPT borings and their associated depths, LOCs, and aquifer zones. Photographs from the field investigation are provided in Appendix G (Field Investigation Photographs).

Immediately after the field investigation of each LOC, a field data deliverable was produced, including:

- A cover letter presenting conclusions of the CPT/MIP investigation
- A decision logic diagram outlining the steps followed during the investigation
- A decision logic summary table describing the results of each field step
- A map showing where each CPT/MIP had been advanced
- A graphical summary of the CPT and MIP logs that supported decisions in the field
- Groundwater monitoring well and DPT groundwater grab results from previous investigations in the vicinity of the LOC
- MIP and CPT logs from the investigation

These field data deliverables (see Appendix C – LOC MIP/CPT Field Data Deliverables) were presented to EPA and the Water Board immediately after the CPT/MIP investigation to obtain feedback on conclusions of the investigation.

As a result of the CPT/MIP investigation, LOCs 1, 2a, 5a, 5b, and 5c were determined not to be on-site source areas. Data obtained during the CPT/MIP investigation for LOCs 2b, 3, and 6b, however, indicated that further investigation during Phase 3 would be warranted. Although the CPT/MIP data did not indicate LOC 4 as an on-site source, the area was included in the DPT investigation because it was subject to a separate investigation for TPH, as described in the PQOs presented in the SAP (Appendix A). Details of the evaluation of each LOC are described in the following sections. The decision logic diagram established before the MIP investigation began guided the dynamic direct-push strategy in the field for each LOC (Figures 13 through 15).

General Description of Decision Logic

The first CPT/MIP advanced for each LOC was MIP #0, the point adjacent to the monitoring well or DPT boring where sample results for TCE were assumed "anomalously high." This point was the downgradient tip of each LOC triangle (Figure 12). As described in Attachment A1 of the SAP (Appendix A), the ECD response at MIP #0 was compared with the depth and magnitude of historical TCE concentrations to ensure that the ECD log deflected from baseline at depth intervals where elevated concentrations of TCE had been detected in the past. The ECD response log was the primary reference for identifying presence of TCE and its potential daughter products within the LOCs. If the ECD response occurred at the same depth interval as historical concentrations, the investigation proceeded according to the decision logic diagram (Figures 13 and 14). If not, such as occurred at LOC 4, the field team determined that either the targeted location had not been found or the MIP instrument was not working correctly, and a new MIP #0 was advanced.

Each ECD profile was evaluated to determine if the ECD response profile indicated a source based on the screening criteria below.

- ECD response that is greatest in the capillary fringe indicates a source area
- ECD response ≥ 7e+6 μV indicates residual or liquid NAPL source
- ECD response ≥ 4e+6 μV indicates proximity to residual or liquid NAPL source
- ECD profile that decreases sharply within the first saturated zone may indicate a source area
- ECD profile that is highest in finer-grained materials in the first saturated zone may indicate proximity to a source

Each screening criterion was assigned a value from 1 to 2 as presented in Table 5. A total score exceeding or equal to 2 would be considered to exceed the screening criteria and would serve as an adequate indication of a potential nearby source; the area would be further delineated following the source investigation guidelines of the decision logic. A total score less than 2 would be considered less than the screening criteria, and would confirm that the area is not a potential source area, and the LOC would be further evaluated following the plume investigation guidelines of the decision logic in an attempt to find a potential alternative source area of VOC contamination.

At the end of each field day, the CPT/MIP data were incorporated into the EVS model along with historical data, as described in Section 2.2, to assess the preferential pathways for the TCE plume or to identify additional data needs. All the MIP #0 points were advanced before any of the MIP #S1 or MIP #P1 points to provide sufficient time to evaluate the data in EVS.

Source Investigation Guidelines

If the total score exceeded the screening criteria at MIP #0, the field team advanced the next CPT/MIP at the first pre-determined, short-step location (approximately 75 feet upgradient), and proceeded down the source branch of the decision logic diagram (see Figures 13 and 14) to investigate a source within the local area and attempt to delineate the source area. Once the next CPT/MIP (MIP #S1) was advanced, the field team evaluated the profile using the criteria presented in Table 5 to see if a source was indicated in that area. If so, an additional CPT/MIP (MIP #S2) was advanced farther upgradient to delineate the source. If not, the source area was considered bounded in that direction.

Plume Investigation Guidelines

If the total score was less than the screening criteria at MIP #0, the field team advanced the next CPT/MIP in the center long-step location (between 200 and 400 feet upgradient) and proceeded down the plume branch of the decision logic diagram to investigate farther upgradient of the MIP #0.

The ECD profile of MIP #P1 was compared with the ECD profile of MIP #0 to determine if the ECD response of MIP #P1 was less than the maximum response at MIP #0 by at least one-half order of magnitude on the µV scale, per the decision logic. This comparison was made to determine if the investigation had proceeded in the correct direction to locate the potential on-site source area causing the elevated downgradient TCE concentration. The primary reasons that the first "long-step" might not be pushed in the correct direction, thereby missing the plume, are: (1) the estimated direction of groundwater flow was inaccurate, or (2) the permeable pathway was oriented in a different direction.

If the peak response of MIP #P1 was less than MIP #0 by at least one-half order of magnitude on the µV scale, the field team assumed that the investigation was not proceeding in the correct trajectory from MIP #0, moved to one of the long-step MIP points located on either side of MIP #P1, and pushed the new point. The same comparison to MIP #0 was then conducted, and the investigation proceeded as indicated on Figure 13. If again the peak ECD response at the step-out location (MIP #P2) was less than MIP #0 by at least one-half order of magnitude on the µV scale, a determination occurred at a third step-out point (MIP #P3) on the other side of MIP #P1. If all three step-outs were less than MIP #0 by at least one-half order of magnitude on the µV scale, it was concluded that the concentrations at MIP #0 represented a localized area of elevated plume concentrations.

If the peak response at MIP #P1 was not less than MIP #0 by at least one-half order of magnitude, the profile was evaluated against the screening criteria presented in Table 5. If a source was indicated at MIP #P1, the immediate area was determined to be a source area, and the LOC investigation proceeded down the source branch as indicated on Figure 13. If no source was indicated at MIP #P1, the investigation concluded that the source was likely upgradient of the LOC and further evaluation of the plume ensued using EVS visual modeling.

3.2.1 LOC 1

The field data deliverable for LOC 1 was released on January 19, 2011 (Appendix C – LOC MIP/CPT Field Data Deliverables). The decision logic diagram outlines the steps taken during the investigation. After MIP #0 was advanced, the depths and magnitudes of historical concentrations of TCE were compared with the ECD response at co-located well MCH-9UA; a response was noted between 13 and 20 feet bgs, an interval mostly within the screened interval of the well (16 to 26 feet bgs, which corresponded to 7.5 to 17.5 feet bgs, because the ground elevation at LOC1-0-UA was 8.5 feet less than the ground elevation of well MCH-9UA).

The initial MIP profile at LOC1-0-UA indicated that the screening criteria were not exceeded based on several observations, including background level ECD responses in the capillary fringe where surface soils would likely record VOC sources. The maximum ECD response of

9.1x10^5 μV occurred in clay materials at approximately 13 feet bgs (corresponding to 21.5 feet bgs at well MCH-9-UA). This response was a half-order of magnitude lower than 4x10^6 μV, the minimum ECD response selected to indicate potential sources within the Site.

Based on lack of evidence of a source at the first direct-push location at LOC 1, the step-out to the next location upgradient was a "long-step" (defined in the decision logic diagram as 200 to 400 feet upgradient). This location was chosen to delineate the slightly elevated ECD response from the LOC1-0-UA profile. Screening criteria were not exceeded at LOC1-P1-UA, and the maximum ECD response at 19 feet bgs of 1.7x10^6 μV was higher than the downgradient response, indicating an upgradient plume.

In conclusion, screening criteria were not exceeded at LOC 1, confirming the area is not a potential source area. Elevated ECD responses observed in the ECD profiles in the A1 aquifer zone may indicate the presence of a plume originating from an upgradient source. Additional data from CPT/MIP borings obtained from LOCs 2a, 5a, and 5b contributed to an evaluation of LOC 1 in EVS. A comparison of the distribution of low-level ECD responses (Figures 17 and 18) and mid-level ECD responses (Figure 19) in the A1 aquifer zone upgradient and in the vicinity of LOC 1 shows that the VOC concentrations detected in LOC 1 are similar to or less than those detected upgradient of the LOC. The distribution of elevated responses supports the assertion that VOCs migrate from the upgradient site boundary near LOC 4, then through the Site to LOC 1.

3.2.2 LOC 2a

The field data deliverable for LOC 2a was released on January 21, 2011 (Appendix C – LOC MIP/CPT Field Data Deliverables). The decision logic diagram outlines the steps taken during the investigation. After MIP #0 was advanced, the depths and magnitudes of historical concentrations of TCE at co-located well MCH-7UA were compared with the MIP profile; a response was noted between 16 and 18 feet bgs, an interval within the screened interval of 10-20 feet bgs where elevated concentration had been detected in the past. The ECD response in the capillary fringe at LOC2a-0-UA, where surface soils would likely record VOC sources, approximated background values. The highest ECD response of 1.3x10^6 μV occurred in clay materials at approximately 17.3 feet bgs. This response was three times lower than 4x10^6 μV, the minimum ECD response selected for evaluating potential sources within the Site; screening criteria were not exceeded. Therefore, the investigation proceeded down the plume branch.

A "long-step" step-out to LOC2a-P1-UA was chosen in order to attempt to locate a source upgradient of LOC2a-0-UA. The second MIP profile results were slightly higher than downgradient results, but screening criteria were not exceeded. The maximum ECD response at 21.1 feet bgs of 1.8x10^6 μV suggested that the plume may extend upgradient. The cross-gradient profile from LOC5b-0-LA showed a maximum response similar to that of LOC2a-0-UA, also suggesting presence of an upgradient plume. The CPT/MIP investigation terminated at this point. EVS visualizations generated for the LOC show the low-level presence of VOCs likely originating from an upgradient source.

In conclusion, screening criteria were not exceeded at LOC 2a, confirming the area is not a potential source area. ECD responses in the A1 aquifer indicate the presence of a low-level VOC plume originating from an upgradient source.

3.2.3 LOC 2b

The field data deliverable for LOC 2b was released on February 8, 2011 (Appendix C – LOC MIP/CPT Field Data Deliverables). The decision logic diagram outlines the steps taken during the investigation. Although the LOC 2b investigation focused on the A1 aquifer zone, the investigation was also extended past the target depth of 35 feet bgs into the A2 aquifer zone. The deviation occurred because a strong ECD response was observed from 26 to 40 feet bgs at LOC2b-P1-UA, and the CPT/MIP was advanced until the response returned to background levels.

After MIP #0 had been advanced, the depths and magnitudes of historical concentrations of TCE were compared with the ECD profile. Historical results at co-located well MCH-11UA ranged from 210 to 380 μg/L within the screened interval of 13 to 23 feet below top of casing (btoc). At LOC2b-0-UA, the maximum response was noted at approximately 16 feet bgs—within the screened interval of 13 to 23 feet bgs, where an elevated concentration had been detected previously. TCE in an upgradient Hydropunch sample at FW19B was non-detect (ND) at 16.5 feet bgs.

The ECD response in the capillary fringe at LOC2b-0-UA was at or below typical background/ baseline values (less than $3x10^5$ μV). The maximum ECD response of $7.2x10^5$ μV was observed in clay materials at approximately 16 feet bgs. This maximum response was almost an order of magnitude lower than the minimum ECD response selected for evaluating potential sources within the Site. As a result, a “long-step” step-out boring was conducted upgradient to LOC2b-P1-UA. Screening criteria were not exceeded in the MIP profile at LOC2b-P1-UA, and the maximum ECD response of $1.7x10^6$ μV occurred at 32 feet bgs, within the A2 aquifer zone. As explained above, this boring was advanced to a depth greater than the target depth of 35 feet bgs, because a strong ECD response had been observed from 26 to 40 feet bgs at LOC2b-P1-UA, and the field team decided to advance the CPT/MIP until the response returned to background levels.

Upgradient, at LOC2b-P2-UA, an additional point was pushed in an attempt to delineate the shallower response detected at LOC2b-0-UA at 16 feet bgs. The maximum ECD response of $4.2x10^6$ occurred at 37 feet bgs within the A2 aquifer zone, similar to the downgradient response at LOC2b-P1-UA. This continuation of maximum ECD responses in the A2 aquifer zone suggested that a plume had migrated to LOC 2b from an upgradient source. The plume in the A2 aquifer zone was further investigated as part of the LOC 6b investigation, which concluded that the elevated responses had derived from an upgradient plume rather than an on-site source.

Screening criteria were exceeded at LOC2b-P2-UA, because a maximum ECD response of $4.1x10^5$ μV, which was low but slightly elevated above background levels, was observed in low permeability soil at 10 feet bgs in the capillary fringe. As part of the combined investigation of

LOCs 2b/6b, a CPT/MIP was pushed approximately 50 feet upgradient of LOC2b-P2-UA; this point was identified as LOC6b-SS2-LA, but was used to investigate the potential for an A1 aquifer zone source area in LOC 2b as well. The ECD response in the capillary fringe at LOC6b-SS2-LA was at or below typical background/baseline values (less than $3x10^5$ µV).

Screening criteria were exceeded within LOC 2b, but the highest ECD responses were deeper within the A2 aquifer zone, and only one minor response was observed in the capillary fringe. The response of $4.1x10^5$ µV was within a range determined indicative of TCE concentrations less than 1 µg/L (see Section 3.3.3), and a subsequent CPT/MIP (LOC6b-SS2-LA) did not exceed screening criteria. Both the A1 and A2 aquifer zones were further investigated as part of the continuing investigation at LOC 6b.

3.2.4 LOC 3

The field data deliverable for LOC 3 was released on February 8, 2011 (Appendix C – LOC MIP/CPT Field Data Deliverables). The decision logic diagram outlines the steps taken during the investigation. This investigation was guided by Figure 5, the decision logic for a suspected source, the paint locker. The location of the paint locker had been previously identified using historical drawings.

Selection of the first CPT/MIP location, LOC3-SS0-UA, was biased to detect potential contamination originating from the former paint locker, a suspected source at the middle of LOC 3. MIP #SS0 was advanced. The ECD profile did not exceed screening criteria; therefore, the investigation of the paint locker (Figure 14) was discontinued, and an indefinite source in the vicinity was investigated, following the decision logic in Figure 13.

MIP #0 was advanced, and the depths and magnitudes of historical concentrations of TCE were compared with the ECD profile generated at LOC 3 (LOC3-0-UA). A maximum historical concentration of 210 µg/L had been detected at 16 to 17 feet bgs from boring FW15B, with which LOC3-0-UA was co-located. This detection corresponded with the maximum ECD response in the MIP profile observed at 17 feet bgs at LOC3-0-UA.

Screening criteria were not exceeded at location LOC3-0-UA, where the highest ECD response was observed at 17 feet bgs, approximately 7 feet below the water table. Location LOC3-SS0-UA (previously advanced) was used as the “long-step” step-out (MIP #P1). The maximum ECD response of $1.3x10^6$ µV at LOC3-SS0-UA occurred at 28.5 feet bgs, in clay soils. The ECD response at MIP #P1 was less than the response at MIP #0, resulting in a “side-step” step-out to the west at LOC3-P2-UA.

Screening criteria were not exceeded in the third MIP profile at LOC3-P2-UA, and the maximum ECD response of $6.6x10^5$ µV occurred at 25 feet bgs, the approximate depth of the A1/A2 aquitard.

A review of the profiles of all CPT/MIPs advanced at the Site up to that time indicated that the elevated ECD responses detected at LOC3-SS0-UA and LOC3-P2-UA had occurred much deeper than the elevated detection at 17.5 feet bgs at LOC3-0-UA within the A1 aquifer zone.

An additional boring was advanced at LOC3-P3-UA to attempt to define the upgradient extents of the contamination detected at LOC3-0-UA. Screening criteria were not exceeded in the ECD profile at LOC3-P3-UA, and the maximum ECD response of $4.7x10^5$ µV occurred at 30 feet bgs, within the A2 aquifer zone.

To detect whether the contamination detected at LOC3-0-UA may have entered the Site through the eastern boundary of the Site, an additional CPT/MIP (LOC3-P4-UA) was advanced upgradient of LOC3-0-UA just inside the Site boundary. The ECD response at the Site boundary (LOC3-P4-UA) was less than the ECD response at MIP #0 (LOC3-0-UA).

Screening criteria were not exceeded at LOC 3. The investigation found a localized area of elevated dissolved concentrations. The CPT/MIP investigation was inconclusive regarding the elevated concentrations at LOC 3, because the MIP profiles did not exhibit source characteristics and the plume could not be traced upgradient.

Because findings at LOC3-P4-UA did not confirm off-site plume migration toward LOC 3, the following groundwater grab samples were collected to confirm that the localized area of elevated ECD response in groundwater had resulted from VOCs desorbing from the fine-grained soils: samples from MIP #0 (LOC3-0-UA) at the two depths where the ECD response had peaked (13 feet bgs and 17 to 17.5 feet bgs). Results from those samples were to be compared with findings at the depth corresponding to the permeable layer at LOC3-P4-UA (15 to 16 feet bgs). The Phase 3 DPT investigation is discussed in Section 3.3.2.

3.2.5 LOC 4

The site-specific decision logic diagram for LOC 4 is included in the field data deliverable released February 4, 2011 (Appendix C – LOC MIP/CPT Field Data Deliverables). Three CPT/MIPs were pushed to evaluate LOC 4 as a suspected source, because a PID reading of 3,500 ppm had been detected at a depth of 11 feet bgs during an investigation in 2002. This LOC was investigated to determine if TCE had caused that elevated PID reading.

The depths and magnitudes of historical concentrations of TCE at former DPT point FW41A were compared with the MIP profile LOC4-0-UA. The ECD response profile suggested detections of low VOC concentrations at 19.5 feet bgs and at 30 to 35 feet bgs, and the PID did not indicate a detection until 23 feet bgs; screening criteria were not exceeded. The response was not consistent with past detections, which had included a PID reading at 11 feet bgs, and detections in groundwater grab samples of 210 µg/L at 9.5 feet bgs and 410 µg/L at 31 feet bgs (Appendix B – Comparison of MIP Response to Historical Data at Co-Located Points). This point was rejected as the MIP #0 point for LOC 4 because the historical detections did not match the MIP or PID response. A point was selected slightly downgradient, closer to well MCH-1UA, to obtain CPT/MIP data to see if those would better match the historical data.

Results from the second MIP #0 point, LOC4-02-UA, were compared to historical results from monitoring well MCH-1UA. The ECD response of $5.8x10^5$ µV detected at 19.5 feet bgs compared well to concentrations in historical monitoring well samples, and this point was accepted as MIP #0. Additionally, a PID response occurred from 11.5 to 13.5 feet bgs, corresponding to the historical PID reading at 11 feet bgs.

Screening criteria were not exceeded at location LOC4-02-UA, where the highest ECD response in the A1 aquifer zone was 5.8×10^5 µV at a depth of 20.2 feet bgs. An upgradient "long-step" CPT/MIP (LOC4-P1-UA) step-out was advanced to investigate upgradient. The maximum ECD response was 2.0×10^6 µV at LOC4-P1-UA, which was higher than the downgradient response. The response was recorded in sandy silt to clayey silt materials at approximately 15 feet bgs. Screening criteria were not exceeded at LOC4-P1-UA, located adjacent to the southern edge of the Site boundary.

In conclusion, screening criteria were not exceeded at LOC 4, confirming the area is not a potential source area. Slightly elevated ECD responses observed in the MIP profile at depth may indicate presence of a deeper plume originating from an upgradient source, particularly given that the step-out (LOC4-P1-UA) was located approximately 50 feet from the southern boundary of the Site. Figures 19 through 21 provide kriged contours of ECD response that indicate the upgradient ECD responses were higher than those measured in the vicinity of FW41A (the northern point of LOC 4).

3.2.6 LOC 5a

The field data deliverable for LOC 5a was released on February 3, 2011 (Appendix C – LOC MIP/CPT Field Data Deliverables). The decision logic diagram outlines the steps taken during the investigation. Six CPT/MIPs were pushed to evaluate LOC 5a as an indefinite suspected source.

Once MIP #0 was advanced, the MIP profile was compared to historical concentrations of TCE at monitoring well MCH-6LA, screened between 41 and 51 feet bgs. Historical TCE concentrations ranged from 390 to 820 µg/L, comparing well with the highest ECD responses from profile LOC5a-0-UA obtained between 43 and 65 feet bgs.

Screening criteria were not exceeded at location LOC5a-0-UA, resulting in a "long-step" step-out upgradient to LOC5a-P1-UA to investigate an upgradient plume. The MIP profile at LOC5a-P1-LA initially was thought to exceed screening criteria based on a high ECD response in the vadose zone, above the capillary fringe. To investigate this area further, the investigation then proceeded down the source branch of Figure 13, and a third MIP (LOC5a-SS1-LA) was advanced approximately 50 feet upgradient, where an elevated ECD response was also observed in the capillary fringe. However, once MIP LOC5a-SS2-LA had been pushed and the MIP logs had been reviewed thoroughly, it was concluded that the response had not been caused by chlorinated solvents, but had been an ECD response to available oxygen in the coarse material in the vadose zone. This conclusion was based on a comparison of the ECD and PID response logs, which are presented for all MIP borings in Attachment 1. The series of ECD and PID response logs shows that in all cases except advancements of borings at LOC5a-P1-LA and LOC5a-SS1-LA (page 4 of 9), the ECD and PID responses at depths greater than approximately 5 feet bgs are generally coupled, which is to be expected when the MIP is detecting VOCs. ECD and PID are generally not coupled at depths shallower than 5 feet bgs due to presence of atmospheric oxygen at these depths (moreover, pre-augering had occurred to 5 feet bgs). In addition to halogen atoms (e.g., chlorine), the ECD responds to other electronegative elements like oxygen, whereas the PID does not (Willard and others 1988; Nedatek 2008).

Results from borings LOC5a-P1-LA and LOC5a-SS1-LA indicated poor agreement between the ECD and PID responses to depths of 10-15 feet bgs, which can be attributed to the presence of oxygen in coarse layers of the vadose zone. Presence of significant coarse (sand and gravel) zones in these depth intervals is verified in the ECD and lithologic logs of these borings (see field data deliverable for LOC 5a in Appendix C – LOC MIP/CPT Field Data Deliverables). Performance checks before and after advancement of each boring verified acceptable detector performance and ruled out potential damage to the MIP from the coarse sediments. Moreover, each boring in question was advanced on a different date, further ruling out equipment failure. Because the ECD responses were low and decoupled from the PID responses at LOC5a-P1-LA and LOC5a-SS1-LA, additional investigation is not warranted within this area.

Once it was determined that the elevated ECD response had not been caused by VOCs, the investigation moved back along the plume branch (Figure 1 of the LOC 5a field data deliverable in Appendix C – LOC MIP/CPT Field Data Deliverables). A “long-step” CPT/MIP was advanced approximately 300 feet upgradient at LOC5a-SS3-LA to evaluate if the plume detected at the downgradient points was originating upgradient. The peak response of 1.80×10^6 µV at 50 feet bgs from LOC5a-SS3-LA was a half order of magnitude greater than the ECD response at all downgradient locations, suggesting that the origin of the VOCs within the A2 aquifer zone is likely upgradient of LOC 5a.

The highest ECD responses were documented between 45 and 55 feet bgs, within the A2 aquifer zone, in MIP profiles of LOC5a-SS1-LA, LOC5a-SS3-LA, and LOC5b-P6-LA. The A2 plume can be traced to LOC5b-P6-LA, which is within 75 feet of the upgradient (southern) boundary of the Site.

In conclusion, once the data was reevaluated, screening criteria were not exceeded at LOC 5a, confirming the area is not a potential source area. Elevated ECD responses observed in the MIP profile of the A2 aquifer zone increase upgradient, closer to the Site boundary, and indicate the presence of a deeper plume that appears to be connected to LOC5b-P6-LA—located adjacent to the southern boundary and at which the Site’s highest ECD response was detected (5.5×10^6 at a depth of 53.5 feet bgs).

3.2.7 LOC 5b

The field data deliverable for LOC 5b was released on February 4, 2011 (Appendix C – LOC MIP/CPT Field Data Deliverables). The decision logic diagram outlines the steps taken during the investigation. Two CPT/MIPs were pushed to evaluate the origin of VOCs detected at LOC 5b.

A comparison of the MIP profile of MIP #0 (LOC5b-0-LA) to historical concentrations of TCE at former borehole FW17B indicated that the responses coincided with the historical VOC results. The ECD response peak of $8.0x10^5$ µV at 42.7 feet bgs occurred at the same approximate depth where a TCE concentration of 1,100 µg/L had been detected in a groundwater grab sample in 2002.

The maximum ECD response at LOC5b-0-LA of $1.60x10^6$ µV was detected at approximately 18 feet bgs. Due to limited ECD responses in the capillary fringe, the ECD profile did not exceed screening criteria, and the plume branch was followed (Figure 13). A "long-step" step-out at LOC5b-P1-LA was pushed upgradient. Multiple ECD peaks were observed at depth in the ECD profile for LOC5b-P1-LA, but none occurred in the capillary fringe. The maximum ECD peak was $1.7x10^6$ µV at 39 feet bgs. Screening criteria were not exceeded at LOC5b-P1-UA, thus confirming the area is not a potential source area, and the MIP investigation ceased. The elevated responses observed at depth indicated presence of a plume within the A2 aquifer zone. The A2 plume can be traced to LOC5b-P6-LA—within 75 feet of the upgradient boundary where the Site's highest ECD response was detected ($5.5x10^6$ at a depth of 53.5 feet bgs).

3.2.8 LOC 5c

The field data deliverable for LOC 5c was released on February 8, 2011 (Appendix C – LOC MIP/CPT Field Data Deliverables). The decision logic diagram outlines the steps taken during the investigation. Four CPT/MIPs were pushed to identify the origin of VOCs detected at LOC 5c, but two of the pushes encountered refusal at approximately 15 feet bgs. ECD responses from MIP #0 (LOC5c-0-LA) at 14 feet and 51 feet bgs matched responses expected based on historical concentrations of TCE in groundwater grab samples previously collected at FW20B.

The maximum ECD response occurred in sandy silt to silty clay at 17 feet bgs at MIP #0 (1.6x106 µV), with the next highest response at 50 feet bgs in clay ($1.2x10^6$ µV). No source characteristics were observed in the ECD response, and a "long-step" step-out to MIP #P1 was chosen to evaluate the extent of elevated responses found at depth. Two separate MIP pushes encountered refusal at approximately 15 feet bgs at locations LOC5c-P1-UA and LOC5c-P1-UA1. MIP #P1 was successfully advanced at LOC5c-P2-LA, and the maximum ECD response occurred at the same interval (17 feet bgs) but was slightly higher than the maximum response at MIP #0 ($1.8x10^6$ µV). Screening criteria were not exceeded at MIP #P1. Further evaluation of the investigation data, using the model of site geology, hydrogeology and contaminant distribution developed with EVS, indicated that the ECD responses in the A2 aquifer zone observed at LOC 5c appear to extend continuously through preferential pathways in the A2 aquifer zone, from the area of elevated ECD responses along the southern site boundary to LOC 5c. Screening criteria were not exceeded at LOC 5c, confirming the area is not a potential source area.

3.2.9 LOC 6b

The field data deliverable for LOC 6b was released on February 8, 2011 (Appendix C – LOC MIP/CPT Field Data Deliverables). The decision logic diagram outlines the steps taken during the investigation. Six MIPs were advanced to determine whether LOC 6b had characteristics of a plume within the A2 aquifer zone, and whether LOC 6b had characteristics of a potential source of contamination within the A1 aquifer zone. The decision logic path followed resulted in continued investigation of both the A1 and A2 aquifer zones in Phase 3.

The assumed direction of groundwater flow in the vicinity of LOC 6b was based on groundwater level measurements in August 2005 (the most recent data set available during the initial planning phase of the project). This flow direction was inconsistent with a subsequent assessment of water level data obtained in November 2010 (see Section 3.1). To account for the apparent change in flow direction, the orientation of LOC 6b was altered from its proposed northwest orientation (see Figure A-12) to the adjusted northeast orientation (Figure 12). The Army investigated both upgradient directions to reduce uncertainty and to help evaluate the orientation of the A2 aquifer zone's chlorinated solvent plume in the LOC 6b area by advancing an additional CPT/MIP (LOC6b-P4-LA) in the southeast direction from MIP #0 (LOC6b-0-LA). Additional details regarding the investigation of LOC 6b are provided below.

3.2.9.1 A2 Aquifer Zone Investigation

The initial target zone of the LOC 6b investigation was the A2 aquifer zone, and the decision logic depicted on Figure 4 for indefinite source areas was followed. A comparison of historic concentrations at monitoring well MCH-10LA with findings at MIP #0 (LOC6b-0-LA) indicated that concentrations detected in the screened interval (35 to 45 feet bgs) coincided with peak ECD responses within the A2 aquifer zone portion of the response profile for LOC6b-0-LA.

