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May 1, 2014

Ms. Dilan Roe
Hazardous Materials Specialist
Alameda County Environmental Health
1131 Harbor Bay Parkway, Suite 250
Alameda, CA 94501-6577

Subject: **Final Feasibility Study and Corrective Action Plan**
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California
Fuel Leak Case No. RO0003014

Dear Ms. Roe:

Enclosed please find the *Final Feasibility Study and Corrective Action Plan* for the Crown Chevrolet Cadillac Isuzu site at 7544 Dublin Boulevard and 6707 Golden Gate Drive, in Dublin, California (Fuel Leak Case No. RO0003014, GeoTracker Global ID T10000001616). This report was prepared by AMEC Environment & Infrastructure, Inc. (AMEC), on behalf of Crown Chevrolet Cadillac Isuzu.

I declare under penalty of perjury that the information and/or recommendations contained in the attached document or report is true and correct to the best of my knowledge.

Please contact me at (925) 984-1426 or Avery Patton of AMEC at 510-663-4154 if you have any questions regarding this Work Plan.

Sincerely yours,

Terri Costello

Terri Costello
Betty J. Woolverton Trust

Attachment: Final Feasibility Study and Corrective Action Plan

cc: Tondria Hendrix, Zurich North American Insurance
Thomas L. Vormbrock, Rimkus Consulting Group, Inc.

FINAL FEASIBILITY STUDY AND CORRECTIVE ACTION PLAN

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

Prepared for:

Crown Chevrolet
Dublin, California

Prepared by:

AMEC Environment & Infrastructure, Inc.
2101 Webster Street, 12th Floor
Oakland, California 94612

May 2014

Project No. OD10160070

amec

FINAL FEASIBILITY STUDY AND CORRECTIVE ACTION PLAN

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California
Fuel Leak Case No. RO0003014

May 1, 2014
Project OD10160070

This report was prepared by the staff of AMEC Environment & Infrastructure, Inc., under the professional supervision of Avery Patton, PG, and Alfonso Ang, PE. The findings, recommendations, specifications, and/or professional opinions presented in this report were prepared in accordance with generally accepted professional geology and engineering practices, and within the scope of the project. There is no other warranty, either express or implied.

AVERY PATTON
No. 8541

Avery Patton, PG #8541
Senior Geologist

ALFONSO ANG
No. C81007
Exp. 9/30/15
CIVIL

Alfonso Ang, PE #C81007
Senior Engineer

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FINAL FEASIBILITY STUDY
AND CORRECTIVE ACTION PLAN

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

EXECUTIVE SUMMARY

AMEC Environment & Infrastructure, Inc. (AMEC), has prepared this *Final Feasibility Study and Corrective Action Plan* (FS/CAP) on behalf of the Betty J. Woolverton Trust and Crown Chevrolet Cadillac Isuzu (collectively, Crown) for the properties located at 7544 Dublin Boulevard and 6707 Golden Gate Drive in Dublin, California (the site; Figure 1). The FS/CAP has been prepared at the request of Alameda County Environmental Health (ACEH). The purpose of the FS/CAP is to evaluate and compare remedial alternatives for addressing groundwater, soil, and soil vapor impacts at the site and to describe the implementation of the selected corrective action.

The primary issues addressed by this FS/CAP are related to the presence of volatile organic compounds (VOCs), specifically tetrachloroethene (PCE) and trichloroethene (TCE) migrating onto the site via groundwater and soil vapor from an unknown off-site source, and residual impacts to soil and groundwater from chlorobenzene and related compounds that remain beneath Building B at the site.

The objective of the FS/CAP is to meet both corrective action objectives (CAOs) for the site, media-specific actions for protecting human health and the environment, which include the following:

1. Mitigate potential vapor intrusion risks to future site occupants.
    - Confirm via 1 year of indoor air sampling that concentrations of COCs are below applicable indoor air screening levels.
    - Obtain temporal shallow groundwater and vent riser (equivalent to sub-slab) data for 5 years.
    - Comply with institutional controls (ICs) regarding property use, mitigation measures, and monitoring.
2. Mitigate potential exposure to future construction and maintenance workers to VOC-impacted soil vapor and groundwater.
    - Comply with a site management plan, which will provide guidance for worker protection and safety measures to be employed during site construction and operations and maintenance (O&M) of remediation systems.

3. Remediate identified residual source material in the vicinity of the former sump and F.E. Pit.
    - Remove residual impacted soil to the extent that COC concentrations in confirmation samples collected from the sidewalls of the excavation are less than Environmental Screening Levels (ESLs), published by the California Regional Water Quality Control Board, San Francisco Bay Region (Regional Water Board, 2013), for shallow soil in a residential land use scenario, where groundwater is considered a potential drinking water resource.
    - Conduct additional removal of impacted soil that may be encountered during site demolition and development, as necessary.

Following a technology screening process, four alternatives were selected for evaluation in this FS/CAP. Each alternative is cumulative; Alternative 2 incorporates the activities proposed in Alternative 1, Alternative 3 incorporates Alternative 2, and so on. Note that the remedial alternatives presented below are designed to fit a currently-proposed site redevelopment; these alternatives may not be applicable in their entirety should the currently-proposed redevelopment not proceed. The alternatives are identified as follows:

- Alternative 1—Soil excavation/disposal, groundwater sampling, and long-term site management and institutional controls.
- Alternative 2—Vapor barrier and sub-slab depressurization system (SSD), plus soil excavation/disposal, groundwater sampling, and long-term site management and ICs.
- Alternative 3—Permeable reactive barrier (PRB) with zero-valent iron (ZVI), plus vapor barrier and sub-slab depressurization, soil excavation/disposal, groundwater sampling, and long-term site management and ICs.
- Alternative 4—In-situ bioremediation, permeable reactive barrier with ZVI, vapor barrier and sub-slab depressurization, soil excavation/disposal, groundwater sampling, and long-term site management and ICs.

Based on a comparative analysis, Alternative 3 represents the most effective and implementable alternative to meet the corrective action objectives presented herein, and is recommended as the corrective action measure for the site. Implementation of Alternative 3 can be accomplished with minor disruption to the planned site development schedule, provides passive, long-term protection against on-site migration of impacted groundwater, represents the third least expensive alternative, and is sustainable as a long-term approach.

Additionally, in order to mitigate the effects of possible changes in site conditions, such as 1) shifts in groundwater flow direction, 2) an increase in plume width along Golden Gate Drive, 3) a change in the distribution of the vapor plume, and/or 4) an increase in the footprint of the vapor plume, contingent measures could be undertaken supplemental to the remedial actions proposed in Alternative 3. The proposed contingency actions, based on the possible changes in site conditions outlined above, would be as follows:

- Extend the Alternative 3 vapor barrier and SSD under all proposed buildings (excluding the parking structure) in the north parcel at the site.
- Extend the PRB an additional 50 feet south along Golden Gate Drive.

Although implementation of the proposed contingency actions would ideally only take place if justified by changes in site conditions, post-development implementation would be impractical and cost-prohibitive. As such, based on the goals to safeguard human health in the event of changes in site conditions, and to minimize the potential for future logistical and financial implementation impacts, the proposed contingencies will be implemented concurrently with the Alternative 3 remedial actions.

The corrective action plan portion of this FS/CAP includes details regarding the implementation of Alternative 3, plus the additional contingencies. Following implementation of Alternative 3, a period of performance monitoring will be necessary to confirm that the mitigation measures are functioning as designed, and additional sampling will be conducted to confirm that concentrations of VOCs in groundwater are acceptably stable or decreasing.

Assuming the vapor barrier/SSD and PRB are shown within one year to function as designed, individual certificates of completion will be requested from ACEH and, following that, No Further Action (NFA) status will be requested for the site. Certificates of completion will be requested following completion of each of the items outlined below:

1. Completion of excavation of impacted soil in the vicinity of the former sump and F.E. Pit.
2. Completion of confirmation sampling and any remediation potentially needed at the hydraulic lifts, sump(s), and drain lines at the site.
3. Confirmation of effective soil vapor mitigation via the vapor barrier and SSD after one year of performance monitoring (indoor air and vent riser sampling); subsequently, the sampling program will be converted to an O&M phase, with only vent riser sampling, for four additional years.
4. Confirmation of effective treatment of migrating impacted groundwater by the PRB after one year of performance monitoring (groundwater sampling); subsequently, the sampling program will be converted to an O&M phase for four additional years.
5. Agreement with ACEH that adequate groundwater sampling has been completed to establish acceptably stable or decreasing concentration trends.

Upon completion and confirmation of the effectiveness of the corrective actions and agreement that concentration trends in groundwater are stable or decreasing, the site owner will request that ACEH grant NFA status for the site.

FINAL FEASIBILITY STUDY
AND CORRECTIVE ACTION PLAN
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

1.0 INTRODUCTION

AMEC Environment & Infrastructure, Inc. (AMEC), has prepared this *Final Feasibility Study and Corrective Action Plan* (FS/CAP) on behalf of the Betty J. Woolverton Trust and Crown Chevrolet Cadillac Isuzu (collectively, Crown) for the properties located at 7544 Dublin Boulevard and 6707 Golden Gate Drive in Dublin, California (the site; Figure 1). The FS/CAP has been prepared at the request of Alameda County Environmental Health (ACEH). The purpose of the FS/CAP is to evaluate and compare remedial alternatives for addressing groundwater, soil, and soil vapor impacts at the site and to describe the implementation of the selected corrective action.

AMEC submitted a *Revised Draft Final Feasibility Study and Corrective Action Plan* to ACEH on March 25, 2013 (AMEC, 2013a). Following that, at the request of ACEH, AMEC submitted *Addendum to Revised Draft Final Feasibility Study and Corrective Action Plan* (First Addendum; AMEC, 2013b) on May 10, 2013. The First Addendum provided information on the anticipated life span of permeable reactive barriers. Additionally, at the request of ACEH, AMEC submitted *Second Addendum to Revised Draft Final Feasibility Study and Corrective Action Plan* (Second Addendum; AMEC, 2013c) on May 31, 2013. The Second Addendum summarized proposed changes to the monitoring program and location of the PRB. ACEH concurred with the proposed corrective action for the site in a letter to Crown dated August 16, 2013 (ACEH, 2013). The August 16, 2013 letter also included changes to the groundwater monitoring program, which are incorporated into this FS/CAP. In order to inform community members and stakeholders about the proposed redevelopment and corrective actions planned, a *Fact Sheet on Environmental Assessment* (Fact Sheet; AMEC, 2013d) was prepared by AMEC and submitted for public comment on August 9, 2013. No comments to the Fact Sheet were received during the 30 day public comment period; therefore, no public comments are incorporated into this FS/CAP.

This FS/CAP includes sections covering the following topics:

- A summary of the conceptual site model (CSM).
- A screening of corrective action technologies.
- An evaluation of corrective action alternatives that could be used to reduce potential risk to future site occupants and construction workers.

- A description of the implementation of the selected corrective action.
- A discussion of the corrective action performance monitoring and operations and maintenance (O&M) program.

Additionally, as requested by ACEH, this document includes a discussion of other considerations related to minimizing the possibility of environmental impacts to on-site soil that could occur during potential future site redevelopment activities.

The activities and time frames presented within this FS/CAP have been adjusted to fit a currently proposed site redevelopment (e.g., excavation activities discussed herein are proposed to be coordinated with building demolition). Should site redevelopment not occur as planned, portions of this FS/CAP may not be applicable.

2.0 BACKGROUND

Background regarding the site, including prior investigations and remediation, is presented in the following sections.

2.1 SITE HISTORY

The site was developed in 1968 as Crown Chevrolet, a car dealership with auto body shops, on land that appears to have been used for agricultural purposes. At that time, the three main site buildings (Buildings A, B, and C) were constructed. Building A was later expanded. Building D was reportedly constructed in 1994. Operations as a car dealership and auto body shop continued from 1968 through the present, although operations have been significantly reduced in the past several years. No operations are currently being conducted in the northern portion of the north parcel of the site at this time. The site originally consisted of one approximately 6.33-acre parcel, but was divided into north (4.97-acre) and south (1.36-acre) parcels in approximately 2000, when a new street, St. Patrick Way, was constructed. The facility operations discussed above were conducted on the north parcel; the south parcel was used for vehicle parking.

A 1,000-gallon gasoline underground storage tank (UST) and a 1,000-gallon waste oil UST were previously located immediately to the south of Building B. The USTs reportedly were replaced in the 1980s with a 1,000-gallon gasoline UST and a 1,000-gallon waste oil UST in approximately the same locations and upgraded in 1998 with spill containment devices.

Removal of these USTs was conducted in November 2012 by ENGEO, Inc. (ENGEO), on behalf of the site owner and under the regulatory oversight of ACEH (ENGEO, 2012b). The UST removal activities are discussed further in Section 2.3, below.

Buildings A through D remain; however, only Building C is in use at this time (as an auto body shop). Several former and existing hydraulic lifts, former sumps, and drain lines are known to be present in Building B.

2.2 INVESTIGATIONS

Multiple investigations have been conducted at the site; these investigations have been performed to address regulatory concerns as well as in support of transactional and potential redevelopment activities. Previous investigations and ongoing groundwater monitoring conducted at the site are documented in the following reports:

- March 16, 2009—Basics Environmental, Inc. (Basics), *Limited Phase II Environmental Site Sampling Report* (Basics, 2009).
- April 4, 2011—AMEC, *Revised Soil and Groundwater Investigation Report* (AMEC, 2011a).
- January 7, 2011—Ninyo & Moore, *Limited Phase II Environmental Site Assessment* (Ninyo & Moore, 2011a).
- September 16, 2011—Ninyo & Moore, *Additional Phase II Environmental Site Assessment* (Ninyo & Moore, 2011b).
- September 27, 2011—AMEC*, Soil, Groundwater, and Soil Vapor Investigation Report* (AMEC, 2011b).
- October 19, 2012—AMEC, *Soil, Groundwater, and Soil Vapor Investigation Report* (AMEC, 2012b).
- December 20, 2012—ENGEO, *Underground Storage Tank Removal Report* (ENGEO, 2012b).
- January 4, 2013—ENGEO, *Groundwater Investigation* (ENGEO, 2013).
- March 25, 2013—AMEC, *First Quarter 2013 Groundwater Monitoring Report* (AMEC, 2013e).
- August 12, 2013—AMEC, *Second Quarter 2013 Groundwater Monitoring Report* (AMEC, 2013f).
- February 18, 2014—AMEC, *Third and Fourth Quarter 2013 Groundwater Monitoring Report and Annual Summary* (AMEC, 2014).

Locations of samples collected during the previous investigations are shown on Figure 2a, along with current and historical site features. Selected samples collected during these investigations have been analyzed for volatile organic compounds (VOCs), total petroleum hydrocarbons (TPH), metals, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and glycols. A complete summary of data collected at the site is presented in AMEC's October 2012 investigation report. Based on the previous sample results, two primary environmental impacts related to the presence of VOCs were identified.

First, VOCs, primarily tetrachloroethene (PCE) and trichloroethene (TCE), have been detected in shallow groundwater and soil vapor throughout the northern portion of the north parcel. Biodegradation byproducts (e.g., cis-1,2-dichloroethene) are also present in groundwater and vapor, but at lower concentrations relative to PCE and TCE and below their respective Environmental Screening Levels (ESLs), published by the California Regional Water Quality

Control Board, San Francisco Bay Region (Regional Water Board, 2013).[1] An exception is that vinyl chloride has been detected in soil vapor at concentrations above its ESL. Based on the results of the most recent investigation performed by AMEC (AMEC, 2012b), the source of PCE (and hence its degradation products) in groundwater is off site.

Second, chlorobenzenes and related compounds (e.g., 1,2-dichlorobenzene and 1,4-dichlorobenzene) have been detected in soil, groundwater, and soil vapor at a former sump and a former front-end alignment pit (F.E. Pit) within Building B.

In addition to these primary impacts, a low concentration (relative to the ESL) of PCE has been detected in soil vapor in the northeastern corner of the south parcel. No PCE has been detected above its reporting limit in groundwater in this area and no facility operations, other than vehicle parking, were conducted in the south parcel. Based on these results, no mitigation appears necessary for the south parcel at this time.

Following the conclusion by AMEC that the source of PCE (and its degradation products) in groundwater is off site, ENGEO performed an off-site investigation in October 2012 (ENGEO, 2013). Four grab groundwater samples (CG-3 through CG-6; Figure 2a) were collected in Golden Gate Drive, upgradient of the site, and analyzed for VOCs and TPH quantified as gasoline (TPHg). The samples were collected west of the sanitary sewer within the street to help identify whether the sanitary sewer may have been the source of PCE in groundwater. PCE and TCE were detected at concentrations similar to those at the western site boundary, confirming that the PCE source is upgradient of the site, but not providing clarity on whether or not the sewer line was a/the source of PCE in groundwater (Figure 4). TPHg was also detected; however, this result is likely a false positive representative of PCE. A complete summary of all analytical results detected above the laboratory reporting limit, including the ENGEO data, is presented in the *First Quarter 2013 Groundwater Monitoring Report* (AMEC, 2013e).

2.3 REMEDIATION

Remedial activities were performed in October 2011 at the former sump and F.E. Pit within Building B. The remediation effort included removing a total of 432 tons of VOC-affected soil, concrete, and pea gravel from the former sump and pit excavations and approximately 5,600 gallons of VOC-affected water from the sump excavation. It was not possible to excavate beneath the existing building walls, and some impacted soil remains beneath them, as documented in AMEC's *Remediation Report* (AMEC, 2011d).

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[1] The soil results are compared to the lowest of the values shown in Table A-1, for shallow soil in a residential land use scenario, where groundwater is a current or potential drinking water resource. The groundwater results are compared to the lowest of the values shown in Table F-1a, for groundwater that is a current or potential drinking water resource (for VOCs, these ESLs also consider the potential for vapor intrusion into buildings). The soil vapor results are compared to Table E-2, to evaluate potential vapor intrusion concerns.

2.4 UST REMOVAL

Two USTs that were no longer in use were removed from the site in November 2012 by ENGEO, as indicated in the *Underground Storage Tank Removal Report* (ENGEO, 2012b). Prior to removal of the USTs, excavation of overburden soils was conducted, and these soils were stockpiled on site. The USTs were emptied and cleaned prior to removal and all lateral and vent pipes associated with the USTs were disconnected and abandoned. Following removal from the ground, the tanks and the excavations were visually inspected. No holes were observed in the tanks and no evidence of leaking was observed in the excavations.

One soil sample was collected from each stockpile of overburden soil (overburden from the gasoline UST and the waste oil UST was placed in separate stockpiles), one sample was collected from beneath the former dispenser, and one sample was collected from the base of each UST excavation using a backhoe. Following sampling, both UST excavations were backfilled using the stockpiled overburden that had been removed from that excavation, supplemented by additional fill material obtained from an off-site source (tested to confirm that metals concentrations were less than their respective residential ESLs or similar to background concentrations). Each excavation area was resurfaced with a 4-inch-thick layer of concrete.

Samples were analyzed for TPH, PCBs, semivolatile organic compounds (SVOCs), and/or selected metals. Metals were detected at background concentrations considered typical for the Dublin area. TPH quantified as diesel (TPHd) was detected in two samples at low concentrations relative to ESLs, for shallow soil and residential land use (Regional Water Board, 2013). None of the analytes were detected at or above ESLs. Based on these results, it does not appear that there are any significant impacts associated with the USTs. In the August 16, 2013 letter to Crown (ACEH, 2013), ACEH indicated they will be issuing a closure letter with respect to the UST removal.

2.5 DEVELOPMENT PLANS AND CONSTRUCTION CONSIDERATIONS

Site redevelopment is tentatively planned for the north and south parcels. Specifically, the north parcel is tentatively planned for development of 314 apartments (a total of approximately 72,000 square feet in multi-unit structures) and 17,000 square feet of retail space at ground level along Dublin Boulevard (Figure 2b); some of the apartments will be located above the retail space. An approximately 40,000-square-foot parking garage is planned for the eastern central portion of the north parcel (discussed further below). The south parcel is tentatively planned for development as 76 units of affordable veterans' and other affordable housing (a total of approximately 20,000 square feet of residential space, plus approximately 16,000 square feet of parking). Residential structures will have a maximum of five floors and parking garages of a maximum of 5½ levels. In addition to structures, an at-grade parking lot, recreational courtyard, and two landscaped courtyards are proposed for the north parcel. An additional landscaped courtyard is proposed for the south parcel.[2]

In association with the features discussed above, elevators, a spa, and a pool are proposed. The spa and pool are currently planned to be approximately 3 feet and 6 feet in depth, respectively. Elevator pits are planned be approximately 5 feet in depth. Storm drains are planned to be approximately 5 feet deep and the sewer line approximately 8 feet in maximum depth (however, these are preliminary estimates and existing pipe depths need to be confirmed with utility agencies). In addition to excavations for improvements, the *Preliminary Geotechnical Report* by ENGEO dated May 8, 2012 (ENGEO, 2012a), reported the presence of 3 to 5 feet of fill in various locations at the project site. The preliminary recommendations include removal and re-compaction of the fill.

In the *Preliminary Geotechnical Report*, preliminary foundation recommendations were given for three different foundation types: conventional footings, mat foundations, and deep foundations. Conventional footings were recommended to have a minimum depth of 24 inches and deep foundations a minimum depth of 40 feet. Mat foundations are typically constructed within the upper 1 to 2 feet of the ground surface. In the preliminary deep foundation recommendations, structures may be supported on drilled piers or piles. Drilled piers in areas with a high groundwater table may require pumping groundwater from within pier hole excavations or treating groundwater displaced during tremie of concrete. Driven piles such as H-piles and pipe piles displace soil as they are driven into the ground. As soil is not excavated, and a drilled hole is not created, groundwater will not be encountered by construction workers and groundwater handling and disposal likely will not be necessary.

Preliminary design estimates for columns loads for the parking garages were 450 to 500 kips with 10,000 pounds per lineal foot wall load at the separation walls between the parking garage and residential structures. Residential structures were estimated to impose a load of 1,500 to 3,000 pounds per linear foot wall loads. Based on the preliminary estimate of the structure loads, piles are anticipated to be placed in groups and be driven 35 to 60 feet into the ground. Due to the groundwater concerns, drilled piers are not currently proposed as a foundation type for the planned structures.

The depth at which groundwater is encountered at the site is described in the Site Conceptual Model (SCM), presented in Section 3, and summarized below.

1. During the exploration for preliminary geotechnical report, the depth of the static groundwater was measured in one of the exploration locations at 12 feet below ground surface (bgs).

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[2] The south parcel has been recently subdivided from the north parcel and placed into a separate case with ACEH; for the purposes of this FS/CAP, they are still treated as one.

2. The California Geologic Survey and the Zone 7 Water Agency have mapped the groundwater level within the project area to be approximately 10 feet below the ground surface.
3. Previous environmental investigations have encountered groundwater between 9 and 15 feet bgs, which is consistent with the published maps.
4. The shallowest depth to groundwater measured to date at the site was 9.35 feet bgs (in MW-02).

Additional site and regional groundwater information follows, as it relates to the possibility of encountering groundwater during the upcoming construction activities. At the former Montgomery Ward site (a former fuel leak clean-up site located on the north side of Dublin Boulevard and near the corner of Dublin Boulevard and Golden Gate Drive), the highest groundwater elevation historically recorded in the site vicinity was observed on April 20, 1995 (Environmental Audit, 1995), including observations wells located along the north and east property boundaries for the Crown site. The quarterly monitoring report included potentiometric contours across the Crown site. Using available survey data for the ground surface at the Crown site and potentiometric contours for April 1995, the minimum depth to water on the Crown site would have been approximately 8.1 feet bgs in the northeast corner of the site. In the middle portion of the site (where the current development plans identify a pool) the April 1995 depth to groundwater would have been greater than 11 feet.[3]

In summary, groundwater should not be encountered shallower than 8 feet bgs in the northeastern corner of the site and 11 feet bgs in the middle portion of the site. Excavations are planned to be 8 feet or shallower (including the pool) and driven piles will be used instead of drilled piers. Given these factors, it is anticipated that impacted groundwater would not be encountered during site development activities. Based on this assessment, AMEC does not believe that impacted groundwater at the site will pose construction challenges during development activities.

3.0 SITE CONCEPTUAL MODEL FOR REMEDIATION

AMEC's October 2012 investigation report includes a detailed discussion of the site conceptual model (SCM). The SCM is provided in Table 1, and various environmental issues at the site are discussed below in the context of the updated SCM, including the following:

- Site geology and hydrogeology,

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[3] It should be noted that, based on comparison of reported ground surface elevations at Montgomery Ward wells adjacent to the Crown property, AMEC assumes the elevation data presented in the 1995 quarterly monitoring report (Environmental Audit, 1995) are based on the National Geodetic Vertical Datum of 1929 (NGVD 29). AMEC's survey results are based on the North American Vertical Datum of 1988 (NAVD 88). At this location in Dublin, California, NAVD 88 records an elevation that is 2.7 feet higher than NGVD 29. This correction has been incorporated into the above described calculation of depths to groundwater.

- PCE and TCE in groundwater and soil vapor in the northern portion of the north parcel, and
- Chlorobenzenes and related constituents in soil and groundwater in the vicinity of the former sump and pit.

3.1 GEOLOGY AND HYDROGEOLOGY

Subsurface investigation findings for the site indicate that subsurface materials consist primarily of finer-grained deposits (clays, sandy clays, silts, and sandy silts) with interbedded sand lenses from ground surface to approximately 20 feet bgs. These units are underlain by approximately 15 to 20 feet of lean clay (with varying amounts of sand, but with no documented coarse lenses). Beneath the thick layer of lean clay is an interval of lean clay interbedded with sand and/or gravel lenses (from approximately 35.5 to 52 feet bgs), followed by another interval of lean clay to approximately 54 to 58 feet bgs, where an apparently continuous zone of clayey sand is encountered to the total depth logged at the site (60.5 feet bgs). A cone penetrometer technology test indicated that even coarser materials (interbedded with finer-grained materials) are present from approximately 60 to 75 feet bgs.

Groundwater is first encountered at the site between approximately 9 and 15 feet bgs, within discontinuous sand and/or gravel lenses that are a few inches to several feet thick, and also within the sandy clays that are present at similar depths. Due to the high clay content of the soil, saturated soil has not been encountered in some borings. There is likely a complex alluvial system in which groundwater (and chemical) movement primarily occurs in channel-like deposits of varying widths and thicknesses. The direction of the lateral hydraulic gradient (only measured in the northern portion of the north parcel) was to the east in October 2013 (Figure 3). The magnitude of the lateral hydraulic gradient has ranged from 0.0016 to 0.0033 foot per foot with an approximate average magnitude of 0.0025 foot per foot.

Additional detail about regional geology and hydrogeology is provided in Table 1.

3.2 PCE AND TCE IN NORTHERN PORTION OF NORTH PARCEL

PCE, TCE, and some biodegradation byproducts have been detected in groundwater and soil vapor in the northern portion of the north parcel. The highest concentrations of PCE in shallow groundwater are at the western property boundary, near the northwest corner of the site (Figure 4). As discussed above, groundwater flow direction is to the east (Figure 3), indicating that the source of PCE is off site to the west; however, the specific source of chlorinated VOCs is not known at this time.

A mass-in-place estimate was performed using data presented in the October 2012 investigation report (AMEC, 2012b). A conservative estimate was developed based on the highest reported VOC concentrations in groundwater and soil vapor, the estimated horizontal and vertical extent of VOC impacts, and the estimated physical characteristics of the affected water-bearing zone and vadose zone. The VOC mass is estimated to be approximately

3.9 pounds in groundwater and 0.3 pounds in soil vapor. In place mass estimate calculations are presented in Table 2.

The distributions of PCE and TCE are discussed by media (groundwater, soil vapor, and soil) in the following sections.

3.2.1 Groundwater

Groundwater impacts at concentrations greater than ESLs extend across the northern portion of the north parcel, extending approximately 180 to 230 feet south of the northern property boundary. The impacted water-bearing zone appears to be from approximately 10 feet bgs to approximately 20 feet bgs, based on the depth to groundwater and the presence of 15 to 20 feet of lean clay encountered at approximately 20 feet bgs. Deeper groundwater samples, collected from water-bearing zones at approximately 40 and 60 feet bgs, were non-detect for all VOCs in September 2012 (with the exception of several acetone detections that are believed to be false positives due to laboratory contamination). However, TCE, cis-1,2-dichloroethene, and 2-hexanone (plus acetone) were detected in deeper groundwater, at concentrations below ESLs, during groundwater monitoring conducted in January 2013 (AMEC, 2013).

PCE concentrations are highest along the western property boundary (up to 210 micrograms per liter [µg/L]) and just upgradient of the site, while TCE concentrations in groundwater are highest at the northeast corner of the site (up to 60 µg/L). The area with higher TCE concentrations was historically impacted by the Montgomery Ward release of TPHg, and it is likely that the TPHg acted as a source of organic carbon that stimulated the biological reduction of PCE in that area. As part of this feasibility study, in order to evaluate the potential for future biological reduction, AMEC collected two groundwater samples in October 2012 from wells MP-01-1 (near the western property boundary) and MW-02 (near the northeastern portion of the site), and tested the samples for the *Dehalococcoides (Dhc)* bacteria. Well sampling records and a copy of the laboratory analytical report are included in Appendix A. *Dhc* is the only known bacteria capable of sequential dechlorination of PCE to the inert compounds ethene and ethane (Maymo-Gatell et. al., 1997). The water samples also were analyzed for the electron receptors sulfate and nitrate. Field measurements recorded at the time of sampling included dissolved oxygen (DO) levels and oxidation reduction potential (ORP). The results of the analyses (Appendix A), are as follows:

- *Dhc* was not present in either sample at or above laboratory quantifiable limits.
- DO levels stabilized at approximately 0.25 milligram per liter [mg/L] and ORP was negative. The results of these analyses indicate potentially favorable conditions for reductive dechlorination.

- Nitrate was not detected in the sample from MW-01, but was detected at 10 mg/L in the sample from MP-01-1. Sulfate was detected in both samples (at 42 mg/L in the sample from MW-01 and at 71 mg/L in the sample from MP-01-1).

These results are discussed further in Section 6.4.1, below.

3.2.2 Soil Vapor

Soil vapor is impacted by PCE, TCE, and vinyl chloride at concentrations greater than ESLs in the northern portion of the north parcel, extending approximately 200 to 240 feet south from the northern property boundary (Figure 5). In the northwest corner of the site, PCE concentrations generally correlate spatially with the higher concentrations of PCE in groundwater (Figure 5), but vary somewhat from the spatial distribution of this constituent in groundwater in the northeast corner of the site. This may indicate that shallow soil vapor transport is at least partially via on-site subsurface utilities, and not solely from volatilization from groundwater at the site. Additionally, utility lines within the nearby streets may provide a conduit for some of the vapors to enter the subsurface at the site. Where nested soil vapor samples were collected (along the eastern property boundary), concentrations of PCE and TCE in soil vapor samples collected are higher in the deeper (8 feet bgs) samples than the shallower (4 feet bgs) samples, confirming that volatilization from groundwater is a contributor to the VOC concentrations in soil vapor at the site.

The spatial distributions of PCE and TCE in shallow soil vapor (i.e., 1 to 4 feet bgs) are similar to each other (Figures 4 and 5), with the exception that only minimal TCE is present north and west of Building A. Within the vicinity of the on-site sewer line and along the eastern property boundary, TCE is present at elevated concentrations relative to PCE (and some vinyl chloride is present), suggesting that natural degradation of PCE is occurring in the unsaturated zone.

PCE was also detected in soil vapor along the floor drain lateral to the sewer line within Building B and in a vapor sample collected from within the former front-end alignment pit in Building B (this pit has since been removed), indicating that PCE may have been used within Building B and that minor releases may have contributed, in part, to the PCE detected in soil vapor beneath Building B. However, PCE is present at non-detectable to very low concentrations in groundwater in this area, suggesting that vapor transport along site utilities likely is a primary contributor to PCE in soil vapor beneath Building B.

3.2.3 Soil

PCE and TCE have been detected at low concentrations in soil samples collected north of and beneath Building A, but it is believed that these detections represent PCE and TCE in the vapor phase, and/or PCE and TCE present in the saturated zone (depending on the sample depth) and not a source of PCE or TCE in soil.

3.3 VOCs IN SOIL VAPOR IN THE SOUTH PARCEL

Several groundwater and soil vapor samples have been collected in the south parcel (Figure 6). Low levels of PCE (i.e., significantly less than the ESL) are present in soil vapor at approximately 5 feet bgs in the northwest corner of the south parcel. PCE was not detected in the groundwater sample collected in this area, and PCE is not present in the groundwater sample or soil vapor samples collected in the eastern portion of the south parcel. No auto servicing activities are known to have been conducted in this area, which was historically used as a parking lot. The low concentrations of PCE in soil vapor in the south parcel may be related to transport via subsurface utilities within Golden Gate Drive and/or Saint Patrick Way.

3.4 CHLOROBENZENES AND RELATED CONSTITUENTS WITHIN BUILDING B

Chlorobenzenes and related constituents were released to the subsurface at a former sump and former F.E. Pit within Building B (Figures 7 through 9). Remediation was conducted at these areas in 2011; however, as discussed above, in Section 2.3, some impacted soil remains (AMEC, 2011d).

At the former sump, chlorobenzenes and petroleum-related constituents were present in soil and shallow groundwater at concentrations greater than ESLs. Most of the mass in soil was removed by soil excavation, which extended to a depth of approximately 16 feet bgs, in 2011. VOC concentrations in soil samples collected approximately 3 feet horizontally from the sump excavation sidewalls were less than ESLs, although some constituents were detected at concentrations greater than ESLs in confirmation samples from the excavation sidewalls (Figure 7). Soil samples have not been collected from the base of the excavation (approximately 16 feet bgs), but, based on the decreasing concentrations with depth (e.g., chlorobenzene was detected at 90,000 micrograms per kilogram [µg/kg] at 3 feet bgs, 26,000 µg/kg at 6.5 feet bgs, and 6,500 µg/kg at 11.5 feet bgs), it is believed that soil is not significantly impacted deeper than the bottom depth of the excavation.

At the F.E. Pit, similar constituents were present in soil at concentrations greater than ESLs. The 2011 excavation removed impacted soil to 12 feet bgs and VOC concentrations were less than ESLs in a soil sample collected from the bottom of the excavation (however, TPHd was detected at a concentration slightly greater than the ESL). Similar to the former sump, some impacted soil remains in place at the sidewalls of the excavation, although VOC concentrations in soil samples collected approximately 3 feet horizontally from the sump excavation sidewalls (from angled borings) were less than ESLs (Figure 8).

The presence of VOCs in groundwater at concentrations above ESLs (e.g., benzene, chlorobenzene, and 1,2-dichlorobenzene) appears to be limited to within approximately 15 feet of the former sump (Figure 9). VOCs were not detected at concentrations greater than ESLs in groundwater samples collected beneath the F.E. Pit. VOCs were not detected in deeper groundwater samples collected downgradient of the former sump.

Soil vapor sampling was conducted in the vicinity of the former sump and former front-end alignment pit in Building B prior to remediation. Some concentrations of PCE, benzene, and 1,4-dichlorobenzene in soil vapor were greater than their respective ESLs during pre-remediation sampling. However, post-remediation soil vapor sampling has not been conducted.

4.0 CORRECTIVE ACTION OBJECTIVES

As discussed above, the identified constituents of concern (COCs) at the site are PCE, TCE, and breakdown products (e.g., vinyl chloride in soil vapor) in the northern portion of the north parcel; and chlorobenzenes and related constituents in the vicinity of the former sump and F.E. Pit.

Corrective action objectives (CAOs) are media-specific actions for protecting human health and the environment. The results of the site investigations indicate that there is potential for chemical exposure to future site occupants via soil, groundwater, and soil vapor that contain VOCs at concentrations that are higher than applicable risk screening criteria.[4] Therefore, we have developed both absolute CAOs and functional CAOs.

Based on the findings of the investigations and the stated rationale, the absolute and functional CAOs for the protection of human health and the environment are the following (functional CAOs as bullets beneath each absolute CAO):

1. Mitigate potential vapor intrusion risks to future site occupants.
   - Confirm via 1 year of indoor air sampling that concentrations of COCs are below applicable indoor air screening levels (e.g., ESLs).
   - Obtain temporal shallow groundwater and vent riser (equivalent to sub-slab) data for 5 years (1 year of performance monitoring followed by 4 years of operations and maintenance [O&M] phase monitoring).
   - Comply with institutional controls (ICs) regarding property use, mitigation measures, and monitoring.
2. Mitigate potential exposure to future construction and maintenance workers to VOC-impacted soil vapor, and groundwater.
   - Comply with a site management plan, which will provide guidance for worker protection and safety measures to be employed during site construction and maintenance.

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[4] Note that generic screening levels, which are developed based on default site parameters and specific exposure scenarios, likely are conservative relative to the planned future use of the site. For this reason, it may be appropriate to develop site-specific risk-based screening levels in the future to evaluate long-term monitoring data.

3. Remediate identified residual source material in the vicinity of the former sump and F.E. Pit.
    - Remove residual impacted soil to the extent that COC concentrations in confirmation samples collected from the sidewalls of the excavation are less than ESLs for shallow soil in a residential land use scenario, where groundwater is considered a potential drinking water resource.
    - Conduct additional removal of impacted soil that may be encountered during site demolition and development, as necessary.

As noted in Section 2.0, the presence of PCE, TCE, and their breakdown products in groundwater and, as a consequence, in soil vapor at the site, originates from an off-site source. As such, protection of the environment by way of minimizing the possibility for vertical migration of VOC-impacted groundwater, or by reducing concentrations of COCs in groundwater to less than drinking water screening levels (i.e., maximum contaminant levels [MCLs]), is not an objective of this FS/CAP. Exposure to groundwater based on a drinking water scenario is considered an incomplete pathway, as potable water at the site is municipally supplied at this time and will continue to be in the foreseeable future. Instead, concentrations of VOCs in groundwater will be compared to their respective ESLs for evaluation of potential vapor intrusion (as presented in Section 6.3, a site-specific screening level for PCE in groundwater has been calculated at this time for the purpose of evaluating the effectiveness of a potential corrective action).

Concentrations of PCE, TCE, and their breakdown products in soil vapor following the implementation of a corrective action will be compared to their respective residential ESLs, which may be modified to consider site-specific factors (see footnote 4). However, it is recognized that the presence of these VOCs in soil vapor is a consequence of the on-site migration of these constituents in groundwater, and to some degree, vapor migration via existing utilities. As such, the overall effectiveness of a corrective action will be assessed based on the concentrations of VOCs in indoor air.

5.0 CORRECTIVE ACTION TECHNOLOGY SCREENING

Corrective action technologies were identified based on their ability to effectively achieve the objectives described above. Technologies were comparatively evaluated and screened on the basis of applicability to site conditions, effectiveness, implementability, and relative cost. A brief description of each technology and the results of the screening are presented in Table 3. The remediation technologies retained for evaluation and consideration in remedial alternatives include the following:

Soil:

- Excavation for the residual source material in the vicinity of the former sump and F.E. Pit, and other areas as necessary (e.g., at hydraulic lifts, other sumps, and drain lines)

Groundwater:

- Permeable reactive barrier for control of PCE plume migration onto the site and remediation of impacted groundwater
- In-situ bioremediation for remediation of PCE- and TCE- impacted groundwater

Soil Vapor:

- Vapor barrier for vapor intrusion mitigation
- Sub-slab depressurization for vapor intrusion mitigation

In addition, administrative controls retained include long-term site management and ICs.

6.0 CORRECTIVE ACTION ALTERNATIVES

Following the identification and screening process, as presented in Table 3, the retained technologies were combined into alternatives to be evaluated relative to one another. Each alternative is cumulative; Alternative 2 incorporates the activities proposed in Alternative 1, Alternative 3 incorporates Alternative 2, and so on. Note that the remedial alternatives presented below are designed to fit a currently-proposed site redevelopment; these alternatives may not be applicable in their entirety should the currently-proposed redevelopment not proceed. However, to meet the CAOs, it is likely that some action could be required for future use of the northern portion of the north parcel, where there are soil vapor and groundwater impacts. Additionally, it is intended that the south parcel will be subdivided from the north parcel in the near future. As such the discussion of corrective actions are focused and intended to apply as stated.

The alternatives are identified as follows:

- Alternative 1—Soil excavation/disposal, groundwater sampling, and long-term site management and ICs.
- Alternative 2—Vapor barrier and sub-slab depressurization, plus soil excavation/disposal, groundwater sampling, and long-term site management and ICs.
- Alternative 3—Permeable reactive barrier with zero-valent iron (ZVI), plus vapor barrier and sub-slab depressurization, soil excavation/disposal, groundwater sampling, and long-term site management and ICs.
- Alternative 4—In-situ bioremediation, permeable reactive barrier with ZVI, vapor barrier and sub-slab depressurization, soil excavation/disposal, groundwater sampling, and long-term site management and ICs.

A “no action” alternative is normally included as a baseline for comparison to other alternatives. However, the no action alternative was not considered an appropriate remedial option, because the “no action” alternative will not effectively achieve the CAOs.

6.1 ALTERNATIVE 1—SOIL EXCAVATION/DISPOSAL, GROUNDWATER SAMPLING, AND LONG-TERM SITE MANAGEMENT AND INSTITUTIONAL CONTROLS

This alternative consists of the removal and off-site disposal of soil impacted by TPH (diesel and motor oil range) and VOCs (benzene, chlorobenzene, and dichlorobenzene) at the former sump and F.E. Pit (Figures 7 and 8). As described above, some impacted soil remains in place following previous remedial activities due to inaccessibility beneath the existing buildings; this soil will be removed during demolition of Building B. The proposed excavation extents are presented on Figure 10a. The horizontal excavation extents are estimated based on the locations of soil samples where VOC and TPH concentrations were less than residential ESLs; the actual horizontal extents will be based on the results of confirmation sample analyses. The vertical extent will be the same as that during the prior remedial activities (i.e., 16 feet bgs at the former sump and 12 feet bgs at the former F.E. Pit). Due to the proposed depth of the sump excavation, groundwater will most likely be encountered during the remedial activities. Accumulated groundwater in the proposed sump excavation will be removed to the extent possible and stored in a temporary holding tank. Based on analytical results for groundwater that was accumulated, sampled, and discharged during the previous excavation activities at the sump and F.E. Pit, it is expected that groundwater removed from the excavation(s) will meet discharge requirements for disposal to the on-site sanitary sewer.

In association with the removal of impacted soil around the former sump and F.E. Pit, hydraulic lifts, sumps (if present), and drain lines will be removed. Confirmation sampling will be conducted to verify that soil has not been affected. Proposed soil sampling locations are presented on Figure 10b. Due to the unknown extent of potential soil impacts associated with the hydraulic lifts, sumps, and drain lines, this FS/CAP only includes costs for the confirmation sampling, and not potential remedial activities. Should additional characterization or corrective actions be necessary, a separate work plan(s) will be prepared and submitted to ACEH for review and approval.

As noted in Section 3.2.2, the presence of chlorinated VOCs in soil vapor (primarily PCE) correlates spatially with the higher concentrations of these VOCs in groundwater beneath the site, although vapor transport appears to be partially via on-site utilities and not entirely from volatilization from groundwater. To evaluate concentration trends in groundwater, and by association, possible concentration trends in soil vapor, groundwater sampling will be conducted in the northern portion of the site. On-site groundwater sampling will occur for a period of 5 years via the current groundwater monitoring wells and new groundwater monitoring wells to be installed during property redevelopment. It is anticipated that this 5-year period will be adequate to confirm that groundwater with higher PCE concentrations is not migrating onto the site, and that the concentrations are stable or decreasing through natural attenuation processes such as dispersion, dilution, volatilization, and/or biodegradation. The current on-site groundwater monitoring wells will be decommissioned prior to site redevelopment and new replacement wells will be installed to continue monitoring groundwater conditions at the site. Groundwater sampling and reporting will continue quarterly for a period of two years and annually for the remaining three years (1 year of performance monitoring followed by 4 years of O&M phase monitoring). Proposed on-site groundwater monitoring well locations are shown on Figure 11.

Long-term site management and ICs will be implemented as administrative restrictions on the use of the property. Site management and ICs are intended to prevent inappropriate activities and use of the property, with consideration of potential risk from existing soil vapor and groundwater impacts. For this alternative, a Site Management Plan (SMP) will be developed that presents guidelines for health and safety, soil management, and groundwater management if subsurface work is conducted at the site. The site owner will have responsibility for implementation of the SMP. Additionally, a deed restriction will be placed on the property to prevent the use of groundwater across the site.

6.2 ALTERNATIVE 2—VAPOR BARRIER AND SUB-SLAB DEPRESSURIZATION, SOIL EXCAVATION/DISPOSAL, GROUNDWATER SAMPLING, AND LONG-TERM SITE MANAGEMENT AND INSTITUTIONAL CONTROLS

This alternative consists of Alternative 1 plus the installation of a vapor barrier, sub-slab depressurization (SSD) system, vapor barriers within on-site utilities, and vent riser, and indoor air sampling. The vapor barrier and SSD system will be installed in the northern portion of the north parcel beneath buildings (excluding parking structures) with footprints above groundwater and/or soil vapor impacts, and will extend at least 100 feet beyond the known impacts (i.e., PCE and TCE in groundwater and potential impacted soil vapor at the former sump and F.E. Pit); based on the currently-proposed redevelopment, the vapor barrier and SSD system extends approximately 190 feet beyond the currently impacted groundwater to provide continuity beneath the footprint of the structures (Figure 12a). As an additional mitigation measure, backfill areas for subsurface utilities and elevator installations will be constructed so as to minimize the possibility of creating preferential pathways for vapor migration.

It should be noted that, as currently proposed, buildings with residential use at ground level are not located over the highest-concentration part of the groundwater plume (Figure 12a). The far northern portion of the site, where concentrations are highest, is planned for ground-level retail use (where commercial/industrial ESLs would be applicable) with apartments on the second floor and above, and for hardscape, landscaping, and a parking structure. Farther south, some of the ground-level apartments are located above groundwater with concentrations currently in the 5 to 20 µg/L concentration range.

A vapor barrier is not planned for the pool and courtyard area, because the courtyard is not above the groundwater or soil vapor VOC plumes.

6.2.1 Rationale

The California Department of Toxic Substances Control (DTSC) has indicated that vapor intrusion mitigation is not intended to be a sole remedial alternative for a site contaminated by volatile chemicals. However, as stated in Section 4.0 of the October 2011 Vapor Intrusion Mitigation Advisory (VIMA) (DTSC, 2011), where source removal is impracticable, the use of engineering methods may be the most feasible long-term response action. Additionally, as stated in Section 2.3.1 of the VIMA document, if a soil vapor plume originates from an off-site source, incorporating vapor intrusion mitigation into a building may be the only viable option, especially if the off-site source is regional in nature and remediation of off-site sources is impractical or not achievable in the near future.

Section 2.2 of the VIMA document also states the following:

> "Vapor intrusion mitigation is intended to minimize entry of volatile chemicals from the subsurface into the indoor air of overlying buildings. Vapor intrusion mitigation is not intended to be a sole remedial alternative for a volatile chemical contaminated site. For most sites in this risk range, remediation will be required to address the subsurface source of vapor contamination. However, based on site-specific considerations, mitigation may become the long-term measure, especially where removal of volatile chemicals may not be technically feasible (such as where the volatile chemical source is located off-site)."

Based on the rationale provided by DTSC, the use of vapor mitigation system would be considered appropriate for the site.

An additional regulatory consideration regarding the appropriateness of a vapor barrier/SSD system as the long-term mitigation measure at the site is the possibility of whether VOC concentrations in groundwater, and thereby soil vapor, could increase over time. Based on the analysis presented below, it appears unlikely that PCE concentrations in groundwater beneath the site will increase over time. While the vapor barrier/SSD system would be in place to effectively mitigate an increase in vapor concentrations, should they occur, regulatory agencies such as ACEH and DTSC have recently indicated an additional preference to cut off the pathway for impacted groundwater to migrate onto a property (Groundwater Resources Association of California [GRA], 2012).

As noted in Section 3.2, the source of PCE on the site is not known at this time. There is no current or known historic nearby source; discharges of water containing PCE (e.g., from dry cleaners) into the sanitary sewer have been prohibited since 1995 (personal communication with Ananthan Kanagasundaram of the City of Dublin on November 15, 2012). An evaluation based on a range of potential hydraulic conductivities and resulting groundwater velocity suggests the source is likely more than 10 years old (with a range of approximately 5 to 35 years since the plume first reached the site). An estimate of the time required for the contaminant to travel across the site (approximately 400 feet) can be calculated using the known hydraulic gradient at the site (approximate average of 0.003 foot/foot in both September 2012 and January 2013) and other hydrogeologic and contaminant transport parameters from literature. Assuming a hydraulic conductivity value of 15 feet per day, corresponding to a silty sand type of material, and a porosity of 0.2, the Darcy flux is 0.045 foot/day and the linear groundwater velocity is 0.225 foot/day. This corresponds to a travel time of approximately 5 years due to simple advection. However, plume retardation due to sorption reduces the velocity significantly. Under the assumption of a simple linear sorption process, and using typical value for soil bulk density (1.6 gm/cm^3) and the adsorption coefficient (0.76 cm^3/gm) (U.S.EPA, 2000), a retardation factor of 7 can be calculated, which corresponds to an effective plume velocity of 0.032 foot/day and a travel time of approximately 35 years.

Based on assumptions described above, it is unlikely that PCE concentrations in groundwater would increase over time (except for the unlikely scenario that the source is very distant and the highest concentrations in groundwater have yet to reach the site). However, because the source of PCE is not known, it cannot be definitively ascertained that concentrations of PCE in groundwater migrating onto the site will not increase with time, and, if such increases occur, concentrations of PCE and other VOCs in soil vapor likely also would increase. However, as noted above, the vapor barrier/SSD system would be in place to effectively mitigate an increase in vapor concentrations, should they occur.