The maximum ECD response of 5.3×10^5 µV at 11.2 feet bgs in the MIP #0 (LOC6b-0-LA) profile was initially interpreted to occur below the capillary fringe, thereby indicating plume characteristics within the A1 aquifer zone. A review of the pore pressure data from the CPT log induced a change in estimated depth of the capillary fringe downward, thus resulting in a score that exceeded screening criteria. (This area was further investigated during Phase 3 by collecting DPT groundwater grab samples at 12 to 13 feet bgs—see Section 3.3.1.) However, because the ECD response at 11.2 feet bgs at LOC6b-0-LA had been initially interpreted to indicate a plume within the A1 aquifer zone, and not to exceed screening criteria, MIP #S1 and MIP #SS2 (as dictated on Figure 13) were not advanced, and the LOC investigation followed the "plume branch."

A second deflection from the baseline level of the ECD response was observed between 40 and 45 feet bgs within the A2 aquifer zone. As a result of responses believed to originate below the water table, a "long-step" step-out upgradient to MIP #P1 (LOC6b-P1-LA) was chosen to further characterize the potential plume within the A1 and A2 aquifer zones. The Phase 2 investigation for the A2 aquifer zone concluded that the plume appeared to extend upgradient, and possibly off site. At LOC6b-P1-LA, the maximum ECD response of 1.9×10^6 µV occurred in fine-grained material between 35 to 40 feet bgs within the A2 aquifer zone. The response was much greater than the maximum ECD response at MIP #0, indicating the presence of an upgradient plume. Two lower-amplitude ECD responses above and below the maximum spike occurred in coarser lithologies, indicating a potential plume within the A1 aquifer zone and more VOC contamination deeper within the A2 aquifer zone. Screening criteria were not exceeded.

Due to uncertainty in the groundwater gradient at LOC 6b, an additional CPT/MIP location was selected adjacent to MIP #P1 at LOC6b-P4-LA to address uncertainty in groundwater flow directions (this location is within what was originally identified as the likely upgradient area, based on August 2005 groundwater level data). The maximum ECD response at LOC6b-P4-LA, which corresponds to the plume branch step-out MIP #P2, was $3.2x10^5$ µV at 29 feet bgs. This response was much lower than the peak response at MIP #P1 (the upgradient point as determined by groundwater level measurements in 2010). Screening criteria were not exceeded at LOC6b-P4-LA. EVS modeling Figures 17 and 18 also show that the plume affecting groundwater in the vicinity of LOC6b-0-UA originates from south-southwest, rather than the southeast. The ECD responses and EVS modeling show that the A2 aquifer zone plume originates from upgradient of MIP #P1 (south-southwest), and not from the direction of MIP#P4 (southeast).

DPT samples were collected during Phase 3 upgradient of LOC 6b to determine if a preferential pathway in permeable soils could be identified for upgradient plume migration.

3.2.9.2 A1 Aquifer Investigation

As discussed in Section 3.2.9.1, the 10- to 15-feet-bgs interval in the ECD profile for LOC6b-0-LA was initially interpreted to be a saturated-zone interval, and thus the minor ECD response of $5.3x10^5$ µV at 11.2 feet at LOC6b-0-LA was believed to be located below, rather than within, the capillary fringe (Appendix C – LOC MIP/CPT Field Data Deliverables). Saturated conditions in vadose-zone soil (due to recent rains) made it difficult to determine the depth of the capillary fringe within the A1 aquifer zone.

The LOC boundaries of LOCs 2b and 6b overlap, and; therefore, the CPT/MIP logs from LOC 2b were also reviewed concurrently with the CPT/MIP logs from LOC 6b. The LOCs overlap because "reverse" groundwater flow paths, drawn from the indefinite sources at LOCs 2b and 6b to the areas estimated to be upgradient of the LOCs, appear to converge in the area near the "elbow" in Stevens Way (Figure 12). (The groundwater flow paths were estimated from November 2010 for the A1 and A2 potentiometric surfaces using flow net analysis techniques [in other words, crossing potentiometric contours at right angles].) The ECD response between 9.5 and 10.5 feet bgs at LOC2b-P2-LA ($4.1x10^5$ µV) was slightly above background for the 9.5 to 10.5-foot bgs interval. Results of a review of ECD, EC, and PID logs of LOC2b-P2-LA, LOC6b-P1-LA, and LOC6b-0-LA, along with the pore pressure log from the CPT, indicated that the highest responses in the A1 aquifer zone appeared to coincide with the capillary fringe—warranting further investigation in Phase 3 as a potential source area.

The indefinite source areas for both LOCs 2b and 6b converged near the location of a former septic tank at the farm that once occupied this part of the Site. The septic tank was investigated by the Army (see description in Section 10.3.6 in the SAP [Appendix A], USACHPPM 2009), and neither the tank itself nor any associated VOC contamination was found. Nevertheless, in keeping with the decision logic, a number of MIP borings (LOC6b-P1-LA, LOC6b-SS1-LA, and LOC6b-SS2-LA) were advanced within this area. A review of the USACHPPM 2009 investigation, along with data from the CPT/MIP investigation, determined that a point downgradient of the septic tank would provide the most new data because several MIPs had been pushed within that area. The area just downgradient of the former septic tank was selected as the best location for the "short-step" CPT/MIP—LOC6b-SS1-LA. Screening criteria were exceeded based on minor ECD responses and PID responses observed within the capillary fringe area.

LOC6b-SS2-LA was advanced upgradient to further investigate the area and to attempt to bound the potential source, if any (Figure 13). No response above background was observed within the A1 aquifer zone; the maximum ECD response of 4.5×10^6 µV at LOC6b-SS2-LA occurred between 32 and 34 feet bgs; screening criteria were not exceeded.

A review of all CPT/MIP data obtained in the vicinity does not indicate presence of an on-site source in the upgradient vicinity of LOCs 6b and 2b. The minor ECD responses at the capillary fringe within the A1 aquifer zone at LOC2b-P2-UA, LOC6b-P1-LA, LOC6b-SS1-UA, and LOC6-0-LA appear to be above background; however, the maximum responses within the A1 aquifer zone (approximately 3.0×10^5 to 5.0×10^5 µV) are much lower than would be expected within a source area. The Army's October 2009 investigation of the former septic tank and drain field yielded similar ECD responses in the 4.0×10^5 to 5.0×10^5 µV range within the capillary fringe that did not correspond to detectable concentrations of VOCs in grab soil samples (USACHPPM 2009).

Elevated ECD responses within the A1 and A2 aquifer zones appear to be associated with the finer-grained material within the estimated A1/A2 aquitard horizon. DPT sampling was recommended to confirm that the low-level ECD responses observed at the capillary fringe do not correspond to a source area.

3.3 PHASE 3 – DIRECT PUSH TECHNOLOGY BORINGS AND HYDROPUNCH GROUNDWATER AND SOIL GRAB SAMPLES

From February 14 to 16, 2011, nine DPT borings were completed within the A1 and A2 aquifer zones at LOCs 2b, 3, and 6b, and 11 groundwater grab samples were collected to identify potential on-site sources of contamination and confirm the preferential pathway through the Site. LOC 2b (A1 aquifer zone) and LOC 6b (A2 aquifer zone) were co-located and treated as a single area during Phase 3.

Groundwater grab samples were analyzed for VOCs. Table 6 summarizes TCE and DCE results, as well as observations of the DPT groundwater grab samples; the full analytical results are presented in Appendix D (Validated Data, Laboratory Report, Data Validation Report, And Quality Control Data Summary). All groundwater grab samples were reviewed and validated. Once the samples were collected and the validated data were received, the groundwater grab sampling data and corresponding lithological data were incorporated into EVS to assess the preferential pathways for the TCE plume. Appendix F (Field Forms) includes soil boring logs from Phase 3 for borings where lithology data were not obtained from co-located CPT/MIP borings. Photographs from the field investigation are provided in Appendix G (Field Investigation Photographs).

In addition, a review of the CPT/MIP data in EVS prior to the DPT investigation indicated that additional data would be needed upgradient of LOC 6b within the A2 aquifer zone to verify the presence of permeable channel deposits at the 40- to 45-foot depth interval, and to evaluate the continuity of the chlorinated solvent plume between the upgradient boundary of the Site and LOC6b. A set of PQOs for these data was prepared (Table 7) to focus the DPT investigation on verifying presence and continuity of VOC contamination within the A2 aquifer zone upgradient of LOC 6b (Figures 22, 23, and 25). New data inputs were to include analytical results for VOCs in groundwater grab samples collected at discrete depth intervals within the A2 aquifer zone at three locations in the predicted upgradient direction of LOC 6b, and associated boring logs. Historical well and groundwater grab sample data were also reviewed, as well as historical borings logs, historical and recent potentiometric surface maps, and the January 2011 CPT/MIP data.

The following analytic approach was used to evaluate if VOC contamination detected by the MIP response at LOC 6b derives from a plume extending from the southern Site boundary:

- If permeable sediments are logged within the A2 aquifer zone at the same depth as the interval of interest at LOC6b-0-LA (the depth interval with the elevated MIP response and CPT response indicating sand within the A2 aquifer zone), a potential migration pathway extends from the upgradient location to downgradient LOC 6b. If permeable sediments are not observed within the A2 aquifer zone at the same depth as the interval of interest at LOC6b-0-LA, a potential migration pathway does not extend from the upgradient location to downgradient LOC 6b, and thus a localized source may be present.

- If VOCs are detected within the A2 aquifer zone at either downgradient location (LOC6b-DP-07 or LOC6b-DP-10) and at the upgradient location (LOC6b-DP-09), and permeable channel deposits appear evident at both locations, VOC contamination at LOC 6b may be an extension of the plume from the upgradient location. If VOCs are not detected within the A2 aquifer zone at either downgradient location and at the upgradient location, or permeable channel deposits do not appear evident at the depth interval of interest at the upgradient location, the VOC contamination detected at LOC6b-0-LA likely derives from a localized source.

Modeling/visualization of Site geology, hydrogeology, and the contaminant plume using EVS-Pro was performed concurrent with Phases 2 and 3. Modeling results were used to select DPT boring locations at LOCs 2b, 3, and 6b.

Sections 3.3.1 through 3.3.3 describe the Phase 3 investigations and subsequent modeling in EVS. Section 3.3.4 discusses results of comparing calculated molar values of analytes in upgradient and downgradient groundwater grab samples.

3.3.1 LOC 6b – A2 Aquifer Zone

DPT samples were collected and soils were logged at three locations to evaluate if widespread VOC contamination detected by the MIP in the LOC 6b area is likely related to the VOC plume detected within the A2 aquifer zone at the southern boundary of the Site.

- LOC6b-DP-07 is located at the center of the Site directly upgradient of LOC6b. Groundwater grab samples were collected at depths of 13 to 14 feet bgs, within the A1 aquifer zone, and between 42 and 43 feet bgs, within the A2 aquifer zone.

- LOC6b-DP-09 is located at the southeastern corner of the Site upgradient of LOCs 3 and 6b. A groundwater grab sample was collected at a depth of 42 to 43 feet bgs, within the A2 aquifer zone.

- LOC6b-DP-10 is located along the east boundary of the Site upgradient of LOC6b. A groundwater grab sample was collected at a depth of 42 to 43 feet bgs, within the A2 aquifer zone.

TCE concentrations were found to decrease from 99 µg/L at the southeastern corner of the Site (LOC6b-DP-09) to approximately 50 µg/L at the center of the Site at LOC6b-DP-07. Results from the sample collected at LOC6b-DP-10 were ND, indicating that the preferential pathway within the A2 aquifer zone is not contaminated in the vicinity of this boring. A lack of contamination along the western boundary within the A2 aquifer zone is further confirmed by the ECD response between 42 and 43 feet bgs in the LOC6b-P4-LA ECD profile.

Also noted is the preponderance of sandy lithologies within a depth interval of 40 to 45 feet bgs at the Site (Figure 25; Cross Section E-E'). This is likely the most significant layer of contaminant transport within the A2 aquifer zone, because of its relative continuity. Deeper, more contaminated zones have been detected at the Site—particularly at the southwestern corner of the Site, at LOC5b-P6-LA, LOC5a-SS3-LA, and LOC5b-P4-LA—but these zones are not as widespread.

Results of the A2 aquifer zone investigation at LOC 6b indicate that permeable lithologic layers could support movement of TCE from off-site sources into LOC 6b, and provide evidence that the trend of TCE concentrations at the DPT boring locations is consistent with movement of TCE from off-site sources.

3.3.2 LOC 3

The Phase 2 investigation of LOC 3 concluded that no source characteristics were indicated in any of the ECD profiles at LOC 3. Screening criteria were not exceeded at any CPT/MIP location in LOC 3. The suspected source was investigated and scored a "1"—but only because of low-level response at the bottom of the A1 aquifer zone. The area was then investigated as an indefinite source, beginning with a downgradient boring (LOC3-0-UA), which also scored a "1." Unlike the A1 aquifer zone at LOC 6b, the maximum response appeared to be in the saturated zone rather than in the capillary fringe, and results from boring LOC3-0-UA did not exceed screening criteria, indicating that a source area is not present in that area. Direct-push samples were collected from two boreholes during Phase 3 to further characterize an area of locally elevated dissolved concentrations (as discussed in Section 3.2.4).

LOC3-DP-01 was drilled adjacent to the indefinite source MIP at LOC 3 (LOC3-0-UA). Two samples were collected—one at the uppermost geologic unit that would likely yield groundwater, as determined by the field geologist, which was a silty sand between 15 and 16 feet bgs and one corresponding to the highest ECD response in LOC3-0-UA (between 17 and 18 feet bgs). The silty sand unit from 15 to 16 feet bgs had a lower ECD response of $4.7x10^5$ µV, relative to the clay units at 13-14 feet and 17-18 feet bgs, which had response of approximately $1x10^5$ µV). However, TCE was detected in the upper interval at 94 µg/L (in the silty sand) and in the lower interval at 110 µg/L (in a clay unit). Thus, while the peak ECD response was confirmed to originate at least several feet below the bottom of the capillary fringe, it was found that the TCE concentrations in the silty sand and the clay were approximately equal. Thus, even where the ECD response varies significantly depending on lithology, the TCE concentrations are similar and the peak recorded in the fine-grained unit is probably more representative of the actual TCE concentration.

A second DPT boring (LOC3-DP-03) was pushed east of LOC 3, on the Site boundary, to: (1) better assess whether the elevated ECD readings at LOC3-0-UA had been caused by a source area adjacent to the Site boundary, and (2) confirm that the low-level ECD response observed at the water table (between 14.5 and 15.5 feet bgs) at LOC3-P4-UA did not indicate significant contamination. A groundwater grab sample collected between 15 and 16 feet bgs at this boring yielded only 0.76 µg/L of TCE, indicating there was not a source in this area contributing to the plume at LOC3-DP-01.

The DPT investigation at LOC 3 confirmed the Phase 2 conclusions that no local source is present at CPT/MIP boring LOC3-0-UA, and that this LOC is a localized area of elevated concentrations. The factors that may lead to variations in concentrations across the Site are discussed in Section 3.3.6.2.

Interestingly, results at LOC3-DP-01 and LOC3-DP-03 confirmed the assumed correspondence between ECD responses and DPT sample results, at different levels of contamination. The low-level ECD response at LOC3-DP-03 ($4.5x10^5$ µV) corresponded to less than 1 µg/L TCE, similar to results at the LOC6b-0-UA/LOC6b-DP-01 pair at LOC 6b. A high-level ECD response of $1.9x10^6$ µV at LOC3-DP-01 at 17.5 feet bgs corresponded to a TCE concentration of 110 µg/L.

3.3.3 LOC 2b and LOC 6b – A1 Aquifer Zone

The rationales for continuing the indefinite source investigation at LOCs 2b and 6b were that the highest response at LOC6b-0-LA within the A1 aquifer zone had been in fine-grained sediments (1 point), the MIP response had decreased with depth within the A1 aquifer zone, and the highest response had originated from within the estimated capillary fringe (2 points) (see Table 5 for source indicator criteria), resulting in a score of "4," which exceeded screening criteria. The ECD response was considered low level, but above background ($5.3x10^5$ µV at a depth of 11.2 feet bgs).

In the re-evaluation of LOC6b-0-LA as a potential source within the A1 aquifer zone, the Army advanced DPT borings at LOC 6b during Phase 3. One DPT boring was advanced at the indefinite source location (LOC6b-DP-05). The groundwater grab sample was collected between 12 and 13 feet bgs, immediately below the peak ECD response at 11.7 feet bgs, and within the first interval from which groundwater would flow into the borehole (water will not flow within the capillary fringe itself). The resulting concentrations were estimated below the quantitation limit of 1 µg/L and do not represent a chlorinated solvent source area. As noted in Section 3.2.9.2, this further supports findings of the septic tank investigation (USACHPPM 2009) that ECD readings considered low-level (approximately 3×10^5 to 5×10^5 µV), but are discernible above the baseline level of ECD response, correspond to laboratory sample results that are either ND or detected below the laboratory quantitation limit (below 1 µg/L; estimated).

Two additional DPT borings were advanced in a direction that was cross-gradient of the first DPT location (LOC6b-DP-05), at distances of 100 feet (LOC6b-DP-06) and 200 feet (LOC6b-DP-12) south of LOC6b-DP-05. These locations were selected because they were oriented along a former drainage ditch that was observed in historical air photos, extending north from the elbow in Stevens Way to the indefinite source area at LOC 6b. They were conducted to investigate the possibility that LOC 6b could be associated with past disposal practices at the farm that may have contaminated sediment and/or groundwater below the ditch. The resulting concentrations were below quantitation limits for TCE and ND for DCE at LOC6b-DP-06 (sample collected at 12 to 13 feet bgs) and 14 µg/L for TCE and 3.9 µg/L for DCE at LOC6b-DP-12 (sample collected at 13 to 14 feet bgs).

Also worth noting is that groundwater grab samples were collected upgradient of LOC-DP-12 at LOC3-DP-01 at two depths (15-16 feet bgs and 17-18 feet bgs). Both samples contained higher TCE concentrations (94 µg/L and 110 µg/L, respectively) than TCE concentrations at LOC6b-DP-12. Thus the concentration gradient from the upgradient to downgradient locations within the A1 aquifer zone at the LOC 6b area decreases in the estimated direction of groundwater flow. Considering that the TCE concentration found at the indefinite source location was less than 1 µg/L (0.66 µg/L), the Army concluded that the A1 aquifer zone at LOC 6b does not have the characteristics of a VOC source.

3.3.4 LOC 4

One soil sample was collected at one location (FW41A) to evaluate whether the high PID reading during advancement of a boring in 2002 had been caused by elevated concentrations of TCE at that location. The soil sample was analyzed for VOCs and for TPH as gasoline, motor oil, and diesel fuel.

None of VOCs, TPH as gasoline, motor oil, or diesel fuel was detected in the soil sample collected at 11 feet bgs. Therefore, the PID field screening values at 11 feet bgs had been caused by something other than TCE or TPH: no TCE or TPH release had occurred at or near this location. No further investigation is required in this area.

3.3.5 Results of the Molar Calculation

Results from the direct-push, groundwater grab sampling event showed a decreasing trend in chlorinated ethene concentrations by mass in groundwater from upgradient sample locations to downgradient sample locations within each LOC, as discussed above. Appendix E (Molar Calculation) presents supporting figures and tables for the molar calculations. Table E-1 presents concentrations of chlorinated ethenes detected at the Site.

Trends within the A1 and A2 aquifer zones were analyzed separately. The molarity calculation results are shown in Table E-1, and trends in molarity from upgradient to downgradient locations are shown on Figures E-1 and E-2. The trend analysis of the A1 aquifer zone included samples collected from LOC 3 and LOC 6, and involved four direct-push locations. The trend analysis of the A2 aquifer zone involved only two direct-push locations, LOC6b-DP-09 and LOC6b-DP-07. Results of cross-gradient samples from LOC6b-DP-07 within the A1 aquifer zone and LOC6b-DP-10 within the A2 aquifer zone were not used in the analysis.

Results mirrored the mass concentration trends found from upgradient to downgradient sample locations. An overall decline in the molarity of chlorinated ethenes correlated well with an overall decline in the mass concentrations reported by the laboratory.

3.3.6 Results of the EVS Modeling

The preliminary CSM (Section 1.2.3) was refined using data collected during the SSI. CPT, MIP, and DPT data were input into the EVS model as described in Section 2.2. The contaminant pathways of the TCE plume through the Site in the A1 and A2 aquifers are shown on Figure 20.

3.3.6.1 General Observations of Site Lithology and Contaminant Transport

The 3D EVS model provides information about lithology and shows preferential flow paths for the TCE plume through the subsurface at the Site. The EVS model provides evidence that a dissolved TCE plume is much more concentrated within the A2 aquifer zone and within the southern half of the Site near the Site boundary. The sand channel figure (Figure 16) and the solid model figures (Figures 17 through 21) indicate the plume follows the southeast-to-northwest trend of the sand deposits, exiting the Site in the vicinity of LOC 1.

The EVS figures (Figures 16 through 21 and Figures 23 through 30) provide the following observations to support this model of contaminant transport:

Solid Model of Geology, Site Lithology

Figure 16 shows the interpolated model of the sand and gravel channels within the A1 and A2 aquifer zones. Sand channels are present throughout the Site; the discontinuity between sand lenses at LOC 3 may be an artifact of lower data density in this area. Most of the sand channels veer from the upgradient southwest border to the northwest, as indicated by the line of CPT borings on the north end of the Site, which have relatively little sand (Figure 16). For instance, a relatively thick zone of sand and gravelly sand in the northern portion of the Site is truncated at the two borings in the lower-right corner. The northwestern trend of the sand deposits is similar to the northwestern slope of the potentiometric surface and the northwestern trend of the contaminant plume, which can be viewed in Figures 17 through 21.

Solid Model of ECD Response

Figures 17 through 21 show that the plume, as characterized by the low-level MIP responses, generally follows the trend of the sand and gravel channels shown in Figure 16. This trend is most evident in the A1 aquifer zone where the brighter part of the plume (the portion above the transparent-gray aquitard surface) bends toward the northwest boundary of the Site. Figures 17 through 21 show that most of the plume that exhibited mid- and high-level MIP responses is located in the A2 aquifer zone, particularly in the eastern half of the Site.

Preferential Flow Paths of TCE Plumes within the Site

Figure 22 (plan view) and Figures 23 through 25 and Figure 29 (cross sections) show the preferential flow paths of the TCE plume through the Site in the A1 and A2 aquifers.

Figure 23 presents evidence of a continuous plume in the north-south direction. Figure 23 shows that cross section A-A' crosses LOC 3 at an oblique angle and bisects LOC 2b. The highest ECD response occurs in two regions: from the upgradient boundary (LOC5c-P5-LA) to LOC 3, and in the LOC 2b/6b area. The apparent discontinuity in the plume is a result of the cross section deflecting slightly to the west to include LOC6B-DP-07. If the cross section took a more direct path, the area of ECD response above the background level ($5x10^5$ µV) would be continuous from south to north.

Figure 23 (Cross Section A-A') and Figure 24 (Cross Section B-B') present evidence that plume concentrations are roughly equal in the A1 and A2 aquifer zones at the center of the Site (at LOC6b-DP-07). The A1/A2 aquitard zone likely is thin or discontinuous in this area, because a sand channel is at approximately the same elevation as the aquitard southwest of LOC6b-DP-07 at LOC5c-P4-LA. Cross section B-B' (Figure 24), which bisects the long axis of LOC 3 before terminating at LOC 6b, also illustrates an upward trend in ECD responses from south to north across the Site.

Figures 23 and 24 also show that the concentrations at the former paint locker location (LOC3-SS0-UA) in the A1 zone are not as high as the A2 concentrations within the same area. The highest concentrations appear to be located in the A2 aquifer zone at the location of the former paint locker (LOC3-SS0-UA), but are in the A1 aquifer zone farther north, at LOC3-0-UA. The area of high concentrations appears to be continuous across the A1/A2 aquitard.

Cross section E-E' (Figure 25) originates near the southern, upgradient boundary of the Site and is parallel to the groundwater gradient within the southern half of the Site (upgradient of LOC 5a). Cross section E-E' then cuts crossgradient through LOCs 5b, 2a, 5c, and 2b, and ends at LOC 6b. Cross section E-E' indicates that the highest A1 aquifer zone concentrations are continuous from the southern boundary through the western half of the Site, but are largely absent at the northeastern corner of the Site. Figure 25 also shows that the most contaminated portion of the Site is the A2 aquifer zone at the southwestern corner of the Site. Figure 25 (cross section E-E') originates near the southern, upgradient boundary of the Site, and is parallel to the groundwater gradient within the southern half of the Site (upgradient of LOC 5a). Cross section E-E' then cuts crossgradient through LOCs 5b, 2a, 5c, and 2b, and ends at LOC 6b. Although some ECD responses above background can be discerned within the A1 aquifer zone in the southern half of the Site, the ECD responses increase to the north, particularly at LOC2a-P1-UA, immediately above the A1/A2 aquitard.

Figure 25 shows what appears to be a relatively isolated area of high concentrations in the A2 aquifer zone in the vicinity of LOC2b-P2-UA. Viewing the entire fence diagram (Figure 30), it is apparent that the plume can be traced back to the LOC5b-P6-LA area and that it appears disconnected on Figure 25 because the section bends away from the northeast-trending plume in the center of Cross Section E-E'. The thickness of permeable deposits diminishes significantly in LOC 6b, which fits with the overall depositional model of the Site, which is discussed in more detail in Section 3.3.6.2. The stratigraphic "pinch-out" may account for the localized area of higher concentrations below LOC 2b.

3.3.6.2 Refined Site-Wide Contaminant Transport Conceptual Site Model

The contaminant plume at the Site is best described as a "middle-stage" to "late-stage" plume in a "Type 3" geologic setting, based on the 14-compartment model of chlorinated solvent distribution in the subsurface (Interstate Technology and Regulatory Council [ITRC] 2011). A Type 3 geologic setting, as described by the National Research Council (NRC) (NRC 2005) consists of granular soils with moderate to high heterogeneity, typical of highly transmissive sand channels and low-transmissivity splay deposits and floodplain silt and clay deposits.

Recent research indicates that Type 1 and 2 geologic media (both consisting of granular media with low heterogeneity) are relatively rare and that almost all sites currently being addressed are at least 20 years old; thus, the most common scenarios are what is observed at the Site. The 14-compartment model, as it relates to these scenarios, is reproduced as Figure 28. The compartments are highlighted in red, yellow, or green, signifying decreasing order of importance.

Late-Stage Plume

Given the model depicted in Figure 28, the results of the SSI strongly suggest the late-stage model is most appropriate for the site plume, as the highest VOC concentrations encountered with use of the MIP were consistently associated with fine-grained sediments, particularly the A1/A2 aquitard. Elevated VOC concentrations were associated with the same 22- to 29-foot-bgs horizon that is thought to constitute the A1/A2 aquitard, particularly in downgradient areas such as the LOC 2b/6b area.

Elevated VOCs appear to be associated with a late-stage plume that crosses the Site from southeast to north-northeast (A1 and A2 aquifer zones) and southwest to north-northwest (A2 aquifer zone) (Figure 27). Figure 29 shows a pair of plume cross sections (C'C' and F-F') viewed at an angle of 65 degrees above the horizontal and from the west-northwest direction (observer standing roughly at Stevens Creek). The two cross sections bracket the swath of the Site that had the highest VOC concentrations in the A1 aquifer zone. The cross section in the foreground (C-C') has the thickest sequences of sand deposits in the A1 aquifer zone, indicating that it bisects the channel deposit, while the A1 sand deposits in the background Cross Section F-F' are relatively thin, indicating the channel begins to pinch out to the east. The proximity of this broad swath of sand to Stevens Creek suggests it may be part of the Stevens Creek meander belt, similar to the center of the depositional model depicted on Figure 31. However, even from this high viewing angle, it can be seen that some of the wells on cross section C-C', with the greatest sand thickness in the A1 zone (at the right-hand extent of LOC 5a), have muted ECD responses.

These cross sections illustrated that the ECD response for VOCs may be weaker in the coarser sediments, with peak concentrations in the silty sand layers that laterally bound the channel deposits above and below. These ECD trends are typical of a late-stage plume, where much of the contamination is retained by the finer-grained sediments (the stagnant compartments), as shown on Figure 28.

Much of the VOC contaminant mass likely resides in the stagnant (low permeability) compartments shown on the 14-compartment model. Figure 30 shows the portion of the Site where the ECD response across the A1 and A2 aquifer zone is approximately equal above and below the A1/A2 aquitard, which is typical of mid- to late-stage VOC plumes (see Figure 28). Figure 18 shows cross sections viewed at angle of 65 degrees above horizontal. Figure 30 incorporates the previous cross sections (Figures 23 through 25 and Figure 29), as well as two additional cross sections (C-C' and F-F') that traverse the Site from west to east. Low-permeability units function as a continuing source in late-stage plume evolution, releasing TCE through diffusion. Periods of high recharge, such as those that occurred in the winter of 2010 and 2011 (while this investigation was being conducted) dilute the plume in the transmissive compartments, increasing diffusion from the low-permeability units until VOC concentrations in the stagnant compartments equilibrate with the surrounding low-permeability units.

A1 Aquifer Zone Preferential Flow Paths

The A1 aquifer zone VOC plume appears to potentially follow the high-permeability channel deposits that are a fairly recent precursor to Stevens Creek. Figure 30 presents a fence diagram of the Site that shows this channel. Figure 30 shows that the main body of the A1 aquifer zone plume is at the southern site boundary at LOC4-P1-UA (southern intersection of cross sections C-C' and F-F'), extending through the southwest portion of the Site on a trajectory roughly parallel to Stevens Creek, and exiting the Site near well MCH-9UA at LOC 1 (southern intersection of Cross Sections C-C' and F-F').

Stevens Creek is a typical alluvial plain depositional environment with meandering stream facies, resulting in stream channel deposits where the uppermost A1 sand deposit may be a precursor to the current Stevens Creek. In this depositional environment, crevasse splay deposits result from small distributary channels that narrow and quickly grade into finer-grained silty sand and silt deposits. Figure 31 shows the three primary depositional units that were identified in the "meandering stream facies model," which best describes the geology of the A1 and A2 aquifer zones at Stevens Creek and Moffett Field (PRC and James M. Montgomery Consulting Engineers 1991): stream channel (primarily sand and gravel), crevasse splay (silty sand and silt), and floodplain (silt and clay).

Splay deposits, as well as the silty sand blanket that wraps around the main channel deposits, have characteristics that are transitional between the "transmissive" and "stagnant" compartments depicted in the 14-compartment model. Splay deposits have a significant effect in contaminant migration, as their large-scale geometry may result in permeable pathways that "dead-end" in stagnant compartments at the northern end of the Site.

A2 Aquifer Zone Preferential Flow Paths

The A2 aquifer zone VOC plume appears to extend from the southern end of the Site along a north-northeastern course to the northern end of the Site (Figure 30), with a smaller branch crossing from the southeastern corner, both appearing to converge near LOCs 2b and 6b. Figure 30 shows the southern end of the main plume at LOC5b-P6-LA on section E-E' extending to the northern end of the site at the approximate intersection of sections A-A', E-E', and B-B'. The VOC plume appears to be following distributary branch channels, similar to those portrayed on Figure 31. The borings at LOCs 2b and 6b appear to be located in splay deposits associated with a distributary channel that "dead-end" in stagnant compartments. MCH-10LA is likely a more stagnant portion of the groundwater flow field because the plume intersects a thinning wedge of sand and appears to be in an area where flow direction shifts from northeast to northwest seasonally.

3.4 PHASE 4 – GROUNDWATER WELL INSTALLATION, MONITORING WELL DEVELOPMENT, GROUNDWATER SAMPLING, AND WELL SURVEYING

Following Step 2 of the PQOs (SAP Worksheet #11 in Appendix A), because no on-site sources were identified, groundwater wells were not installed and an additional round of groundwater sampling was not conducted.

3.5 PHASE 5 – IDW HANDLING AND MANAGEMENT

IDW was generated at three stages of the field investigation. Approximately 20 gallons of liquid IDW were generated as purge water during groundwater sampling from January 3 through 5, 2011 (Phase 1). Approximately 50 gallons of liquid IDW were generated as equipment standard test water during the CPT/MIP investigation (Phase 2) between January 14 and 28, 2011. Approximately 30 gallons of decontamination water and 35 gallons of soil tailings were generated as IDW during the DPT investigation (Phase 3) between February 14 and 16, 2011. The drums were transported off site as nonhazardous waste by AIS on August 1, 2011 and disposed of at the Crosby & Overton disposal facility in Long Beach (Appendix F – Field Forms).

4.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions of this SSI are summarized in Table 8 and below. Phase 2, the CPT/MIP investigation, found that six of nine LOCs (LOCs 1, 2a, 4, 5a, 5b, and 5c) showed no evidence of any on-site sources, and the MIP responses indicated that the contamination was part of a larger chlorinated solvent plume crossing the Site from south to north. No further investigation or modeling of these LOCs was deemed necessary. Screening criteria were exceeded at LOCs 2b and 6b during Phase 2, indicating the need for further investigation with DPT during Phase 3. MIP profiles from CPT/MIPs advanced at LOC 3 did not show source characteristics; however, a localized area of elevated VOC concentrations indicated the need for further investigation with DPT. Although the CPT/MIP data did not indicate an on-site source at LOC 4, the area was included in the DPT investigation because it was subject to a separate investigation for TPH in soil, as specified in the PQOs (SAP Worksheet #11 in Appendix A).

At LOCs 2b and 6b, the results of the Phase 3 DPT investigation and a review of the CPT/MIP and DPT data in the contaminant-transport EVS model indicate that elevated concentrations of VOCs on site are not from local sources, but rather are from a late-stage chlorinated solvent plume originating upgradient, as discussed in Section 3.3.6.2.

At LOC 3, the Phase 3 DPT investigation concluded that the localized area of elevated VOC concentrations is not a result of a suspected source (paint locker), but rather a variation in plume concentrations caused by local geologic heterogeneities.

A second purpose of the SSI was to investigate the LOC 4 area around boring FW41A, where field PID screening of vapors from soil cores in 2002 showed between 9.2 and 3,500 ppm VOCs in the capillary fringe; soil samples were not collected in 2002 at the corresponding depth interval to identify the source of the high PID screening result. Therefore, as part of the SSI, the Army collected and analyzed a soil sample at this location to identify those compounds. The soil sample was analyzed for VOCs and TPH as gasoline, motor oil, and diesel fuel. The results of the soil sample show that VOCs and TPH as gasoline, motor oil, or diesel fuel were not detected in the soil sample collected at 11 feet bgs; therefore, the PID field screening values at 11 feet bgs had been caused by something other than TCE or TPH, and no TCE or TPH release had occurred at or near this location. No further investigation is required in this area.

The potential sources of on-site releases identified in the preliminary CSM (agricultural workers, residential backyard mechanics, construction workers, and commercial workers) are unlikely to have contributed to the TCE plume underlying the Site due to the low volume and infrequency of release. The results of the evaluation of data obtained during the SSI and previous investigations indicate no on-site sources of TCE contamination at the nine LOCs investigated at the Site and allude to a late-stage plume that crosses the Site. The elevated VOCs within the plume appear to be associated with an aging plume that originates upgradient of the Site, crosses the Site from southeast to north-northeast (A1 and A2 aquifer zones) and southwest to north-northwest (A2 aquifer zone) (Figure 27).

In a late-stage plume, most of the contamination is sorbed to fine-grained sediments, which are referred to as the "stagnant compartment" in the 14-compartment model (ITRC 2011). The most important fate-and-transport process in a late-stage plume is back-diffusion, by which the chemical equilibrium is maintained between the stagnant (silt and clay) and transmissive (sand and gravel) zones. The chemical equilibrium is disturbed when recharge through the aquifer is increased as a result of heavy precipitation and infiltration. Many of the observations noted in this report (such as concentrations appearing to be greater in finer-grained deposits) are likely a result of disequilibrium between the stagnant and transmissive compartments caused by dilution in the transmissive layers from groundwater recharge. The variations in TCE concentrations noted throughout the Site are probably the result of geologic heterogeneity and the dynamic response of VOC concentrations in the stagnant and transmissive zones.

The Army; therefore, recommends no further action for the TCE plume underlying the Site. Because no sources of TCE were found on site, the Army plans to seek site closure.

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FIGURES

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FIGURE 1
SITE VICINITY

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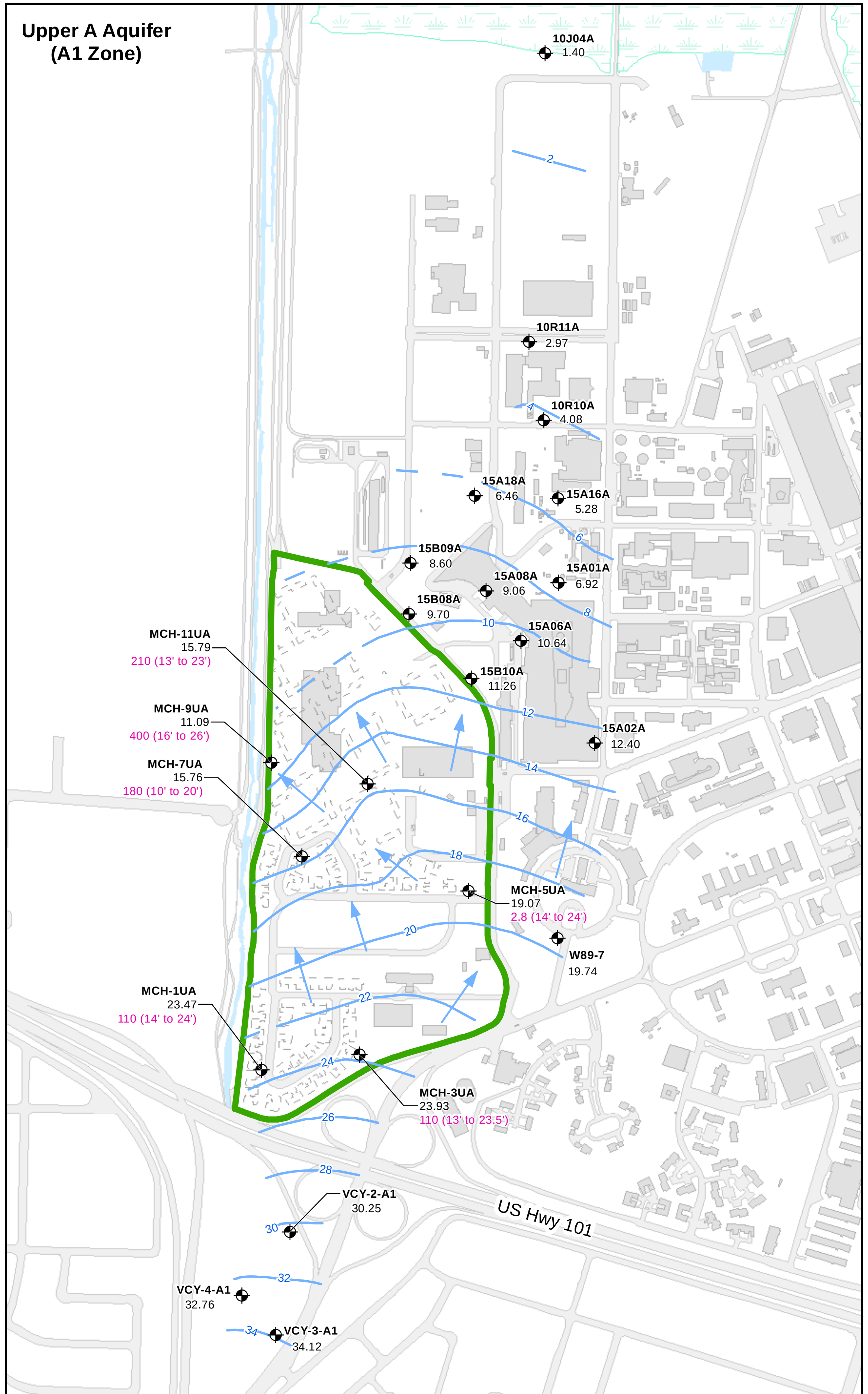

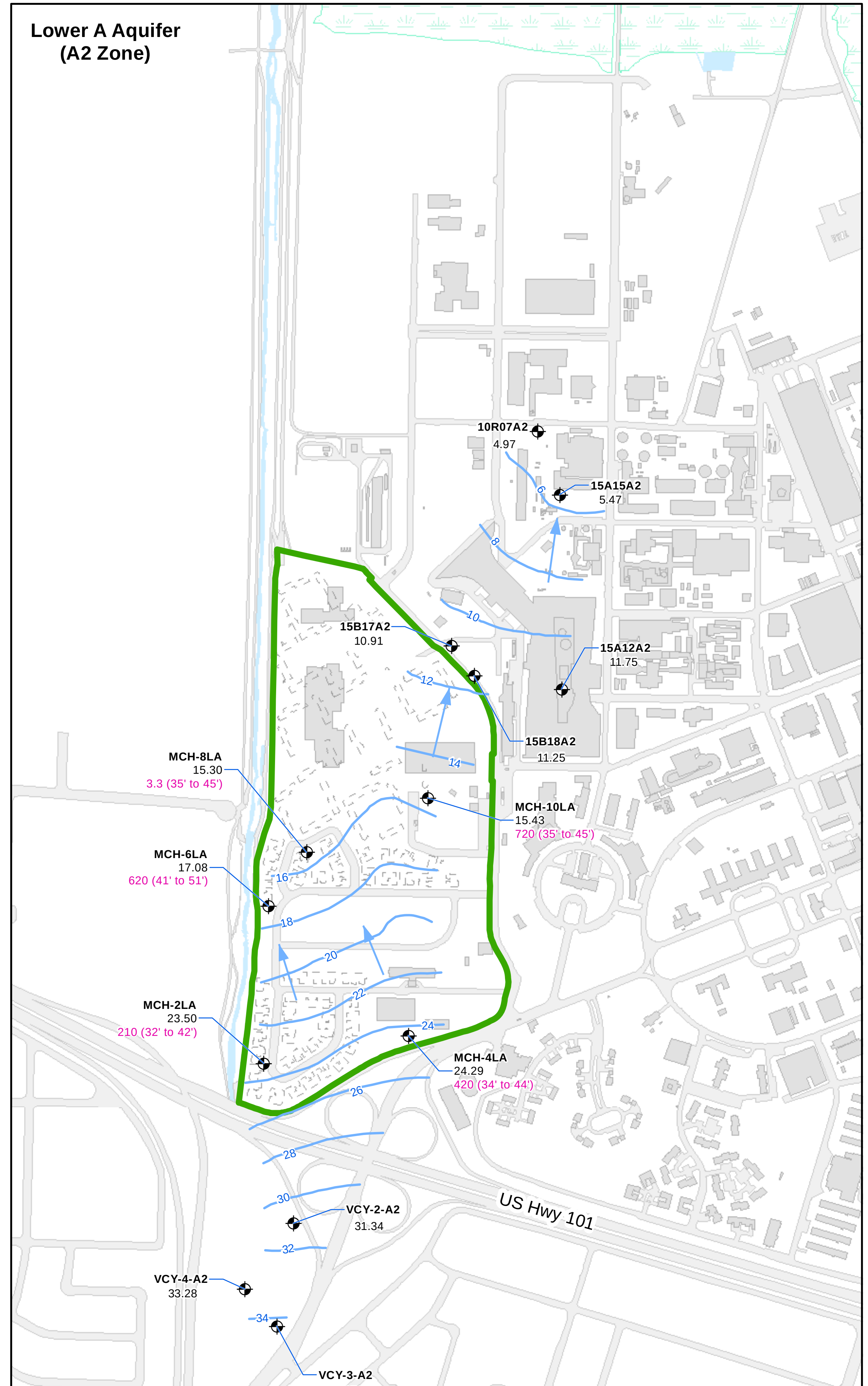

Groundwater Monitoring Well with Groundwater Elevation and, in Some Cases, TCE Concentration from January 2011 in µg/L with Well Screen Depth Interval in Feet Below Ground Surface

Groundwater Elevation Contour in Feet Above NAVD 88, Dashed Where Inferred (Data collected November 18, 2010)

General Flow Direction

Orion Park Housing Area Boundary

Building/Structure

Demolished Building Footprint

Road

Water

Seasonally Flooded Mud Flat

Wetland

Note: Groundwater elevations listed below well names indicate the elevation above NAVD 88, measured on November 18, 2010.

NAVD 88 North American Vertical Datum of 1988
TCE Trichloroethene
µg/L Micrograms per Liter

0 800 1,600
Feet

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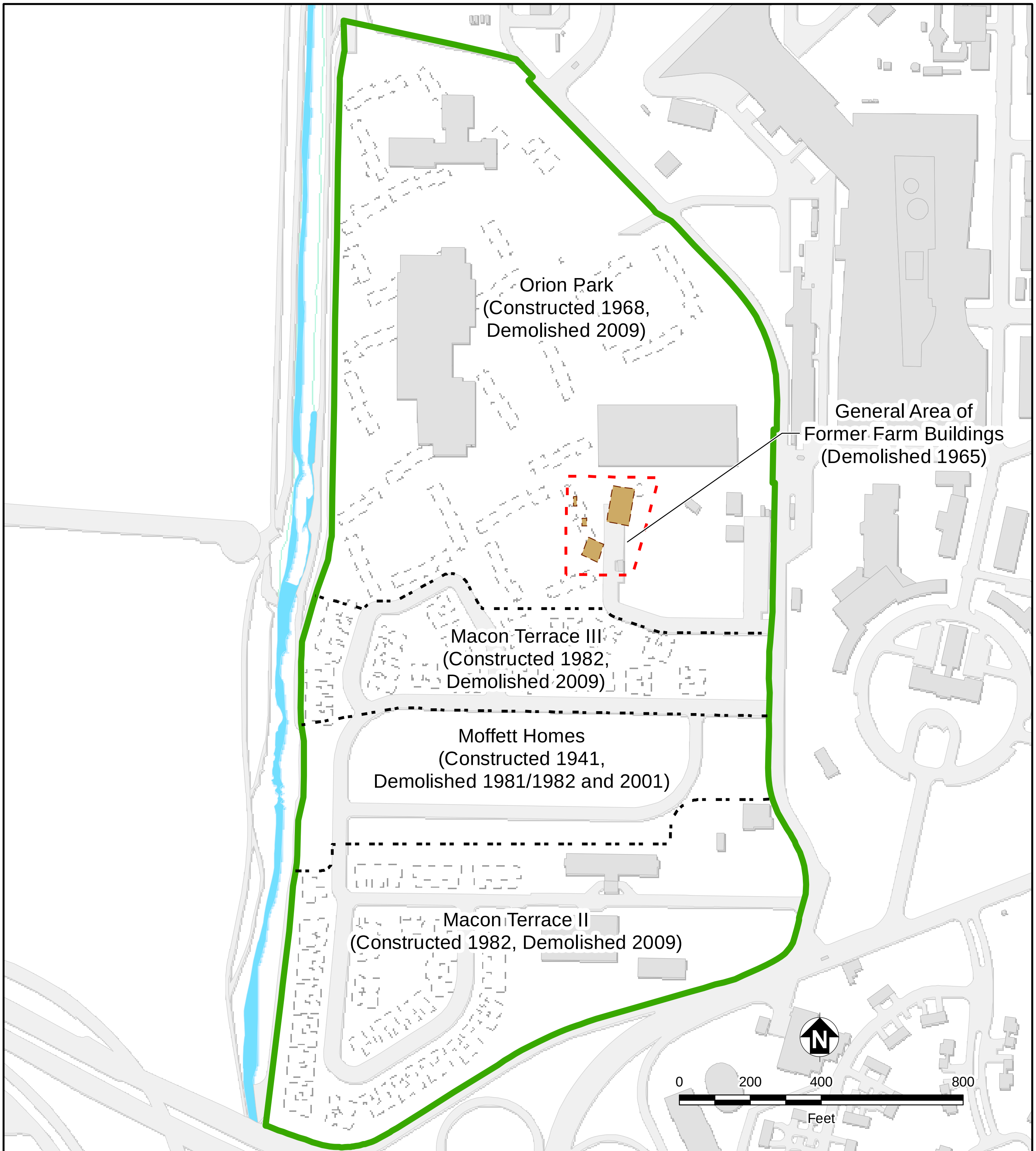
FIGURE 2
POTENTIOMETRIC SURFACE MAPS FROM NOVEMBER 2010 WITH TCE CONCENTRATIONS FROM JANUARY 2011, UPPER A AQUIFER (A1 ZONE) AND LOWER A AQUIFER (A2 ZONE)
Supplemental Site Investigation



Former Orion Park Housing Area Boundary

Former Farm Building

Building/Structure

Road

Water

Housing Development Boundary

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FIGURE 3
FORMER ORION PARK
HOUSING AREA DEVELOPMENTS

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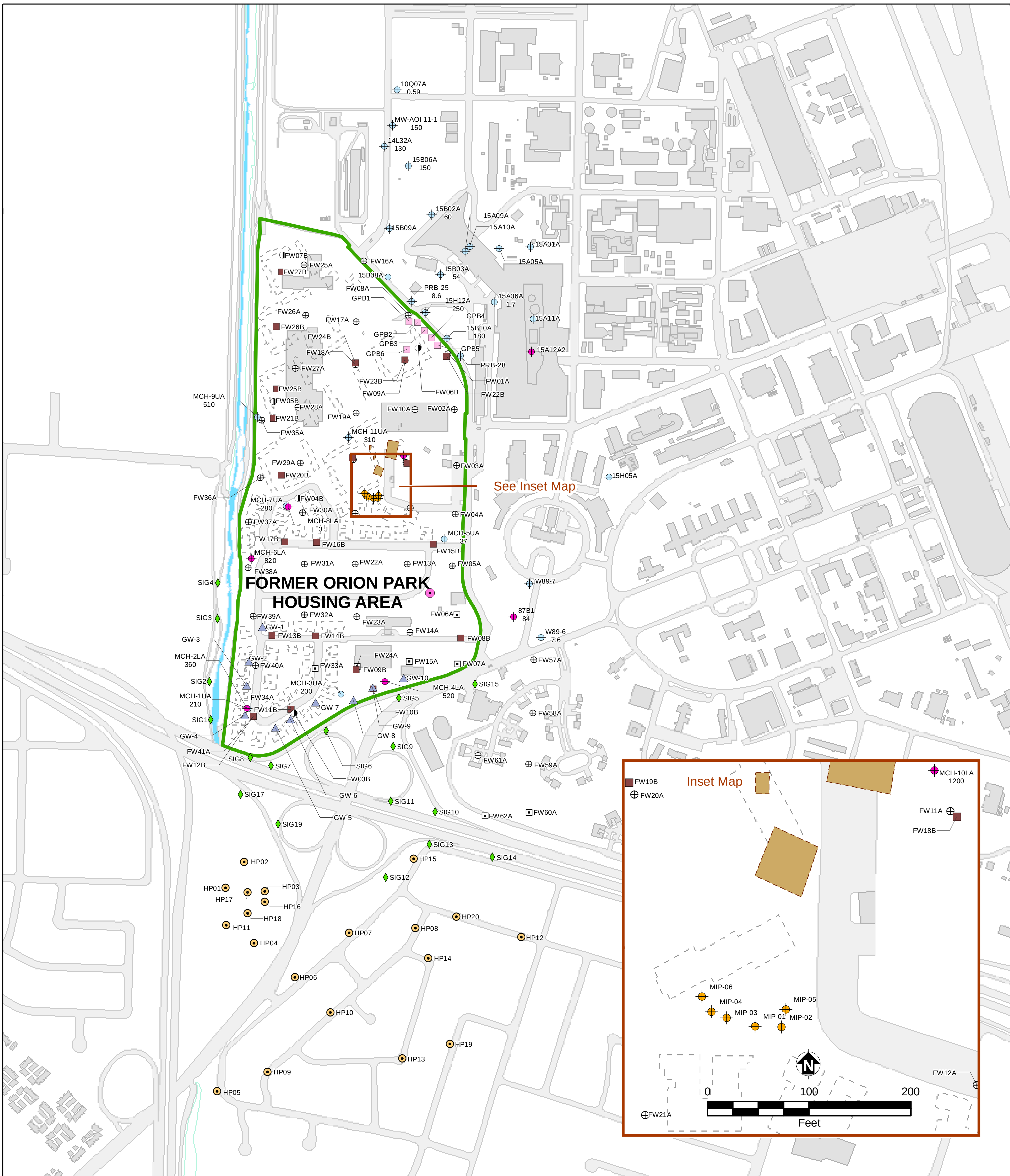

⊕ Phase 1 DPT/Temporary Well Sample Location, 2002

⊡ Phase 1 DPT/Temporary Well, CPT, and DPT/Hydropunch Sample Location, 2002

■ Phase 2 CPT and DPT/Hydropunch Sample Location, 2002

◑ Phase 2 DPT/Temporary Well Sample Location, 2002

Upper A Aquifer (A1 Zone) Well Location

Lower A Aquifer (A2 Zone) Well Location

Army MIP Boring for Septic Tank Investigation, 2009

Army CPT and DPT/Hydropunch Sample Location, 2003

SAIC DPT/Hydropunch Sample Location, 1999

IT Corp DPT/Hydropunch Sample Location, 2000

EPA CPT and DPT/Hydropunch Sample Location, 2005

Location of Former Paint Locker

Former Orion Park Housing Area Boundary

Former Farm Building

Building/Structure

Road

Water

Notes:

CPT	Cone penetrometer test
DPT	Direct push technology
EPA	U.S. Environmental Protection Agency
IT	International Technology Corporation
MIP	Membrane interface probe
SAIC	Science Applications International Corporation

N

0 600 1,200
Feet

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FIGURE 4
PREVIOUS INVESTIGATION SAMPLE LOCATIONS

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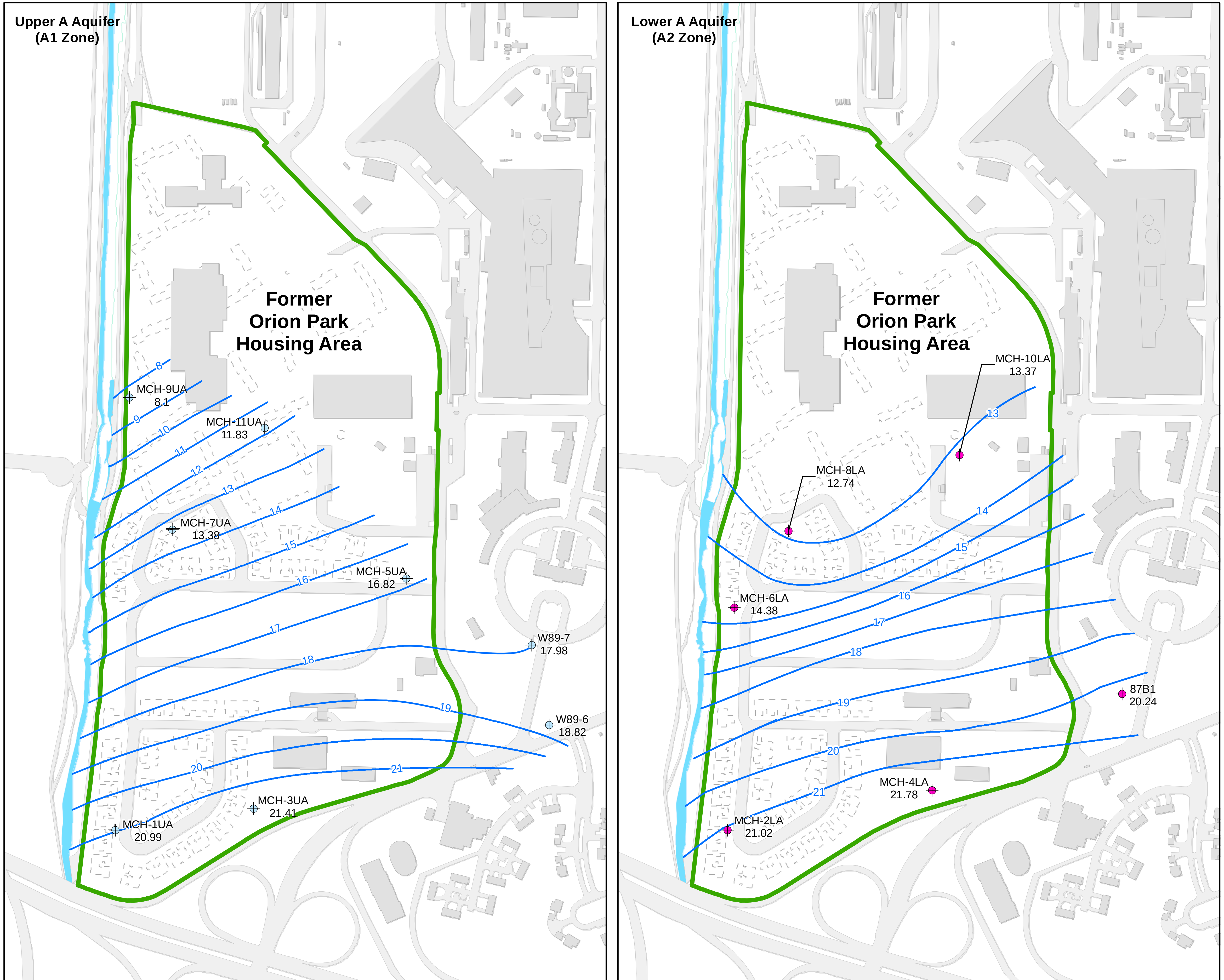

Upper A Aquifer (A1 Zone) Well

Lower A Aquifer (A2 Zone) Well

Former Orion Park Housing Area Boundary

Building/Structure

Road

Water

Groundwater Elevation Contour in Feet, (MSL)
(Collected August 2005 by Tetra Tech EC)

MSL Mean Sea Level

N

0 400 800

Feet

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FIGURE 5
POTENTIOMETRIC SURFACE MAP FROM AUGUST 2005, UPPER A AQUIFER (A1 ZONE) AND LOWER A AQUIFER (A2 ZONE)

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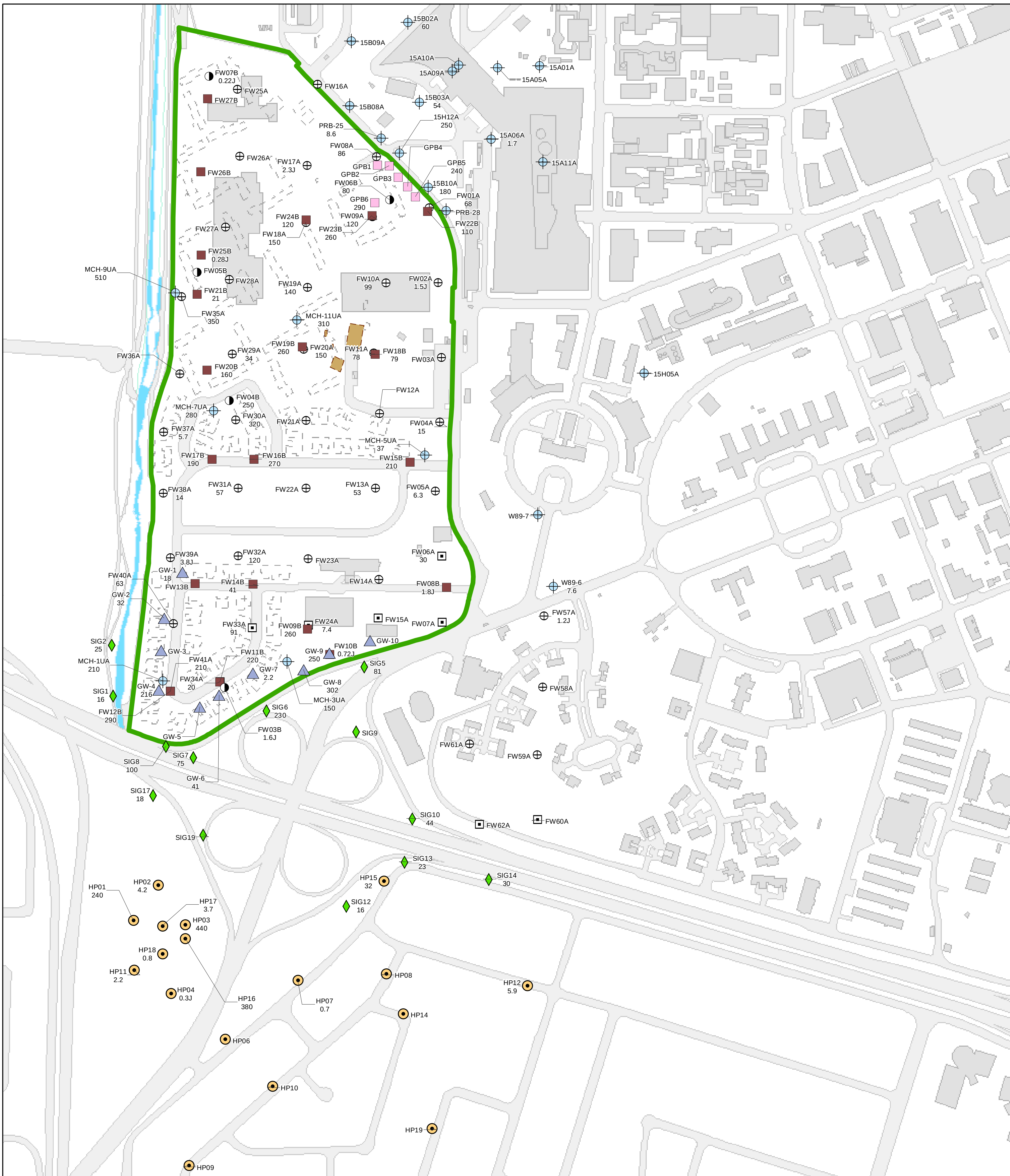

Phase 1 DPT/Temporary Well Sample Location, 2002

Phase 1 DPT/Temporary Well, CPT, AND DPT/Hydropunch Sample Location, 2002

Phase 2 CPT and DPT/Hydropunch Sample Location, 2002

Phase 2 DPT/Temporary Well Sample Location, 2002

Upper A Aquifer Well Location

Army CPT and DPT/Hydropunch Sample Location, 2003

SAIC DPT/Hydropunch Sample Location, 1999

IT Corp DPT/Hydropunch Sample Location, 2000

EPA CPT and DPT/Hydropunch Sample Location, 2005

Former Orion Park Housing Area Boundary

Former Farm Building

Building/Structure

Road

Water

0 450 900
Feet

Notes:
The highest concentration detected during the 3rd quarter of 1999 (GP borings), 2000 (GW borings), 2002 (FW DPT borings), 2003 (SIG borings) or 2005 (MCH borings) within the A1 aquifer at each well or boring is presented. Locations without concentrations indicate the result is below laboratory reporting limits.