6.2.2 Description

The vapor barrier system includes a reinforced concrete slab on the ground floor of each building, with a geomembrane vapor barrier installed beneath the concrete slab. The geomembrane vapor barrier will consist of a cold, spray-applied asphaltic emulsion membrane installed between two protective high-density polyethylene/polypropylene bonded geotextiles constructed beneath the new reinforced concrete building foundation slabs. The vapor barrier will prevent impacted soil vapor from entering the building that might otherwise pass through various pathways, such as expansion joints, utility penetrations, or cracks in the slab. The spray-applied membrane has a thickness of approximately 60 to 80 dry mil (one dry mil is approximately 0.001 inch).

In addition to the vapor barrier, a SSD system will be installed beneath the spray-applied membrane to build negative pressure in the sub-slab zone (i.e., to create a slight vacuum in the area beneath the building) and extract soil vapors for venting to the atmosphere. The U.S. Environmental Protection Agency (EPA) has defined a passive SSD system as "a system designed to achieve lower sub-slab air pressure relative to indoor air pressure by use of a vent pipe routed through the conditioned space of a building and venting to the outdoor air, thereby relying solely on the convective flow of air upward in the vent to draw air from beneath the slab" (U.S. EPA, 2008). The passive SSD will consist of perforated pipe or pre-fabricated low-profile (flat), three-dimensional vent cores for sub-slab soil vapor collection laid within the base rock beneath the building's foundation. The collection piping will then connect to a series of risers that direct extracted soil vapor to the outside of the building. The SSD vacuum will be produced using passive wind turbines mounted on exhaust stacks located above the building roof line, away from windows and air supply intakes. The resulting sub-slab negative pressure inhibits soil vapor from flowing into the building, by creating a preferential pathway toward the outside.

Based on the extent of VOC impacts in soil vapor and groundwater, the vapor barrier and SSD system will be installed under approximately 50,100 square feet of building area. The proposed extent of the vapor barrier and SSD system and conceptual designs are presented on Figures 12a and 12b.

The results of sampling in the south parcel (i.e., south of St. Patrick Way) did not indicate a significant impact to soil vapor (PCE concentrations in soil vapor were less than ESLs), and VOCs were not detected in groundwater in this area. A vapor barrier/SSD system is not proposed for buildings constructed on the south parcel.

6.2.3 Sampling and Operations and Maintenance

Performance monitoring to confirm the effectiveness of the vapor barrier will be conducted for a period of 1 year (post–building construction and commissioning) via indoor air sampling. Indoor air monitoring will consist of two sampling events. Both sampling events will be conducted after building construction (and commissioning, if appropriate). Confirmation of the effectiveness of the SSD will be conducted for a period of 5 years following building construction and commissioning via sampling of vapor in the vent risers that connect the subsurface to the atmosphere (vent riser samples are effectively sub-slab samples, as VOCs in the riser represent those VOCs being removed from beneath the slab). The vent riser sampling will include 1 year of monthly performance monitoring and 4 years of quarterly O&M phase monitoring.

Specific O&M activities will be specified in the SMP, in an O&M Plan, and via the ICs, which all will include elements related to the presence, protection, and requirements of the vapor barrier.

6.3 ALTERNATIVE 3—PRB, VAPOR BARRIER AND SUB-SLAB DEPRESSURIZATION, SOIL EXCAVATION/DISPOSAL, GROUNDWATER SAMPLING, AND LONG-TERM SITE MANAGEMENT AND INSTITUTIONAL CONTROLS

This alternative consists of Alternative 2 plus the installation of a permeable reactive barrier (PRB) for treatment of impacted groundwater migrating onto the site along the western and northern property boundaries. The purpose of the PRB would be to provide a permeable treatment zone to facilitate dechlorination of PCE-impacted groundwater that moves though the wall. Once the PRB is installed, concentrations of PCE at the downgradient side of the wall should decrease with time. However, it should be noted that if the off-site source of PCE is identified, characterized, and remediated, concentrations of PCE would attenuate over time and preclude the need for installation of a PRB.

6.3.1 Rationale

The PRB represents a recognized technology with regulatory agency acceptance for the containment and treatment of a variety of groundwater contaminants. A PRB is an appropriate technology to treat impacted groundwater migrating onto the site based on the following:

1. Treatable Contaminants—PCE and TCE have been successfully treated in the past by suitable reactive media such as ZVI. The degradation process of PCE and TCE to less-toxic compounds by the reactive media is understood and accepted as abiotic reductive dehalogenation involving the corrosion of the ZVI by the chlorinated ethenes (U.S. EPA, 1998a). ZVI, a strong reducing agent, reacts with chlorinated organic compounds through electron transfers, in which ethane and chloride are the primary products. The observation that intermediate breakdown products (e.g., dichloroethene or vinyl chloride) are not commonly formed in significant quantities has led to identification of multiple degradations process other than the step-wise dechlorination mediated by bacteria such as *Dehalococcoides* (Air Force Research Laboratory, 2000). One such degradation mechanism involves ZVI as a catalyst. During this breakdown the PCE or TCE molecule is held on the surface of the ZVI by either polar bonding or pi-bonding until all the chlorine atoms are removed (Orth and Gillham, 1996).
2. Defined Plume Migration—Over 50 groundwater samples have been collected in the northern portion of the north parcel, identifying the horizontal extent of the plume. The groundwater flow direction has been established through on-site groundwater elevation measurements and review of data for neighboring sites. The definition of the plume at the site allows for proper placement of a continuous PRB to capture and treat migrating groundwater.
3. Hydrogeology—As indicated in Section 3.0, the site consists primarily of low permeability, finer grained deposits with interbedded sand lenses to a depth of approximately 20 feet bgs, below which an approximately 20-foot-thick lean clay layer. The PRB, with a much higher hydraulic conductivity than native soil and “keyed” to the bottom clay layer, will represent a preferential pathway for the flow of impacted groundwater and will provide plume capture.
4. Groundwater Geochemistry—A groundwater sample collected from MP-01-1 indicates low dissolved sulfate concentrations and low dissolved oxygen in the proposed location of the PRB. Low-sulfate conditions should be less susceptible to clogging and buildup of microbial mass (Oak Ridge National Laboratory, 2001). In addition, the low dissolved nitrate levels (10 mg/L) are favorable. Higher nitrate concentrations can result in the progressive reduction of available iron surfaces for reaction (Interstate Technology & Regulatory Council [ITRC], 2005).
5. Site Accessibility—Installation of the PRB will take place after site demolition activities are completed. Removal of existing site infrastructure and open access to the site will allow for unhindered placement of the PRB using conventional

installation techniques (e.g., trenching). The conventional installation of the PRB will allow for greater PRB installation quality assurance and quality control.

6.3.2 Time Frame to Achieve Cleanup Goals

To evaluate the time frame to achieve cleanup goals for groundwater subsequent to the installation of a PRB, site-specific risk-based groundwater cleanup goals of 94 µg/L for PCE and 176 µg/L for TCE were calculated for the site using a Johnson & Ettinger model, with assumptions based on the known site stratigraphic conditions (Appendix C).[5]

The PRB will immediately reduce PCE concentrations in site groundwater within the PRB, and in the short term downgradient of the barrier. However, the dominantly fine-grained lithology and a relatively flat gradient at the site, as well as available PRB performance case studies literature and case studies evaluated by AMEC (see Section 7.0, below) suggest that a reduction in the concentrations of PCE in groundwater in downgradient wells may not be measured in the short term (DTSC, 2008; ITRC, 2005).

Modeling was performed by AMEC to estimate the possible time period that may be required for the on-site concentrations of PCE to reach the cleanup goal of 94 µg/L (concentrations of TCE are already below the site-specific goal, and all other concentrations of VOCs in groundwater are currently less than their respective groundwater ESLs for evaluation of potential vapor intrusion concerns). Modeling results suggest that the concentrations of PCE throughout the site may be reduced to concentrations less than the cleanup goal in 33 to 80 years. Additional discussion of the analysis performed is included in Appendix D.

6.3.3 Description

The PRB will consist of a trench filled with reactive material in the saturated zone for groundwater to pass through. The PRB will use ZVI metal, Fe(0), as the reactive media. Treatment of the chlorinated VOCs in groundwater takes place in the form of abiotic reductive dehalogenation through reactions at the surfaces of the Fe(0) particles. Chlorinated ethenes, such as PCE and TCE, are reduced due to electron transfers from the iron to the halocarbon at the iron surface. The result of the halocarbon reduction is ethene or ethane (U.S. EPA, 1998a).

The PRB will be installed along the northwestern boundary of the north parcel. The proposed PRB is approximately 200 feet long and 1.5 feet wide, with an anticipated total depth of 20 feet bgs. The bottom 12 feet of the trench will be filled with a mixture of granular ZVI and clean quartz sand, followed by clean controlled density fill (CDF) to the ground surface. The conceptual location of the PRB is presented on Figure 13. The PRB location will be in the city

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[5] Currently, ESLs are used as criteria for evaluating the presence of chemicals in soil vapor and groundwater at the site. As described in Section 4.0, site-specific cleanup goals for groundwater and soil vapor may be calculated in the future.

right-of-way, approximately 15 to 20 feet from the nearest building; the final location of the PRB will be developed in consultation with the City of Dublin.

6.3.4 Sampling and Long-term PRB Requirements

The PRB is expected to reduce chlorinated VOC concentrations to less than drinking water ESLs. To confirm the expected reduction in groundwater concentrations, nine groundwater monitoring wells will be installed throughout the site to evaluate concentration trends. Additionally three monitoring wells are proposed within the PRB to confirm the reduction in VOC concentrations. Proposed groundwater monitoring well locations are presented on Figures 11 and 13.

Performance monitoring of the effectiveness of the PRB and evaluation of concentration trends in groundwater will be conducted for a period of 5 years (post–PRB construction) via groundwater sampling within and downgradient of the PRB (1 year of performance monitoring, followed by 4 years of O&M phase monitoring).

Guidance and requirements related to the presence, long-term protection, and other requirements of the PRB will be specified in the SMP and via the ICs.

6.3.5 PRB Life Span

The anticipated life span of the PRB is discussed in this section. We assume that the PRB will be designed and constructed properly, such that it will only be subject to typical factors that influence PRB life span, including flow rate, total dissolved solids, dissolved oxygen, carbonate, and sulfate concentrations, and corrosion. Design and construction issues are the most common reasons for PRB failure, including improper hydraulic characterization of a site (Henderson and Demond, 2007).

The use history of PRB technology is short relative to other, traditional remediation technologies, which limits in-field data regarding the longevity of PRB life spans. AMEC designed and installed the first full-scale commercial-used PRB, which has been operating since 1995 at the Intersil Corporation site in Sunnyvale, California (Appendix F). Groundwater monitoring results from samples collected from the PRB performance wells from 1996 through 2006 indicate that, the cleanup goals have been consistently met throughout the 18 years the PRB has been in place.

In 2005, the Interstate Technology & Regulatory Council (ITRC) produced a document that presented an evaluation of PRBs and provided lessons learned (ITRC, 2005). This document indicates that the life span of a zero-valent iron (ZVI) PRB (like the one proposed in the FS/CAP) should range from 10 to 30 years or more. However, these estimates are based on laboratory-scale testing and modeling. As indicated in the document, “no ZVI PRBs have reached the useful life of the media, therefore no data exist on which to base these estimates”

(ITRC, 2005). The Henderson and Demond paper summarized various estimates of PRB life spans, ranging from 10 to 117 years (Henderson and Demond, 2007). They also note that laboratory-scale testing may underestimate the anticipated life span of a PRB, noting that "field experience suggests that PRBs are a more robust technology than one might anticipate based on laboratory column experiments" (Henderson and Demond, 2007).

Given the information cited above, it is anticipated that the PRB proposed for the site will meet its performance goals for at least several decades. An evaluation of the PRB performance and its required life span will be performed following the proposed 5 years of groundwater monitoring. At this time, the current and future need for the PRB will be evaluated relative to site conditions, including published and site-specific screening levels, site use in the vicinity of impacts (i.e., commercial or residential), source identification, and plume stability. Additionally, more site-specific data will be available regarding temporal concentrations of constituents of concern, and the presences of fouling agents and other factors that could reduce the PRB life span. Pending this analysis, recommendations for maintenance of the PRB could include replacement, or less intrusive options could be employed to break up precipitate formation (including ultrasound or using drilling augers, or a reagent flush). However, the technologies available will be evaluated at the time of PRB repair/replacement, if needed.

6.4 ALTERNATIVE 4—IN-SITU BIOREMEDIATION, PRB (ZVI), VAPOR BARRIER AND SUB-SLAB DEPRESSURIZATION, SOIL EXCAVATION/DISPOSAL, GROUNDWATER SAMPLING, AND LONG-TERM SITE MANAGEMENT AND INSTITUTIONAL CONTROLS

Alternative 4 consists of remedial elements presented in Alternative 3 and additional implementation of an in-situ bioremediation program to provide treatment of impacted groundwater within the north parcel. The following two alternative approaches are presented for the implementation of a bioremediation option:

- Alternative 4a—Implementation of a bioremediation program prior to site redevelopment; or
- Alternative 4b—Implementation of a bioremediation program following site redevelopment, but with the infrastructure required for this option being installed during site redevelopment.

The details for implementation of Alternative 4a and 4b are presented below. However, prior to discussing alternatives, a brief evaluation of site conditions with respect to the implementation of a bioremediation program is presented.

6.4.1 Rationale

Bioremediation of chlorinated volatile organic compounds (CVOCs), such as PCE, occurs through the process known as reductive dechlorination. In this process chlorine atoms are sequentially removed from the parent compound and replaced by hydrogen atoms. The exchange of the chlorine and hydrogen atoms is facilitated by certain bacteria under suitable environmental conditions.

As discussed above in Section 3.2.1, as part of the feasibility study, AMEC collected two groundwater samples from monitoring wells MP-01-1 and MW-02, and tested the samples for the *Dhc* bacteria*. Dhc* was not present in either sample at or above laboratory quantifiable limits, but dissolved oxygen levels are below 1 mg/L, which is generally considered to be anaerobic (oxygen deficient) and favorable for reductive dechlorination processes. ORP, which is a measure of electron availability in aqueous environments, was measured as negative in both wells, and within the range of pE (electron activity) values that would facilitate reductive dechlorination.

Limited data regarding bio-nutrients is available for the site. Regarding electron receptors, nitrate was found to be present in monitoring well MP01-1 and was not detected in monitoring well MW-02. Notably, nitrate was not found in the area where TPH impacts to groundwater from the historical Montgomery Ward release were formerly present and where TCE is present at higher concentrations than elsewhere at the site, suggesting that some bioattenuation likely occurred in this area, depleting this electron receptor.

Based on the above, the following modifications to site conditions will be required to successfully implement a bioremediation program.

1. Addition of an organic substrate to foster and maintain current reductive groundwater conditions and supply an electron donor in the reductive dechlorination process, with the VOCs acting as the terminal electron acceptor.
2. Addition of the *Dhc* bacteria to provide an organism capable of the complete reductive dechlorination of the PCE.
3. Addition of essential bio-nutrients (nitrogen, phosphate, and trace metal compounds) to help maintain an effective and healthy microbial population.

6.4.2 Description of Alternative 4a

As Alternative 4a, in-situ bioremediation will be conducted prior to redevelopment, and represents a one-time effort to mitigate VOCs in groundwater. The following steps will be performed to implement the program:

1. Inject carbon substrate and bio-nutrients in groundwater to create a favorable reductive environment for the *Dhc* bacteria.
2. Allow time for carbon substrate and bio-nutrients to disperse and impact the environment. As time is critical in this option, a low-carbon organic substrate will be used (e.g., lactate).
3. Inject *Dhc* bio-augmentation cultures to inoculate groundwater.
4. Evaluate bioremediation system performance through collection of groundwater samples, as specified in Alternative 1.

The carbon substrate would be emplaced using direct-push drilling technology at each location indicated on Figure 14. For three to six months following the injection, the carbon substrate would be allowed to disperse, break down, and create an anaerobic environment. Upon sampling to determine that favorable conditions had been achieved (typically by an indication of iron or sulfate reducing conditions) for *Dhc* bacteria to reduce CVOCs; the *Dhc* culture would be injected into the impacted area. However, the fine-grained nature of the subsurface lithology limits the possibility of successfully targeting and delivering bacteria and nutrients.

Successful implementation is often judged by the formation of ethane and/or ethene. However, the reduced groundwater conditions created by a one-time application of a carbon substrate typically will last between one to three years, depending on site conditions and the type of carbon substrate used. As such, a one-time bioremediation implementation likely would not be sufficient to provide complete remediation of groundwater impacts, and incomplete remediation could result in the formation of vinyl chloride, which is more toxic than PCE and TCE.

6.4.3 Description of Alternative 4b

As Alternative 4b, a bioremediation system would be installed during redevelopment to allow for multiple applications over time of bioremediation amendments to the subsurface. The following steps would be performed to implement the program:

Install injection wells at critical locations across the site.

1. Construct a permanent treatment facility during redevelopment, which would contain a bio-amendment/nutrient holding tank, injection pumps, sensors, valves and a distribution manifold.
2. Add *Dhc* bio-augmentation culture to bio-amendment/nutrient holding tank.
3. Evaluate bioremediation system performance, and repeat injection of bio-amendments as required to maintain and optimize system performance.

The treatment facility will consist of amendment mixing and bio-amendment/nutrient holding tanks, dosage meters, injection pumps, pressure gauges, sensor, a distribution manifold, and support appurtenances. The construction of the treatment facility, conveyance piping, and injection well installation would need to be coordinated with site redevelopment activities. Permanent injection wells will be installed both perpendicular to and along the axis of the plume with respect to the groundwater flow gradient, as possible relative to the currently-proposed redevelopment footprint. However, because of the fine-grained nature of the material beneath the site, it may not be possible to adequately space or have an adequate number of injection points to adequately distribute bio-nutrients and *Dhc* augmentation culture. A series of conveyance pipes would be installed to connect the injection wells to the treatment facility.

Bio-nutrients will first be injected into the subsurface to establish optimal conditions for reductive chlorination. A *Dhc* bio-augmentation culture will be added to the injectant mix and delivered to the subsurface. The bioremediation system will be monitored over time and amendment adjustments made to optimize remedial performance.

Implementation of Alternative 4b would involve considerable coordination with site redevelopment and, substantial ongoing operation and maintenance of the in-situ bioremediation process. It is uncertain whether a system could be coordinated with the development that would adequately deliver bio-nutrients and bacterial culture to the subsurface. As such, implementation of Alternative 4b is considered to be an extensive burden on a future property owner/manager, and this alternative is not retained for further consideration.

6.4.4 Sampling and Operations and Maintenance

To confirm the effectiveness of the in-situ bioremediation, nine groundwater monitoring wells will be installed throughout the site to evaluate concentration trends. Proposed groundwater monitoring well locations are presented on Figure 11.

Confirmation of the effectiveness of the in-situ bioremediation and evaluation of concentration trends in groundwater will be conducted for a period of 5 years (post–implementation of the in-situ bioremediation) via groundwater sampling.

No specific operations and maintenance activities are needed, as only one injection event is practical.

7.0 CASE STUDIES

At the request of ACEH, case studies were reviewed for sites where vapor barriers and/or PRBs were installed, in order to provide documentation regarding regulatory acceptance of the technology and the associated monitoring programs at similar sites in California. The case studies are presented in Appendices E and F and each includes a summary of the case background, site geology, identification of the oversight agency, history of related remedial actions for the site, a review of the cleanup goals and a description of monitoring activity and results (when available). These case studies are discussed briefly below.

7.1 VAPOR BARRIER CASE STUDIES

AMEC reviewed cases that included the installation of a vapor barrier and/or SSD systems in the San Francisco Bay Area; case studies were developed for six sites with a vapor barrier and/or SSD. Because there is a long history of mitigating soil vapor intrusion into structures using SSD systems in other parts of the country (including for radon mitigation), a white paper based on a case study in Denver, Colorado also was reviewed (included in Appendix E).

The Regional Water Board appears to have been the agency most commonly overseeing vapor barrier and/or SSD systems to date. The Regional Water Board is the lead oversight agency for three of the six cases reviewed and was the secondary oversight agency in a fourth case (the DTSC or U.S. EPA is the lead oversight agency for the other cases). All six vapor barriers and/or SSD systems were installed to mitigate chlorinated VOCs (the primary contaminant was either PCE or TCE). Concentrations beneath the vapor barrier and/or SSD systems ranged over several orders of magnitude, with PCE specific concentrations reported as high as 190,000 µg/m^3 (at John Swett High School in Crockett). In two cases, only a vapor barrier was installed; in the other six cases, both a vapor barrier and an SSD system were installed.

In one case (Shinsei Gardens), no indoor air or sub-slab vapor monitoring was required. At the MEW Superfund site, indoor air monitoring is currently being conducted, but a formal monitoring program is not yet in place. Construction is not yet complete at John Swett High School. At the remaining three sites, monitoring results indicate that the vapor barrier and/or SSD systems are effective in mitigating the intrusion of VOC vapors into structures. As a result, at two sites (901 San Antonio Road in Palo Alto and the former General Electric site in San Jose), vapor monitoring frequencies were reduced or eliminated. At the Palo Alto site, the SSD system was converted from active to passive, garage air monitoring was eliminated, and sub-slab sampling was reduced from quarterly to annually. At the San Jose site in San Jose, vent riser vapor monitoring requirements were terminated based on stable, decreasing, or non-detect vapor sample results between 2008 and 2012. Publically available documents do not indicate that indoor air sampling was conducted at the Palo Alto or San Jose sites.

The vapor barrier white paper evaluated 301 soil vapor mitigation systems located in Colorado (U.S. EPA, 1993). The results of the study indicated that SSD systems were reliable and effective (in most cases only a SSD system was in place, but in some cases a liner was placed under the home and the SSD was installed under the liner). The study suggested indoor air monitoring should be performed to verify the system is working properly, however once verified, “the mitigation system should be considered reliable, as long as it continues to operate normally” and that SSD systems have a proven track record based on radon mitigation experience. The white paper noted factors that affected the long term reliability of SSD systems; these included homeowners turning off a fan, ignoring an inoperative fan, or damaging the ventilation piping or vapor barrier liner.

AMEC was unable to identify cases where vapor barriers and SSDs have failed while their integrity was maintained. At the MEW site, TCE concentrations in indoor air were recently measured above the screening level because a building’s ventilation system, which was being used to provide a positive pressure in the building and prevent vapor intrusion, was turned to manual mode and therefore was not constantly running. Additionally, as indicated by the white paper, vapor barrier failure is primarily a result of poor communication or oversight between the responsible party and the current occupant.

Overall, a review of the case studies and white paper indicates that vapor barriers with SSD systems are effective at mitigating vapor intrusion into structures and that the systems have a track record of long term reliability. Indoor air monitoring has been required in some cases where there is significant vapor intrusion potential (in others no indoor air monitoring has been conducted), but the case studies indicate a precedent to reduce or eliminate indoor air monitoring once the effectiveness of the remedy has been confirmed.

7.2 PERMEABLE REACTIVE BARRIER CASE STUDIES

AMEC reviewed PRB cases in California where ZVI was the reactive media, and where ZVI was placed in the subsurface using a trenching or boring installation method; case studies were developed for three sites and a DTSC document assessing ZVI PRB projects in California (DTSC, 2008). The case studies are included in Appendix F.

The Regional Water Board appears to be the California agency most commonly overseeing PRBs cases (the Regional Water Board was the oversight agency for the three cases reviewed). The PRBs were installed to treat chlorinated VOCs, and the primary contaminant treated was PCE or TCE. Concentrations of VOCs upgradient of the PRB ranged over several orders of magnitude, with PCE concentrations reported as high as 7,300 µg/L. The cases reported significant or complete reduction of PCE and TCE concentrations in groundwater samples collected within the PRB, confirming that ZVI is effective at reducing PCE and TCE to ethenes.

The DTSC document reviewed 10 projects where PRBs were installed to treat impacts from VOCs, primarily PCE and/or TCE, some with maximum concentrations two orders of magnitude greater than those at the Crown site. The PRBs operated with varying levels of success. The most likely reasons for PRB failure are related to design and construction (ITRC, 2005, and DTSC, 2008):

1. Flow of contaminated groundwater around the PRB. In order to prevent flow around the PRB, it is important that the length of the PRB perpendicular to groundwater flow extends beyond the lateral extents of the groundwater plume (at concentrations greater than the cleanup goal) and also to "key" the base of the PRB into a low permeability soil below the primary conductive zone to minimize the possibility of groundwater flow beneath the PRB.

2. Flow through preferential pathways within the PRB. Preferential pathways are possible if voids develop during PRB construction. Additionally, a high flow zone in the subsurface can create an effect like a preferential pathway if the PRB design is based on an average soil type and does not take into account the heterogeneity of the subsurface and areas of higher groundwater flow rates (which can result in insufficient residence time for groundwater flowing through the PRB). This situation

can be mitigated by using a conservative groundwater flow rate assumption or by using a vertical layer of sand or pea-gravel on the upgradient side of the PRB to help spread out the groundwater flow, if needed.