CPT	Cone penetrometer test
DPT	Direct push technology
EPA	U.S. Environmental Protection Agency
IT	International Technology Corporation
SAIC	Science Applications International Corporation
TCE	Trichloroethene
µg/L	Micrograms per liter

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FIGURE 6
TCE DISTRIBUTION (1999 - 2005), UPPER A AQUIFER (A1 ZONE)

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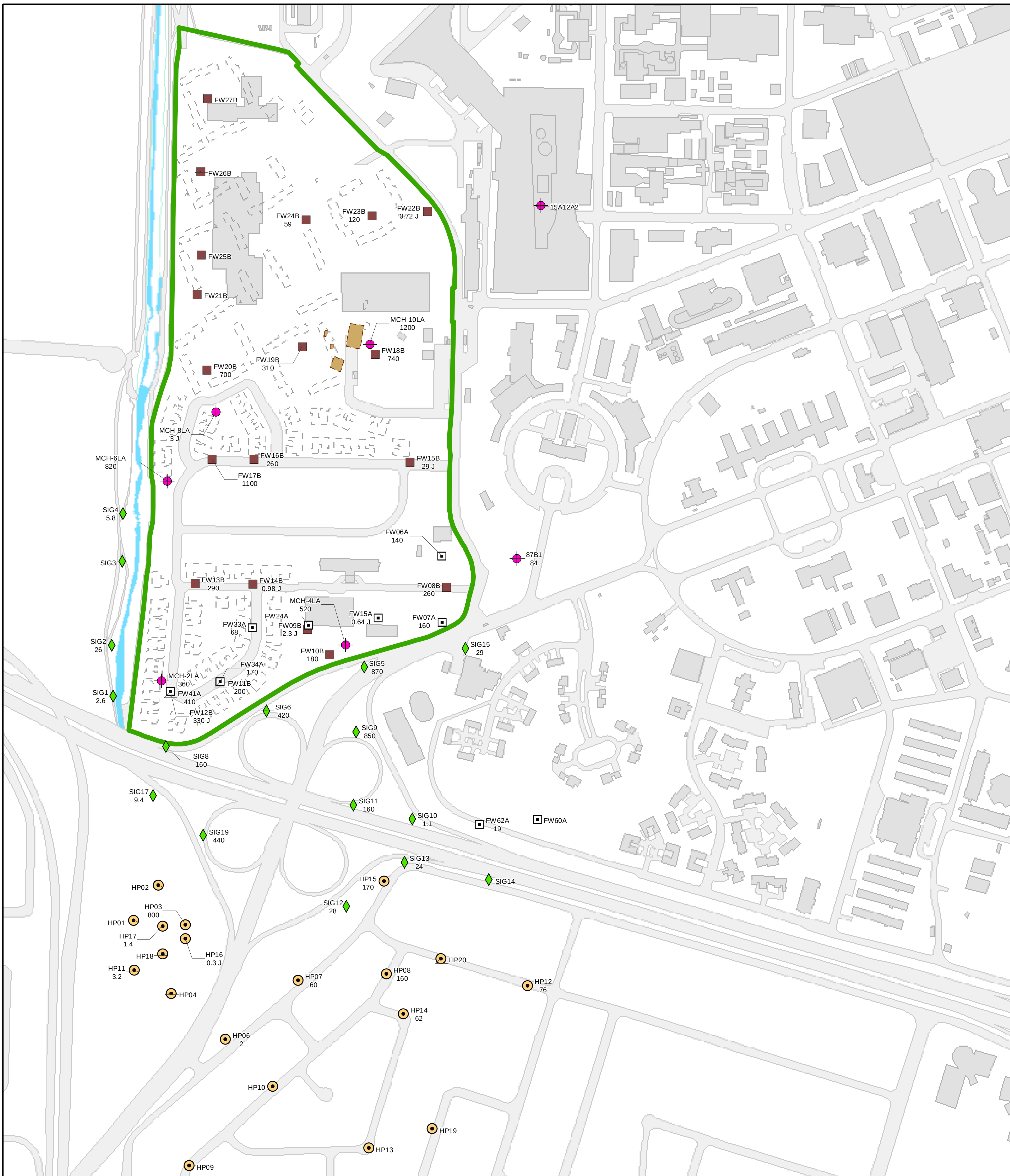

- Phase 1 CPT and DPT/Hydropunch Sample Location, 2002
- Phase 2 CPT and DPT/Hydropunch Sample Location, 2002
- Lower A Aquifer (A2 Zone) Well Location
- Army CPT and DPT/Hydropunch Sample Location, 2003
- EPA CPT and DPT/Hydropunch Sample Location, 2005
- Former Orion Park Housing Area Boundary
- Former Farm Building
- Building/Structure
- Road
- Water

N

0 450 900
Feet

Notes:
The highest concentration detected during the 3rd quarter of 2002 (FW DPT borings), 2003 (SIG borings), or 2005 (HP boring and MCH wells) within the A2 aquifer at each well or boring is presented. Locations without concentrations indicate the result is below laboratory reporting limits.

CPT	Cone penetrometer test
DPT	Direct push technology
EPA	U.S. Environmental Protection Agency
IT	International Technology Corporation
J	Estimated
SAIC	Science Applications International Corporation
TCE	Trichloroethene

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FIGURE 7
TCE DISTRIBUTION (1999 – 2005), LOWER A AQUIFER (A2 ZONE)

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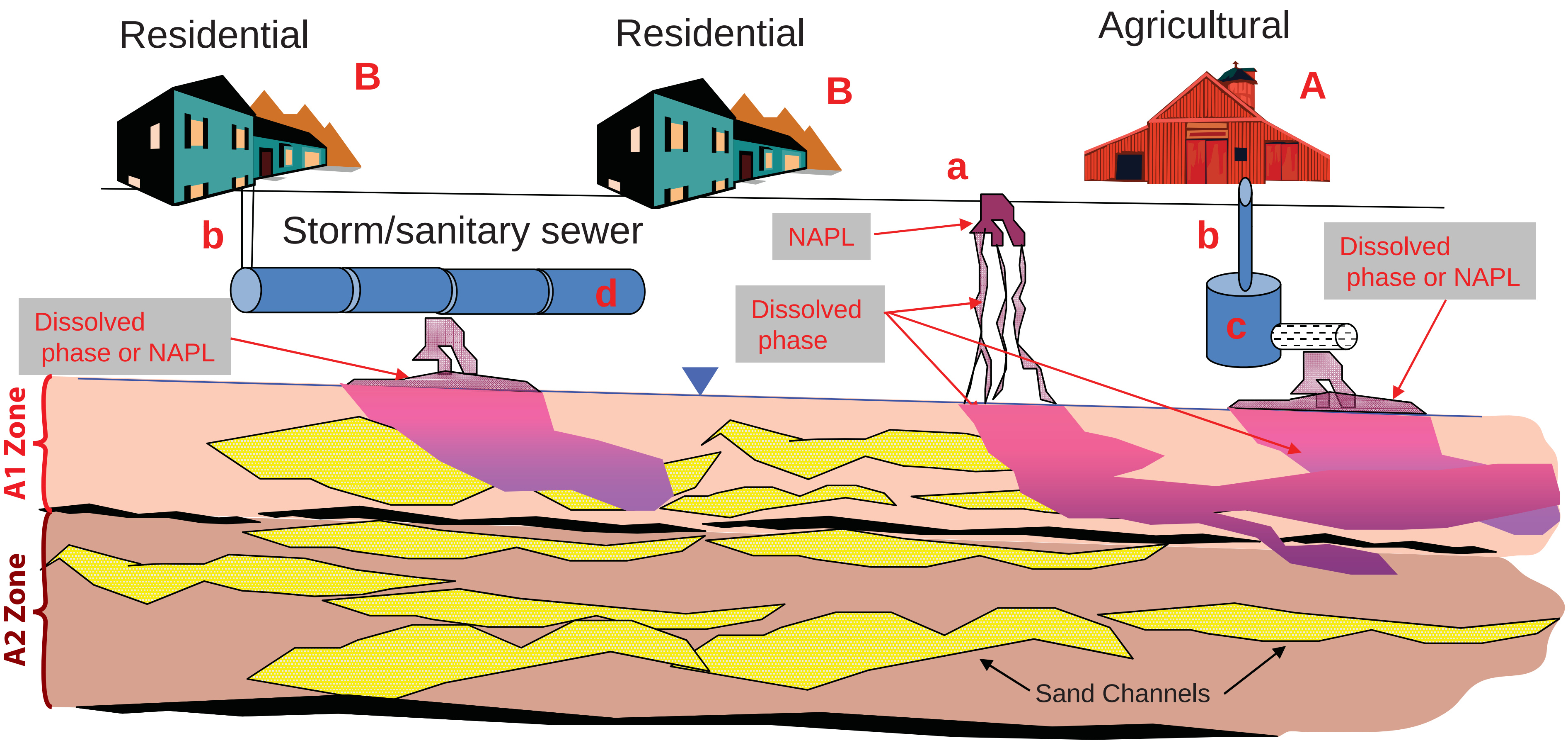

Notes:
Agricultural worker(A)/backyard mechanic(B), who either releases directly to ground surface (a), or to a drain (b), which leads to a secondary release point, such as septic tank/leach field (c), or sanitary sewer (d).

A	Agricultural: Farmer or Worker
A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
B	Residential: Backyard Mechanic
NAPL	Non-aqueous phase liquid

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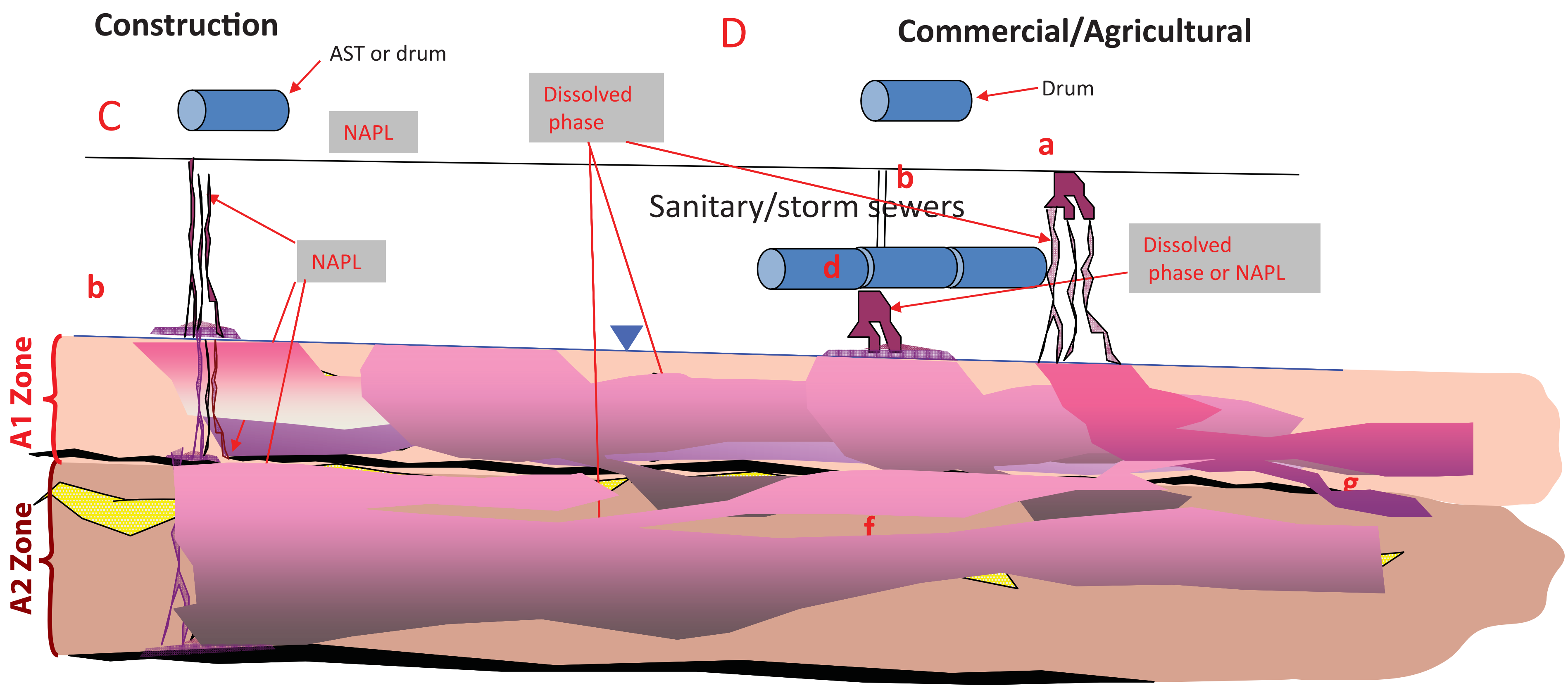
FIGURE 8
PRELIMINARY CONCEPTUAL SITE MODEL FOR POTENTIAL ON-SITE RESIDENTIAL AND AGRICULTURAL SOURCES

Supplemental Site Investigation



Notes:

On-site construction spill(C), discharge to ground surface, (a) NAPL of sufficient volume penetrates aquifer and moves down through permeable sediments (g) to deeper A2 zone (f).

On-site commercial(D) (paint storage locker) discharge to ground (a) or drain (b) and leaks from sanitary sewer (d).

AST	Aboveground storage tank
A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
C	Construction Worker
D	Commercial Worker
NAPL	Non-aqueous phase liquid

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Former Orion Park Housing Area
Former Naval Air Station Moffett Field, Moffett Field, CA

FIGURE 9
PRELIMINARY CONCEPTUAL SITE MODEL FOR POTENTIAL ON-SITE CONSTRUCTION AND COMMERCIAL/AGRICULTURAL SOURCES

Supplemental Site Investigation

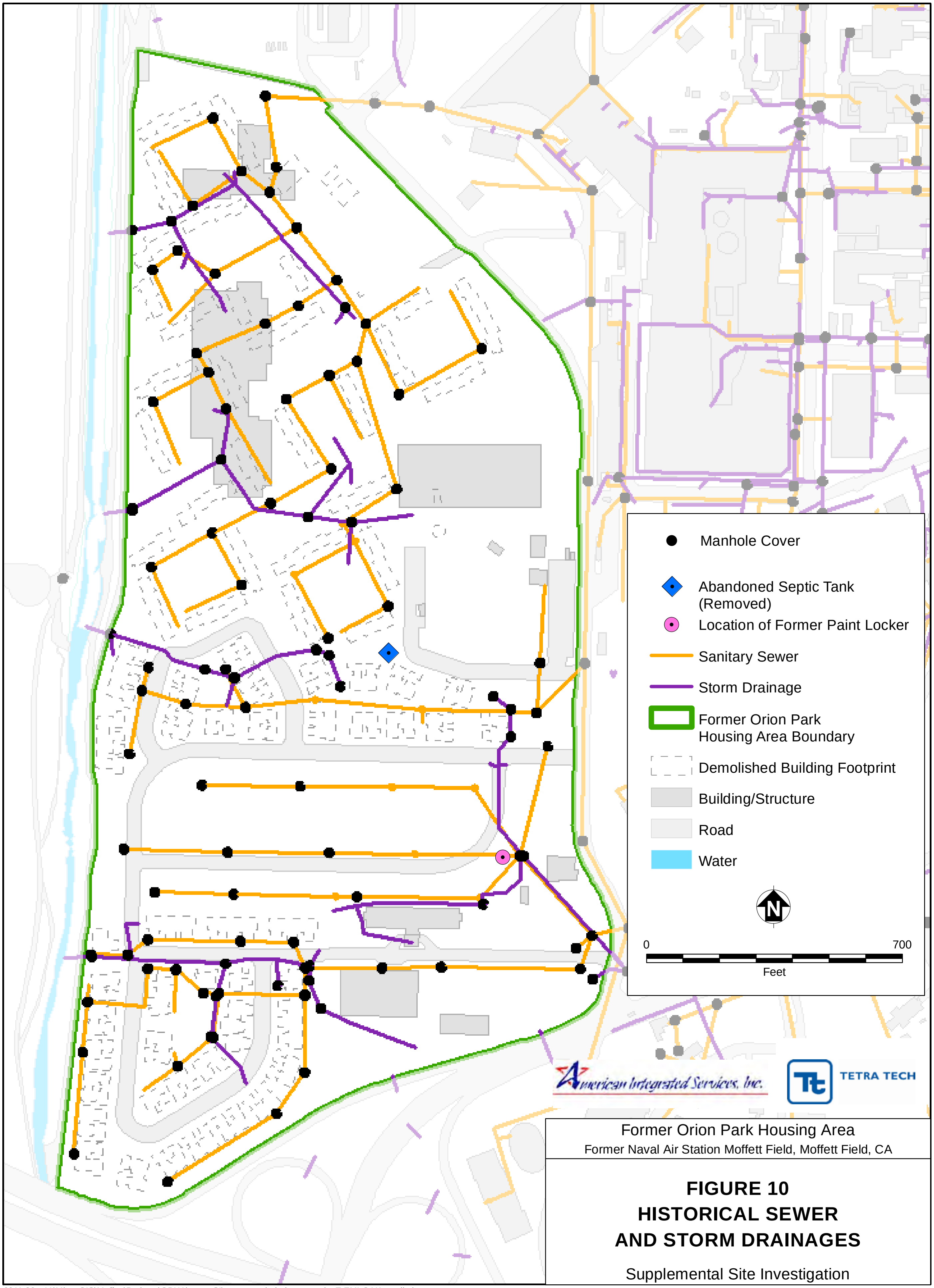

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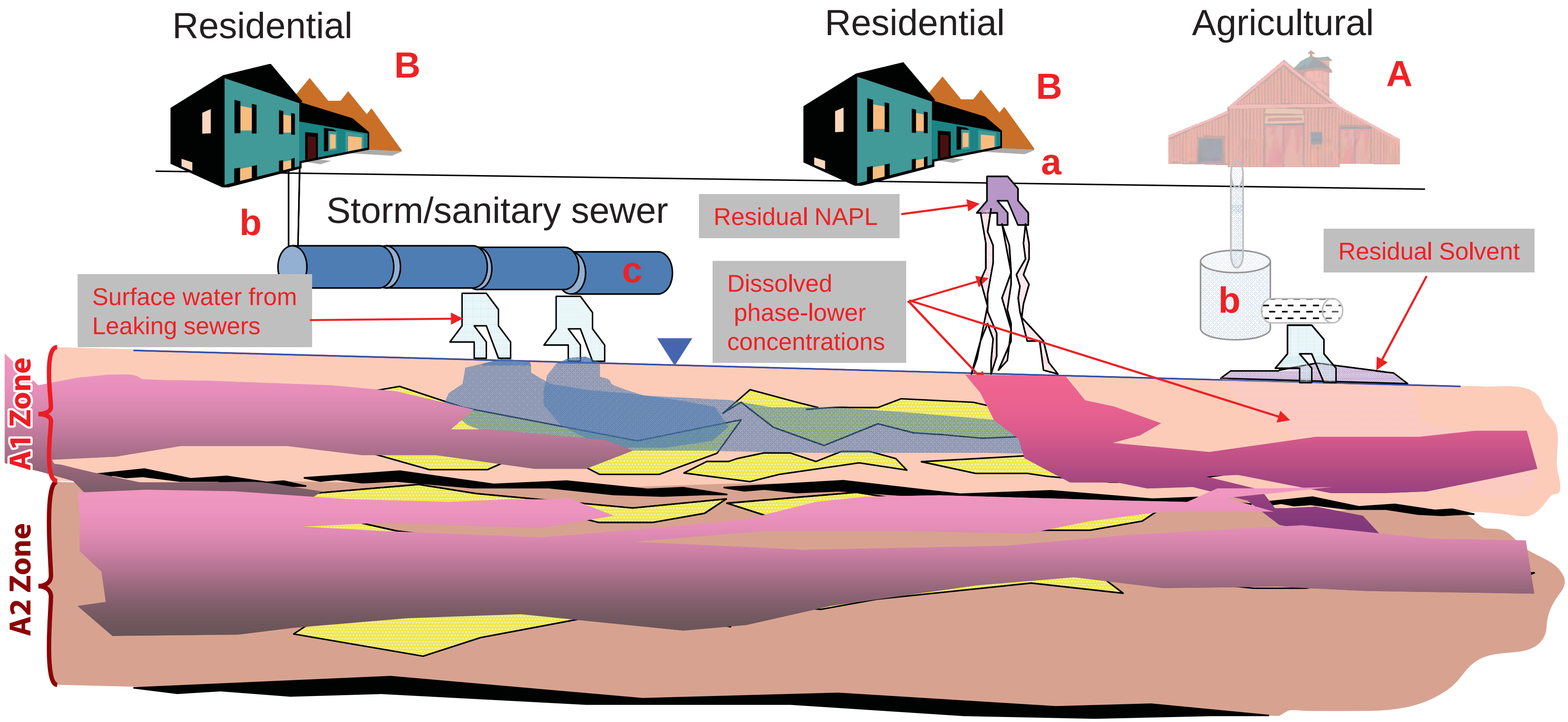
FIGURE 10
HISTORICAL SEWER AND STORM DRAINAGES

Supplemental Site Investigation

2011-30 V:\Misc_GIS\Moffett\Projects\OPHA\supp_SI\sewer_and_drainage.mxd TtEMI-OAK colin.lee



Notes:

Water from rain or lawn irrigation (a) or from septic tank (b) continues to leach solvent through vadose zone to water table. Water from leaks in storm sewers (c) and infiltrating rainwater dilute concentration of solvents in A1 zone of aquifer. Water losses from Stevens Creek to A1 zone during rainy season dilute A1 zone on western side of site.