3. Insufficient treatment media. A lack of adequate treatment media can occur if there is incomplete mixing of sand and ZVI (when such a mix is used), resulting in portions of the PRB that contain less ZVI than specified in design documents.

Each of the PRBs evaluated was installed within an existing groundwater plume to isolate a source zone, and downgradient contaminant concentrations were elevated prior to PRB installation. Groundwater monitoring at wells installed farther downgradient of the PRB generally indicated some decrease in contaminant concentrations compared to upgradient concentration, but in some cases concentrations increased. If VOC concentrations within the PRB were low, the ongoing presence of VOCs farther downgradient of the PRB was generally attributed to back diffusion from fine-grained sediments or to commingling of plumes from other sources not being treated by the PRB.

8.0 EVALUATION CRITERIA FOR ALTERNATIVE SCREENING

The corrective action alternatives were screened based on three primary evaluation criteria and one secondary criterion. The three primary evaluation criteria used to evaluate the alternatives were: effectiveness, implementability, and cost. A fourth evaluation criterion used to evaluate the alternatives was sustainability. The evaluation criteria are described in the following sections.

8.1 EFFECTIVENESS

Effectiveness is evaluated based on the proven reliability of the corrective action technology to achieve the corrective active objectives for the site, including its relative short-and long-term effectiveness and permanence, as well as reduction in toxicity, mobility, and volume of the constituents of concern.

8.2 IMPLEMENTABILITY

Implementability is assessed by considering the following qualities:

- Technical feasibility, including the ability to construct and operate the alternative and the ability to evaluate remedial effectiveness.
- Administrative feasibility, including regulatory acceptance and the ability to obtain other needed approvals and permits.
- Availability of project-related goods and services.

8.3 COST

Preliminary engineering cost estimates were developed for the corrective action alternatives based on experience with similar projects and on the projected remedial implementation time frames associated with each alternative. The cost estimates for each alternative are presented in Appendix B.

It should be noted that some remedial activities, such as soil excavation and PRB installation, assume implementation after demolition of existing buildings, foundations, and asphalt/concrete surfaces has taken place at the site. However, demolition is a redevelopment activity and costs for such activities are not accounted for in the cost estimates presented.

8.4 SUSTAINABILITY

Sustainability of each remedial alternative is assessed by considering the following:

- Waste minimization
- Water conservation
- Energy savings
- Local economy boost
- Greenhouse gas emissions
- Stakeholder satisfaction

The evaluation of each corrective action alternative relative to these criteria is presented in Table 4 and discussed further below.

8.5 EVALUATION OF ALTERNATIVES AND COMPARATIVE ANALYSIS

The alternatives are evaluated and compared below according to the aforementioned three primary evaluation criteria of effectiveness, implementability, and cost; and the fourth criterion of sustainability.

Alternative 1 would potentially meet the CAOs in the short term. Direct exposure to contaminated soil will be eliminated by the removal of remaining impacted soil at the former sump and F.E. Pit. Exposure to soil vapor and groundwater during subsurface activities will be mitigated by implementation of a SMP. However, long-term protection against potential vapor intrusion concerns is not adequately addressed by Alternative 1. Therefore, Alternative 1, which has an order-of-magnitude cost of approximately $0.68 million, is rejected as a remedial alternative for the site.

Alternative 2 provides the short-term benefits of Alternative 1 and also provides long-term mitigation of potential vapor intrusion risks. The alternative is easily implementable during redevelopment and provides long-term protection relative to the potential for vapor intrusion; the SSD system passively creates a negative pressure such that VOCs in vapor will discharge via the system to the atmosphere. However, Alternative 2 is less likely to receive regulatory acceptance, as it does not prevent the potential ongoing migration of VOCs in groundwater onto the site. Indoor air and vent riser sampling will be conducted to confirm the effectiveness of the action, and a SMP and ICs will be in place so the long-term implementation of the alternative is assured. It also represents a more sustainable approach relative to Alternatives 3 and 4. The order-of-magnitude cost for Alternative 2, including operations and maintenance, is approximately $1.36 million.

Alternative 3 builds further onto Alternative 2 by mitigating the potential for additional impacted groundwater to migrate onto the site. The installation of the PRB would prevent concentrations of PCE from increasing; however, the PRB does not directly contribute to the mitigation of VOCs in soil vapor, except to the extent that it prevents higher concentration groundwater, and by extension, higher soil vapor concentrations that could result, from coming onto the site. The installation of the PRB likely will reduce PCE concentrations in site groundwater immediately downgradient of the barrier; however, it is unlikely to affect the concentrations of VOCs in groundwater through most of the impacted area in the foreseeable future, as groundwater movement appears to be slow (based on clayey lithology and a relatively flat gradient). The PRB is a passive remedial technology and is sustainable as a long-term approach (AMEC, 2013b). However, the installation of the PRB will consume significant resources in the short term, making it less sustainable than Alternative 2. The order-of-magnitude cost for Alternative 3 is approximately $2.28 million.

Alternative 4a is designed to mitigate VOC concentrations in on-site groundwater; however, it is highly uncertain that it could be effective in either the short-or long-term, given the limited time frame to implement a bio-augmentation and nutrient injection program. The fine-grained nature of the subsurface lithology limits the possibility of successfully targeting and delivering bacteria and nutrients. This alternative has the highest estimated implementation cost and there is not sufficient time to perform a pilot test to confirm the technology's potential effectiveness. Due to the increased resources required for the enhanced bioremediation implementation, Alternative 4a is less sustainable than Alternative 3. The order-of-magnitude cost for Alternative 4a is approximately $2.97 million.

8.6 RECOMMENDED CORRECTIVE ACTION ALTERNATIVE

Based on the comparative analysis, Alternative 3 represents the most effective and implementable alternative to meet the CAOs, and is recommended as the corrective action measure for the site. Implementation of Alternative 3 can be accomplished with minor disruption to the planned site development schedule, provides passive, long-term protection against on-site migration of impacted groundwater, represents the third least expensive alternative, and is sustainable as a long-term approach.

9.0 CORRECTIVE ACTION PLAN

The selected alternative, Alternative 3, will consist of excavation of remaining soil impacts in the vicinity of the former sump and F.E. Pit and removal and confirmation sampling beneath removed hydraulic lifts, sumps, if present, and drain lines (Figures 10a and 10b). In addition,

Alternative 3 will include installation and sampling of replacement groundwater monitoring wells and the installation of a vapor barrier and sub-slab depressurization system beneath future buildings (excluding parking structures) with footprints within the impacted groundwater plume (Figures 11, 12a, and 12b). Finally, Alternative 3 will include installation of a PRB along the northern and western boundary of the north parcel and groundwater sampling within the PRB (Figure 13). The corrective action consists of the following pre-development, development, and
post-development site activities:

- Following demolition of Building B and prior to site redevelopment, excavation and off-site disposal of approximately 60 in-place cubic yards (cy) of remaining impacted soil in the vicinity of the former sump and dewatering of encountered groundwater (pre-development).
- Following demolition of Building B and prior to site redevelopment, excavation and off-site disposal of approximately 40 in-place cy of remaining impacted soil in the vicinity of the former F.E. Pit (pre-development).
- Following demolition of Building B and prior to site redevelopment, confirmation soil sampling beneath removed hydraulic lifts, sumps, and drain lines (pre-development).
- Destruction of existing groundwater monitoring wells (pre-development).
- Installation of a PRB and in-barrier performance monitoring wells (pre-development).
- Installation of a vapor barrier and sub-slab depressurization system beneath proposed buildings overlying the existing groundwater plume (during development).
- Protection of new utilities to minimize the possibility of creating preferential pathways for vapor migration using protective measures that could include installation of transverse barriers across utility trenches, or use of low permeability or controlled-density fill material.
- Protection of elevator shafts to minimize the possibility of creating preferential pathways for vapor migration using measures similar to those for utilities or by installing self-enclosed (holeless) elevator systems.
- Installation of replacement groundwater wells and PRB performance monitoring wells (during development).
- Implementation of long-term site management and ICs (post-development).
- Implementation of a long-term a sampling and analysis plan for groundwater, indoor air, and vapor from SSD, and a sampling schedule.

Although proposed replacement groundwater monitoring well and PRB performance monitoring well locations are presented conceptually in this FS/CAP (Figures 11 and 13), final well locations will be determined based on final site development plans and in coordination with ACEH.

Likewise, final extent of the vapor barrier and layout of the SSD collection system will be based on the finalized building design and will be coordinated with the building designers (e.g., architects).

9.1 PRE-IMPLEMENTATION ACTIVITIES

Prior to implementing the CAP elements, design documents that will require approval by various agencies, including ACEH, and permitting activities will be initiated.

9.1.1 Design Documents

The following work plans will be prepared and submitted to the ACEH for approval and other agencies, as applicable.

Excavation Work Plan—The excavation work plan will detail the methodology, permits, extents, soil and groundwater handling and disposal procedures, confirmation sampling, and analytical methods related to the additional soil removal in the areas of the former sump and F.E. Pit.

Well Destruction and Well Installation Work Plan(s)—Prior to proceeding with well destruction and installation activities, a work plan will be submitted that presents well locations and details methodologies, permits, and material handling and disposal procedures for ACEH's review and approval. A single work plan that addresses both well destruction and future installation, or separate work plans can be submitted, depending on the requirements of the ACEH.

Vapor Intrusion Mitigation System Installation and Operation and Maintenance (O&M) Plan(s)—Final design plans for the installation and construction of the vapor barrier and the sub-slab depressurization system will be prepared as part of the construction drawings to obtain necessary building permits from the City of Dublin. Prior to submittal of the permit documents, copies of the construction drawings relevant to the installation of the vapor barrier and SSD will be furnished to ACEH for review and approval.

PRB Field Investigation Work Plan—The field investigation work plan will outline the data to be acquired for the design of the PRB, the field methodologies, necessary permits, and handling of investigation-derived waste.

PRB Installation Work Plan—Following collection and evaluation of additional data, the detailed PRB design will be completed and the logistics for the installation of the PRB will be evaluated. The PRB installation work plan will detail the methodology, materials to be used, required permits, extents of excavation, and soil and groundwater (if any) handling procedures for the installation of the PRB.

Construction Quality Assurance (CQA) Plans—It is anticipated that two CQA plans may be developed: one focused on the construction of the vapor barrier/SSD system and the other focused on the PRB. The vapor barrier/SSD system CQA may be incorporated into the vapor intrusion mitigation system installation plan. In general, the CQA plans will provide procedures for construction monitoring and documentation, and will include information regarding responsibility and authority, personnel qualifications, construction inspections that will be performed, and documentation that will be provided. The documents will also specify the appropriate qualifications and experience necessary for contractors and inspectors involved in the construction of the vapor barrier/SSD system and PRB.

Health and Safety Plan—The pre-design investigation and PRB installation will be conducted under a site-specific health and safety plan (HSP) similar to that submitted for previous site work (AMEC, 2011c). The HSP will include health and safety precautions for known and potential physical and chemical hazards anticipated for the field efforts. A map of the route to the nearest hospital and information regarding constituents of concern will also be included in the HSP. The HSP will be distributed to all members of the field team.

9.1.2 Permitting and Notifications

In order to conduct the remedial activities and install the corrective measures, the following permits and/or notifications may be required:

Sump and F.E. Pit Excavations

- ACEH approval of Excavation Work Plan
- Soil excavation permit from the City of Dublin Community Development Department, Building Safety Division (Dublin Building Department)
- Industrial Wastewater Discharge Permit from the Dublin San Ramon Services District (DSRSD)
- Soil Excavation Notice to the Bay Area Air Quality Management District (BAAQMD)
- ACEH notification and permits for removal of hydraulic lifts (USTs) and sumps (if defined as USTs), if present

Groundwater Monitoring Well Destruction and Installation

- ACEH approval of Well Destruction and Well Installation Work Plan(s)
- Well destruction and well construction permits from Zone 7 Water Agency

Vapor Barrier and SSD Installation

- ACEH approval of vapor barrier and SSD system design and CQA Plan
- Building construction permit from the Dublin Building Department
- Permit exemption from the BAAQMD for SSD (the SSD system is expected to qualify for an exemption under Regulations 2, Section 2-1-103 [BAAQMD, 2012] for a source with pollutant emissions of less than 10 pounds (lbs)/day and less than 150 lbs/year)

ZVI Permeable Barrier Installation

- ACEH approval of pre-design investigation program and ZVI bench scale testing

- ACEH approval of design and installation specifications and CQA Plan
- Boring permits from Zone 7 Water Agency
- Construction permit from the Dublin Building Department
- Soil excavation notice to the BAAQMD

Institutional Controls

- ACEH approval of additional documents created to manage future risk, including the SMP and covenants restricting use of the property

Additionally, the following permits/notifications will be instituted in order to protect the integrity of the PRB and the vapor barrier/SSD:

- An easement in the vicinity of the PRB so that no construction work occurs in the area without appropriate notifications.
- Permitting requirements at the City of Dublin such that in order to perform any construction, a permit is required that will indicate the locations of the PRB and vapor barrier/SSD.

9.1.2 Utility Location

Prior to soil removal, advancing soil borings, installing the PRB, or performing well destruction and installation activities, subsurface utilities will be marked with white paint, and Underground Service Alert will be contacted at least 48 hours in advance of beginning work, in accordance with California law. A private utility locator will also evaluate the excavation and proposed well locations for underground utilities.

9.1.4 Health and Safety Plan

Soil excavation, well destruction, and well installation activities will be conducted under a site-specific HSP and similar to that submitted for previous site work (AMEC, 2011c). The HSP will include health and safety precautions for known and potential physical and chemical hazards anticipated for the field effort. A map of the route to the nearest hospital and information regarding constituents of concern will also be included in the HSP. The HSP will be distributed to all members of the field team.

The installation of the vapor barrier and SSD are part of the building construction. As such, the installation of the vapor intrusion mitigation system will be conducted under the HSP for general site construction, as prepared by the site developer.

9.2 SOIL EXCAVATION/DISPOSAL (SUMP AND F.E. PIT) AND ADDITIONAL CONFIRMATION SAMPLING

Soil excavation and disposal and associated additional sampling are described in the following sections.

9.2.1 Soil Excavation/Disposal (Sump and F.E. Pit)

Excavation of the remaining impacted soil at the former sump and F.E. Pit, estimated to be a total of 100 cy, will be conducted using a slot-cutting method similar to the one used during the previous excavation effort (AMEC, 2011d). It is currently anticipated that the excavations will extend to 16 feet bgs and 12 feet bgs for the former sump and F.E. Pit, respectively. Excavation will proceed until no staining is observed and the results of confirmation samples indicate that concentrations of petroleum-related constituents and VOCs are below their respective residential screening levels.

Slot cutting will allow for removal of soil in thin slices to minimize the amount of exposed vertical surface and avoid the need to install traditional shoring. The maximum width of each vertical excavation trench will be 1.5 feet. As during the previous work, each trench will be backfilled with a mixture of sand and cement (a slurry) and allowed to cure for a minimum of 24 hours before adjacent slots can be excavated (if needed). Excavated soil will be temporarily stockpiled on site and subsequently disposed of off-site at an approved facility. It is assumed that the excavated soil will be disposed of off-site at a Class II (non-hazardous waste) facility, based on the prior remedial activities. Excavations will be conducted under the same health and safety protocols set forth in the previously submitted *Environmental Health and Safety Plan, Sump Remediation and Soil Excavation and Disposal* (AMEC, 2011d).

Groundwater encountered during the excavation will be removed, to the extent possible, from the open excavation trench prior to backfilling. Extracted groundwater will be containerized on site pending disposal in a steel storage tank. The extracted groundwater will be profiled and it is expected to meet discharge requirements set forth in the previously issued Industrial Waste Discharge Permit No. 11012 used during the previous groundwater disposal events. Permit No. 11012 will be renewed, or a new permit will be obtained from the DSRSD, as necessary. Extracted groundwater will be discharged to the DSRSD Publicly Owned Treatment Works.

9.2.2 Additional Confirmation Sampling

As noted above, several former and existing hydraulic lifts and drain lines are known to be present in Building B, and it is possible that additional former sumps also are present in this building. For example, during excavation of the waste oil UST, three pipes were observed (which were not connected to the UST). ENGEO hypothesized that these pipes may have connected to a UST previously in that location.

Following removal of the slab in Building B and the identified features, confirmation soil sampling will be conducted beneath existing and historical hydraulic lifts (as shown on Figure 10b) and along the known drain lines. A soil sample will be collected at each former hydraulic lift and sump locations and one soil sample will be collected for every 20 linear feet of removed utility trench (single or combined drain lines). The collected samples will be analyzed for the presence of VOCs and TPHg using U.S. EPA Method 8260B, TPHd and TPH quantified as motor oil (TPHmo) by U.S. EPA Method 8015, SVOCs by U.S. EPA Method 8270C, and CA LUFT-5 Metals (cadmium, chromium, lead, nickel, and zinc) by U.S. EPA Method 6010B.

Sample results will be compared against their respective ESLs. Should sample results exceed their respective ESLs, separate work plans for the characterization and, if needed, remediation action will be submitted to ACEH for review and approval.

9.3 MONITORING WELL DESTRUCTION AND INSTALLATION

The seven existing groundwater monitoring wells will be destroyed prior to site redevelopment. Groundwater wells will be destroyed in accordance with Zone 7 Water Agency well destruction requirements and will include overdrilling and/or pressure grouting.

Nine shallow groundwater monitoring wells will be installed to evaluate concentrations of constituents of concern in the first encountered water-bearing zone. The locations of the replacement groundwater monitoring wells and the timing of installation will be coordinated with the site redevelopment. The locations of the proposed groundwater monitoring wells are shown on Figure 11, based on current redevelopment plans; however, the final number and location of the replacement wells will be determined in consultation with ACEH.

The monitoring wells will be installed using hollow-stem auger or other appropriate drilling methodology. The monitoring wells will be constructed within an up-to-8.25-inch-diameter borehole using up to 2-inch-diameter, schedule 40 polyvinyl chloride (PVC) blank well casing and 5 feet of slotted (0.010-inch slots) well screen. The monitoring wells will be screened within the first-encountered water-bearing unit. Based on previous depth-to-groundwater data, we anticipate that the wells will be installed to a total depth of between 15 and 22 feet bgs.

The annular space between the well screen and borehole in each well will be backfilled with an appropriately sized sand filter pack. The filter sand in each well will be placed such that the top of the filter sand is approximately 1 foot above the screened interval. Approximately 2 feet of bentonite chips will then be placed above the filter sand and will be allowed to hydrate in place. The remaining annular space above the hydrated bentonite chips will be sealed using neat cement or a cement/bentonite grout mixture and concrete (for setting the well box). The wells will be completed at the surface using flush-mounted, traffic-rated boxes. A locking, watertight plug will be placed in the top of the casing at each well.

The groundwater monitoring wells will be constructed in accordance with the appropriate state (California Department of Water Resources, 1991) and Zone 7 Water Agency requirements.

The new groundwater monitoring wells will be developed no sooner than 48 hours after the construction of the wells. The monitoring wells will be developed by a combination of bailing, surging, and purging until the water is relatively visibly clear and field parameters (e.g., dissolved oxygen, oxidation/reduction potential, temperature, pH, and specific conductance) are relatively stable and the water becomes relatively clear and free of solids.

The groundwater monitoring wells will be installed by a California-licensed C-57 contractor and under the direct supervision of a California-licensed Professional Geologist. A continuous core of soil will be collected at each well location for lithologic logging. Lithology will be described using the visual-manual procedures of the ASTM International Standard D 2488 for guidance, which is based on the USCS. Recovered soil will be screened for the presence of volatile organic compounds using a photoionization detector (PID). The PID readings will be recorded on the lithologic logs prepared for each boring. Field observations of the presence of any staining or odor will also be recorded.

9.4 VAPOR BARRIER AND SUB-SLAB DEPRESSURIZATION SYSTEM

The general components of the vapor barrier/SSD system are described below, and schematically presented on Figures 12a and 12b. Long-term operations and maintenance of the system also is described below.

9.4.1 Vapor Barrier and Sub-Slab Depressurization System Installation

The vapor barrier and SSD system will be installed during the construction of the building foundation. Currently, the footprints of two proposed buildings and part of a third building are within the identified extent of the groundwater plume, as shown on Figure 12a. The vapor barrier and SSD system will be installed beneath the two retail/apartment buildings along Dublin Boulevard and partially beneath the apartment building surrounding the recreational courtyard. The vapor intrusion and SSD system beneath the apartment building will extend approximately 190 feet beyond the identified edge of the on-site plume. The 190-foot extension is in excess of the 100-foot lateral distance criteria set forth by the DTSC and California Environmental Protection Agency (Cal/EPA) for determining if buildings are candidates for vapor intrusion (DTSC and Cal/EPA, 2012). The main components of the vapor barrier and SSD are described below.

Base Layer/Fabric – The base layer will consist of non-woven polypropylene, ethlylene vinyl alcohol (EVOH) with linear low density polyethylene (LLDPE), or high density polyethylene (HDPE) heat-bonded geotextile installed between the ground and the spray-applied membrane. The fabric will serve as the base layer for the application of the spray-applied membrane and separates the membrane from soil substrate.

Core/Spray-Applied Membrane – The spray-applied membrane will consist of a single course, high-build, polymer-modified asphaltic emulsion. The emulsion is water based and spray-applied at ambient temperatures. The membrane is non-toxic and odorless (CETCO®, 2012a), and typically applied to a nominal dry thickness of 60 to 80 dry mil (as noted earlier herein, 1 mil is approximately 0.001 inch. Commercially available spray-applied membranes include

Liquid Boot® by CETCO® and Geo-Seal® by Land Science Technologies™ (LST; a brief cost-benefit analysis of Liquid Boot® versus Geo-Seal® is presented at the end of this section). The integrity of the spray-applied membrane will be tested by smoke testing during construction. Smoke will be pumped under the membrane for a specific period of time and under specific pressure. Holes or breaches in the membrane detected during the testing, if any, will be patched by additional membrane application.

Plumbing, electrical, mechanical, and structural items planned to be placed under or through the membrane will be positively secured in their proper positions and appropriately protected prior to membrane application. Special care will also be taken to apply the membrane appropriately at penetration points per the manufacturer's specifications.

Protection/Bond Layer/Fabric – The protection/bond layer is similar to the base fabric and will consist of non-woven polypropylene or HDPE geotextile installed between the spray-applied membrane and the building slab. The protection fabric is used to enhance the curing of the membrane and increase puncture resistance. In addition, the protection fabric provides adhesion protection and remains attached to the underslab of the building. The adhesion ensures that the membrane will remains in place even during potential soil settlement (CETCO, 2012b).

Soil Vapor Collection System – The soil vapor collection system will consist of pre-fabricated, low-profile (flat), three-dimensional vent cores wrapped in non-woven, needle-punched filter fabric. The collection vents will be fabricated of HDPE. The vapor collection system will be installed directly on the subgrade and beneath the vapor barrier. The collection system will collect gas vapors and direct them to the conveyance and discharge system.

Passive Soil Vapor Conveyance/Discharge System – The soil vapor conveyance/discharge system will consist of vent risers connected to the soil vapor collection system at selected sub-slab locations. The vent risers are piping typically made of PVC or HDPE. The vent risers will be routed from beneath the slab to the roof of the building through an interior wall or on the outside of the building (Figure 12c). Each individual vent riser will be equipped with a wind-driven turbine fan that creates a negative pressure to convey the soil vapor from beneath the slab to the top of the riser. Extracted soil vapors will be discharged to the atmosphere. The vent risers will be equipped with sampling ports that allow the periodic sampling of the extracted vapor.

Although the currently proposed passive SSD system is expected to effectively mitigate the potential for vapor intrusion, the SSD system will be designed and installed with features that will allow for conversion to an active SSD system (i.e., with motor-driven fans), should that be necessary in the future. The determination to convert to an active system will be based on the results of the sampling, as presented in Section 10.0.

9.4.2 Liquid Boot® and Geo-Seal® Cost-Benefit Analysis

Liquid Boot® and Liquid Boot® Plus, manufactured by CETCO, and Geo-Seal®, manufactured by Land Science Technologies, are commercially available vapor management systems for mitigation of potential indoor air quality health risks associated with vapor intrusion. The systems are designed for placement between the foundation of a building and the soil beneath, and consist of three layers: base, core/spray-applied layer, and protection/bond layer (described above). The systems utilize a similar polymer-modified asphaltic emulsion for the core layer. However, material make-up of the base and protection layer varies from each vendor. The Standard Liquid Boot® system consists of a polypropylene base and protection layers. Liquid Boot® Plus replaces the base layer with an LLDPE membrane that has an EVOH core. Geo-Seal® is only offered with an HDPE sheet thermally bonded to a non-woven geotextile as the base and protection/bond layers.