A	Agricultural: Farmer or Worker
A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
B	Residential: Backyard Mechanic
NAPL	Non-aqueous phase liquid

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FIGURE 11
PRELIMINARY FATE AND TRANSPORT MODEL FOR GROUNDWATER CONTAMINATION

Supplemental Site Investigation

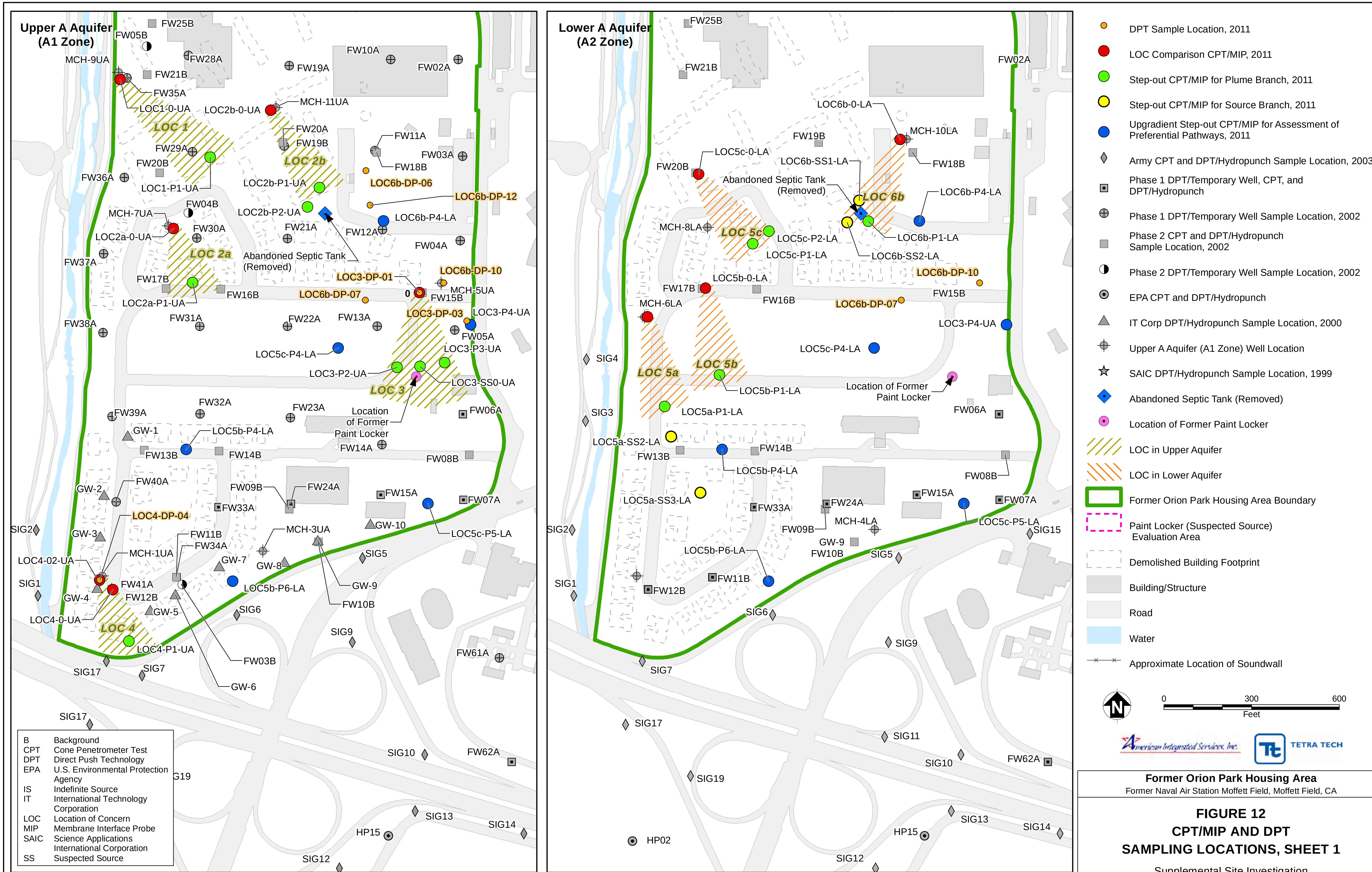

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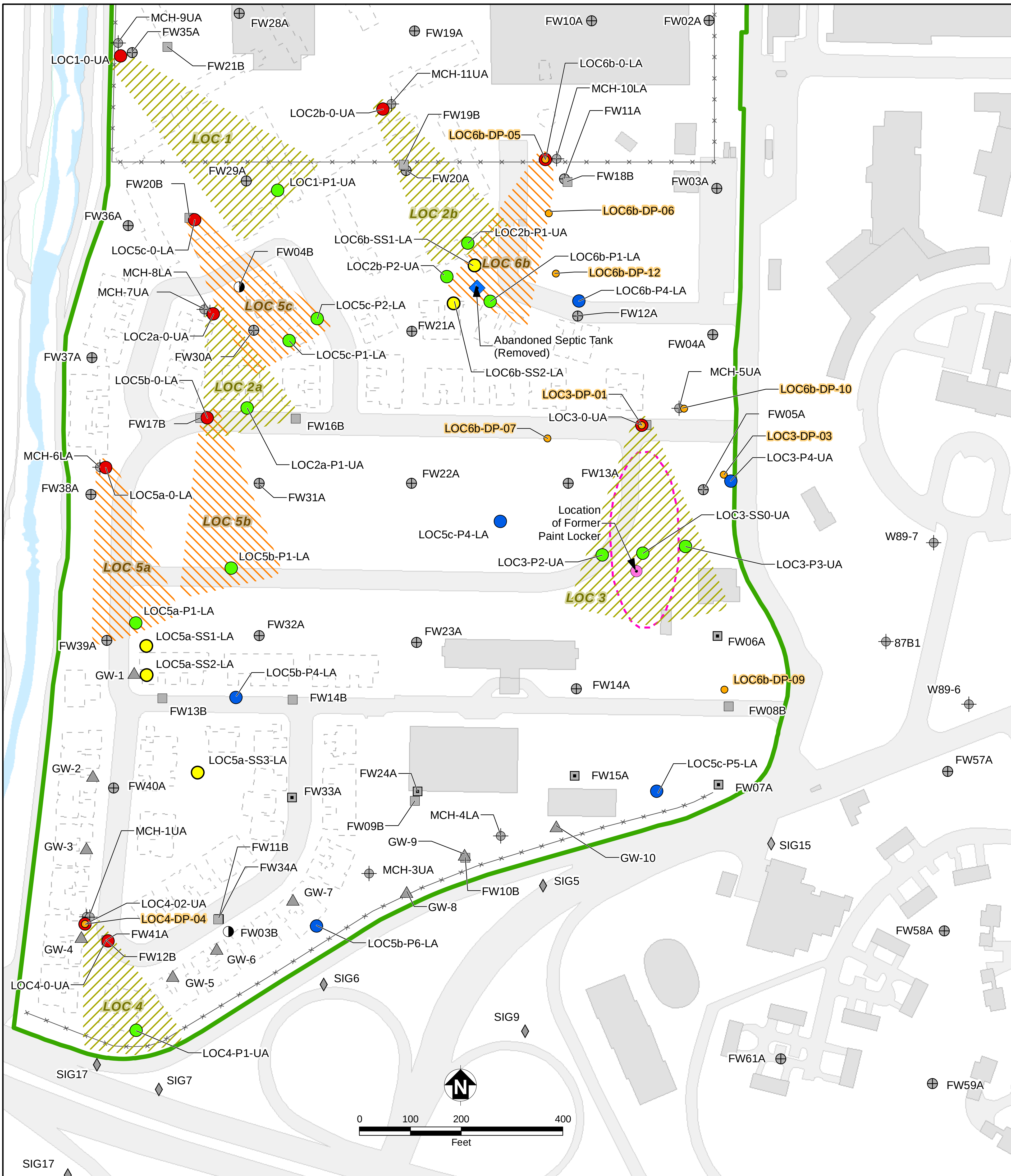
FIGURE 12
CPT/MIP AND DPT SAMPLING LOCATIONS, SHEET 1

Supplemental Site Investigation



DPT Sample Location, 2011

LOC Comparison CPT/MIP, 2011

Step-out CPT/MIP for Plume Branch, 2011

Step-out CPT/MIP for Source Branch, 2011

Upgradient Step-out CPT/MIP for Assessment of Preferential Pathways, 2011

Army CPT and DPT/Hydropunch Sample Location, 2003

Phase 1 DPT/Temporary Well, CPT, and DPT/Hydropunch

Phase 1 DPT/Temporary Well Sample Location, 2002

Phase 2 CPT and DPT/Hydropunch Sample Location, 2002

Phase 2 DPT/Temporary Well Sample Location, 2002

EPA CPT and DPT/Hydropunch

IT Corp DPT/Hydropunch Sample Location, 2000

Upper A Aquifer (A1 Zone) Well Location

SAIC DPT/Hydropunch Sample Location, 1999

Abandoned Septic Tank (Removed)

Location of Former Paint Locker

LOC in Upper Aquifer

LOC in Lower Aquifer

Former Orion Park Housing Area Boundary

Paint Locker (Suspected Source) Evaluation Area

Demolished Building Footprint

Building/Structure

Road

Water

Approximate Location of Soundwall

B	Background
CPT	Cone Penetrometer Test
DPT	Direct Push Technology
EPA	U.S. Environmental Protection Agency
IS	Indefinite Source
IT	International Technology Corporation
LOC	Location of Concern
MIP	Membrane Interface Probe
SAIC	Science Applications International Corporation
SS	Suspected Source

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FIGURE 12
CPT/MIP AND DPT
SAMPLING LOCATIONS, SHEET 2

Supplemental Site Investigation

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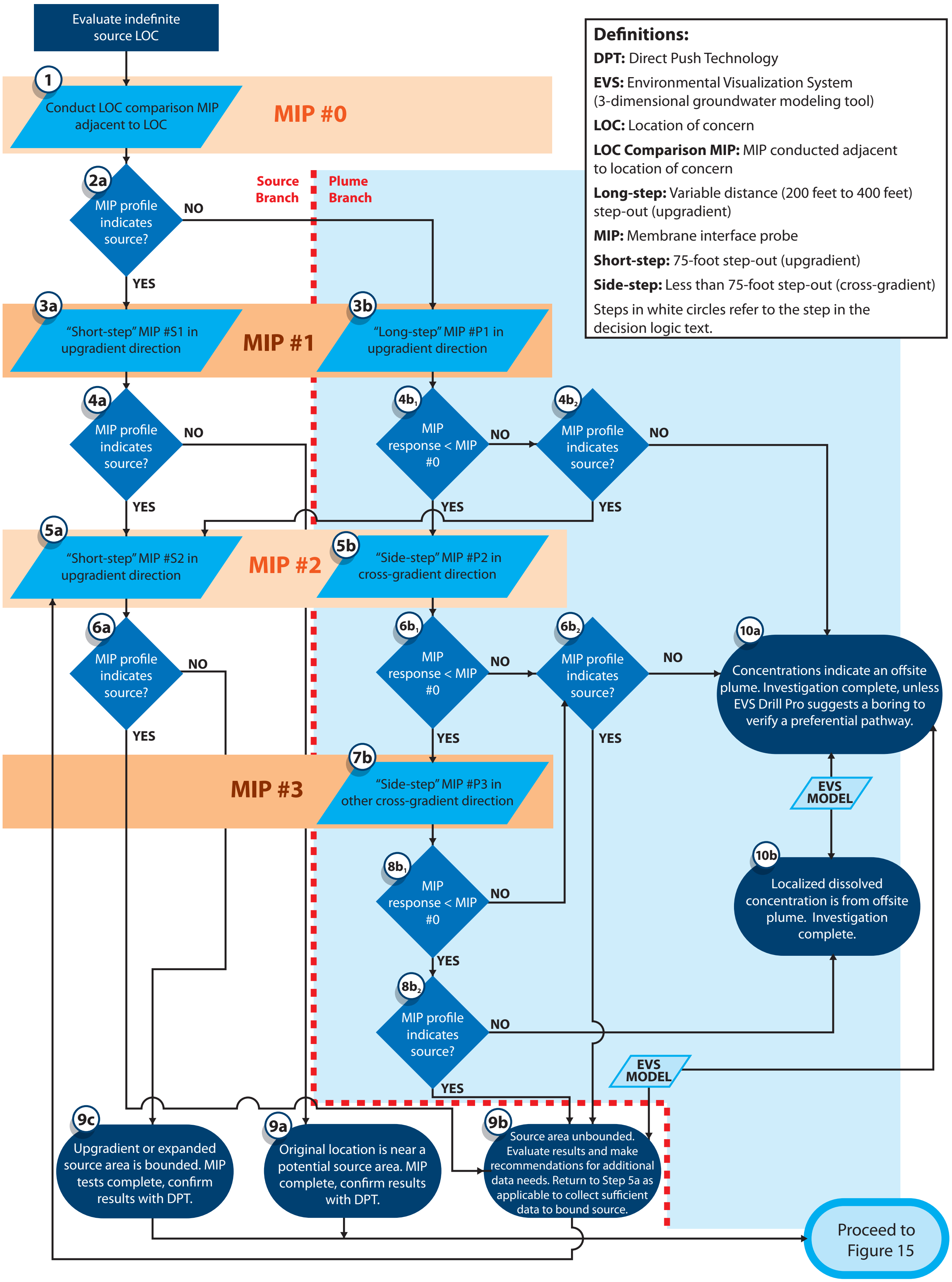

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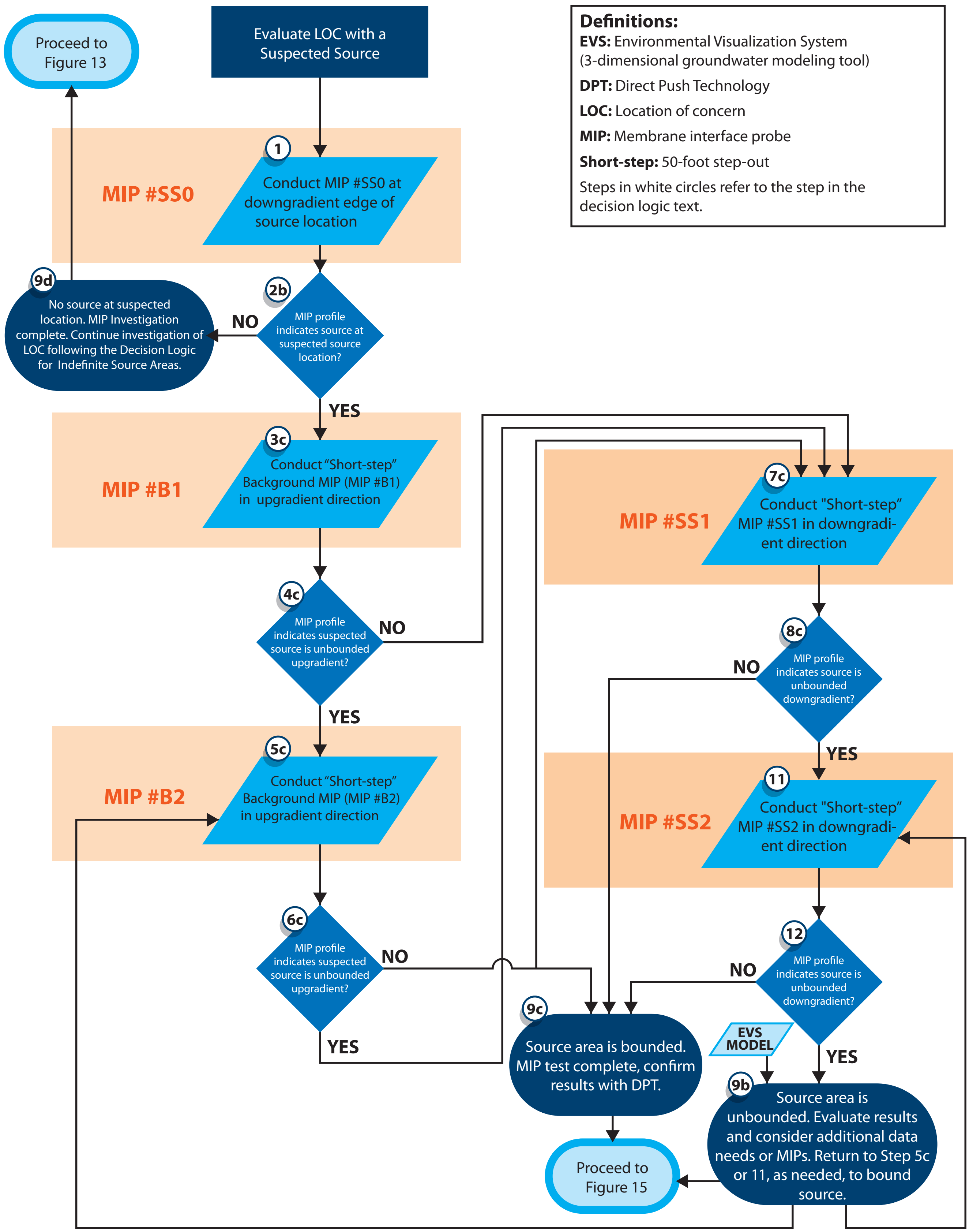
Former Naval Air Station Moffett Field, Moffett Field, CA

FIGURE 13
DECISION LOGIC FOR
INDEFINITE SOURCE AREAS

Supplemental Site Investigation



Definitions:

EVS: Environmental Visualization System (3-dimensional groundwater modeling tool)

DPT: Direct Push Technology

LOC: Location of concern

MIP: Membrane interface probe

Short-step: 50-foot step-out

Steps in white circles refer to the step in the decision logic text.

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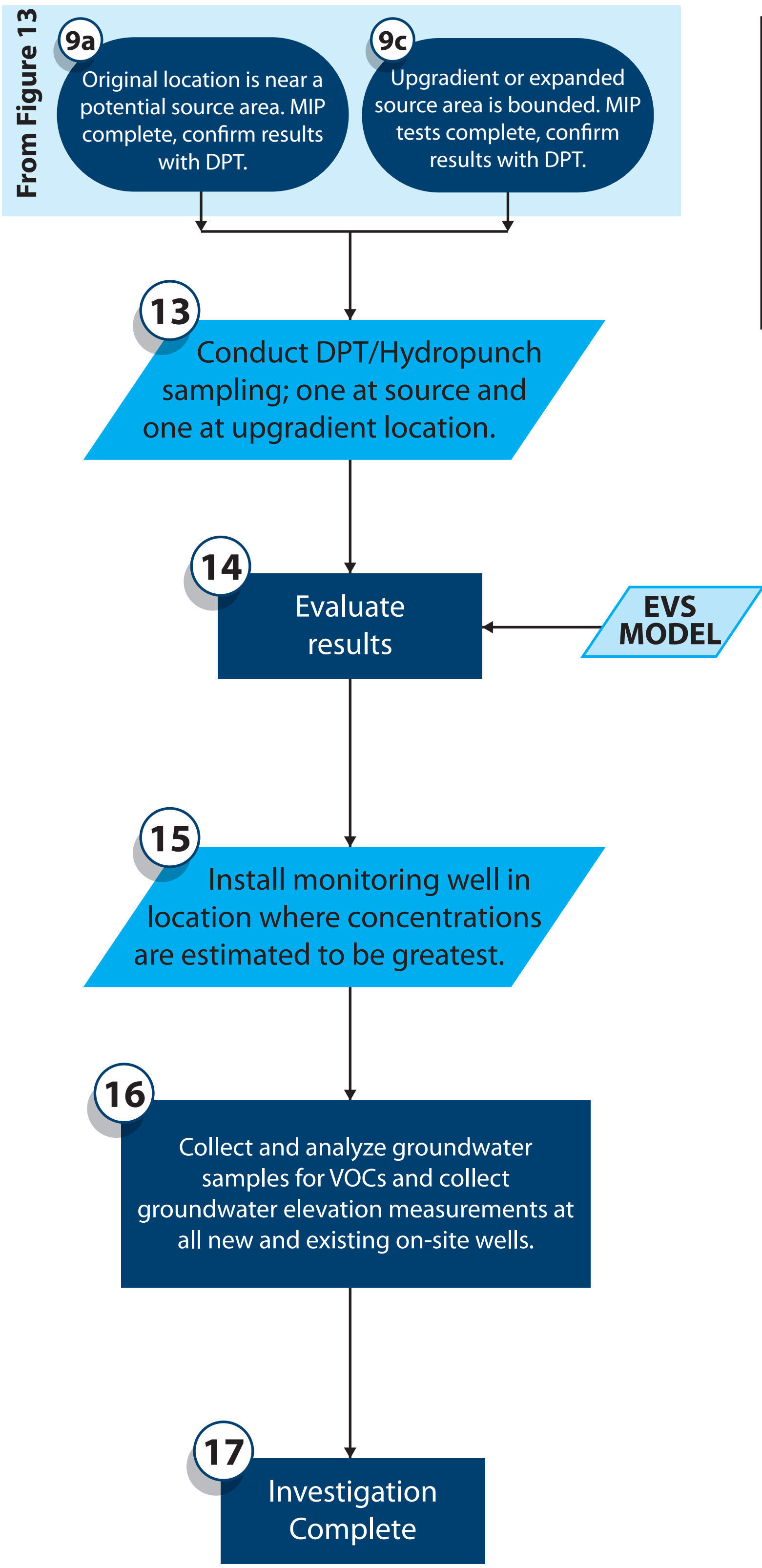
FIGURE 14
DECISION LOGIC FOR
FOR THE PAINT LOCKER
(SUSPECTED SOURCE)

Supplemental Site Investigation



Definitions:

DPT: Direct Push Technology

EVS: Environmental Visualization Software - (3-dimensional groundwater modeling tool)

MIP: Membrane interface probe

VOCs: Volatile organic compounds

Steps in white circles refer to the step in the decision logic text.

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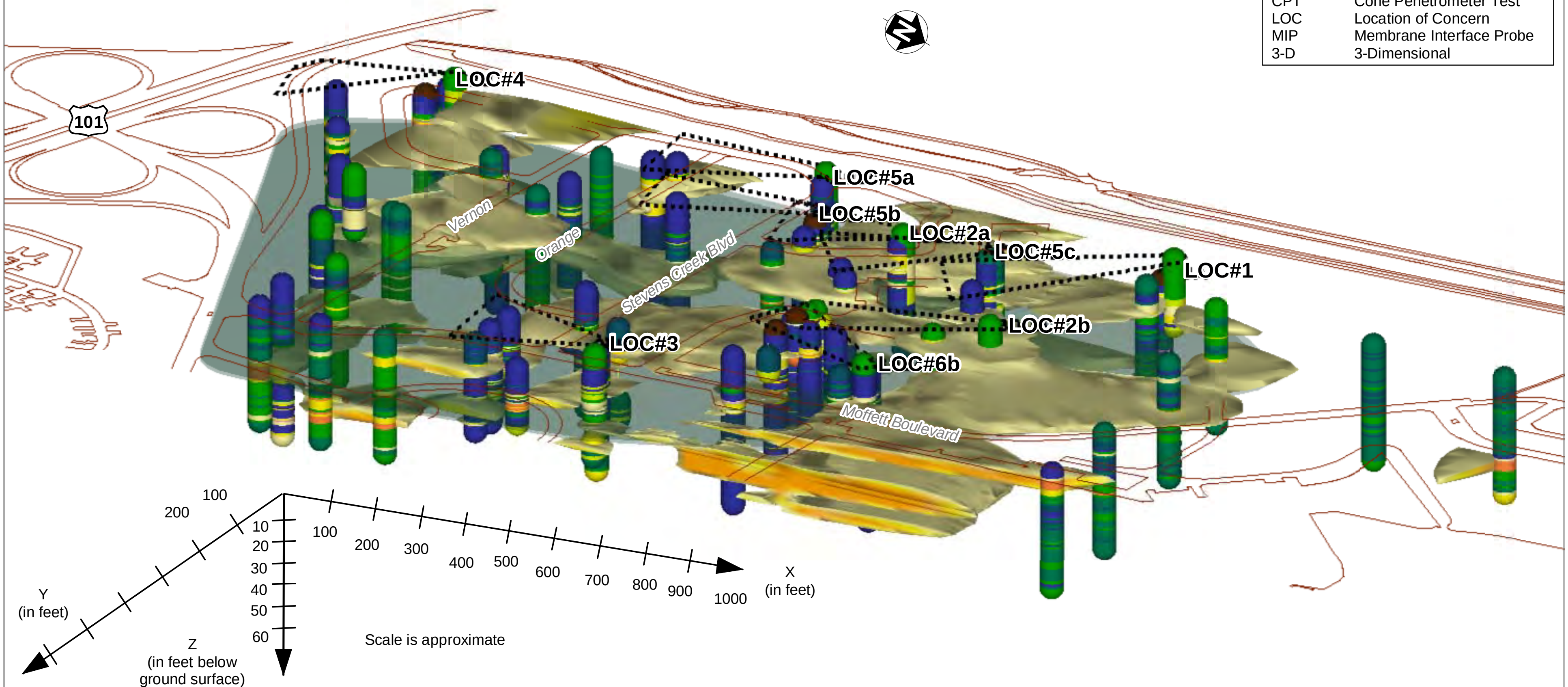
Former Naval Air Station Moffett Field, Moffett Field, CA

FIGURE 15
DECISION LOGIC FOR DPT/HYDROPUNCH SAMPLES AND MONITORING WELL INSTALLATION

Supplemental Site Investigation

Notes:
1. View from the northeast at 60 degrees from horizontal.
2. See Section 2.2.3 of the report text for an explanation of figure interpretation.

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
CPT	Cone Penetrometer Test
LOC	Location of Concern
MIP	Membrane Interface Probe
3-D	3-Dimensional



CPT/MIP or CPT Boring Location with Soil Types Indicated By Depth

LOC Boundary

Road

A1/A2 Aquitard

Soil types shown in 3-D model; other soil types are excluded from the 3-D model.

Soil Types
- Caliche
- Gravelly Sand to Sand
- Sand
- Sand to Silty Sand
- Silty sand to sandy silt
- Sandy silt to clayey silt
- Clayey silt to silty clay
- Silty clay to clay
- Clay
- Organic clay
- No Data

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FIGURE 16
DISTRIBUTION OF SAND AND GRAVELLY SAND

Supplemental Site Investigation

Notes:
See Section 2.2.3 of the report text for an explanation of figure interpretation.

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
CPT	Cone Penetrometer Test
DPT	Direct Push Technology
ECD	Electron Capture Detector
LOC	Location of Concern
MIP	Membrane Interface Probe
SSI	Supplemental Site Investigation
µV	Microvolt

CPT Boring from Previous Investigation

CPT/MIP Boring from SSI

Upper A Aquifer Potentiometric Surface from November 2010

Lower A Aquifer Potentiometric Surface from November 2010

LOC Boundary

Road Edge

A1/A2 Aquitard

Former Orion Park Housing Area Boundary

Approximate Location of Soundwall

Demolished Building Footprint

Building/Structure

Water

ECD Response

5.7E+006µV
3.0E+006µV
2.0E+006µV
1.0E+006µV
6.0E+005µV
3.0E+005µV
2.0E+005µV
1.0E+005µV
6.4E+004µV

Current Level >>>

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FIGURE 17

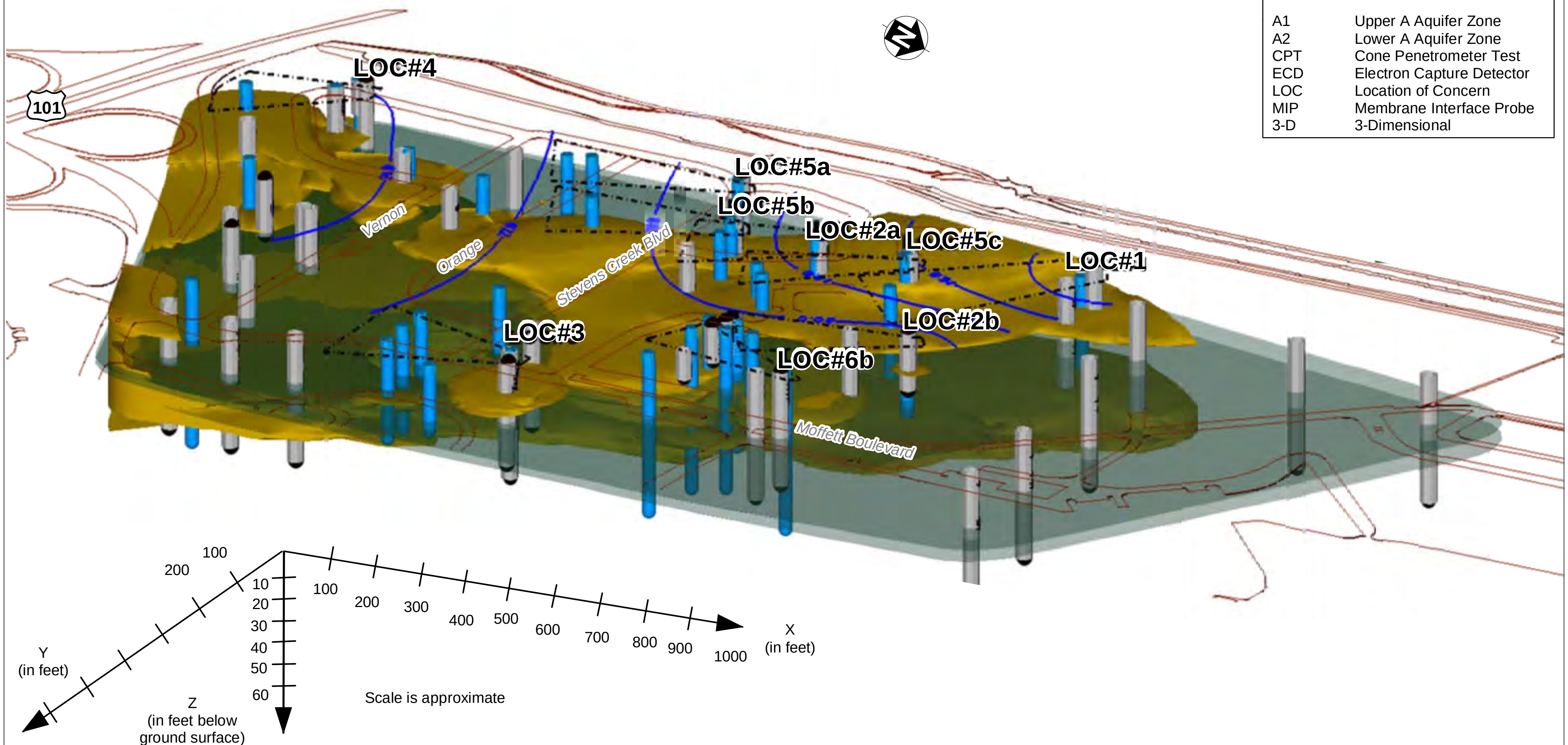
LOW-LEVEL (5.0E+005µV)

ECD RESPONSES – TOP VIEW

Supplemental Site Investigation

Notes:
1. View from the northeast at 60 degrees from horizontal.
2. See Section 2.2.3 of the report text for an explanation of figure interpretation.

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
CPT	Cone Penetrometer Test
ECD	Electron Capture Detector
LOC	Location of Concern
MIP	Membrane Interface Probe
3-D	3-Dimensional



CPT Boring from Previous Investigation

CPT/MIP Boring from SSI

Upper A Aquifer Potentiometric Surface from November 2010

LOC Boundary

Road

A1/A2 Aquitard

ECD Response

5.5E+006µV
3.0E+006µV
2.0E+006µV
1.0E+006µV
6.0E+005µV
3.0E+005µV
2.0E+005µV
1.0E+005µV
6.3E+004µV

Current Level >>>

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FIGURE 18
LOW-LEVEL (5.0E+005µV)
ECD RESPONSES

Supplemental Site Investigation

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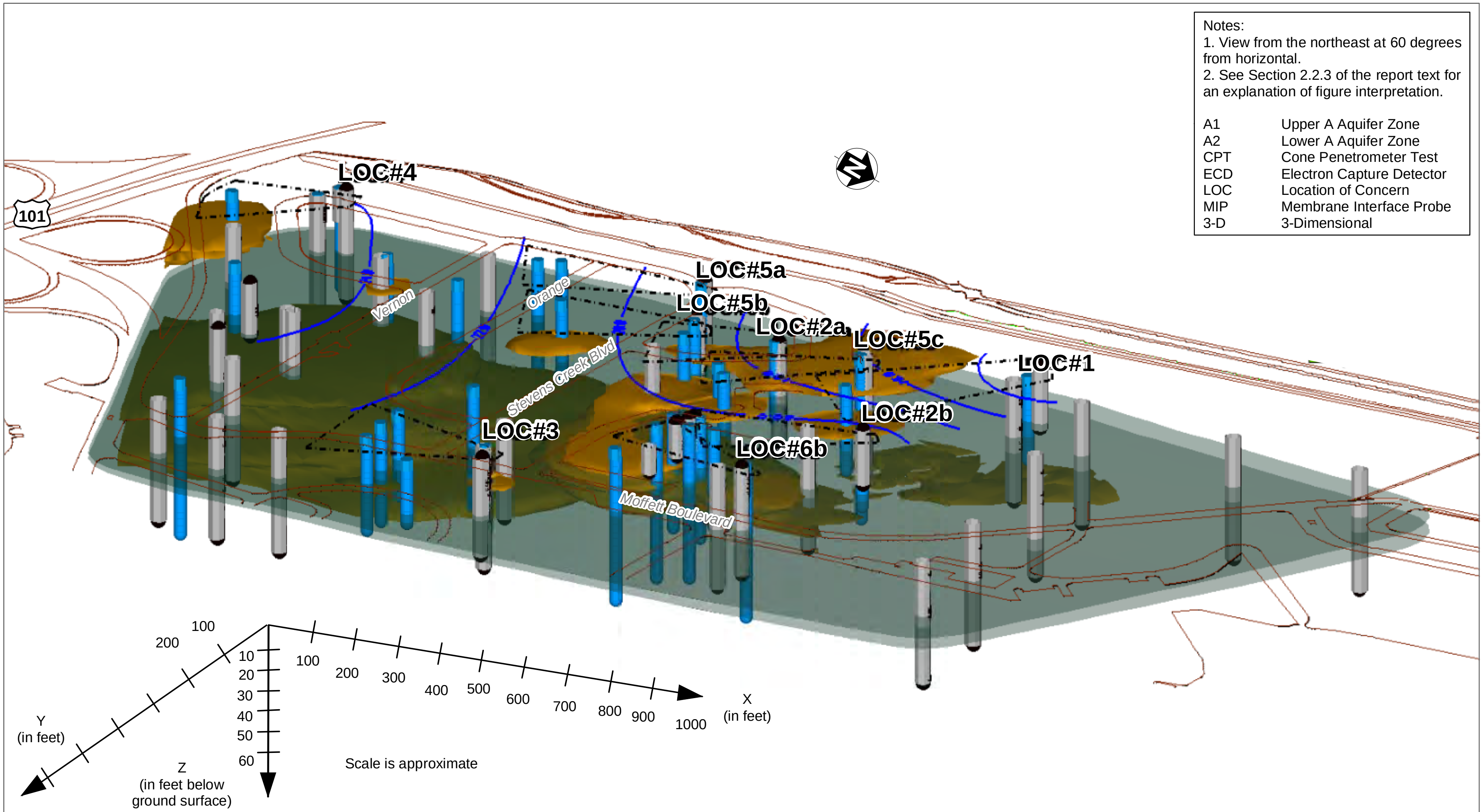

Legend	
CPT Boring from Previous Investigation	Road
CPT/MIP Boring from SSI	A1/A2 Aquitard
Upper A Aquifer Potentiometric Surface from November 2010	
LOC Boundary	

ECD Response

Current Level >>>

5.5E+006µV
3.0E+006µV
2.0E+006µV
1.0E+006µV
6.0E+005µV
3.0E+005µV
2.0E+005µV
1.0E+005µV
6.3E+004µV

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FIGURE 19
MID-LEVEL (7.5E+005µV) ECD RESPONSES

Supplemental Site Investigation

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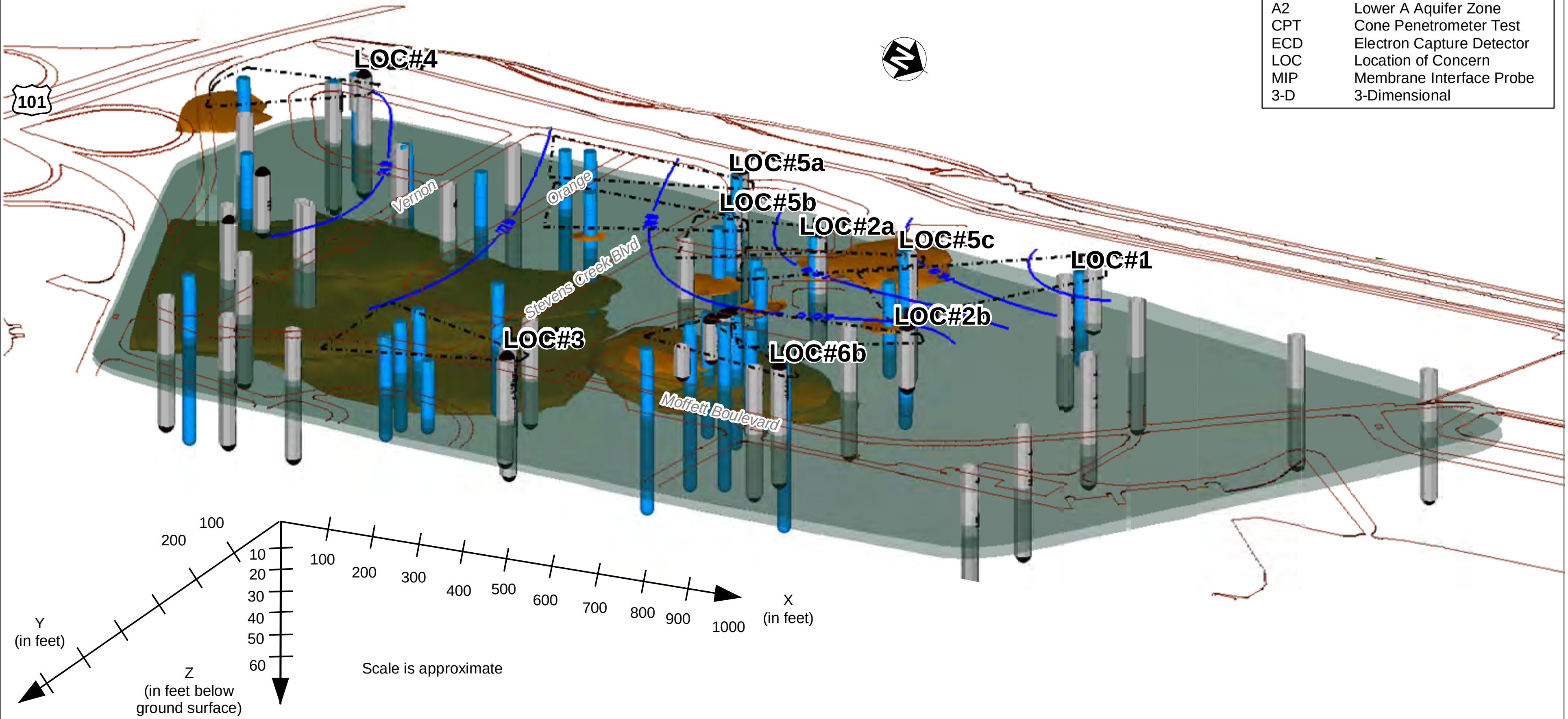

Notes:
1. View from the northeast at 60 degrees from horizontal.
2. See Section 2.2.3 of the report text for an explanation of figure interpretation.

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
CPT	Cone Penetrometer Test
ECD	Electron Capture Detector
LOC	Location of Concern
MIP	Membrane Interface Probe
3-D	3-Dimensional

CPT Boring from Previous Investigation

CPT/MIP Boring from SSI

Upper A Aquifer Potentiometric Surface from November 2010

LOC Boundary

Road

A1/A2 Aquitard

ECD Response

Current Level >>>

5.5E+006µV
3.0E+006µV
2.0E+006µV
1.0E+006µV
6.0E+005µV
3.0E+005µV
2.0E+005µV
1.0E+005µV
6.3E+004µV

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FIGURE 20
HIGH-LEVEL (1.0E+006µV)
ECD RESPONSES

Supplemental Site Investigation

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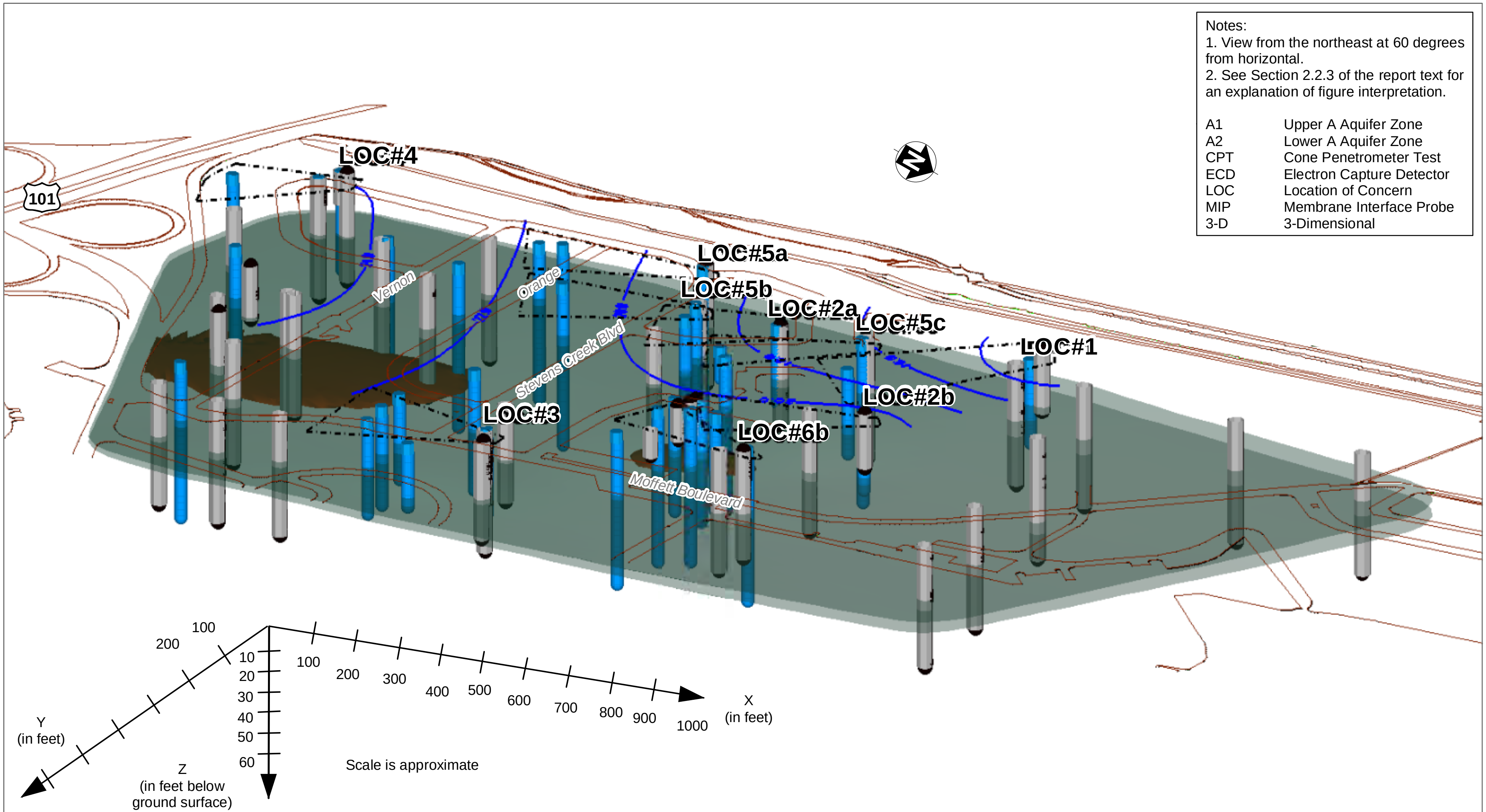

Notes:
1. View from the northeast at 60 degrees from horizontal.
2. See Section 2.2.3 of the report text for an explanation of figure interpretation.

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
CPT	Cone Penetrometer Test
ECD	Electron Capture Detector
LOC	Location of Concern
MIP	Membrane Interface Probe
3-D	3-Dimensional

CPT Boring from Previous Investigation

CPT/MIP Boring from SSI

Upper A Aquifer Potentiometric Surface from November 2010

LOC Boundary

Road

A1/A2 Aquitard

ECD Response

Current Level >>>

5.5E+006µV
3.0E+006µV
2.0E+006µV
1.0E+006µV
6.0E+005µV
3.0E+005µV
2.0E+005µV
1.0E+005µV
6.3E+004µV

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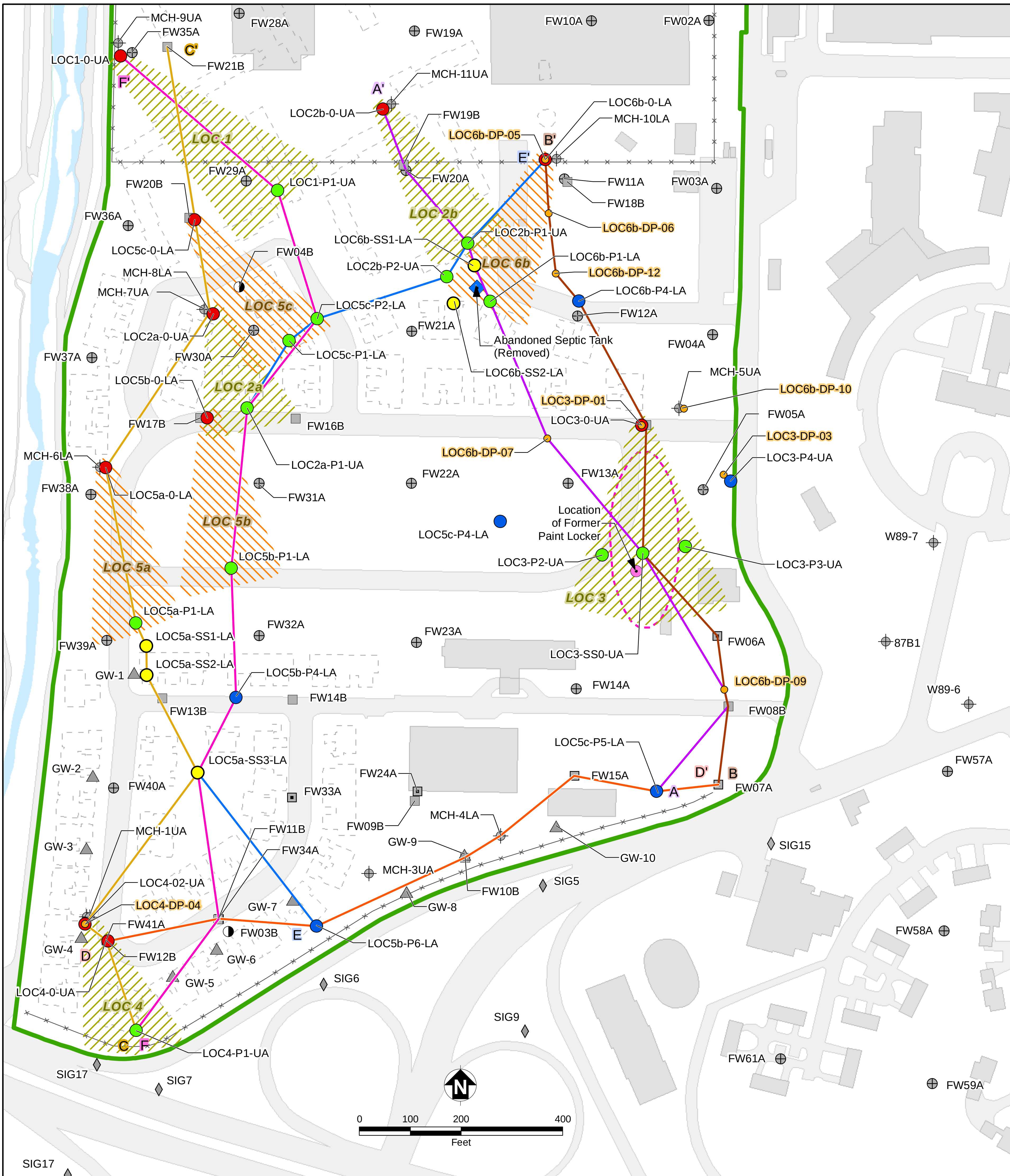
FIGURE 21
HIGH-LEVEL (2.5E+006µV) ECD RESPONSES

Supplemental Site Investigation



Cross-Section Type

- A-A'
- B-B'
- C-C'
- D-D'
- E-E'
- F-F'
- LOC in Upper Aquifer
- LOC in Lower Aquifer
- Former Orion Park Housing Area Boundary
- Paint Locker (Suspected Source) Evaluation Area
- Demolished Building Footprint
- Building/Structure
- Road
- Water
- Approximate Location of Soundwall

- DPT Sample Location, 2011
- LOC Comparison CPT/MIP, 2011
- Step-out CPT/MIP for Plume Branch, 2011
- Step-out CPT/MIP for Source Branch, 2011
- Upgradient Step-out CPT/MIP for Assessment of Preferential Pathways, 2011
- Army CPT and DPT/Hydropunch Sample Location, 2003
- Phase 1 DPT/Temporary Well, CPT, and DPT/Hydropunch
- Phase 1 DPT/Temporary Well Sample Location, 2002
- Phase 2 CPT and DPT/Hydropunch Sample Location, 2002
- Phase 2 DPT/Temporary Well Sample Location, 2002
- EPA CPT and DPT/Hydropunch
- IT Corp DPT/Hydropunch Sample Location, 2000
- Upper A Aquifer (A1 Zone) Well Location
- SAIC DPT/Hydropunch Sample Location, 1999
- Abandoned Septic Tank (Removed)
- Location of Former Paint Locker

B	Background
CPT	Cone Penetrometer Test
DPT	Direct Push Technology
EPA	U.S. Environmental Protection Agency
IS	Indefinite Source
IT	International Technology Corporation
LOC	Location of Concern
MIP	Membrane Interface Probe
SAIC	Science Applications International Corporation
SS	Suspected Source

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FIGURE 22
CROSS SECTION GUIDE

Supplemental Site Investigation

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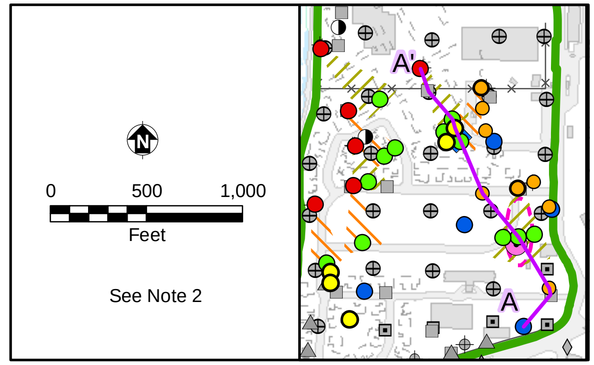
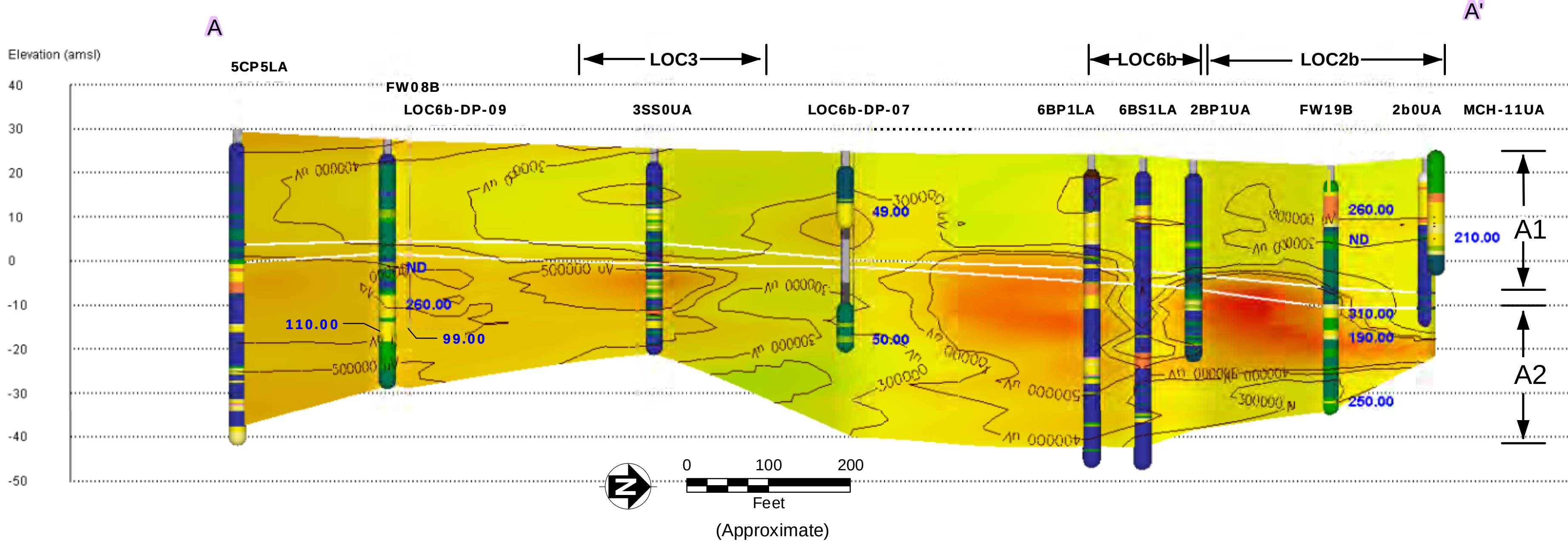
Notes:
1. Point names have been shortened. The letters "LOC" at the beginning of the point name and hyphens within the point name have been removed.
2. See Figure 22 for definitions of the symbols shown in the inset.
3. See Section 2.2.3 of the report text for an explanation of figure interpretation.

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
amsl	Above Mean Sea Level
CPT	Cone Penetrometer Test
ECD	Electron Capture Detector
LOC	Location of Concern
MIP	Membrane Interface Probe
TCE	Trichloroethene
µg/L	Micrograms per Liter
µV	Microvolt





ECD Response

5.5E6µV
3.2E6µV
1.8E6µV
1E6µV
5.6E5µV
3.2E5µV
1.8E5µV
1E5uV
6.3E4uV

A1 — Approximate Extent of A1 and A2 Aquifer Zones (as divided by the A1/A2 aquitard signified by white horizontal lines)

—300000-µV— ECD Response Contour

LOCX — Approximate Extent of LOC

5CP5LA — CPT/MIP or CPT Boring Point Name (see note 1)

CPT/MIP or CPT Boring Location with Soil Types Indicated By Depth

50.00 — TCE Concentrations from Groundwater Samples (µg/L)

Soil Types

Caliche
Gravelly sand to sand
Sand
Sand to silty sand
Silty sand to sandy silt
Sandy silt to clayey silt
Clayey silt to silty clay
Silty clay to clay
Clay
Organic clay
No Data

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FIGURE 23
CROSS SECTION A-A'

Supplemental Site Investigation

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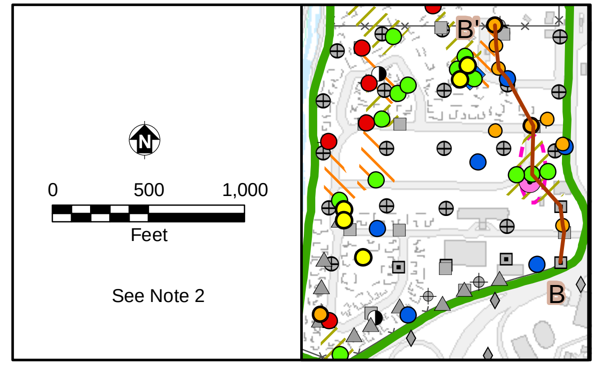
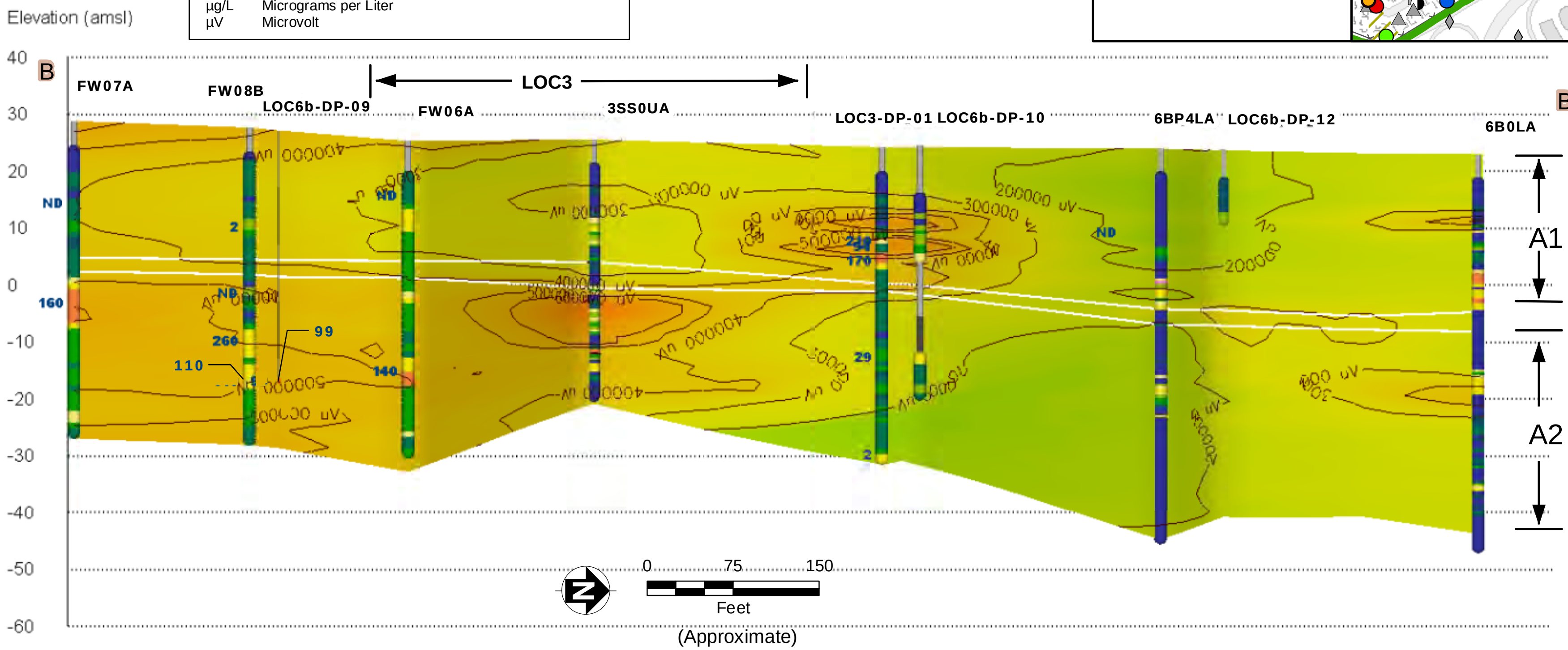
Notes:
1. Point names have been shortened. The letters "LOC" at the beginning of the point name and hyphens within the point name have been removed.
2. See Figure 22 for definitions of the symbols shown in the inset.
3. See Section 2.2.3 of the report text for an explanation of figure interpretation.