Based on available literature from both vendors, the systems from CETCO and LST both exhibit extremely low VOC calculated diffusion coefficients under testing conditions. Vapor diffusivity tests conducted by CETCO using PCE as the control contaminant indicated Liquid Boot® and Liquid Boot® Plus exhibited calculated diffusion coefficients of 1.07 x 10^{-13} meters squared per second (m^2/s) and 5.61 x 10^{-16} m^2/s, respectively, with PCE vapor concentrations of 1,200 milligrams per cubic meter (mg/m^3; Olsta, 2010). The reported calculated PCE diffusion coefficient for Geo-Seal® is 4.0 x 10^{-17} m^2/s with a PCE vapor concentration of 90,000 mg/m^3 (LST, 2013a).

To determine the efficacy of the available vapor barriers, a simplified Johnson and Ettinger (Johnson and Ettinger, 1991) model using available U.S. EPA model spreadsheets (U.S. EPA, 1998b) was generated to calculate an attenuation factor provided by the vapor barrier. Using the highest available PCE diffusion coefficient (in this case Liquid Boot® at 1.07 x 10^{-13} m^2/s), the calculated attenuation factor provided by the vapor barrier was 1.67 x 10^{-8}. Once the attenuation factor was determined, the maximum theoretical soil vapor concentration (immediately below the vapor barrier) was calculated using the published ambient and indoor air residential exposure ESLs (Regional Water Board, 2013) or the indoor air California Human Screening Levels (CHHSLs; Cal/EPA, 2005), as follows:

$$MaxSVsub = ESLia \text{ or } CHHSLia/\alpha$$

Where:

$MaxSVsub$ = Soil vapor concentration beneath the membrane in micrograms per cubic meter ($\mu g/m^3$)

$ESLia$ = Residential Ambient and Indoor Air Screening Level in $\mu g/m^3$

$CHHSLia$ = Residential Land Use CHHSL in $\mu g/m^3$ (used when no ESL is available)

α = Calculated attenuation factor (unitless)

The calculated maximum soil vapor concentrations that Liquid Boot® system would be protective against are summarized as follows:

Contaminant	Indoor Air ESL or CHHSL (µg/m^3)	Calculated α	Maximum Concentration Allowable beneath Vapor Barrier (µg/m^3)	Maximum Detected On-Site Concentration (µg/m^3)
PCE	0.41[a]	1.67×10^{-8}	2.5×10^{7}	35,000
TCE	0.59[a]	1.67×10^{-8}	3.5×10^{7}	12,000
cis-1,2-Dichloroethene	36.5[b]	1.67×10^{-8}	2.2×10^{9}	1,300
trans-1,2-Dichloroethene	63[a]	1.67×10^{-8}	3.8×10^{9}	3,600
Vinyl chloride	0.031[a]	1.67×10^{-8}	1.9×10^{6}	510

[a] ESL, [b] CHHSL

Based on the above analysis, Liquid Boot® system is effective at mitigating vapor intrusion concerns for VOC concentrations up to four orders of magnitude greater than what has been detected to date at the site. Even greater mitigation capacities are expected for Liquid Boot® Plus and Geo-Seal® systems as both systems have lower published diffusion coefficients than the standard Liquid Boot®.

In addition to a performance comparison, unit pricing was also compared to determine which alternative represents a more cost-effective remedy. Approximate unit prices provided by each manufacture were as follows:

- Liquid Boot®—$2.50 to $3.50 per square foot (CETCO, 2012c).
- Liquid Boot® with SSD (GeoVent™)—$2.75 to $3.90 per square foot (CETCO, 2012c)
- Geo-Seal®—$2.70 to $3.50 per square foot (LST, 2013b)
- Geo-Seal® and with SSD (VaporVent™)—$3.00 to $3.75 per square foot (LST, 2013b)

As indicated above, the systems are comparable in price.

Overall, the vapor barrier systems by CETCO and LST offer more than sufficient mitigation of vapor intrusion concerns based on current data and account for possible increases up to approximately four orders of magnitude (however, as noted elsewhere in this report, vapor concentrations are expected to decline following development),. Based on vendor-provided diffusion coefficients, Geo-Seal® appears to represent a higher estimated level of protection with an equivalent unit price when compared to Liquid Boot®.

9.4.3 Vapor Barrier and SSD System Operation and Maintenance

The vapor barrier, once properly installed beneath the building slab, will not require maintenance, unless re-construction in some areas of the structures encroaches or inadvertently damages the barrier. This possibility will be addressed in the SMP, which will be distributed to all contractors involved in subsurface work. The SSD system is expected to operate continuously and will require minimal maintenance. Expected maintenance of the SSD will include inspection of the risers and wind-driven turbine fans, lubrication (as necessary) of the turbine fans, and replacement of any potential worn/damaged equipment. System O&M will be conducted in accordance with the elements presented herein and in the forthcoming O&M Plan.

As recommended in the VIMA document, an O&M Plan will be developed before construction is completed. The O&M Plan will include measures to evaluate the efficacy and performance of the system on an ongoing basis. The goal of the O&M Plan is to confirm that the vapor mitigation system is operating on a continuous basis as designed and in accordance with the manufacturer's specifications. The O&M plan will contain information on the O&M of the system, including the following:

- regular inspection and maintenance procedures,
- compliance sampling procedures,
- assessment procedures for site conditions/uses to confirm vapor mitigation system will not be compromised,
- equipment specifications and manuals,
- contact information,
- monitoring and sampling procedure forms, and
- permits.

Pending results of the long-term monitoring outlined in the O&M Plan, it is anticipated that elements of the O&M Plan could be modified, as appropriate and with regulatory concurrence.

9.4.4 Additional Vapor Intrusion Mitigation

As an additional mitigation measure, backfill areas for subsurface utilities and elevator installations will be constructed so as to minimize the possibility of creating preferential pathways for vapor migration.

For example, installation of transverse barriers across utility trenches, or use of low permeability or controlled-density fill material, could be implemented to minimize vapor migration. Where an elevator is installed, preventative measures such as a holeless elevator and water-proofing could be used to mitigate potential vapor intrusion. The holeless elevator is a single piston design where all equipment is contained within the elevator shaft so that there are no penetrations through the elevator pit. This design is coupled with a water-proof seal to further mitigate any vapor intrusion.

9.5 ZERO-VALENT IRON PERMEABLE BARRIER

Details regarding design, installation, and monitoring of the PRB are presented in the following sections.

9.5.1 Additional Field Investigations

Implementation of the PRB will require an additional field investigation to determine the final design of the barrier, as well as bench scale testing of available ZVI products. As discussed above, a work plan (or work plans) will be submitted to ACEH for review and approval, and appropriate soil boring permits will be obtained from Zone 7 Water Agency.

Prior to conducting the investigation, subsurface utilities will be marked with white paint, and Underground Service Alert will be contacted at least 48 hours in advance of beginning work, in accordance with California law. A private utility locator will also evaluate the proposed boring locations for underground utilities.

Depth-discrete grab groundwater samples will be collected from approximately five soil borings installed along the proposed length of the PRB. The borings (approximately one boring per every 50 linear feet of barrier) will be advanced to depths of approximately 25 feet bgs, and grab groundwater samples will be collected at several intervals from each boring, based on soil lithology and/or electrical conductivity. The concentrations of PCE in groundwater will be used to determine the final installation depth of the PRB (i.e., the bottom depth of the PRB will be designed to intercept the bottom of the PCE plume); it is currently assumed that PCE concentrations decline rapidly below 20 feet bgs, where a clay layer is present.

In addition to the soil borings, bench scale testing of available ZVI products will be conducted using impacted groundwater collected from the site. The column testing will help determine which ZVI product exhibits the maximum treatment capacity for the site groundwater conditions. A work plan for the installation of the soil borings and the bench scale test will be submitted to ACEH for review and approval.

9.5.2 PRB Design

The PRB will be located at the northwestern corner of the site, along the length of the currently identified plume as it enters the site (Figure 13). However, the final location of the PRB will be based on the results of ongoing groundwater monitoring.

The thickness of the PRB will be developed based on the following formula from the California Department of Toxic Substances Control (DTSC, 2008):

$$L = \frac{0.54}{k_1} \mu \ln\left(\frac{P_0}{P}\right)$$

Where:

L = barrier thickness in centimeters (cm)

The units of the 0.54 term are cubic centimeters per gram (cm^3/g; as derived in the DTSC document referenced above)

k_1 = temperature compensated rate constant, cm^3/g-day (20.7 cm^3/g-day for PCE per the DTSC document referenced above)

μ = groundwater flow rate, cm/day

P_0 = initial contaminant concentration, µg/L

P = final contaminant concentration, µg/L

Using the above formula and the k_1 rate constant for PCE, the following PRB wall thickness design equation is derived:

$$L = 0.026\mu \ln\left(\frac{P_0}{P}\right)$$

Where:

The units of the 0.026 term are day^{-1}

μ = groundwater flow rate, cm/day or feet/day

P_0 = initial contaminant concentration, µg/L

P = final contaminant concentration, µg/L

The theoretical required thickness of the PRB was calculated using the derived formula above and using the current the maximum site PCE concentration of 200 µg/L along the western site boundary (AMEC, 2012b) and using a conservative 100-fold (i.e., 20,000 µg/L) increase in the concentration of PCE. The groundwater flow rate through the PRB is assumed to be 10 times faster than the estimated linear groundwater velocity of the surrounding formation. The following table shows a calculated thickness using a target PCE concentration of 5 µg/L (current California MCL for PCE).

Contaminant	Max Concentration (P_0; µg/L)	Estimated Groundwater Flow Rate (feet/day)	Target Concentration (P; µg/L)	Wall Thickness Required (feet)
PCE	200 µg/L	2.25	5 µg/L	0.22
PCE	20,000 µg/L	2.25	5 µg/L	0.49

The calculated required thickness (assuming the PRB is 100 percent ZVI) to treat impacted groundwater based on a conservative assumption of PCE concentrations (i.e., 20,000 µg/L, approximately two orders of magnitude greater than what has been seen at the site) is approximately 0.49 feet (approximately 6 inches). However, the calculated barrier thickness is the minimum recommended thickness to achieve the treatment target concentration. A thicker barrier is commonly installed to increase the factor of safety. A 1-foot-thick pure ZVI barrier represents a design safety factor of 6 for current site PCE concentrations and a design safety factor of 2 for a potential 100-fold PCE concentration increase (i.e., to 20,000 µg/L). A 1.5-foot-thick PRB is proposed with a ZVI-to-sand ratio of 2:1 (equivalent to a 1-foot thick barrier of pure ZVI).

The final depth of the PRB will be determined based on the results of the grab groundwater investigation conducted as part of the pre-design activities, as described above in the "Additional Field Investigation" section. Based on investigative activities that have been conducted to date along the western property boundary, it is anticipated that the PRB will extend to a depth of 20 feet bgs, which is the approximate depth at which a clay layer has been observed throughout the site.

9.5.3 PRB and In-Barrier Performance Well Installation

Once the final location, thickness, and depth of the PRB and type of ZVI to be used are determined, the PRB installation methods will be evaluated relative to the site conditions at the time. Common continuous PRB installation methodologies include conventional backhoe excavation, clamshell excavation, and continuous trenching. The final installation methodology (or combination of installation methods), will be determined based on several factors, which might installation depth, site access and work space, health and safety constraints, geotechnical constraints, construction schedule constraints, and costs.

As recommended in the ITRC document *Permeable Reactive Barriers: Lessons Learned/New Directions* (ITRC, 2005), in-barrier wells will be installed during the construction of the PRB. The wells will be installed in the center (widthwise) of the PRB. The monitoring wells will be constructed using up to 2-inch-diameter, schedule 40 PVC blank well casing and 5 feet of slotted (0.010-inch slots) well screen. The monitoring wells will be screened within the first-encountered water-bearing unit, through which the PRB will be installed. Anticipated total depths of in-barrier wells will depend on the depth of the barrier at the installation location. The well bottom will be terminated approximately 1 foot above the bottom of the PRB, anticipated to be at a depth of approximately 20 feet bgs. The annular space between the trench walls and the well casing will be filled with the ZVI/sand mixture from the bottom of the trench to approximately 8 feet bgs, followed by controlled density fill to the surface. The wells will be completed at the surface using flush-mounted, traffic-rated boxes. A locking, watertight plug will be placed in the top of the casing at each well.

9.5.4 Reporting

Following construction of the PRB, a completion report will be submitted that includes as-built drawings, disposal of soil that is removed during construction of the PRB, copies of permits, and other information relevant to the installation of the PRB.

9.6 INSTITUTIONAL CONTROLS

Institutional controls will be implemented for the north parcel to supplement engineering controls; Based on the investigative findings, it is not contemplated at this time that ICs are necessary for the south parcel. However, pending the results of additional planned sampling on this parcel, it may be necessary to develop ICs that are specifically applicable to this area of the site.

The ICs will provide legal and administrative controls and methods for dissemination of information to minimize risk during property development, future below-ground construction and maintenance, and long-term site use. Prior to site development, an IC Plan will be prepared to set forth the general requirements and necessary controls dictated by property restrictions or contractual agreements (e.g., leases) The IC Plan will be developed in consultation with and approval by the ACEH. It is anticipated that documents implementing ICs will include the following:

- Land use covenants (LUCs) and activity use limitations (AULs)—these documents will document legal and regulatory requirements for the site.
- SMP—this document provides for communication primarily with contractors who will be constructing and maintaining the site. The SMP will provide details regarding the location and construction of the remedies (i.e., PRB, monitoring wells, vapor barrier, etc.), precautions should subsurface work be required in the area of installed remedies, precautions for handling potentially impacted groundwater, and notification procedures should the PRB, vapor barrier, or associated systems be damaged.
- Lease documents that include codes, covenants, and restrictions (CCRs)—these will serve as the primary communication tool for site residents and businesses.

As currently planned, the site development will consist of mixed use multi-unit structures housing commercial and residential spaces. To minimize contact with impacted media, the recorded land use covenants and the CCRs for the site will prohibit use of groundwater and alteration, disturbance, or removal of any component of the vapor barrier/SSD system and its associated components. Additional components of both the LUCs/AULs and the CCRs likely will include:

- Notification to the Dublin Building Department of the vapor mitigation system, and the potential “flagging” of the property such that ACEH would be notified if building permits were issued (to prevent impacting the vapor mitigation system);
- Prohibition of construction activities that could encounter/breach the vapor mitigation system without the express knowledge of ACEH and the Dublin Building Department, including utility repair or installation;
- Right of access to the property for ACEH to inspect, sample, and perform other related activities pertaining to the vapor mitigation system;
- Right of access to the property for the person responsible for implementing the O&M activities relative to the vapor mitigation system; and
- The provision to maintain inspection and monitoring records associated with the vapor mitigation system.

This documentation will be maintained at the site address by the property manager or designated representative and will be recorded at the Alameda County Clerk-Recorder’s Office.

In addition, the IC Plan will include activities to maintain the integrity of the remedy, ongoing O&M, and record compliance with the ICs. Activities might include annual inspections of the property and remedy, and associated reporting.

The SMP that will be prepared as an element of the long-term site management and will include a discussion of environmental conditions within the north parcel and the mitigation elements, including the vapor barrier/SSD system and monitoring wells that must be maintained and protected during site maintenance. Additionally, the SMP will include general procedures for health and safety, soil and groundwater management, and notification and documentation requirements for subsurface work or activities that have the potential to breach the vapor barrier. The SMP will be submitted to ACEH for its review and approval. The SMP will be maintained on site.

9.7 REPORTING

Following implementation of the components of the corrective action, it is anticipated that the following reports will be submitted to ACEH:

- Completion Reports—Excavation3 Completion Report and Monitoring Well Destruction and Installation Reports
- Vapor barrier/SSD system as-built drawings and field installation documentation (e.g., results of smoke testing, etc.), and

- Monitoring reports (ongoing, as described below)

9.8 CONTINGENCY IMPLEMENTATION

Based on the evaluation of current site conditions, Alternative 3 is the recommended corrective action. However, in order to mitigate the effects of possible changes is site conditions such as 1) shifts in groundwater flow direction, 2) an increase in plume width along Golden Gate Drive, 3) a change in the distribution of the vapor plume and/or 4) an increase in the footprint of the vapor plume, contingent measures could be undertaken, supplemental to the remedial actions proposed in Alternative 3. The proposed contingency actions, based on the possible changes in site conditions outlined above, would be as follows:

- Extend the Alternative 3 vapor barrier and SSD under all proposed buildings (excluding the parking structure) in the north parcel, to an approximately 84,600 square feet of building area (an additional 34,500 square feet beyond the proposed area outlined in Section 6.2). The proposed contingency vapor barrier and SSD extent is shown on Figure 12a.

- Extend the PRB an additional 50 feet south along Golden Gate Drive, for a total length of 250 feet. The proposed contingency PRB extension is shown on Figure 13.

Although implementation of the proposed contingency actions would ideally only take place if changes in site conditions dictated their requirement, their post-development implementation would be impractical and cost-prohibitive. As such, based on the goal to safeguard human health against changes in site conditions, and to minimize the potential for future logistical and financial implementation impacts, the proposed contingencies will be implemented concurrently with the Alternative 3 remedial actions. The estimated additional cost to implement the contingencies during the implementation of Alternative 3 is approximately $0.40 million, in addition to the base cost of $2.28 million for Alternative 3, as shown in Table 4. Therefore, the total estimated cost for implementation of Alternative 3 and contingencies is approximately $2.68 million.

10.0 CORRECTIVE ACTION PERFORMANCE EVALUATION

The performance of the corrective action will be evaluated by conducting groundwater sampling, PRB performance monitoring, vent riser, and indoor air sampling, as described in the following sections.

10.1 VAPOR BARRIER AND SSD

The primary objective of vapor barrier and SSD system sampling is to confirm that the remedial system is functioning as designed. Vapor barrier monitoring will be conducted via indoor air sampling and SSD monitoring will be conducted via direct sampling of the extracted soil vapor.

10.1.1 Indoor Air Sampling

Indoor air sampling will be conducted semiannually for a proposed period of 1 year. The proposed period is expected to be sufficient to demonstrate the long-term efficacy of the remedy.

Both indoor air sampling events will be conducted pre-occupancy. Indoor air sampling will be conducted during two seasons; late summer/early autumn (as allowed by the construction schedule) and late winter/early spring. Air samples will be collected from typical vapor intrusion pathways, such as bathrooms, kitchens, and other identifiable potential points of entry. Air samplers will be situated in the breathing zone (3 to 5 feet off the floor) and will be collected over a 24-hour period using laboratory-provided SUMMA™ canisters, or over a similar or longer period of time using passive samplers.

The indoor air samples will be analyzed for VOCs using U.S. EPA Method TO-15 (or the currently approved method at the time of sampling).

10.1.2 Vent Riser Sampling

Samples of the extracted soil vapor will be collected from sampling ports installed at each of the vent risers (equivalent to sub-slab sampling). SSD vent riser sampling will be conducted for a proposed period of 5 years at the following frequency:

- Monthly for year 1, and
- Quarterly for years 2 through 5.

The proposed period of 5 years is expected to be sufficient to demonstrate the long-term effectiveness of the remedy. It is anticipated that vent riser sampling will confirm the effective soil vapor mitigation after 1 year of performance monitoring and the sampling program will be converted to an O&M phase for the additional 4 years.

Samples collected from each vent will be analyzed for VOCs using U.S. EPA Method TO-15 (or the currently approved method at the time of sampling). Additional operational parameters may be collected from the riser, such as flow rate, temperature, and riser vent vacuum to determine a vapor extraction rate.

10.2 GROUNDWATER SAMPLING

Groundwater sampling will be conducted to monitor the performance of the PRB and VOC plume stability and/or attenuation. Groundwater sampling is expected to be conducted at the PRB performance monitoring wells and replacement groundwater wells for a period of approximately 5 years after installation of the PRB and replacement wells and at a frequency as follows:

- Quarterly for the first 2 years, and

- Annually for the years 3 through 5.

It is expected that the proposed groundwater monitoring time frame will be sufficient to demonstrate effective PRB performance and assess VOC concentration trends at the site. Although 5 years of groundwater sampling are proposed, effective PRB performance will be demonstrated by stable or decreasing concentration trends for a period of 1 year. If concentrations of VOCs in groundwater exhibit stable or decreasing concentrations after the first year, the monitoring may transition to an O&M phase for the remaining 4 years.

Groundwater sampling will be conducted using similar sampling protocols as those used to sample the existing groundwater wells (AMEC, 2012a; AMEC, 2013). The groundwater samples will be analyzed for the VOCs using U.S. EPA Method 8260B (or the currently approved method at the time of sampling) and PRB performance related analytes (e.g., alkalinity, sulfate, and ethane/ethene).

10.3 SITE INSPECTIONS AND REPORTING

The site inspections will be arranged by the site owner and will be conducted to observe and document the integrity and maintenance of the corrective action, including observation of roof turbines, auditing of on-site maintenance and monitoring records, and confirming that required on-site documentation is available (e.g., copy of the SMP). The site inspections will be conducted until such time that all ICs are terminated with approval of ACEH. Following each site inspection, the site owner (or designated inspection entity) will provide ACEH with a site inspection report and IC compliance certificate indicating that all IC objectives have been maintained.

For the purpose of the FS/CAP, a period of 20 years has been proposed for the implementation of the site inspections and reporting with the following frequency:

- Semiannually for years 1 and 2,
- Annually for years 3 and 4, and
- Every 5 years for years 5 through 20.

Should any action inconsistent with IC restrictions be discovered during the site inspection, the owner and/or designated inspection entity will notify ACEH. A written explanation will be submitted to the ACEH that describes the nature of the specific, inconsistent action, and the efforts or measures that have been or will be taken to correct the action. The associated time frame to correct the inconsistent action also will be provided.

11.0 FINANCIAL ASSURANCE

An appropriate financial instrument will be obtained to assure ACEH of implementation and maintenance of the proposed corrective action. The details of this financial assurance will be worked out by project proponent and ACEH as mitigation and monitoring plans are finalized and approved.

12.0 CORRECTIVE ACTION COMPLETION

Assuming the vapor barrier/SSD and PRB are shown within one year to function as designed, individual certificates of completion will be requested from ACEH and, following that, No Further Action (NFA) status will be requested for the site. Should the vapor barrier/SSD and/or PRB not function as designed, corrective actions will be undertaken as specified in the O&M plan, and may include converting the passive SSD to an active system, additional sealing of floors and utility stub-ups, and correction of any identified defects in the PRB.

Certificates of completion will be requested following completion of each of the items outlined below:

1. Completion of excavation of impacted soil in the vicinity of the former sump and F.E. Pit.
2. Completion of confirmation sampling and any remediation potentially needed at the hydraulic lifts, sump(s), and drain lines at the site.
3. Confirmation of effective soil vapor mitigation via the vapor barrier and SSD after 1 year of sampling, after which time the sampling program will be converted to an O&M phase.
4. Confirmation of effective treatment of migrating impacted groundwater by the PRB (concentrations of PCE and breakdown products at wells within the PRB are below drinking water ESLs) after 1 year of monitoring, after which time the sampling program will be converted to an O&M phase.
5. Agreement with ACEH that adequate groundwater monitoring has been completed to establish stable or decreasing concentration trends.

A description of what constitutes completion of each of the above items is provided below.

Items 1 and 2—Completion of the corrective action at the sump, F.E. Pit, hydraulic lifts, sumps, and drain lines within Building B and other locations as identified during redevelopment will be demonstrated via soil confirmation sampling conducted during the excavation activities. Confirmation sample results will be compared to residential ESLs. If the confirmation sample results are below the residential ESLs, the excavation(s) will be backfilled and excavated soil will be appropriately disposed of off-site and, at that time, the corrective action will be deemed complete.

Item 3—Completion of the soil vapor intrusion corrective action will be demonstrated via indoor air sampling prior to building occupancy. Indoor air sampling results will be compared to Regional Water Board ambient/indoor air ESLs (Regional Water Board, 2013) for evaluation of indoor air. The vapor intrusion corrective action (vapor barrier and SSD) will be deemed effective if concentrations of constituents of concern in indoor air are below their respective screening levels and are due to vapor intrusion, versus indoor sources (i.e., based on comparison to the vent riser [sub-slab equivalent] samples). Should implementation of an active SSD system be required, due to vapor intrusion and not indoor sources, the performance period to demonstrate effectiveness of the active SSD system will be another year from the date of system commissioning.

Item 4—Confirmation of the effective treatment of impacted groundwater migrating onto the site by the PRB will be demonstrated by the performance monitoring wells located upstream and within the PRB. Groundwater sample results from samples collected within the PRB will be compared against drinking water ESLs (Regional Water Board, 2013). The corrective action will be deemed effective if concentrations of constituents of concern in groundwater within the PRB are below their respective ESLs.

Item 5—A recommendation to transition the groundwater monitoring from performance monitoring phase to O&M phase will be made when on-site concentrations of PCE in groundwater are deemed stable or decreasing for a period of 1 year. Concentration trends in groundwater will be evaluated using the Mann-Kendall methodology (or other analysis methodology, as agreed upon with ACEH). The Mann-Kendall trend analysis is a non-parametric statistical evaluation that uses the relative magnitudes of the data to evaluate the probability that a concentration trend (positive or negative) exists. Groundwater monitoring will be conducted for 5 years, as set forth in the proposed corrective action.

Upon completion and confirmation of the effectiveness of the corrective actions and agreement that concentration trends in groundwater are stable or decreasing, the site owner will request that ACEH grant NFA status for the site.

Additional indoor air sampling and site inspections may continue, if needed, following the planned sampling period. If the continued monitoring is deemed necessary, the continuation of the indoor air sampling program will be evaluated every year (after issuance of the NFA) and in coordination with ACEH or the regulatory agency at the time. Should ACEH (or other regulatory agency) concur that indoor air monitoring and/or site inspections are no longer necessary, the post-NFA monitoring activities will cease.

13.0 OTHER REDEVELOPMENT CONSIDERATIONS

As discussed throughout this FS/CAP, site redevelopment will involve demolition of the existing site buildings. Subsurface utilities will also be removed prior to redevelopment. Separate from addressing known subsurface VOC impacts through a site management plan, demolition activities will be conducted so as to consider possible impacts that have not yet been discovered, and to minimize the possibility of causing subsurface contamination during demolition.

Prior to decommissioning the existing facility, a Facility Closure and Demolition Plan will be prepared by a qualified contractor. The specific activities associated with demolition and facility closure will be presented in this plan, which will be submitted to ACEH for its review. ACEH is the Certified Unified Program Agency with jurisdiction over the City of Dublin; therefore, the plan will be prepared in accordance with ACEH requirements.

To facilitate the preparation of the demolition plan, a Hazardous Materials Mitigation Report will be prepared. Site reconnaissance will be performed to assess and document hazardous materials and petroleum products that may be present at the site. An inventory will be made of sumps, pits, or other underground structures that may remain at the site.

Additionally, a building materials survey will be performed by appropriate licensed personnel. The survey will focus on inventory, sampling, and analysis of suspect building materials, including, but not limited to, lead-based paint, asbestos-containing building materials, fluorescent light ballasts, and thermostats. Subsurface conduits or portions thereof that exist above the ground surface or finished floor will be sampled as accessible and as appropriate depending on material type (e.g., transite pipe). The results of the site reconnaissance and building materials survey will be presented in a final report, which will be provided to a licensed abatement contractor(s). The abatement of suspected hazardous materials will be performed prior to site demolition activities, and materials will be transported and disposed of in an appropriate manner based on the specific type of material. Requisite permits, monitoring, and reporting will be performed in association with the abatement procedures as appropriate in accordance with BAAQMD and California Occupational Safety and Health Association guidelines.

During facility demolition, an environmental professional will be on site on a full-time basis during activities that result in ground disturbance or the removal of hardscape, slabs, subsurface piping, or other similar features. Sampling will be conducted beneath the slabs of Buildings B and C immediately following slab removal, and beneath process and drain line piping (e.g., sewer drain line, UST piping) that is removed. Samples also will be collected at areas where field observations indicate potential impacted soil, and at other locations to be identified in the field. It is anticipated that a minimum of five samples will be collected beneath each building, and that samples will be collected beneath piping at one per 20 linear feet or, depending on field observations, at joints or locations where impacts appear to have occurred.

In the event that unanticipated features are encountered (e.g., sumps, product lines), such facilities will be observed for the presence of suspected petroleum products or hazardous materials. If present, these features will be removed, containerized, and subsequently sampled for characterization for disposal purposes. Following analysis, such materials would be transported and disposed of in an appropriate manner by appropriately licensed personnel. Additionally, adjacent soil (i.e., base materials and sidewalls) will be sampled for the presence of potential contamination following DTSC protocols (the analytical suite will be dependent on the former use of the feature. If suspected asbestos-containing materials (e.g., transite pipe) are encountered, an appropriately licensed professional will sample suspect material for subsequent analysis. Such materials would be removed, transported, and disposed of in an appropriate manner, pending the results of the analysis. If sampling and analysis is required, ACEH personnel will be notified, and documentation of sampling activities, analysis results, and recommendations and conclusions will be prepared.

The specific details of sampling, observation, and notification to be performed during site redevelopment will be presented in the SMP, which will be prepared as details of site demolition and redevelopment are developed. Additionally, records pertaining to transport and disposal of the aforementioned petroleum products and hazardous materials will be provided to ACEH in report format.

14.0 IMPLEMENTATION SEQUENCE AND SCHEDULE

The following steps provide an outline for implementing the corrective action, and the approximate commencement date of activities and estimated durations (if applicable), are as follows.[6] Other related site activities are included, as needed.

1. Quarterly groundwater sampling of existing wells and reporting (next event in July 2014).
2. Preparation of final building construction plans incorporating vapor barrier and SSD design (begins May 2014; approximate duration of 6 months).
3. Preparation of excavation, confirmation sampling, additional PRB investigation (soil borings and bench-scale pilot testing), and well destruction/installation work plans and permit acquisition (work plans completed by May 15, 2014; permit acquisition to follow).
4. Preparation of SMP and design and construction quality assurance documents for PRB and vapor intrusion mitigation system (begins May 2014; approximate duration of 3 months)
5. General site demolition activities, well destructions, soil excavation (begins July 2014; approximate duration of 3 months).
6. Submission of next semiannual groundwater monitoring report (by July 30, 2014).
7. Installation of PRB (begins October 2014; approximate duration of 2 months)
8. Building construction, installation of vapor barrier and SSD, and replacement groundwater wells (begins November 2014; duration of approximately 18 months).
9. Preparation of final O&M plans, record of completion reports, and IC Plans (begins December 2014; approximate duration of 4 months).

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[6] These timeframes are estimated based on professional experience and a tentative accelerated site redevelopment schedule, and are subject to change. A final schedule will be developed when the proposed development is schedule. The schedule will be submitted to ACEH for review and approval.

10. SSD system startup and initial evaluation (begins approximately one month after building completion; duration of one month).
11. Performance monitoring (begins approximately 1 month after PRB and building completion, respectively).
12. Request for certificates of completion from ACEH (begins following receiving results of initial performance monitoring).

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TABLES

TABLE 1

SITE CONCEPTUAL MODEL

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

CSM Element	CSM Sub-Element	Description	Potential Data Gap(s)
Geology and Hydrogeology	Regional	The site is in the northwest portion of the Livermore Valley, which consists of a structural trough within the Diablo Range and contains the Livermore Valley Groundwater Basin (referred to as “the Basin”).[1] Several faults traverse the Basin, which act as barriers to groundwater flow, as evidenced by large differences in water levels between the upgradient and downgradient sides of these faults.[1] The Basin is divided into 12 groundwater basins, which are defined by faults and non-water-bearing geologic units.[2] The hydrogeology of the Basin consists of a thick sequence of fresh-water-bearing continental deposits from alluvial fans, outwash plains, and lacustrine environments to up to approximately 5,000 feet bgs.[1] Three defined fresh-water bearing geologic units exist within the Basin: Holocene Valley Fill (up to approximately 400 feet bgs in the central portion of the Basin), the Plio-Pleistocene Livermore Formation (generally between approximately 400 and 4,000 feet bgs in the central portion of the Basin), and the Pliocene Tassajara Formation (generally between approximately 250 and 5,000 or more feet bgs).[2] The Valley Fill units in the western portion of the Basin are capped by up to 40 feet of clay.[1] Within the immediate vicinity of the site, the depth to groundwater has been measured in shallow monitoring wells from approximately 7.4 to 18 feet bgs. Groundwater movement, as evaluated at the former Montgomery Ward site (7575 Dublin Boulevard), which is located north of the site, is reported to be to the east. An investigation at Quest Laboratory (6511 Golden Gate Drive), which is immediately south of the site, identified groundwater movement to the north, toward the site. Later measurements indicated groundwater flow to the southeast.	None
	Site	***Geology:*** Borings advanced at the site indicate that subsurface materials consist primarily of finer-grained deposits (clay, sandy clay, silt, and sandy silt) with interbedded sand lenses to approximately 20 feet below ground surface (bgs). Lean clays (with varying amounts of sand, but with no documented coarse lenses) are present from shallower than 20 feet bgs to depths ranging from to 35.5 to 43 feet bgs. An interval of lean clays interbedded with sand and/or gravel lenses is present from approximately 35.5 to 52 feet bgs, followed by another interval of lean clays to approximately 54-58 feet bgs, where an apparently continuous zone of clayey sands is encountered to the total depth logged (60.5 feet bgs). A cone penetrometer technology test indicated that even coarser materials (interbedded with finer-grained materials) are present from approximately 60 to 75 feet bgs. The lithology documented at the site is similar to that reported at other nearby sites, specifically the former Montgomery Ward site (7575 Dublin Boulevard), the former Quest Laboratory site (6511 Golden Gate Drive), the Shell Service Station site (11989 Dublin Boulevard), and the Chevron site (7007 San Ramon Road).	None
		Hydrogeology: Three water-bearing zones have been encountered at the site, as follows: • Groundwater is first encountered between approximately 9 and 15 feet bgs, within discontinuous sand and/or gravel lenses that are a few inches to several feet thick, and also within the sandy clays that are present at similar depths. Due to the high clay content of the soil, saturated soil has not been encountered in some borings (however, it was possible to collect grab groundwater samples from these borings by leaving them open overnight). There is likely a complex alluvial system in which groundwater (and chemical) migration primarily occurs in channel-like deposits of varying widths and thicknesses, versus within continuous horizontal continuous layers. The direction of the lateral hydraulic gradient (only measured in the northern portion of the north parcel) has been primarily toward the east-northeast during the five quarters of observation. • Groundwater is generally next encountered between approximately 35.5 and 52 feet bgs within thin (i.e. several inches to several feet thick), discontinuous sand and/or gravel lenses. The water-bearing zone does not appear to be significant, but does appear to be hydrogeologically separated from the water-bearing zones above and below. The direction of the lateral hydraulic gradient was not calculated for this water-bearing zone. • A third water-bearing zone is present from approximately 58 feet bgs to 75 feet bgs, the total depth drilled. This appears to be a significant water-bearing zone, based on the CPT log at the site and information from nearby sites. The direction of the lateral hydraulic gradient (only measured in the northern portion of the north parcel) appears to be to the northeast; however, the wells are located close to an east-west trending line, making it difficult to gauge the precise direction of groundwater movement. Downward hydraulic gradients were calculated between all three water-bearing zones (and at the former Montgomery Ward site, to the north). The calculated magnitude of the vertical hydraulic gradient was significantly greater than that of the horizontal gradients; however, disparate head measurements can indicate the lack of vertical flow. If it were possible for water to flow between one water-bearing zone and another, the hydrostatic pressure would begin to equilibrate and head measurements would be more similar. This conclusion is also supported by the lack of detections of constituents of concern in deeper groundwater and the thickness of the clay layers between the water-bearing zones.	None
Surface Water Bodies	--	The closest surface water bodies are culverted creeks. Martin Canyon Creek flows from a gully west of the site, enters a culvert north of the site, and then bends to the south, passing approximately 1,000 feet east of the site before flowing into the Alamo Canal. Dublin Creek flows from a gully west of the site, enters a culvert approximately 750 feet south of the site, and then joins Martin Canyon Creek approximately 750 feet southeast of the site.	None
Nearby Wells	--	A well survey was requested from the California Department of Water Resources in August 2012 and Zone 7 Water Agency in October 2012 in order to identify water-producing, monitoring, cathodic protection, and dewatering wells in the vicinity of the site. No water-producing wells were identified within 1/4 mile of the site. The nearest water-producing wells are located approximately 1/3 mile to the east and 1/2 mile northwest and southeast of the site.	None

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7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

CSM Element	CSM Sub-Element	Description	Potential Data Gap(s)
Constituents of Concern	--	Constituents of concern have been identified by comparing analytical results to ESLs for residential land use and for groundwater that is considered a current or potential drinking water source.[3] PCE and TCE have been identified as the primary constituents of concern at the site; these constituents have been detected in soil, groundwater and soil vapor in the northern portion of the site. Biodegradation byproducts (e.g., cis-1,2-DCE and trans-1,2-DCE) have also been detected in groundwater, but at lower concentrations relative to PCE and TCE and below their respective ESLs. Vinyl chloride has been detected in soil vapor at concentrations above its ESL. In the northern portion of the site, benzene and ethylbenzene have been detected in soil vapor at concentrations above their respective ESLs. Chlorobenzene and related constituents, and to a lesser extent, benzene, are present in soil, groundwater, and soil vapor above ESLs at a former sump and/or former front-end alignment pit in Building B. Accessible impacted soil was excavated from these areas in October 2011 in order to reduce the mass of these constituents in the subsurface. The Crown Chevrolet case was initially opened as a leaking underground fuel tank case, based on an investigation performed by Basics Environmental in 2009 that identified TPHd and TPHmo in groundwater at concentrations exceeding their respective ESLs in eight of nine grab groundwater samples collected, suggesting widespread TPHd and TPHmo impacts to groundwater at the site. However, as discussed in AMEC's April 2011 report, sampling conducted by AMEC in 2010 to delineate the extent of impacts did not detect any TPHd and TPHmo in groundwater, other than two TPHd detections below the reporting limit. Additional sampling conducted at the site has confirmed the absence of TPHd and TPHmo impacts (TPHd detections from groundwater samples within the sump excavation are not likely representative of diesel, according to the analytical laboratory). Two underground storage tanks were removed in October 2012; all analytical results reportedly were non-detect for petroleum hydrocarbons, with the exception of some very low TPHd concentrations (significantly less than the ESL). Groundwater samples have also been analyzed for TPHg throughout the site, and TPHg has only been detected above ESLs in shallow groundwater in the vicinity of the sump; however, these detections are judged to be representative of VOCs quantified by the TPHg analysis. TPHg was also detected in one groundwater sample collected from the third water-bearing zone (i.e., approximately 60 feet bgs) at a concentration less than its ESL, which may be related to the historical Montgomery Ward release (TPHg also detected at very low concentrations in borings SB-01 and SB-02 in the northern portion of the site, likely also related to the historical Montgomery Ward release). While groundwater elevation data indicate that groundwater flow in the deepest water-bearing zone is to the northeast, as discussed above, the limited data make it difficult to evaluate the precise groundwater flow direction.	None
Potential Sources	On-site	The north parcel of the site has been used as a car dealership with an auto body and service center since approximately 1968, when the site was developed from vacant land. Prior to 1968, site use appears to have been agricultural, based on a review of available historical aerial photographs. The south parcel of the site has reportedly only been used for vehicle storage. Building A has reportedly only been used as a showroom. Operations within Building B included automobile servicing (likely including parts cleaning). A hazardous materials storage area was formerly present within Building B, on top of a former front-end alignment pit, where remediation was conducted. Building C has been used as an auto body shop (including painting). A portion of the southern parking lot within the north parcel was designated on historical maps as "bulk storage." Based on the minor detections of PCE in soil vapor (in an area where groundwater is not impacted) beneath a drain line in Building B and in groundwater beneath the former sump in Building B, it is possible that a limited amount of PCE entered the subsurface at the sump or via drain line from the sump within Building B. However, the data do not indicate that the PCE in groundwater north of Building A is related to its potential historical use within Building B. Additionally, a subsurface utility survey was performed in September 2012, which did not indicate the presence of any sewer line connections north of Building A that might have acted as a conduit for PCE from Building B to the area of higher concentrations in groundwater. There is no likely source in Buildings A or D. Investigation performed within and downgradient of Building C (including the former "bulk storage" area) indicates that there are no significant impacts from activities in this area.	None
		Two USTs (one 1,000-gallon gasoline and one 1,000-gallon waste oil) were formerly present just south of Building B, and were removed in 2012. Available information indicates that the USTs were replaced once in the 1980s and upgraded in 1998. Data collected in the vicinity of the USTs prior to and during UST removal indicate that there are no significant impacts to soil and groundwater from the USTs.	None

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SITE CONCEPTUAL MODEL
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Dublin, California

CSM Element	CSM Sub-Element	Description	Potential Data Gap(s)
Potential Sources	Off-site, PCE	Four currently operating dry cleaners have been identified west (upgradient) of the Crown site, including Crow Canyon Cleaners at 7272 San Ramon Road, which has a known groundwater contamination issue (however, that site is approximately 0.5 mile from the Crown site and groundwater at the site has limited impact with a maximum PCE concentration of 23 µg/L). Two of the other identified dry cleaners, VIP Quality Cleaners at 7214 Regional Street and "Dry Clean 1 Hour" at 7257 Regional Street, are slightly closer to the Crown site (approximately 0.3 mile west); however, there are no documented releases at these two properties. These three properties appear to be served by sewers that flow north, away from the Crown site, but any potential releases from these dry cleaners or sewers serving them could have impacted groundwater moving toward the Crown site. The fourth dry cleaner, 1-800-DryClean of Dublin at 7172 Regional Street, may be served by a sewer line that flows south, toward the Crown site. No currently operating or historical dry cleaners have been identified south of Dublin Boulevard (i.e., west-southwest of the highest PCE concentrations) at this time. It should be noted that discharges of water containing PCE into (e.g., from dry cleaners) into the sanitary sewer have been prohibited since 1995 (based on personal communication with Anathan Kanagasundaram of the City of Dublin on November 15, 2012). The site is located within a commercial/industrial area, and several vehicle-maintenance related shops are located south of the site; these facilities appear to be served by a sewer that flows north along the western edge of the Crown site. Other such facilities are located west of the site. It is possible that PCE was released to the subsurface upgradient of the site via the sewer line. However, if a release were from an automobile-related source, it is likely that other fuel-related VOCs would be present as well (only PCE and TCE are present in groundwater at the upgradient property boundary of the Crown site).	A specific off-site source of PCE is not known at this time.
	Off-site, Fuels	***Quest Laboratory:*** The former Quest Laboratory site is located adjacent to the Crown Chevrolet property (south of the south parcel). The site was developed as a biomedical laboratory in 1982, and a 2,000-gallon underground fuel storage tank (of unknown contents) was installed at that time. The tank and associated piping were removed in 1989; limited petroleum hydrocarbon impacts were found in soil. Groundwater samples collected in 2004 indicated that TPHg and TPHd were present in groundwater at concentrations up to 5,100 and 64,000 µg/L, respectively, in a boring advanced at the former tank location, adjacent to the Crown site. Three groundwater monitoring wells were installed in 2009 to depths of 20 to 25 feet bgs in the vicinity of the former tank, and were monitored quarterly for one year. TPHg and TPHd were only detected during the first monitoring event, at maximum concentrations of 140 and 89 µg/L, respectively. One round of groundwater measurements indicated groundwater flow was to the north; subsequent measurements indicated groundwater flow was to the east-southeast. The case was closed, in April 2012, with the caveat that ACEH be notified of any potential changes to land use. The facility is currently owned by Safeway, Inc. Groundwater samples collected on the Crown property near the former Quest fuel tank did not indicate that impacts from the tank extend to the Crown site.	None
		Montgomery Ward: The former Montgomery Ward site is located across Dublin Boulevard from the Crown Chevrolet property (to the north). A gasoline fuel release was noted in 1988 from one of three 10,000-gallon gasoline USTs at the site. Total petroleum hydrocarbons were detected in soil samples nearby at concentrations up to 2,180 mg/kg. The USTs were removed in 1989, and some soil excavation conducted at that time. 1,350 gallons of free product were reportedly also removed. A groundwater extraction and treatment system began operating in 1990. Monitoring wells were installed at the Montgomery Ward property in 1992, as well as in the northern portion of the Crown site and at the property adjacent to Crown to the east in 1993. TPHg was detected in groundwater at the Montgomery Ward site at concentrations up to 100,000 µg/L in 1993. During the final groundwater monitoring event in 1996, TPHg was detected in a well at the northern boundary of the Crown property at 280 µg/L, with a historical maximum detection of 24,000 µg/L. As the case involved a leaking UST, groundwater was not tested for chlorinated solvents; however, in 1994, a selected number of grab groundwater samples collected at a property immediately east of the Crown site were tested for VOCs (including PCE) by U.S. EPA Method 8260, and no VOCs were detected.	
Potential Presence of DNAPL	--	The data indicate that the source of PCE is west of the site. Therefore, it is not likely that there would be separate-phase product (i.e., DNAPL) in soil or groundwater at the site. Additionally, the detected concentrations of VOCs in groundwater at the site are not indicative of the presence of DNAPL.	None
Nature and Extent of Environmental Impacts	Extent in Soil, PCE and TCE	PCE and TCE have been detected in soil samples collected north of Buildings A and B and beneath Building A. All concentrations are less than their respective ESLs for residential shallow soil, applicable to groundwater considered to be a potential source of drinking water (ESLs of 370 and 460 µg/kg for PCE and TCE, respectively). PCE has been detected at concentrations up to 48 µg/kg in unsaturated soil in the vicinity of the highest PCE concentrations in groundwater and soil vapor (i.e., north of Building A). It is likely that these PCE detections represent PCE in the vapor phase and not a source of PCE in soil. PCE and TCE were detected in deeper soil samples (between 12.5 and 14.5 feet bgs) at concentrations up to 36 and 13 µg/kg, respectively (in the same area of the site). These soil samples were generally located within the saturated zone and it is likely that the detected concentrations represent PCE and TCE in groundwater. Soil was screened during advancement of the direct-push probe approximately every 1 to 4 feet using a PID; readings in most borings north of Building A and near the on-site sewer lateral were 0 ppm. No PID readings in this area indicated the presence of VOC impacts to soil.	None

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CSM Element	CSM Sub-Element	Description	Potential Data Gap(s)
Nature and Extent of Environmental Impacts	Extent in Soil, TPHg	Soil from the far northern and northeastern portions of the north parcel was also screened using a PID; readings up to 306 ppm (in boring MW-02) were recorded near the top of the zone of saturation in borings SB-01, SB-02, SB-37, SB-46, MW-02, and MP-02. Soil samples were collected from the depths of the PID readings at SB-01, SB-02, SB-46, and MW-02. TPHg was detected in those samples at concentrations up to 13 mg/kg. Samples were not collected from SB-37 and MP-02, but it is likely that TPHg is also present in soil at comparable depths in those borings. There is no likely on-site source of TPHg in the vicinity of the borings, but TPHg has been detected at low concentrations in groundwater in the northern portion of the site (i.e., SB-01 and SB-02). The former Montgomery Ward fuel release site was located northwest of the borings in which TPHg was detected. Groundwater was historically impacted by TPHg and BTEX at and downgradient of the Montgomery Ward site, extending to the east-southeast through the Crown Chevrolet site. The TPHg detected in soil at the Crown site is likely a remnant of historical Montgomery Ward contamination that remained in soil in the capillary fringe after most of the TPHg impacts had attenuated.	None
Nature and Extent of Environmental Impacts	Extent in Soil, Chlorobenzenes	Chlorobenzenes and petroleum-related constituents were detected in soil in the vicinity of the former sump and former front-end alignment pit at concentrations greater than their respective ESLs; soil remediation was performed in 2011. Currently inaccessible impacted soil remains in place under existing building foundation walls; concentrations of some constituents are greater than ESLs.	Soil samples have been collected to a total depth of 11.5 feet bgs pre-remediation and 8 feet bgs post-remediation beneath the sump. The remediation consisted of soil excavation to a depth of 16 feet bgs. No soil samples were collected at the base of the excavation because the soil was saturated; there is currently no data confirming the absence of significant impacts to soil beneath the sump.
	Extent in Soil, TPHho and PCBs	TPHho (at concentrations greater than the residential ESL) was detected in soil sample SB-20-11 near a hydraulic lift east of the former front-end alignment pit in Building B (an elevated concentration of TPHho also was detected in soil sample SB-25-8; this sample location subsequently was excavated). Analysis for PCBs was performed on 13 samples, which were collected in the vicinity of hydraulic lifts within Building B. One PCB, Aroclor 1242, was detected in a soil sample collected at location NM-B-5 just north of the pit in Building B; however, the concentration of Aroclor 1242 at this location was an order of magnitude lower than its ESL. No other PCBs were detected in soil samples (however, the reporting limits for PCBs in 1 sample of the 13 samples analyzed were above the ESL).	None
Nature and Extent of Environmental Impacts	Extent in Shallow Groundwater, PCE and TCE	Grab groundwater and monitoring well data are available for VOCs throughout the northern portion of the site, including beneath Building A, as well as in Golden Gate Drive, upgradient of the site. PCE and TCE are present in groundwater in the northern parking lot at concentrations greater than their respective ESLs that consider groundwater to be a current or potential drinking water resource (the ESL is 5 µg/L for both PCE and TCE). The highest concentrations of PCE in groundwater are at the western (upgradient) property boundary (with concentrations in this area range up to 210 µg/L) and farther upgradient in Golden Gate Drive (with concentrations up to 130 µg/L). Concentrations decline to the north, east, and south. At the eastern (downgradient) property boundary, concentrations of PCE in shallow groundwater are approximately 25% of the concentrations at the upgradient property boundary (concentrations at the eastern property boundary are up to 58 µg/L). The concentrations of PCE and TCE in shallow groundwater have been relatively stable over the five quarters of groundwater monitoring conducted to date. TCE is present at higher concentrations relative to PCE in the northeast corner of the site; cis- and trans-1,2-DCE also were detected in some groundwater samples in this area (at concentrations below their respective ESLs). The area where TCE concentrations are higher (and PCE concentrations lower) was historically impacted by the Montgomery Ward release of TPHg. It is likely that the TPHg acted as a source of organic carbon and stimulated the biological reduction of PCE in that area. As part of the feasibility study, AMEC collected two groundwater samples from monitoring wells MP-01-1 and MW-02, and tested the samples for the *Dehalococcoides* (*Dhc*) bacteria, nitrate, and sulfate, and assessed field parameters. *Dhc* was not present in either sample, but dissolved oxygen levels stabilized below 1 mg/L, which is generally considered to be anaerobic (oxygen deficient) and favorable for reductive dechlorination processes. ORP, which is a measure of electron availability in aqueous environments, was measured as negative in both wells, and within the range of pE (electron activity) values that would facilitate reductive dechlorination. Regarding electron receptors, nitrate was found to be present in monitoring well MP01-1 and was not detected in monitoring well MW-02. Notably, nitrate was not found in the area where TPH impacts to groundwater from the historical Montgomery Ward release were formerly present and where TCE in present at higher concentrations than elsewhere at the site, suggesting that some bioattenuation likely occurred in this area, depleting this electron receptor. With the exception of two shallow grab groundwater samples (from Basics boring B8 and monitoring well MW-03, both located at the former sump) in which PCE was detected at 9.6 µg/L and 9.3 µg/L, respectively, only low concentrations of PCE (less than 5 µg/L) were detected in shallow groundwater in the vicinity of the former sump and former front-end alignment pit. These detections are isolated to a small area and may represent a minor release of PCE to groundwater from the sump.	None