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
amsl	Above Mean Sea Level
CPT	Cone Penetrometer Test
ECD	Electron Capture Detector
LOC	Location of Concern
MIP	Membrane Interface Probe
TCE	Trichloroethene
µg/L	Micrograms per Liter
µV	Microvolt





ECD Response
5.5E6µV
3.2E6µV
1.8E6µV
1E6µV
5.6E5µV
3.2E5µV
1.8E5µV
1E5uV
6.3E4uV

A1 — Approximate Extent of A1 and A2 Aquifer Zones (as divided by the A1/A2 aquitard signified by white horizontal lines)

—300000-µV— ECD Response Contour

LOCX — Approximate Extent of LOC

FW07A — CPT/MIP or CPT Boring Point Name (see note 1)

CPT/MIP or CPT Boring Location with Soil Types Indicated By Depth

110 — TCE Concentrations from Groundwater Samples (µg/L)

Soil Types
Caliche
Gravelly sand to sand
Sand
Sand to silty sand
Silty sand to sandy silt
Sandy silt to clayey silt
Clayey silt to silty clay
Silty clay to clay
Clay
Organic clay
No Data

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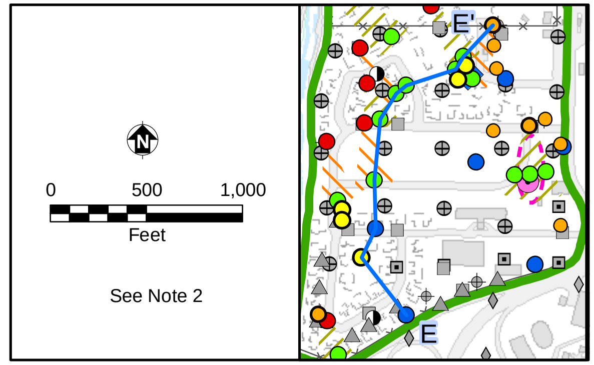
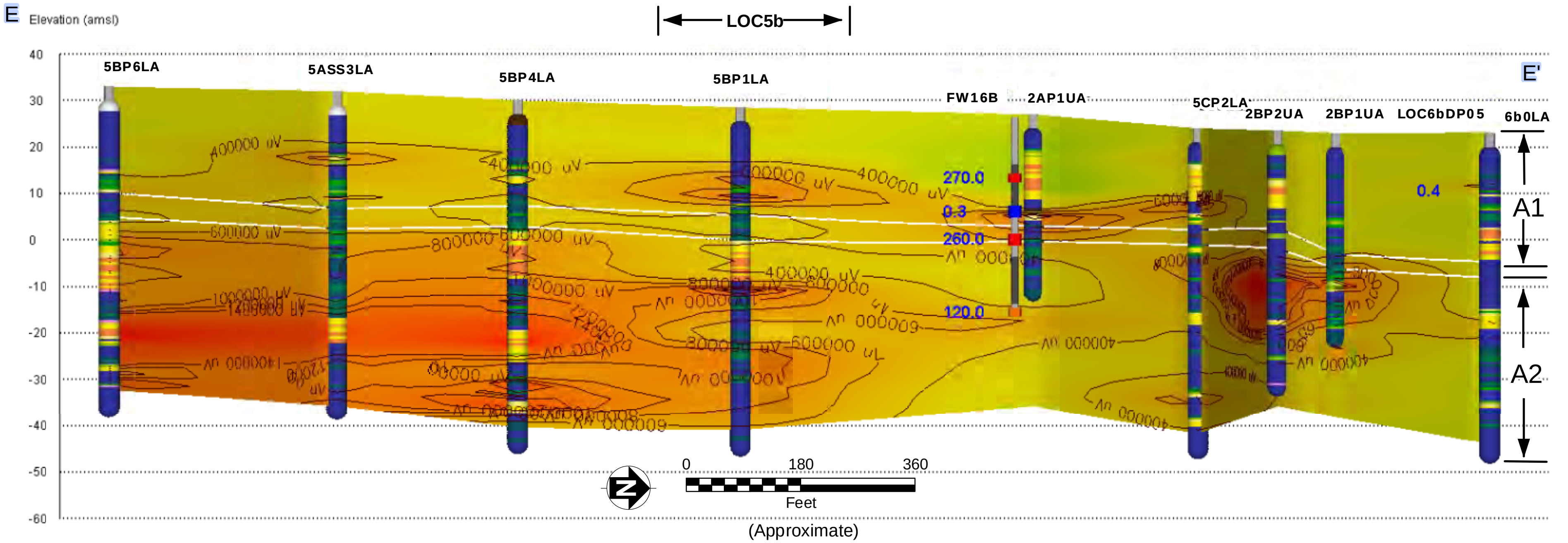
FIGURE 24
CROSS SECTION B-B'

Supplemental Site Investigation

Notes:
1. Point names have been shortened. The letters "LOC" at the beginning of the point name and hyphens within the point name have been removed.
2. See Figure 22 for definitions of the symbols shown in the inset.
3. See Section 2.2.3 of the report text for an explanation of figure interpretation.

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
amsl	Above Mean Sea Level
CPT	Cone Penetrometer Test
ECD	Electron Capture Detector
LOC	Location of Concern
MIP	Membrane Interface Probe
TCE	Trichloroethene
µg/L	Micrograms per Liter
µV	Microvolt





ECD Response

- 5.5E6µV
- 3.2E6µV
- 1.8E6µV
- 1E6µV
- 5.6E5µV
- 3.2E5µV
- 1.8E5µV
- 1E5uV
- 6.2E4uV

A1 — Approximate Extent of A1 and A2 Aquifer Zones (as divided by the A1/A2 aquitard signified by white horizontal lines)

—300000–µV— ECD Response Contour

←LOCX→ Approximate Extent of LOC

6B0LA — CPT/MIP or CPT Boring Point Name (see note 1)

CPT/MIP or CPT Boring Location with Soil Types Indicated By Depth

120.00 — TCE Concentrations from Groundwater Samples (µg/L)

Soil Types

- Caliche
- Gravelly sand to sand
- Sand
- Sand to silty sand
- Silty sand to sandy silt
- Sandy silt to clayey silt
- Clayey silt to silty clay
- Silty clay to clay
- Clay
- Organic clay
- No Data

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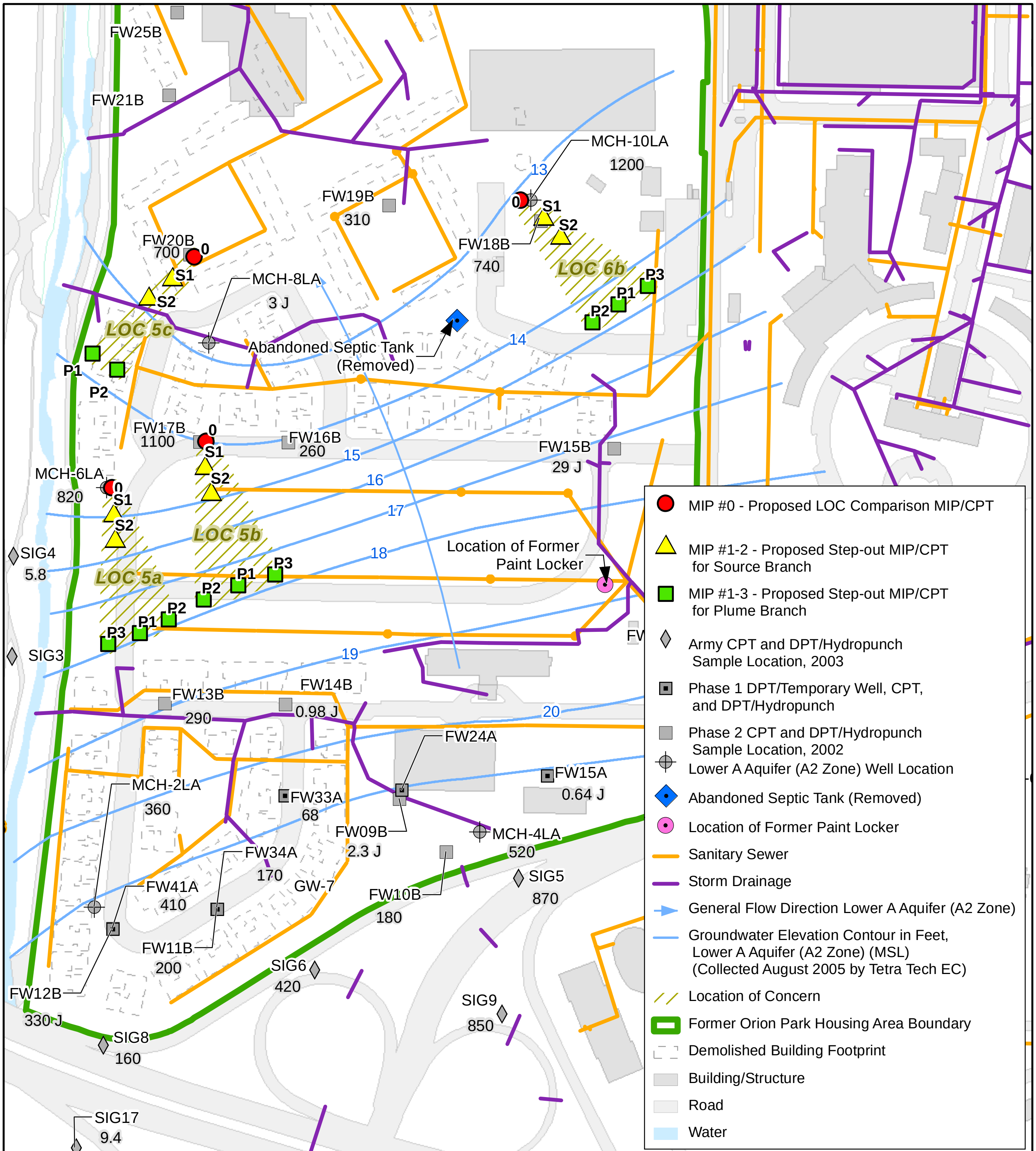
FIGURE 25

CROSS SECTION E-E'

Supplemental Site Investigation



Note: The highest concentration detected during the 3rd quarter of 2002 (FW DPT borings), 2003 (SIG borings), or 2005 (HP boring and MCH wells) within the A2 aquifer at each well or boring is presented. Locations without concentrations indicate the result is below laboratory reporting limits.

CPT	Cone Penetrometer Test
DPT	Direct Push Technology
LOC	Location of Concern
MSL	Mean Sea Level
MIP	Membrane Interface Probe
µg/L	Micrograms per liter
TCE	Trichloroethene

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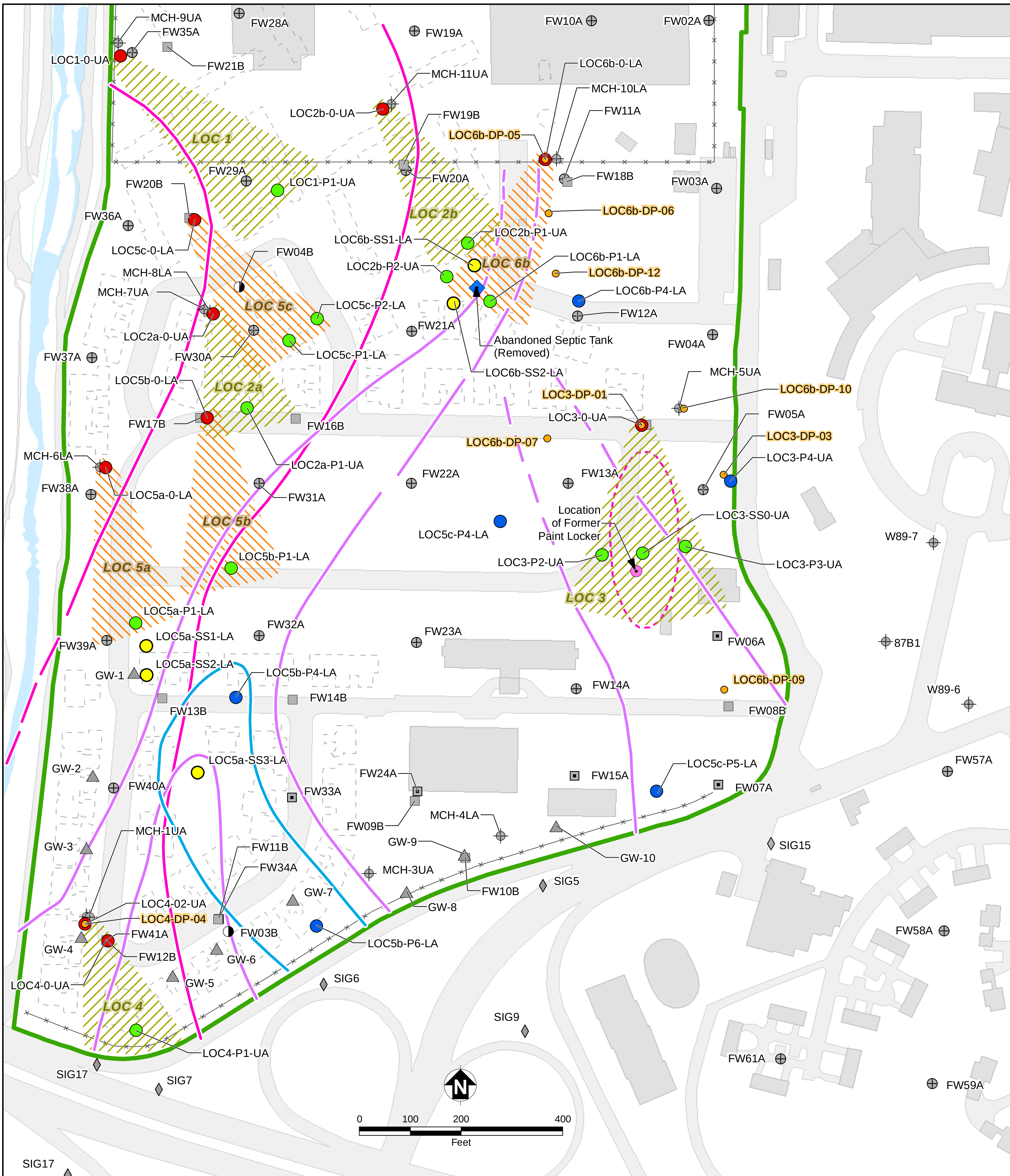
FIGURE 26

PROPOSED CPT/MIP LOCATIONS, LOWER A AQUIFER (A2 ZONE)

Supplemental Site Investigation



Chlorinated Solvent Plume Trends (Dashed Where Inferred)

- A1 Aquifer Zone Channel/Plume Trend
- A2 Aquifer Zone Channel/Plume Trend - Shallow
- A2 Aquifer Zone Channel/Plume Trend - Deep
- DPT Sample Location, 2011
- LOC Comparison CPT/MIP, 2011
- Step-out CPT/MIP for Plume Branch, 2011
- Step-out CPT/MIP for Source Branch, 2011
- Upgradient Step-out CPT/MIP for Assessment of Preferential Pathways, 2011
- Army CPT and DPT/Hydropunch Sample Location, 2003
- Phase 1 DPT/Temporary Well, CPT, and DPT/Hydropunch
- Phase 1 DPT/Temporary Well Sample Location, 2002
- Phase 2 CPT and DPT/Hydropunch Sample Location, 2002
- Phase 2 DPT/Temporary Well Sample Location, 2002
- EPA CPT and DPT/Hydropunch
- IT Corp DPT/Hydropunch Sample Location, 2000
- Upper A Aquifer (A1 Zone) Well Location
- SAIC DPT/Hydropunch Sample Location, 1999

- Abandoned Septic Tank (Removed)
- Location of Former Paint Locker
- LOC in Upper Aquifer
- LOC in Lower Aquifer
- Former Orion Park Housing Area Boundary
- Paint Locker (Suspected Source) Evaluation Area
- Demolished Building Footprint
- Building/Structure
- Road
- Water
- Approximate Location of Soundwall

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
B	Background
CPT	Cone Penetrometer Test
DPT	Direct Push Technology
EPA	U.S. Environmental Protection Agency
IS	Indefinite Source
IT	International Technology Corporation
LOC	Location of Concern
MIP	Membrane Interface Probe
SAIC	Science Applications International Corporation
SS	Suspected Source

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FIGURE 27
INFERRED TRENDS OF CHLORINATED SOLVENT PLUMES

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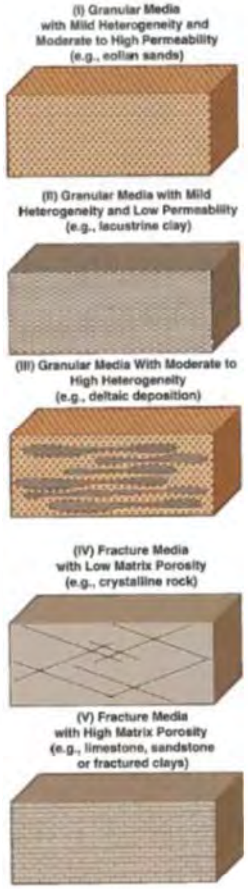
Subsurface Settings



Red, yellow and green compartments indicate high, moderate and low importance of the compartments, respectively.

Middle Stage

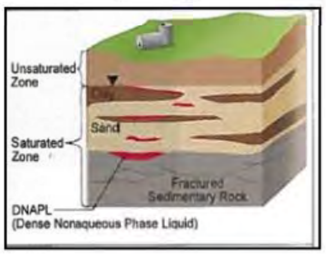
Type 3

Zone/Phase	Source Zone: Stagnant	Source Zone: Transmissive	Plume: Transmissive	Plume: Stagnant
Vapor	MODERATE	HIGH	MODERATE	MODERATE
DNAPL	MODERATE	HIGH		
Aqueous	MODERATE	HIGH	MODERATE	MODERATE
Sorbed	MODERATE	HIGH	MODERATE	MODERATE

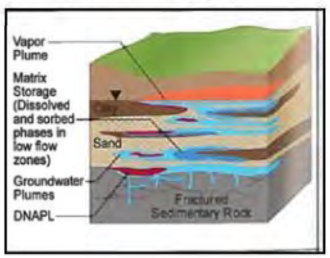
Late Stage

Zone/Phase	Source Zone: Stagnant	Source Zone: Transmissive	Plume: Transmissive	Plume: Stagnant
Vapor	LOW	MODERATE	MODERATE	LOW
DNAPL	LOW	LOW		
Aqueous	HIGH	MODERATE	MODERATE	HIGH
Sorbed	HIGH	MODERATE	MODERATE	HIGH

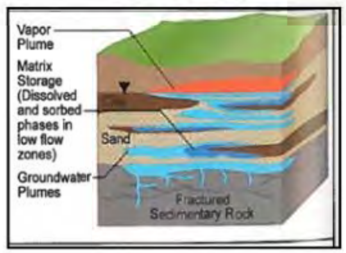
Early Stage



Middle Stage



Late Stage



Source: SERDP/ESTCP. 2010. In Situ Remediation of Chlorinated Solvent Plumes H.F. Stroo, and C.H. Ward, editors. Springer Science+Business Media LLC.

DNAPL	Dense Non-Aqueous Phase Liquid
ESTCP	U.S. Department of Defense Environmental Security Technology Certification Program
SERDP	U.S. Department of Defense Strategic Environmental Research and Development Program

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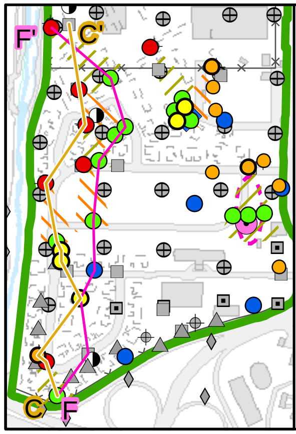
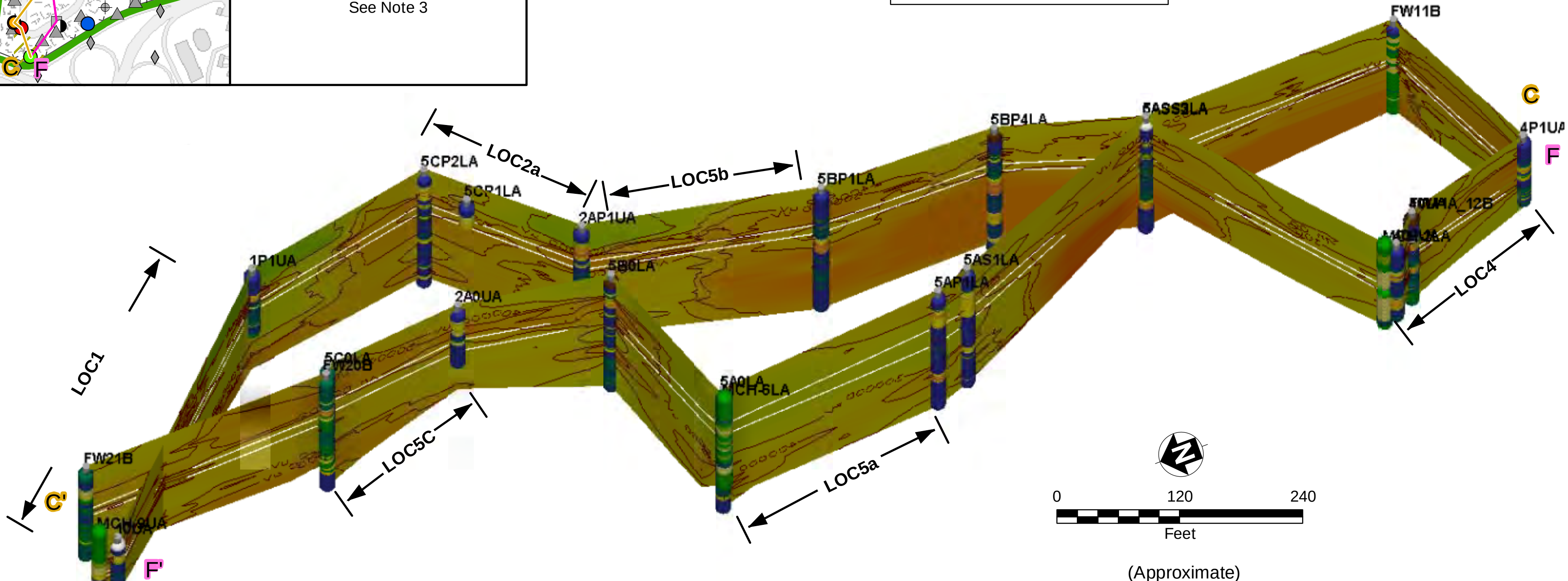
FIGURE 28
FOURTEEN COMPARTMENT MODEL OF CHLORINATED SOLVENT DISTRIBUTION AND PLUME EVOLUTION
Supplemental Site Investigation



Notes:
1. View from the northwest at 285 degrees from horizontal.
2. Point names have been shortened. The letters "LOC" at the beginning of the point name and hyphens within the point name have been removed.
3. See Figure 22 for definitions of the symbols shown in the inset.

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
CPT	Cone Penetrometer Test
ECD	ECD Response Contour
LOC	Location of Concern
MIP	Membrane Interface Probe
µV	Microvolt



ECD Response

5.5E6µV
3.2E6µV
1.8E6µV
1E6µV
5.6E5µV
3.2E5µV
1.8E5µV
1E5uV
6.3E4uV

—300000–µV— ECD Response Contour

LOCX — Approximate Extent of LOC

5CP5LA — CPT/MIP or CPT Boring Point Name (see note 2)

CPT/MIP or CPT Boring Location with Soil Types Indicated By Depth (white horizontal lines signify the approximately placement of the A1/A2 aquitard)

Soil Types

- Caliche
- Gravelly sand to sand
- Sand
- Sand to silty sand
- Silty sand to sandy silt
- Sandy silt to clayey silt
- Clayey silt to silty clay
- Silty clay to clay
- Clay
- Organic clay
- No Data

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FIGURE 29
CROSS SECTIONS
C-C' AND F-F'

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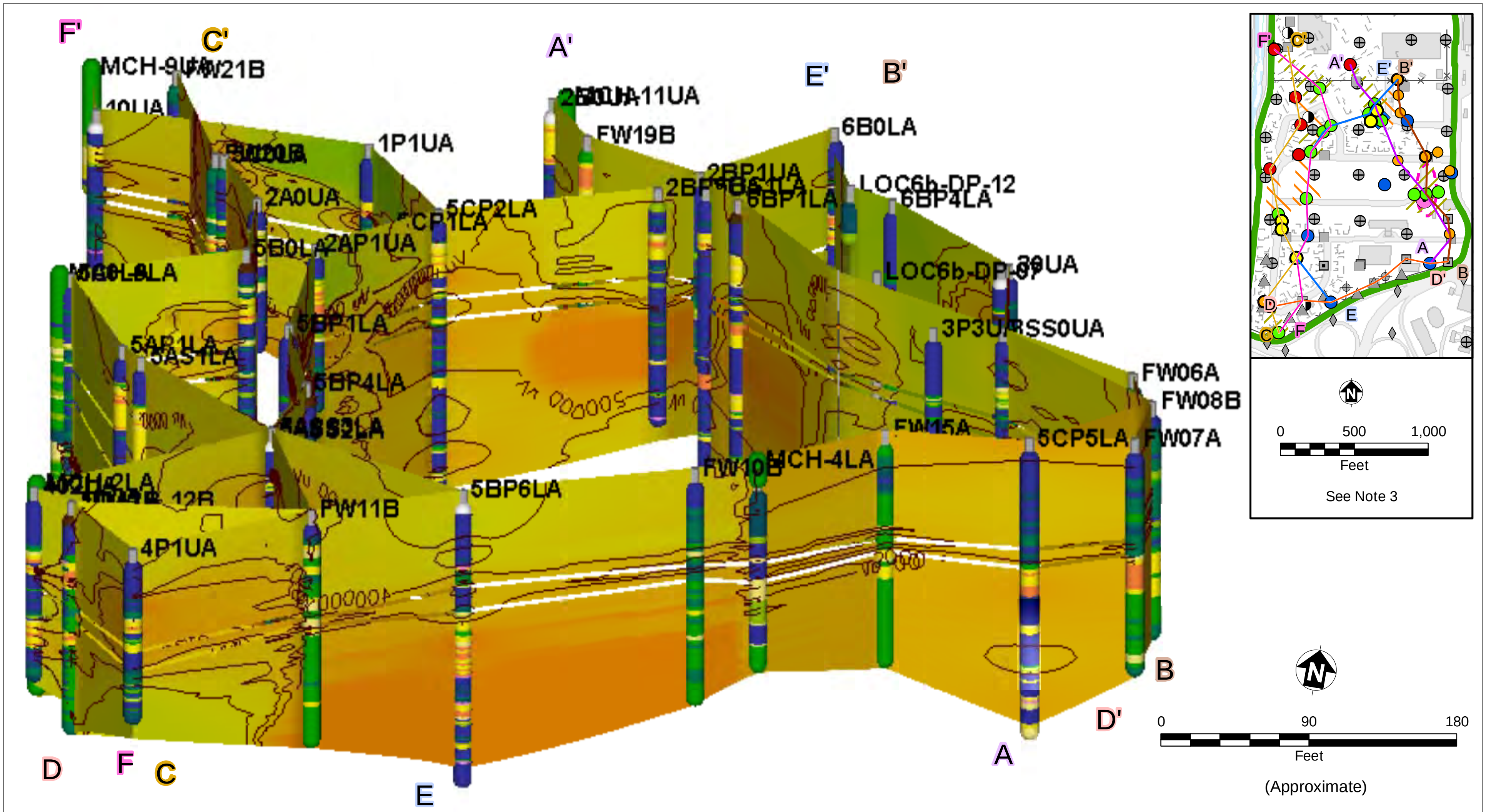

ECD Response

5.5E6µV
3.2E6µV
1.8E6µV
1E6µV
5.6E5µV
3.2E5µV
1.8E5µV
1E5uV
6.3E4uV

—300000–µV— ECD Response Contour

Notes:
1. View from the south at 180 degrees from horizontal.
2. Point names have been shortened. The letters "LOC" at the beginning of the point name and hyphens within the point name have been removed.
3. See Figure 22 for definitions of the symbols shown in the inset.

A1	Upper A Aquifer Zone
A2	Lower A Aquifer Zone
CPT	Cone Penetrometer Test
ECD	ECD Response Contour
LOC	Location of Concern
MIP	Membrane Interface Probe
µV	Microvolt

5CP5LA — CPT/MIP or CPT Boring Point Name (see note 2)

CPT/MIP or CPT Boring Location with Soil Types Indicated By Depth (white horizontal lines signify the approximately placement of the A1/A2 aquitard)

Soil Types

- Caliche
- Gravelly sand to sand
- Sand
- Sand to silty sand
- Silty sand to sandy silt
- Sandy silt to clayey silt
- Clayey silt to silty clay
- Silty clay to clay
- Clay
- Organic clay
- No Data

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FIGURE 30
FENCE DIAGRAM

Supplemental Site Investigation

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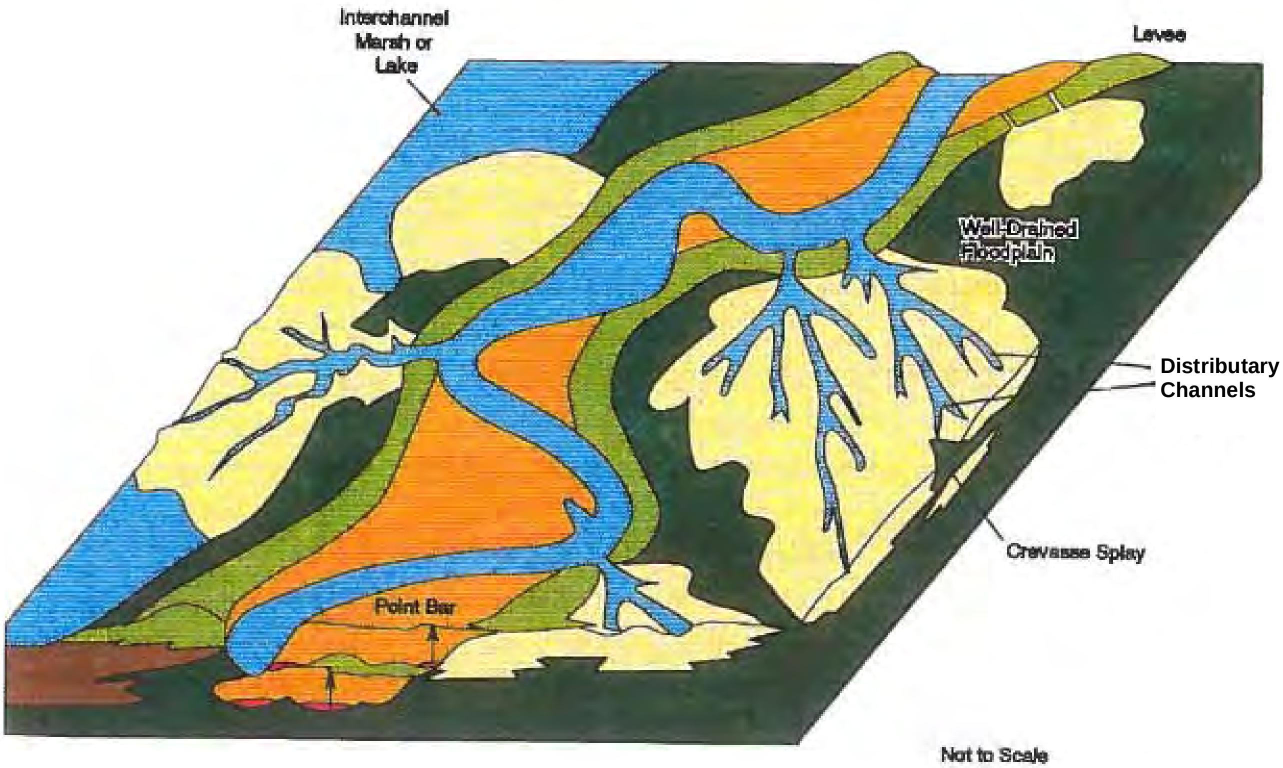

EXPLANATION

Dominant Grain Size	Depositional Site	
Clay	Interchannel marsh or lake	
Silt and Clay	Floodplain	
Silt	Levee	
Fine Sand	Crevasse splay or delta	
Sand	Channel sands	Point Bar Sequence
Gravel	Channel Lag	
Surface Water		

After Fogg (1986)

Source: PRC Environmental Management, Inc. (PRC) and James M. Montgomery Consulting Engineers, Inc. 1992. Technical Memorandum: Geology and Hydrogeology of NAS Moffett Field, California. July.