TABLE 1

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CSM Element	CSM Sub-Element	Description	Potential Data Gap(s)
Nature and Extent of Environmental Impacts	Extent in Shallow Groundwater, Chlorobenzenes	Chlorobenzenes and related constituents are present in shallow groundwater at concentrations greater than ESLs in the vicinity of the former sump within Building B (where soil remediation was conducted in 2011). The presence of these constituents (e.g., benzene and chlorobenzene) in groundwater appears to be limited to an area within approximately 15 feet of the former sump. The concentrations of chlorobenzenes in shallow groundwater have been relatively stable over the five quarters of groundwater monitoring conducted to date. These constituents were not detected above ESLs in groundwater samples collected at the former front-end alignment pit in Building B.	None
	Extent in Shallow Groundwater, TPH	TPHho (at a concentration greater than its ESL) was detected in an unfiltered groundwater sample (SB-20) collected near one hydraulic lift east of the former front-end alignment pit in Building B; however, no TPHho was detected in a filtered groundwater sample from the same location. The unfiltered sample result is likely representative of TPHho sorbed onto soil particles, as TPHho was also detected in soil at 11 feet bgs at this location. The reporting limits for TPHho (and TPHd and TPHmo) in groundwater are greater than the respective ESLs for these constituents. However, no TPH was detected at the laboratory's method detection limit for the filtered samples. While concentrations less than the laboratory reporting limit are estimated, the absence of detections indicates that dissolved TPHd, TPHmo, and TPHho are not present.	None
Nature and Extent of Environmental Impacts	Extent in Shallow Groundwater, Chromium	Total chromium was detected above the residential ESL at one location (SB-06), but dissolved concentrations in the vicinity were less than the ESL.	None
Nature and Extent of Environmental Impacts	Extent in Deeper Groundwater	Groundwater samples have been collected from two deeper water-bearing zones at six locations in the northern portion of the north parcel, including just downgradient of the former sump within Building B. The samples were collected from what appear to be discontinuous sand and gravel lenses at approximately 40 feet bgs and/or from a more significant water-bearing unit at approximately 60 feet bgs (actual sample depths/screen intervals varied based on the lithology encountered in each boring). PCE, TCE, cis-1,2-DCE, TPHg, 2-hexanone and acetone have been sporadically detected in deeper groundwater samples from site monitoring wells. The detections appear to be sporadic and without a clear trend. All of the detections have been at concentrations less than the ESL, with the exception of cis-1,2-DCE in MP-02 during October 2013. The acetone and 2-hexanone detections were previously believed to be false positive results due to laboratory contamination, but these constituents have not been detected in the first water-bearing zone, and may therefore represent valid detections. TPHg was detected in the third water-bearing zone of monitoring well MP-04 (at the eastern/downgradient property boundary) at a concentration less than its ESL during the first groundwater sampling event (September 2012), but not during any of the four subsequent sampling events. TPHg was not present in the up- or cross-gradient deeper groundwater samples, nor is TPHg a constituent of concern in shallow groundwater at the site. The TPHg may be related to the historical Montgomery Ward release; while groundwater elevation data indicate that groundwater flow in that water-bearing zone is to the northeast, the groundwater flow direction may have been different in the past.	PCE, TCE, cis-1,2-DCE, TPHg, 2-hexanone and acetone have been sporadically detected in deeper groundwater samples from site monitoring wells. Their source is not known, but does not appear to be related to the site.
Nature and Extent of Environmental Impacts	Extent in Soil Vapor, PCE, TCE, and Vinyl Chloride in North Parcel	PCE, TCE, vinyl chloride, and some related breakdown products have been detected in soil vapor in the northern portion of the north parcel (Figure 10). PCE, TCE, and vinyl chloride concentrations are greater than residential ESLs for evaluation of potential vapor intrusion concerns (410, 1,200, and 31 µg/m^3, respectively [Table E-2]) in some areas. The highest concentrations of PCE and TCE detected in soil vapor (up to a maximum concentration of 35,000 µg/m^3 at location SV-22) were in the vicinity of higher concentrations of PCE in groundwater (north of Building A). Vinyl chloride was also detected in soil vapor at concentrations greater than the ESL, but was limited to the north-central area of the north parcel (borings SG-03, SG-04, and SV-23). The spatial distributions of PCE and TCE in shallow soil vapor (i.e., 1 to 4 feet bgs) are similar, but they vary somewhat from the spatial distribution of these constituents in groundwater. This may indicate that shallow soil vapor transport is attributable, in part, to transport via on-site subsurface utilities, and not solely from volatilization from groundwater at the site. Additionally, utility lines within the nearby streets may provide a conduit for some of the vapors to enter the subsurface at the site. Concentrations of PCE and TCE in soil vapor samples collected from nested vapor monitoring points along the eastern property boundary are higher in the deeper (8 feet bgs) samples than the shallower (4 feet bgs) samples, indicating that volatilization from groundwater is a contributor to the VOC concentrations in soil vapor at the site. PCE was also detected along the floor drain lateral to the sewer line within Building B and in a sample collected from within the former front-end alignment pit in Building B (this pit has since been removed), indicating that PCE may have been used within Building B and may have contributed, in part, to the PCE detected in soil vapor beneath Building B. However, note that PCE, where detected, is present at only low concentrations in groundwater in this area, suggesting that vapor transport along site utilities likely contributes to PCE in soil vapor beneath Building B.	None

TABLE 1

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CSM Element	CSM Sub-Element	Description	Potential Data Gap(s)
Nature and Extent of Environmental Impacts	Extent in Soil Vapor, PCE in South Parcel	PCE has been detected in soil vapor at concentrations ranging from 48 to 94 µg/m^3 (approximately an order of magnitude less than the ESL) in the northwestern corner of the south parcel. No auto servicing activities are known to have been conducted in this area, which was historically used as a parking lot. PCE was not detected in the groundwater sample collected in this area. PCE is not present in groundwater or soil vapor samples collected in the eastern portion of the south parcel. The low levels of PCE in soil vapor are likely related to transport via subsurface utilities within Golden Gate Drive and/or Saint Patrick Way.	None
	Extent in Soil Vapor, Benzene	Benzene and ethylbenzene have been detected in shallow soil vapor (i.e., collected from 1.5 to 5 feet bgs) north of Buildings A and B at concentrations exceeding their respective ESLs (84 µg/m^3 for benzene and 980 µg/m^3 for ethylbenzene). Benzene concentrations generally ranged from 90 to 160 µg/m^3, with one concentration of 1,300 µg/m^3 detected in the shallowest soil vapor sample (from a depth of 1.5 to 2 feet bgs at location SV-16) in the northeastern portion of the north parcel. Ethylbenzene concentrations were greater than the ESL at two locations, up to a maximum concentration of 1,300 µg/m^3 at location SV-16. These constituents were not detected in corresponding soil and groundwater samples, and there was not a visible pattern to the soil vapor sample concentrations in plan view. Concentrations of benzene and ethylbenzene in soil vapor samples collected from nested vapor monitoring points along the eastern property boundary are lower in the deeper (8 feet bgs) samples than the shallower (4 feet bgs) samples. Based on the lack of a known source, lack of a spatial pattern to the detections, and the higher concentrations in the shallower samples, the presence of these constituents may be related to the long-term use of the area as a parking lot.	None
	Extent in Soil Vapor, Former Sump and Pit	Soil vapor sampling was conducted in the vicinity of the former sump and former front-end alignment pit in Building B prior to remediation, and some concentrations of PCE, benzene, and 1,4-dichlorobenzene were greater than their respective ESLs at that time.	Post-remediation soil vapor concentrations are not known.
Migration Pathways	Potential Conduits	Figure 2 shows the known locations of on-site utilities, including sanitary sewer laterals, water, gas, and electrical lines, based on a geophysical survey conducted in September 2012. Based on the spatial distribution of PCE in groundwater, it does not appear that PCE was released to the subsurface via the on-site sewer lateral or any other subsurface utilities in the northern parking lot. However, based on the distribution of PCE in soil vapor, it appears that these facilities could act as conduits for vapor migration throughout the site.	None
Potential Receptors/Risk	On-site	Potable water at the site currently is provided via municipal supply and will continue to be in the foreseeable future. As such, direct contact to groundwater is not contemplated. Receptors at the site could include the following: • Current worker via vapor intrusion to indoor air, • Future construction worker via soil, groundwater, and soil vapor, • Future resident via vapor intrusion to indoor air, and/or • Future maintenance worker via soil and soil vapor.	Based on evaluation of the data relative to ESLs, it is likely that some risk for longer-term site occupants exists.
Potential Receptors/Risk	Off-site	Potential receptors in the vicinity include: • Nearby water-producing wells to the east and northeast • Concrete-lined Dublin Creek and Martin Canyon Creek	Potential risk to receptors in the surrounding area is unknown. The impacts to groundwater and soil vapor are attributed to an off-site source; therefore, potential impacts and risks to the surrounding areas have not been evaluated.

TABLE 1

SITE CONCEPTUAL MODEL

Crown Chevrolet Cadillac Isuzu
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Dublin, California

Notes

1. California Department of Water Resources, 2006, California's Groundwater, Bulletin 118, Livermore Valley Groundwater Basin, January 20.
2. California Department of Water Resources, 1974, Evaluation of Ground Water Resources: Livermore and Sunol Valleys, Bulletin 118-2, June.
3. California Regional Water Quality Control Board, San Francisco Bay Region, 2008, Screening For Environmental Concerns at Sites With Contaminated Soil and Groundwater, May.
4. AMEC, 2011, Revised Soil and Groundwater Investigation Report, Crown Chevrolet Cadillac Isuzu, 7544 Dublin Boulevard and 6707 Golden Gate Drive, Dublin, California, April 4.
5. U.S. Environmental Protection Agency, 1992, Quick Reference Fact Sheet entitled "Estimating Potential for Occurrence of DNAPL at Superfund Sites," January.
6. Pankow, J., et al, 1996, Dense chlorinated solvents in groundwater: background and history of the problem: in Pankow D. and Cherry J. (eds.), Dense Chlorinated Solvents and other DNAPLs in Groundwater, Waterloo Press, Portland, Ore., Ch. 1, pp. 1-52.

Abbreviations

bgs = below ground surface
cis-1,2-DCE = cis-1,2-dichloroethene
trans-1,2-DCE = trans-1,2-dichloroethene
DNAPL = dense non-aqueous phase liquid
ESLs = Environmental Screening Levels
mg/kg = milligrams per kilogram
PCE = tetrachloroethene
PCBs = polychlorinated biphenyls
PID = photoionization detector
ppm = parts per million
ppmv = parts per million by volume
TCE = trichloroethene
TPHd = total petroleum hydrocarbons as diesel
TPHg = total petroleum hydrocarbons as gasoline
TPHho = total petroleum hydrocarbons as hydraulic oil
TPHmo = total petroleum hydrocarbons as motor oil
µg/kg = micrograms per kilogram
µg/L = micrograms per liter
µg/m^3 = micrograms per cubic meter

TABLE 2

MASS IN-PLACE ESTIMATES

Crown Chevrolet Cadillac Isuzu
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Mass In Soil Vapor

Estimated soil vapor contaminant mass (assumes impacted area = 80,000 sf x 10 feet thick, 50% porosity)

Impacted Zone						
Width (ft)	*Length (ft)*	*Thickness (ft)*	*Porosity*	*Area (sf)*	*Pore Volume (cf)*	*Pore Volume (m^3)*
200	400	10	0.5	80,000	400,000	11,328

Contaminant	*Reported Concentrations (µg/L)*													
	SV-24	*SV-23*	*SV-22*	*SG-03*	*SG-02*	*SG-04*	*SV-12*	*SV-13*	*SG-01*	*SV-16*	*SV-14*	*Average*	*Mass - Kg*	*Mass - lbs*
PCE	9.6	2.3	35	17	4.9	1.4	0.054	7.3	0.58	0.4	0.79	7.21	0.082	0.180
TCE	0.41	9.1	0.033	3.2	0.065	5.8	0.3	12	0.02	0.027	8.3	3.57	0.040	0.089
VC	0.0052	0.51	0.0052	0.091	0.0055	0.13	0.0052	0.5	0.003	0.0052	0.5	0.16	0.002	0.004
													Total =	**0.269**

Dissolved Mass

Estimated groundwater contaminant mass (assumes impacted area = 80,000 sf x 12 feet thick, 50% porosity)

Impacted Zone						
Width (feet)	*Length (feet)*	*Thickness (feet)*	*Porosity*	*Area (sf)*	*Pore Volume (cf)*	*Pore Volume (liters)*
200	400	12	0.5	80,000	480,000	13,592,088

Contaminant	*Reported Concentrations (mg/L)*																
	SB-33	*SB-34*	*SB-35*	*SB-38*	*B-39*	*SB-40*	*SB-42*	*MP-01-1*	*MP-03-1*	*MW-01*	*MP-02-1*	*NM-B-28*	*SB-02*	*NM-B-26*	*Average*	*Mass - Kg*	*Mass - lbs*
PCE	0.13	0.21	0.17	0.1	0.14	0.16	0.14	0.12	0.12	0.16	0.0016	0.016	0.015	0.0017	0.106	1.4	3.2
TCE	0.00057	0.0025	0.00058	0.002	0.002	0.0005	0.0005	0.0005	0.0064	0.0013	0.019	0.048	0.06	0.056	0.014	0.2	0.4
																Total =	**3.60**

Soil Vapor Mass		**0.27**	
Dissolved Mass		**3.60**	
	Total	**3.87**	**lbs**

Notes

1. All reported concentrations and thicknesses as presented in the *Soil, Groundwater, and Soil Vapor Investigation Report* (AMEC, 2012). Reported concentrations for non-detected results are shown as the laboratory reporting limit.
2. 1 kg = 2.2 lbs
3. 1 cf = 28.32 liters = 7.43 gallons

Abbreviations

-- = not used in calculation
cf = cubic feet
kg = kilograms
lbs = pounds
µg/L = micrograms per liter

mg/L = milligrams per liter
PCE = tetrachloroethene
sf = square feet
TCE = trichloroethene
VC = vinyl chloride

TABLE 3

SCREENING OF CORRECTIVE ACTION TECHNOLOGIES

Crown Chevrolet Cadillac Isuzu
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Dublin, California

Technology	Description	Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation?
Monitored Natural Attenuation (MNA)	MNA relies on natural processes to achieve corrective action objectives. These processes may include biodegradation, sorption, dispersion and dilution, chemical reactions, and/or volatilization. In order to consider MNA, it must first be verified that subsurface conditions are suitable for the attenuation processes, especially bioremediation; it also requires monitoring to verify progress.	*Potentially effective if combined with other remedial technologies* Natural attenuation appears to have occurred (with the presence of a carbon source) at the site as described in the *Soil, Groundwater, and Soil Vapor Investigation Report,*[1] with the reduction of PCE and increased in TCE concentrations at the northeast corner of the site. The slow rate of natural attenuation observed to date (i.e., high concentrations of PCE relative to TCE and other breakdown products) indicates that MNA will not be effective in the short term. With respect to the long-term effectiveness, slow, natural attenuation may occur, but PCE and TCE concentrations in groundwater are expected to remain constant for a substantial time period.	*Easy to Implement* MNA requires only monitoring to verify progress; therefore, implementation is not complex. Agency and community acceptance of this method alone may be low. The materials and services needed to implement MNA are readily available.	Low	No
Groundwater Extraction and Treatment (GWET)	GWET involves the physical removal of impacted groundwater from the subsurface, followed by above ground treatment. Once treated, groundwater is discharged either to the sanitary sewer under permit from the POTW or to a storm drain under NPDES permit.	*Can be effective under medium to high permeability subsurface conditions* GWET could be effective in the short- and long term in providing a hydraulic barrier to VOC migration onto the site. Groundwater extraction is a well-proven technology for hydraulic containment. Additionally, GWET could be effective in the short-term and long-term in removing PCE and TCE in groundwater. However, due to mostly low-permeability lithology at the site (mostly lean clays), closely spaced groundwater extraction wells would be required to effectively remove VOC-impacted water.	*Moderate to Difficult to Implement* Personnel and equipment are generally available for implementation; however, specialized design work is required. Discharging treated water may require extensive permitting. Implementation will require extensive operation, maintenance and administrative effort.	High	No

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[1] AMEC, 2012. Soil, Groundwater, and Soil Vapor Investigation Report, 7544 Dublin Boulevard and 6707 Golden Gate Drive, Dublin, California. October 19

TABLE 3

SCREENING OF CORRECTIVE ACTION TECHNOLOGIES
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

Technology	Description	Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation?
In-Situ Bioremediation (Aerobic)	Aerobic *in-situ* bioremediation is accomplished by introducing oxygen and/or other substrates to the subsurface. Oxygen could be introduced at the site by installing diffusive oxygen emitters in the subsurface or by injecting oxygen-enhanced water. Diffusive oxygen emitters consist of coiled silicone tubing that can be lowered into a well. The tubing is pressurized with oxygen, resulting in a slow, continuous release of oxygen to the subsurface.	*Not effective* The COCs at the site are not amenable to aerobic biodegradation.	*Moderate to Implement* Personnel and equipment are generally available for implementation; however, specialized design work is required.	High	No
Enhanced In-Situ Bioremediation (Anaerobic)	Anaerobic *in-situ* bioremediation involves introducing an electron donor and/or bacterial amendment to the treatment area to create strongly reducing conditions and foster contaminant biodegradation. PCE and TCE have been shown to be degraded by appropriate bacteria (e.g. Dhc) under highly reducing conditions. Electron donor addition would likely occur by injecting substrate (e.g., lactate) into the target treatment zone. Recirculation would potentially be used to more effectively distribute the injected substrate throughout the treatment area.	*Potentially effective* The site groundwater chemistry appears to be favorable for reductive dechlorination. The COCs at the site are amenable to anaerobic biodegradation and *in-situ* bioremediation. Anaerobic biodegradation of PCE by Dhc bacteria could potentially result in the complete breakdown of PCE to ethene; however, if the breakdown was not complete, vinyl chloride could be produced. Effective implementation of the technology would be difficult to assess without a pilot treatability study to determine full site-wide implementation. Consistent delivery of amendments would require closely spaced injection points and possible permanent infrastructure for additional amendment delivery post site development.	*Moderate to Difficult to Implement* Personnel and equipment are generally available for implementation; however, specialized design work is required for long term implementation.	Medium to High (dependent on time frame and infrastructure required for implementation)	Yes

TABLE 3

SCREENING OF CORRECTIVE ACTION TECHNOLOGIES

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Dublin, California

Technology	Description	Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation?
Permeable Reactive Barrier (PRB) using Zero-Valent Iron	A PRB is a trench filled with a reactive media that will remediate groundwater as it flows through (assuming an adequate residence time). For chlorinated VOCs, the PRB would use zero-valent iron (ZVI), Fe(0), as the reactive media. Treatment of the COCs takes place in the form of abiotic reductive dehalogenation through reactions at the surfaces of Fe(0) particles. PCE and TCE and are reduced due to electron transfers from the iron to the halocarbon at the iron surface.	*Potentially effective* Can be used to manage COC flux from the off-site source area and partially effective to reduce VOC concentrations on-site as treated water migrates across the site. The migrating groundwater COCs at the site are amenable via the ZVI PRB. The long-term effectiveness of various available ZVI may require bench scale testing to determine product with higher treatment capabilities and longevity.	*Moderate to Implement* The ZBI PRB would be moderate to construct with minimal operation and maintenance post construction. The equipment and materials necessary for installation are commercially available, and the permitting complexity is low to moderate.	High	Yes
In Situ Chemical Oxidation (ISCO)—Liquid-Based Injection	ISCO involves injecting chemical oxidants (e.g., persulfate or hydrogen peroxide) into the subsurface where they oxidize contaminants *in situ*. Oxidants are typically injected using temporary direct-push points or permanent injection wells.	*Potentially effective if proper subsurface delivery of the chemical oxidant can be accomplished* The COCs at the site are potentially amenable to oxidation reactions, and ISCO could potentially be an effective means of reducing constituent concentrations in the source area. However, there can be challenges in the delivery of the oxidant, unfavorable side reactions, and effectiveness can be limited by complexities in site geochemistry.	*Difficult to Implement* Due to mostly low-permeability lithology at the site, many closely-spaced injection points would be needed to cover the plume area, and repeated injections would likely be necessary, resulting in high cost. Personnel and equipment are generally available for implementation; however, specialized design work is required. The chemical oxidant injection system may require extensive permitting.	High	No

TABLE 3

SCREENING OF CORRECTIVE ACTION TECHNOLOGIES

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

Technology	Description	Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation?
Excavation/Disposal (Former Sump and Front-End Alignment Pit [F.E. Pit] Areas)	Excavation represents the physical removal and off-site disposal of the impacted soil. This remedial action eliminates the source of any groundwater contamination from the constituents currently present in the soil.	*Effective for removing impacted soil* Excavation has been proven effective to address TPH and VOC impacts to soil at the sump and F.E. Pit areas, as detailed in the *Remediation Report.*[2] This technology is effective in both the short- and long-terms.	*Easy to Implement* Excavation of remaining TPH and VOC impacted soil at the sump and F.E. Pit areas can be accomplished using the same excavation techniques utilized during the initial remedial action.	Low (based on identified remaining sump and F.E. Pit soil impacts)	Yes
Soil Vapor Extraction (SVE)	SVE involves applying a vacuum (negative pressure) that induces subsurface vapor flow through soil in the vadose zone to reduce the mass of contaminants in soil. The induced negative pressure volatilizes COCs adsorbed to soil particles. The COCs are then carried with the induced subsurface flow and treated above ground using a treatment system (e.g., granulated activated carbon, thermal oxidation).	*Effective for removal of VOCs; not effective for denser hydrocarbons such a motor oil range compounds* Although SVE would be an effective treatment for the remaining chlorobenzene and dichlorobenzene impacts at the former sump and F.E. Pit, SVE would not be effective for the treatment of the heavier hydrocarbon–impacted soil at the F.E. Pit. SVE would not be effective for chlorinated VOCs in soil vapor, as no source for these constituents is present in soil at the site.	*Easy to Implement* Personnel and equipment are generally available for implementation; however, specialized design work is required. Implementation of SVE for the small areas identified with remaining soil impacts would not result in a favorable cost/benefit ratio when compared to the excavation approach.	Moderate	No
Vapor Barrier	A vapor barrier involves the use of high density polyethylene (HDPE) sheets or sprayed-applied asphaltic emulsions placed beneath new building foundations. The applied vapor barrier prevents vapors from entering the building by sealing typical soil vapor pathways such as expansion joints, slab cracks, and utility penetrations.	*Effective in controlling vapor intrusion into new buildings* Although effective on its own over both the short-and long-term for the control of minor soil vapor impacts, the vapor barrier would be used in combination with a sub-slab depressurization system for additional protection.	*Easy to Implement* Personnel and equipment are generally available for implementation; however, specialized design work is required. Implementation of the remedy would take place during a site development.	Low to High (dependent on square footage requiring vapor barrier)	Yes

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[2] AMEC, 2011. Remediation Report, Crown Chevrolet Cadillac Isuzu, 7544 Dublin Boulevard and 6707 Golden Gate Drive, Dublin, California. December.