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Former Naval Air Station Moffett Field, Moffett Field, CA

FIGURE 31
MEANDERING STREAM FACIES MODEL SHOWING TYPICAL ALLUVIAL PLAIN DEPOSITIONAL ENVIRONMENTS

Supplemental Site Investigation

TABLES

Table 1. Conceptual Site Model for On-Site Sources

Supplemental Site Investigation, Former Orion Park Housing Area, Former Naval Air Station Moffett Field, Moffett Field, California

Source	Time Period	Source Loading	Initial Release Point	Secondary Release Point
[A] Agricultural: Farmer / worker	Up to 1965	Low volume, infrequent (septic tank), low volume periodic	Degreasing septic tank, agricultural equipment cleaning	(c) Discharge to leach field, discharge to ground surface
[B] Residential: Backyard Mechanic	Early 1960s through 2001	Low volume, infrequent	(a) Ground surface (b) Drain	(d) Leak from pipes or sewers
[C] Construction Worker	1-2 years during 1960s	Low to moderate volume, irregular	Ground surface	Subsurface soil through leaching
[D] Commercial Worker	Early 1960 through 2001	Low to moderate volume, irregular	(a) Ground surface (b) Drain	(d) Leak from pipes or sewers

Note:

Letters (A , B, C, D) and (a, b, c, d) relate to objects presented on Figure A-7 of Appendix A (Conceptual Site Model for Potential On-Site Residential and Agricultural Sources) and Figure A-8 of Appendix A (Conceptual Site Model for Potential On-Site Construction and Commercial/Agricultural Sources).

Table 2. Lithologic Classification Scheme for EVS Input File

Supplemental Site Investigation, Former Orion Park Housing Area, Former Naval Air Station Moffett Field, Moffett Field, California

Lithology from Boring Logs						CPT Classification	
		USCS Grain-size Criteria					
USCS Codes	**USCS Description**	**% Granular (gravel+sand)**	**% Fines (silt+clay)**	**Lithologic Description**	**SBT Equivalent**	**SBT Value**	**SBT Lithologic Description**
				liquified fines	**1**	**1**	sensitive fine-grained
OL, OH	organic clay,	< 50%	>50%	organic clay	**2**	**2**	organic clay to clay
CL, CH	clay with high or low plasticity			clay	**3**	**3**	clay
				silty clay	**4.5**	**4**	silty clay to clay
ML, MH	silt with high or low plasticity			clayey silt	**5.5**	**5**	clayey silt to silty clay
				silt	**6**	**6**	sandy silt to clayey silt
				sandy silt	**6.5**		
SC	clayey sand	50-87%	13-50%	clayey sand	**7**	**7**	silty sand to sandy silt
SM	silty sand			silty sand	**7.5**		
GC	clayey gravel			clayey gravel	**7.75**	**8**	sand to silty sand
GM	silty gravel			silty gravel	**8**		
SP-SC, SW-SC	(poorly- or well-graded) sand with clay	88-94%	6-12%	sand w/ clay	**8.25**		
SP-SM, SW-SM	(poorly- or well-graded) sand with silt			sand w/ silt	**8.5**	**9**	sand
SP, SW	poorly- or well- graded sand	≥ 95%	≤ 5%	sand	**9**		
				gravelly sand	**9.5**		
GP-GC, GW-GC	(poorly- or well-graded) gravel with clay	88-94%	6-12%	gravel w/ clay	**9.25**	**10**	gravelly sand to sand
GP-GM, GW-GM	(poorly- or well-graded) gravel with silt			gravel w/ silt	**9.5**		
GP, GW	poorly- or well-graded gravel	≥ 95%	≤ 5%	sandy gravel	**10**		
				gravel	**10.5**		
				caliche	**11**	**11**	overconsolidated - coarse-grained
				caliche	**12**	**12**	overconsolidated - fine-grained

Notes:

%	Percent
CPT	Cone penetrometer technology
EVS	Environmental Visualisation System-Pro
SBT	Soil behavior type
USCS	Unified Soil Classification System

Table 3. TCE Concentrations in Groundwater Wells

Supplemental Site Investigation, Former Orion Park Housing Area, Former Naval Air Station Moffett Field, Moffett Field, California

Well ID	Sample Date	Top Depth (ft bgs)	Bottom Depth (ft bgs)	Result (µg/L)	Qualifier
MCH-1UA	8/8/2005	14	24	210	
MCH-1UA	12/8/2005	14	24	190	
MCH-1UA	3/21/2006	14	24	120	
MCH-1UA	6/13/2006	14	24	160	
MCH-1UA	1/4/2011	14	24	110	
MCH-2LA	8/8/2005	32	42	360	
MCH-2LA	12/8/2005	32	42	330	
MCH-2LA	3/21/2006	32	42	220	
MCH-2LA	6/13/2006	32	42	230	
MCH-2LA	1/4/2011	32	42	210	
MCH-3UA	8/8/2005	13	23.5	150	
MCH-3UA	12/8/2005	13	23.5	210	
MCH-3UA	3/21/2006	13	23.5	160	
MCH-3UA	6/14/2006	13	23.5	110	
MCH-3UA	1/4/2011	13	23.5	110	
MCH-4LA	8/8/2005	34	44	520	
MCH-4LA	12/7/2005	34	44	480	
MCH-4LA	3/21/2006	34	44	330	
MCH-4LA	6/14/2006	34	44	400	
MCH-4LA	1/3/2011	34	44	420	
MCH-5UA	8/9/2005	14	24	37	
MCH-5UA	12/8/2005	14	24	36	
MCH-5UA	3/22/2006	14	24	50	
MCH-5UA	6/13/2006	14	24	50	
MCH-5UA	1/3/2011	14	24	2.8	
MCH-6LA	8/9/2005	41	51	820	
MCH-6LA	12/8/2005	41	51	750	
MCH-6LA	3/21/2006	41	51	390	
MCH-6LA	6/13/2006	41	51	590	
MCH-6LA	1/4/2011	41	51	620	
MCH-7UA	8/9/2005	10	20	280	
MCH-7UA	12/8/2005	10	20	250	
MCH-7UA	3/22/2006	10	20	160	
MCH-7UA	6/13/2006	10	20	220	
MCH-7UA	1/4/2011	10	20	180	
MCH-8LA	8/9/2005	35	45	3	J
MCH-8LA	12/8/2005	35	45	5	U
MCH-8LA	3/22/2006	35	45	0.37	J
MCH-8LA	6/13/2006	35	45	5	U

Table 3. TCE Concentrations in Groundwater Wells

Supplemental Site Investigation, Former Orion Park Housing Area, Former Naval Air Station Moffett Field, Moffett Field, California

Well ID	Sample Date	Top Depth (ft bgs)	Bottom Depth (ft bgs)	Result (µg/L)	Qualifie r
MCH-8LA	1/3/2011	35	45	3.3	
MCH-9UA	8/9/2005	16	26	510	
MCH-9UA	12/9/2005	16	26	610	
MCH-9UA	3/22/2006	16	26	380	
MCH-9UA	6/13/2006	16	26	450	J
MCH-9UA	1/3/2011	16	26	400	
MCH-9UA	1/3/2011	16	26	400	
MCH-10LA	8/9/2005	35	45	1200	
MCH-10LA	12/8/2005	35	45	1100	
MCH-10LA	3/22/2006	35	45	71	
MCH-10LA	6/13/2006	35	45	870	
MCH-10LA	1/3/2011	35	45	720	
MCH-11UA	8/9/2005	13	23	310	
MCH-11UA	12/8/2005	13	23	380	
MCH-11UA	3/22/2006	13	23	210	
MCH-11UA	6/13/2006	13	23	270	
MCH-11UA	1/3/2011	13	23	210	

Notes:

µg/L	Micrograms per liter
ft bgs	Feet below ground surface
J	Estimated
TCE	Trichloroethene
U	Non-detect results

Table 4. CPT/MIP Borehole Depths and Associated LOCs

Supplemental Site Investigation, Former Orion Park Housing Area, Former Naval Air Station Moffett Field, Moffett Field, California

Point ID	Date	Depth (feet bgs)	Associated LOC	Associated Aquifer or Upgradient Step-Out
LOC2a-0-UA	1/17/2011	35	2a	A1
LOC3-SS0-UA	1/17/2011	45	3	A1
LOC4-0-UA	1/17/2011	46	4	A1
LOC1-0-UA	1/18/2011	38	1	A1
LOC2b-0-UA	1/18/2011	37	2b	A1
LOC5c-0-UA	1/18/2011	74	5c	A2
LOC1-P1-UA	1/19/2011	38	1	A1
LOC2a-P1-UA	1/19/2011	37	2a	A1
LOC2b-P1-UA	1/19/2011	44	2b	A1
LOC2b-P1-Uadiss	1/19/2011	15	2b	A1
LOC5b-0-LA	1/19/2011	69	5b	A2
LOC3-0-UA	1/20/2011	39	3	A1
LOC5a-0-LA	1/20/2011	73	5a	A2
LOC5a-P1-LA	1/20/2011	69	5a	A2
LOC5b-P1-LA	1/20/2011	72	5b	A2
LOC5c-P1-LA	1/21/2011	14	5c	A2
altLOC5c-P1-LA	1/21/2011	16	5c	A2
LOC6b-0-LA	1/21/2011	69	6b	A2
LOC6b-P1-LA	1/21/2011	69	5b	A2
LOC2b-P2-UA	1/24/2011	55	2b	A1
LOC3-P2-UA	1/24/2011	43	3	A1
LOC5c-P2-LA	1/24/2011	69	5c	A2
LOC6b-P4-LA	1/24/2011	69	6b	Upgradient Step-out
LOC3-P3-UA	1/25/2011	39	3	A1
LOC5a-A1-LA	1/25/2011	70	5a	A2
LOC6b-S1-LA	1/25/2011	69	6b	A2
LOC4-02-UA	1/26/2011	44	4	A1
LOC4-P1-UA	1/26/2011	40	4	A1
LOC5b-P4-LA	1/26/2011	75	NA	Upgradient Step-out
LOC5a-SS2-LA	1/27/2011	26	5a	A2
LOC5a-SS3-LA	1/27/2011	69	5a	A2
LOC5c-P5-LA	1/27/2011	71	NA	Upgradient Step-out
LOC6b-SS2-UA	1/27/2011	51	2b/6b	A2
LOC3-P4-UA	1/28/2011	29	3	Upgradient Step-out
LOC5c-P4-LA	1/28/2011	55	5c	Upgradient Step-out
LOC5b-P6-LA	1/28/2011	69	5b	Upgradient Step-out

Notes:

A1	Upper A Aquifer Zone	ID	Identification
A2	Lower A Aquifer Zone	LOC	Location of concern
bgs	Below ground surface	MIP	Membrane interface probe
CPT	Cone penetrometer technology	NA	Not applicable

Table 5. Response Profile Source Indicator Criteria
Supplemental Site Investigation, Former Orion Park Housing Area, Former Naval Air Station Moffett Field, Moffett Field, California

Criterion	Points
ECD response that is greatest in the capillary fringe indicates a source area	2
ECD response ≥ 7e+6 μV indicates residual or liquid NAPL source	2
ECD response ≥ 4e+6 μV indicates proximity to residual or liquid NAPL source	1
ECD profile that decreases sharply within the first saturated zone may indicate a source area	1
ECD profile that is highest in finer-grained materials in the first saturated zone may indicate proximity to a source	1
Maximum Total Score	**7**

Notes:

μV Microvolt
ECD Electron capture detector
NAPL Non-Aqueous Phase Liquid

Table 6. Summary of Phase 3 Groundwater Grab Samples and Observations

Supplemental Site Investigation, Former Orion Park Housing Area, Former Naval Air Station Moffett Field, Moffett Field, California

LOC (Aquifer Zone)	Point ID	Sample ID	Depth (ft bgs)	Relative Location	TCE Result (µg/L) [a]	DCE Result (µg/L) [b]	Observations	Justification for No Further Investigation
3 (A1)	LOC3-DP-01	SSI-HP-004	15-16	Downgradient	94	5.6	1) No trend of TCE or DCE concentrations in groundwater increasing upgradient of LOC3-0-UA. 2) TCE and DCE concentrations in groundwater at LOC3-0-UA are slightly elevated above concentrations of TCE recorded in wells near LOC 3, though the concentrations detected in LOC 3 are not high compared to other areas of the site. 3) TCE and DCE concentrations from the DPT grab groundwater samples verified the MIP response observed that TCE concentrations are higher at the downgradient location. 4) TCE and DCE concentrations from the DPT grab groundwater samples at LOC3-DP-01 disproved the MIP response observed that VOC concentrations in less-permeable zone of clayey soils (17-18 ft bgs) are higher than in the overlying more permeable zone of sandy soils (15-16 ft bgs) at LOC3-0-UA. DPT grab groundwater results indicate the concentrations in the clayey soils and sandy soils are similar. 5) It is indeterminate whether (a) a local source is present between LOC3-0-UA and the upgradient MIPs (LOC3-SS0-UA, LOC3-P2-UA, LOC3-P3-UA) (all of which had less response) and LOC3-DP-03, or (b) the plume is being pulled up from the A2 aquifer zone or deeper in the A1 aquifer zone. However, no source characteristics were observed during the MIP investigation.	Concentrations detected in LOC 3 are not high compared to other areas of the site. The initial purpose of this investigation was to investigate the paint locker area upgradient of LOC3-DP-UA; no indications of a source were found. Assessment of data obtained using EVS indicates that the plume may be migrating from the A2 aquifer zone upgradient into the A1 aquifer zone within the downgradient portion of LOC 3 (see Figure 6).
3 (A1)	LOC3-DP-01	SSI-HP-005	17-18	Downgradient	110	6.8		
3 (A1)	LOC3-DP-03	SSI-HP-004A	15-16	Upgradient	0.76 J	0.24		
6b (A1)	LOC6b-DP-05	SSI-HP-001	12-13	Downgradient	0.36 J	0.2	1) Decreasing trend of TCE and DCE concentrations in groundwater downgradient, indicating that the plume is migrating from upgradient location. 2) Concentrations are very low at LOC6b-0-LA where a low response in the MIP profile was observed—does not support presence of a local source.	DPT groundwater data indicate that an upgradient plume is migrating into LOC 6b within the A1 aquifer zone.
6b (A1)	LOC6b-DP-06	SSI-HP-002	12-13	Upgradient (100 ft)	0.66 J	ND		
6b (A1)	LOC6b-DP-12	SSI-HP-003	10-11	Upgradient (200 ft)	14	3.9		
6b (A1), LOC 2b (A1)	LOC6b-DP-07	SSI-D-002 (Dup)	13-14	Upgradient (mid-site)	49	4.9		
6b (A1), LOC 2b (A1)	LOC6b-DP-07	SSI-HP-007	13-14	Upgradient (mid-site)	45	4.8		
6b (A2)	LOC6b-DP-07	SSI-HP-008	42-43	Upgradient (mid-site)	50	4.9	1) Increasing trend of TCE concentrations in groundwater upgradient; appears that concentrations increase with movement off the Site. 2) TCE plume is present upgradient. 3) Continuous sand channel present at about 43-44 feet bgs, as indicated by geologic boring logs of locations LOC6b-DP-07 and LOC6b-DP-09. 4) Appears that the plume moves from LOC6b-DP-07 through the center of the Site, not along the east border.	TCE plume is present upgradient at higher concentrations than at downgradient locations, indicating that the plume is moving onto the Site from off site. EVS model supports downgradient movement of the plume.
6b (A2)	LOC6b-DP-10	SSI-HP-009	42-43	Upgradient (mid-site)	0.25 J	ND		
6b (A2)	LOC6b-DP-09	SSI-HP-006	43.5-44.5	Upgradient (site border)	99	3.8		

Notes:

a Other VOCs detected include 1,1-dichloroethane (max 0.23 J µg/L), 1,1-dichloroethene (max 0.28 J µg/L), 1,2,4-trimethlybenzene (max 0.5 J µg/L), benzene (max 0.22 J µg/L), carbon disulfide (max 0.83 J µg/L), ethylbenzene (max 0.28 J µg/L), m,p-xylenes (max 1.6 J µg/L), o-xylene (max 0.66 J µg/L), toluene (max 0.82 J µg/L), and *trans* -1,2-dichloroethene (max 0.69 J µg/L).

b Environmental Visualization Software, by Scientific Software Group. www. scisoftware.com

µg/L	Micrograms per liter	EVS	Environmental Visualization Software ©	N	Not applicable
A1	Upper A Aquifer Zone	ft	Feet	N	Not detected
A2	Lower A Aquifer Zone	ID	Identification	T(	Trichloroethene
bgs	Below ground surface	LOC	Location of concern	V	Volatile organic compound
DPT	Direct push technology	max	Maximum		
Dup	Duplicate	MIP	Membrane interface probe		

Table 7. Project Quality Objectives/Systematic Planning Process Statements to Investigate the A2 Aquifer Zone in LOC 6b

Supplemental Site Investigation, Former Orion Park Housing Area, Former Naval Air Station Moffett Field, Moffett Field, California

STEP 1: State the Problem – *Define the problem(s) that necessitates the study (e.g., further characterization).*

A review of the cone penetrometer technology (CPT)/ membrane interface probe (MIP) data in the Environmental Visualization Software[1] (EVS) indicated that additional data were needed upgradient of location of concern (LOC) 6b within the lower portion of the A aquifer (A2 aquifer zone) to confirm the hypothesis that the contamination within the A2 aquifer zone at LOC 6b derives from contamination at an upgradient source.

STEP 2: Identify the Goals of the Study – *Identify the decisions that need to be made and possible actions that may be taken as a result of the decision.*

Verify presence of VOC contamination within the A2 aquifer zone upgradient of LOC 6b.

STEP 3: Identify Information Inputs – *Identify specific information needed (could be existing or newly generated) to make decisions and achieve study goal.*

The following existing and new data inputs will be used to confirm that VOC contamination present at LOC 6b within the A2 aquifer zone derives from contamination within an upgradient, off-site plume:

Existing data:

- Validated analytical results for VOCs from existing monitoring well MCH-10LA
- Validated analytical results for VOCs from historical grab groundwater samples in the area of LOC 6b and in the area upgradient of LOC 6b
- MIP data from borings near and in the area upgradient of LOC 6b
- Historical lithological data from CPT and hollow-stem auger boring logs near and in the area upgradient of LOC 6b
- Hydaulic head measurements (groundwater contours) obtained on November 18, 2010, from on-site wells and off-site wells north, south, and east of the Site.

New data:

- Analytical results for VOCs in grab groundwater samples collected at discrete depth intervals within the A2 aquifer zone using direct-push technology (DPT) at three locations in the predicted upgradient direction of LOC 6b
- Lithology recorded at the same three locations.

STEP 4: Define the Boundaries of the Study – *Define spatial and temporal boundaries considering site-specific contaminants, potential migration pathways, and current and future uses of site.*

- Spatial boundaries –
  - Vertical: A2 aquifer zone (28 to 65 feet bgs)
  - Lateral: within the boundary of the Site and focused on the area upgradient of LOC 6b (southeastern portion of the site)
- Temporal boundaries –
  - From 2002 (date of historical groundwater grab sampling) through 2011
  - Historical groundwater and lithologic data obtained on-site and off-site between 2002 and 2006
  - Additional groundwater, soil, and lithologic data obtained as part of this investigation

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[1] *Environmental Visualization Software, by Scientific Software Group. www. Scisoftware.com*

Table 7. Project Quality Objectives/Systematic Planning Process Statements to Investigate the A2 Aquifer Zone in LOC 6b (Continued)

Supplemental Site Investigation, Former Orion Park Housing Area, Former Naval Air Station Moffett Field, Moffett Field, California

STEP 5: Develop the Analytic Approach – *Define specific parameters of interest, specify action levels/criteria to be considered, and basis for selected action levels (e.g., "if…then…" decision rules).*
To evaluate whether VOC contamination detected by the MIP response results from contamination from a plume migrating downgradient to LOC 6b from an upgradient source within the A2 aquifer zone, the following analytic approach will be used: • If permeable sediments are logged within the A2 aquifer zone at a depth that would indicate a continuous permeable conduit between the new locations and the interval of interest at LOC6b-0-LA (the depth interval showing elevated MIP and CPT responses, indicating sand within the A2 aquifer zone), a migration pathway may be present from the upgradient location to downgradient LOC 6b. If permeable sediments are not observed within the A2 aquifer zone at a depth that would indicate a continuous permeable conduit between the new locations and the interval of interest at LOC6b-0-LA, then there is not a potential migration pathway from the upgradient location to downgradient LOC 6b, and thus, a localized source may be present. • If VOCs are detected within the A2 aquifer zone at either location LOC6b-DP-07 or LOC6b-DP-10 and at location LOC6b-DP-09, and a permeable channel deposit appears to be connecting the plume at the upgradient location to CPT/MIP LOC6b-0-LA, VOC contamination may be migrating from the upgradient location to downgradient LOC 6b. If VOCs are not detected within the A2 aquifer zone at either location LOC6b-DP-07 or LOC6b-DP-10 and at location LOC6b-DP-09, or a permeable channel deposit does not appear to be connecting the plume at the upgradient location to CPT/MIP LOC6b-0-LA, the VOC contamination detected at LOC6b-0-LA likely derives from a localized source.
STEP 6: Specify Performance or Acceptance Criteria – *How to address inherent uncertainty? Consider consequences of incorrect conclusions and specify the degree of certainty decisions must achieve by defining acceptance limits.*
The three upgradient locations were selected based on a review of historical analytical data, spatial data gaps in the VOC plume as modeled in EVS, groundwater contours, and lithology. These three locations are believed to be in the upgradient direction of LOC 6b. The assessment of whether VOC contamination detected by the MIP response at LOC 6b derives from contamination within a plume migrating downgradient to LOC 6b from an upgradient source within the A2 aquifer zone will minimize uncertainty and inaccuracy through: • Applying standard sample collection and test methods, and established laboratory performance criteria. • Modeling the new data with the existing data in EVS.
STEP 7: Develop the Plan for Obtaining Data – *Develop approaches to achieve the goal of the study in the most resource-effective way.*
For the assessment of VOC contamination in groundwater upgradient of LOC 6b: 1. Collect groundwater grab samples from the A2 aquifer zone at three locations upgradient of LOC 6b, and analyze these samples for VOCs. 2. Compare VOC concentrations in those groundwater samples collected at locations upgradient of LOC 6b within the A2 aquifer zone. 3. Compare lithologies at downgradient and upgradient locations.

Table 8. Summary of Supplemental Site Investigation Results

Supplemental Site Investigation, Former Orion Park Housing Area, Former Naval Air Station Moffett Field, Moffett Field, California

LOC	Aquifer Zone of Interest	CPT/MIP Investigation Conclusion*	Path Forward after CPT/MIP Investigation	DPT Investigation Conclusion	Path Forward after DPT investigation	EVS Conclusion	Molar Concentration Evaluation Conclusion	Figure References
1	A1	No on-site source characteristics observed (Step 10a)	Confirm with EVS	NA	No further investigation. Additional wells will not be installed because data do not indicate presence of an on-site source.	Low concentrations result from upgradient plume migration; continuity of sand channels (geologic conduit, preferential pathway) evident.	NA	Figure 3: CPT/MIP and DPT Locations Figure 7: Distribution of Sand and Gravelly Sand Figure 8: Low-Level (5.0E + 005µV) ECD Responses – Top View Figure 9: Low-Level (5.0E + 005µV) ECD Responses
2a	A1							
2b	A1	Potential on-site source (Step 9c)	Investigate as part of LOC 6b (A1) investigation	Elevated concentrations are a result of upgradient plume migration (connection with upgradient DPT point LOC-6b-DP-07).		Plume connected to plume at LOC 6b (see conclusions for LOC 6b).	Investigated as part of LOC 6b (A1 aquifer zone) investigation	Figure 8: Low-Level (5.0E + 005µV) ECD Responses – Top View Figure 9: Low-Level (5.0E + 005µV) ECD Responses
3	A1	No source characteristics observed; localized area of elevated dissolved concentrations (Step 10b)	Investigate with DPT grab groundwater samples; confirm with EVS	Localized area of elevated concentrations is not a result of a suspected source (paint locker) (no source characteristics observed), but rather a variation in plume concentrations caused by local geologic heterogeneities.		Off-site plume could not be connected to local concentrations in EVS; however, neither MIP/CPT nor DPT data indicate an on-site source. Potential connection with plume from upgradient A2 aquifer zone via vertical migration of groundwater.	Molarity decreased in grab groundwater samples collected within the A1 aquifer zone from LOC3 to LOC6. The decreasing trend begins at upgradient location LOC3-DP-01, and continues downgradient to LOC6b-DP-12, LOC6b-DP-06, and LOC6b-DP-05.	Figure 12: Cross-Section Guide Figure 14: Cross-Section B-B'
4	A1	No on-site source characteristics observed (Step 10a)	No further investigation of on-site source; additional investigation of high PID result observed in 2002 with soil sample as specified in work plan	VOCs and TPH not detected in soil—no on-site source present.		Low concentrations result from upgradient plume migration.	NA	Figure 8: Low-Level (5.0E + 005µV) ECD Responses – Top View Figure 9: Low-Level (5.0E + 005µV) ECD Responses Figure 10: Mid-Level (7.5E + 005µV) ECD Responses
5a	A2	No on-site source characteristics observed (Step 10a)	Confirm with EVS	NA		Low concentrations result from upgradient plume migration.		Figure 7: Distribution of Sand and Gravelly Sand Figure 8: Low-Level (5.0E + 005µV) ECD Responses – Top View Figure 9: Low-Level (5.0E + 005µV) ECD Responses
5b	A2					Elevated concentrations result from upgradient plume migration.		Figure 10: Mid-Level (7.5E + 005µV) ECD Responses Figures 11A, 11B: High-Level (1.0E + 006µV and 2.5E + 006µV) ECD Responses
5c	A2					Low concentrations result from upgradient plume migration.		Figure 7: Distribution of Sand and Gravelly Sand Figure 8: Low-Level (5.0E + 005µV) ECD Responses – Top View Figure 9: Low-Level (5.0E + 005µV) ECD Responses
6b	A1	Potential on-site source (Step 9c)	Investigate with DPT grab groundwater samples; confirm with EVS	Elevated concentrations are a result of upgradient plume migration.		Elevated concentrations result from upgradient plume migration.	Molarity decreased in grab groundwater samples collected within the A1 aquifer zone from LOC 3 to LOC 6. The decreasing trend begins at upgradient location LOC3-DP-01, and continues downgradient to LOC6b-DP-12, LOC6b-DP-06, and LOC6b-DP-05. LOC6B-DP-07 is crossgradient of LOC3-DP-01 within the A1 aquifer zone.	Figure 8: Low-Level (5.0E + 005µV) ECD Responses – Top View Figure 9: Low-Level (5.0E + 005µV) ECD Responses Figure 12: Cross-Section Guide Figure 13: Cross-Section A-A' Figure 15: Cross-Section E-E'
6b	A2	No on-site source characteristics observed (Step 10a)	Investigate data gaps to confirm plume originating off site				Molarity decreases from upgradient (LOC6B-DP-09) to downgradient (LOC6B-DP-07) within the A2 aquifer zone. LOC6B-DP-10 is crossgradient of LOC6B-DP-07 and has a much lower molar concentration.	Figure 12: Cross-Section Guide Figure 13: Cross-Section A-A' Figure 15: Cross-Section E-E'

Notes:

* Steps referenced are from decision logic in the former OPHA SSI Work Plan (AIS and Tetra Tech 2010), Figure A-13.

A1	Upper A Aquifer Zone	EVS	Environmental Visualization Software, by Scientific Software Group. www. scisoft	PID	Photoionization detector
A2	Lower A Aquifer Zone	LOC	Location of concern	Tetra Tech	Tetra Tech EM Inc.
AIS	American Integrated Services, Inc.	MIP	Membrane interface probe	TPH	Total petroleum hydrocarbons
CPT	Cone penetrometer technology	NA	Not applicable	VOC	Volatile organic compound
DPT	Direct-push technology				