TABLE 3

SCREENING OF CORRECTIVE ACTION TECHNOLOGIES

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

Technology	Description	Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation?
Sub-Slab Depressurization (SSD)	SSD involves the installation of vapor collection piping underneath a building to create negative pressure and extract accumulated soil vapors beneath the building foundations. Extracted soil vapors are vented to the atmosphere. Depending on extracted concentrations, extracted soil vapors might require pre-treatment prior to discharge to atmosphere.	*Effective in controlling vapor intrusion into new buildings* Although effective on its own for the control of minor soil vapor impacts, the use of a SSD system is typically used in combination with a vapor barrier for additional protection. A SSD is an effective mitigation measure in the long term, as the negative pressures induced by the system create a convective flow of air upward through the system to draw air from beneath the slab and vent it to the outdoors.	*Easy to Implement* Personnel and equipment are generally available for implementation; however, specialized design work is required. Implementation of the remedy would take place during a site development.	Moderate	Yes
Institutional Controls (ICs) and Long-Term Site Management	ICs and long-term site management are administrative and legal restrictions implemented and/or imposed on the property to minimize the human exposure to contamination and protect the integrity and stability of the remedy. ICs might include deed restrictions on the use of the soil and groundwater, scheduled inspections of the remedy, site management plans, Codes, Covenants and Restrictions (CCRs) as a legal document that remains in place with the property, and review of compliance with any covenant restricting the use of the property, among others.	*Effective as a supplement to engineering controls to facilitate short- and long-term management of risk by preventing and limiting exposure to COCs*	*Easy to Implement* Personnel and equipment are generally available for implementation. Enforcement of ICs is effective at the site until such time the site is deemed as requiring no further action.	Low to Moderate	Yes

Abbreviations

CCRs = codes, covenants, and restrictions
COC = contaminant of concern
Dhc = Dehalococcoides
F.E. Pit = front end alignment pit
GWET = groundwater extraction and treatment
HDPE = high density polyethylene
ICs = institutional controls
ISCO = in-situ chemical oxidation
MNA = monitored natural attenuation
MTBE = methyl tertiary butyl ether
NPDES = National Pollutant Discharge Elimination System
PCE = tetrachloroethene
POTW = publicly owned treatment works
SSD = sub-slab depressurization
SVE = soil vapor extraction
TBA = tertiary butyl alcohol
TCE = trichloroethylene
TPH = total petroleum hydrocarbons
VOC = volatile organic compounds
ZVI = zero valent iron

TABLE 4

EVALUATION OF REMEDIAL ALTERNATIVES

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Feasibility Evaluation Criteria									
	Overall Protection of Human Health and Environment (Corrective Action Objectives)			Effectiveness			Implementability	Cost		Sustainability
				Short-Term Effectiveness	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume				
Corrective Action Alternative	**Mitigate Vapor Intrusion Risk to Future Site Occupants**	**Mitigate Potential Exposure to Future Construction and Maintenance Workers**	**Remediate Residual Source Material in the Vicinity of the Former Sump and F.E. Pit**	**Risk Associated with Alternative Implementation and Risk Reduction in Short Term due to Alternative Implementation**	**Reduction of COCs or Mitigation of Health Risks to Reduce Long-Term Reliance on O&M**	**COC Distribution and Concentration**	**Technical Feasibility, Engineering Services, Materials, Approvals, and Permits**	**Estimated Cost of Remedial Action**	**Estimated Additional Cost of Contingency Remedial Action**	**Water Conservation, Energy Saving, Waste and GHG Minimization, Local Economy Boost, and Stakeholder Satisfaction**
Alternative 1 Soil excavation/ disposal, groundwater monitoring, long-term site management and institutional controls	**No** No action is taken to remediate or mitigate vapor concentrations from PCE-impacted groundwater at the site.	**Yes** A SMP will be prepared to provide health and safety guidance during subsurface intrusive activities.	**Yes** Impacted soil at the former sump and F.E. Pit will be removed.	Alternative 1 implementation poses relatively low risk associated with soil removal and future subsurface work at the site. Alternative 1 does actively reduce soil impacts, but does not remove VOCs from impacted GW or prevent possible vapor intrusion.	Alternative 1 does not reduce the extent and concentrations of VOCs in site GW, and does not provide mitigation against possible vapor intrusion concerns, except to the extent that institutional controls will control future site use in the northern portion of the site and prevent the use of groundwater.	Alternative 1 effectively reduces or eliminates the presence of soil impacts at the former sump and F.E. Pit. Alternative 1 does not reduce VOC concentrations in GW or soil vapor.	Materials and engineering services are readily available. Regulatory approvals and discharge permits for implementation of the proposed remedial alternative are expected to be readily obtainable. Services to implement institutional controls are expected to be readily obtainable.	$680,000	---	***Sustainable*** *:* Relatively limited excavation will generate soil that will require disposal off site. Requires long-term monitoring involving travel to the site, which produces greenhouse gas emissions as well as waste from sampling activities.
Alternative 2 Vapor barrier and sub-slab depressurization, plus soil excavation/ disposal, groundwater monitoring, long-term site management and institutional controls	**Yes** A vapor barrier and SSD will effectively mitigate intrusion of VOC-impacted vapor to newly-constructed structures. The SSD creates a negative pressure, venting impacted vapors to the atmosphere. Monitoring will be used to determine the effectiveness of the corrective action. A SMP, long-term monitoring, and institutional controls will be in place to assure the long-term implementation of the alternative.	**Yes** A SMP will be prepared to provide health and safety guidance during subsurface intrusive activities.	**Yes** Impacted soil at the former sump and F.E. Pit will be removed.	Alternative 2 implementation poses relatively low risks associated with subsurface work at the site. Alternative 2 does actively reduce soil impacts and mitigates vapor intrusion but does not remove VOCs from impacted GW.	Alternative 2 provides long term protection against vapor intrusion, but does not reduce the extent and concentrations of VOCs in site GW.	Alternative 2 effectively reduces or eliminates the presence of soil impacts at the former sump and F.E. Pit and mitigates soil vapor intrusion. Alternative 2 does not reduce VOC concentrations in GW.	Materials and engineering services are readily available. Regulatory approvals and discharge permits for implementation of the proposed remedial alternative are expected to be readily obtainable. Services to implement institutional controls are expected to be readily obtainable.	$1,360,000	$220,000	***Sustainable*** *:* Relatively limited excavation will generate soil that will require disposal off site. Requires long-term monitoring involving travel to the site, which produces greenhouse gas emissions as well as waste from sampling activities. Installation of the vapor barrier is material- and equipment-intensive and will produce GHG emissions in the short term.

TABLE 4

EVALUATION OF REMEDIAL ALTERNATIVES

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

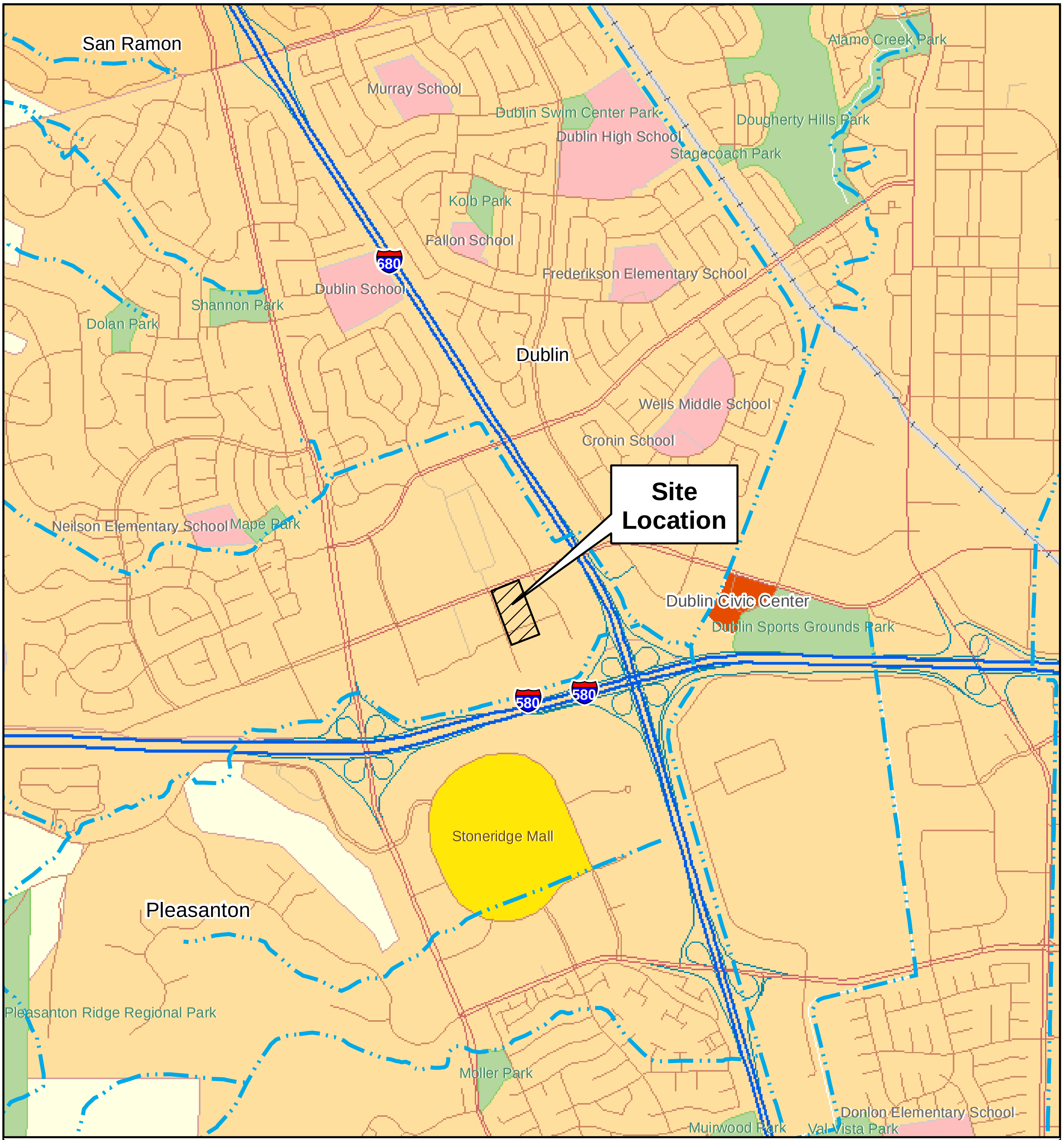
	Feasibility Evaluation Criteria									
	Overall Protection of Human Health and Environment (Corrective Action Objectives)			Effectiveness			Implementability	Cost		Sustainability
				Short-Term Effectiveness	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume				
Corrective Action Alternative	Mitigate Vapor Intrusion Risk to Future Site Occupants	Mitigate Potential Exposure to Future Construction and Maintenance Workers	Remediate Residual Source Material in the Vicinity of the Former Sump and F.E. Pit	Risk Associated with Alternative Implementation and Risk Reduction in Short Term due to Alternative Implementation	Reduction of COCs or Mitigation of Health Risks to Reduce Long-Term Reliance on O&M	COC Distribution and Concentration	Technical Feasibility, Engineering Services, Materials, Approvals, and Permits	Estimated Cost of Remedial Action	Estimated Additional Cost of Contingency Remedial Action	Water Conservation, Energy Saving, Waste and GHG Minimization, Local Economy Boost, and Stakeholder Satisfaction
Alternative 3 Permeable reactive barrier with zero-valent iron, plus vapor barrier and sub-slab depressurization, soil excavation/disposal, groundwater monitoring, and long-term site management and institutional controls	**Yes** The vapor barrier and SSD effectively mitigate vapor intrusion concerns. The PRB does not directly contribute to the mitigation of vapor intrusion risks, except to the extent that it prevents the possibility of higher-concentration groundwater from entering the site. Further, the vapor barrier/SSD system would be in place to effectively mitigate an increase in vapor concentrations, should they occur.	**Yes** A SMP will be prepared to provide health and safety guidance during subsurface intrusive activities.	**Yes** Impacted soil at the former sump and F.E. Pit will be removed.	Alternative 3 implementation poses low risks associated with subsurface work at the site. Alternative 3 does actively reduce soil impacts and mitigates vapor intrusion, but does not remove VOCs across the site from impacted GW in the short term. It would, however, mitigate VOC concentrations in groundwater near the PRB in the short term, and prevent any potential higher-concentration groundwater from entering the site.	Alternative 3 provides long term protection against vapor intrusion and long term protection against increases in VOCs concentrations in site GW, but likely will not reduce the extent and concentrations of existing VOCs in site GW. Although this alternative prevents higher-concentration groundwater from entering the site, it does not directly contribute to the mitigation of vapor intrusion, which will be effectively mitigated by the vapor barrier/SSD system.	Alternative 3 effectively reduces or eliminates the presence of soil impacts at the former sump and F.E. Pit and mitigates soil vapor intrusion. Alternative 3 does prevent future increases of VOC concentrations in GW, but does not address existing VOC concentrations in GW in a reasonable amount of time.	Materials and engineering services are readily available. Regulatory approvals and discharge permits for implementation of the proposed remedial alternative are expected to be readily obtainable. Services to implement institutional controls are expected to be readily obtainable.	$2,280,000	$400,000	***Moderately Sustainable*:** Installation of the PRB will generate additional soil that will have to be disposed of off site. Installation of the PRB and substrate is equipment intensive and will produce greenhouse gas emissions in the short term. However, a PRB is a passive, low-maintenance alternative that is sustainable in the long-term.
Alternative 4a In-situ bioremediation, permeable reactive barrier with zero-valent iron, vapor intrusion barrier and sub-slab depressurization, soil excavation/disposal, groundwater monitoring, and long-term site management and institutional controls	**Yes** The vapor barrier and SSD effectively mitigate vapor intrusion concerns. The *in situ* bioremediation, if effective, would reduce VOC concentrations in groundwater, such that reliance on the vapor barrier/SSD system is not necessary.	**Yes** A SMP will be prepared to provide health and safety guidance during subsurface intrusive activities.	**Yes** Impacted soil at the former sump and F.E. Pit will be removed.	Alternative 4a implementation poses low risks associated with subsurface work at the site. Alternative 4a does actively reduce soil impacts and mitigates vapor intrusion. However, it is uncertain that this alternative, which would require nutrient injection and bio-augmentation over a limited time frame, could effectively reduce VOC concentrations in the short term.	Alternative 4a provides long term protection against vapor intrusion and long term protection against increases in VOC concentrations in site GW. It is uncertain, given the limited time frame over which to inject nutrients and bio-augment site groundwater, that this alternative would be effective in the long term.	Alternative 4a effectively reduces or eliminates the presence of soil impacts at the former sump and F.E. Pit, mitigates soil vapor intrusion, and has the potential to reduce VOC concentrations in GW. However it is uncertain that an *in situ* program over a limited time frame could be effective at the site.	Materials and engineering services are readily available. Regulatory approvals and discharge permits for implementation of the proposed remedial alternative are expected to be readily obtainable. Services to implement institutional controls are expected to be readily obtainable.	$2,970,000	$400,000[1]	***Moderately Sustainable*:** Installation of the PRB will generate additional soil that will have to be disposed of off site. Installation of the PRB and substrate is equipment intensive and will produce greenhouse gas emissions in the short term. However, a PRB is a passive, low-maintenance alternative that is sustainable in the long-term. Additionaly resources will be expended to perform the *in situ* injections.

Notes
1. Contingency costs shown for Alternative 4a are associated with the vapor barrier/sub-slab depressurization system and the permeable reactive barrier.

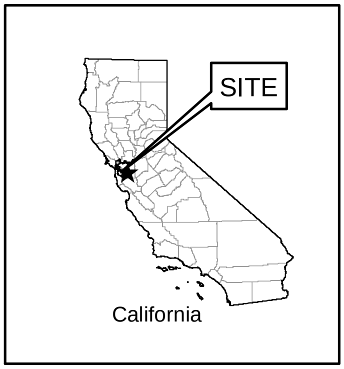
Abbreviations

COC = constituent of concern
F.E. Pit = Front End Alignment Pit
GW = groundwater
IC = institutional control
PRB = permeable reactive barrier
SMP = site management plan
SSD = sub-slab depressurization
VI = vapor intrusion
VOC = volatile organic compound

FIGURES



Street map from ESRI, 2007.



SITE LOCATION MAP
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 11/08/2013	Project No. OD10160070
amec		Figure 1

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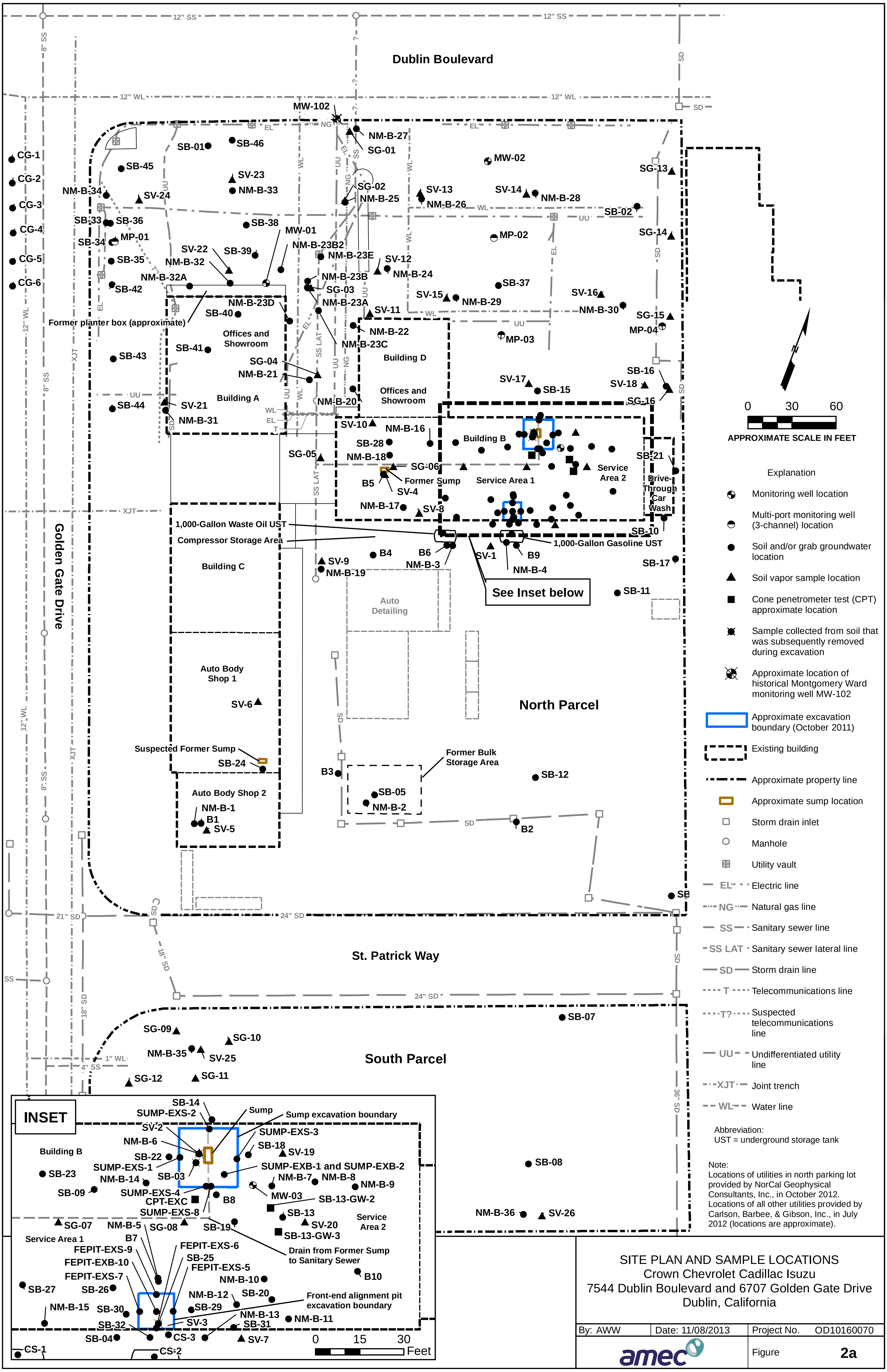

Abbreviation:
UST = underground storage tank

Note:
Locations of utilities in north parking lot provided by NorCal Geophysical Consultants, Inc., in October 2012. Locations of all other utilities provided by Carlson, Barbee, & Gibson, Inc., in July 2012 (locations are approximate).

SITE PLAN AND SAMPLE LOCATIONS
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 11/08/2013	Project No.	OD10160070
amec		Figure	2a

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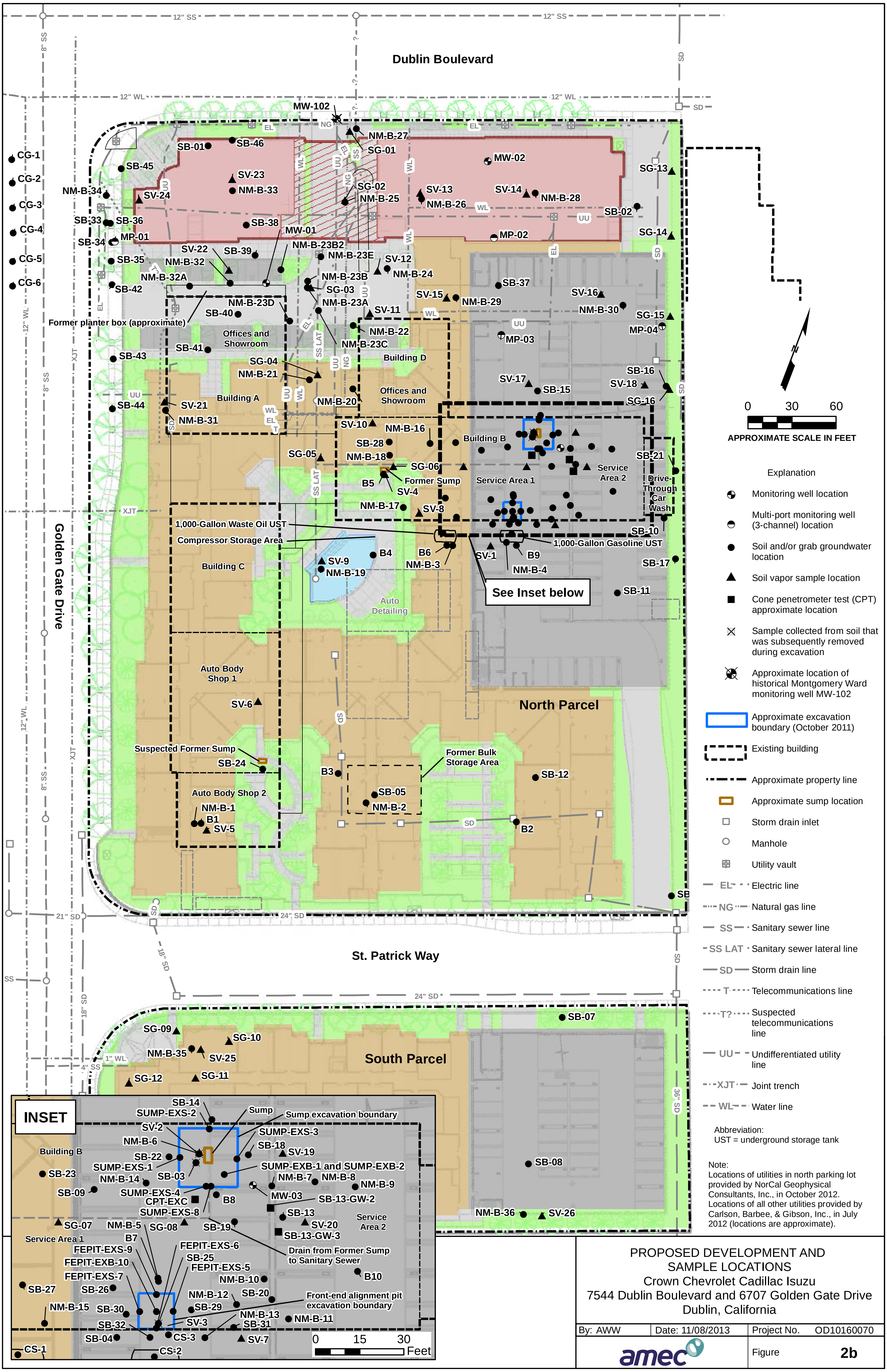


Explanation

◕	Monitoring well location
◓	Multi-port monitoring well (3-channel) location
●	Soil and/or grab groundwater location
▲	Soil vapor sample location
■	Cone penetrometer test (CPT) approximate location
✕	Sample collected from soil that was subsequently removed during excavation
✕	Approximate location of historical Montgomery Ward monitoring well MW-102
▭	Approximate excavation boundary (October 2011)
▭	Existing building
— · —	Approximate property line
▭	Approximate sump location
□	Storm drain inlet
○	Manhole
⊞	Utility vault
— EL —	Electric line
— NG —	Natural gas line
— SS —	Sanitary sewer line
— SS LAT —	Sanitary sewer lateral line
— SD —	Storm drain line
— T —	Telecommunications line
— T? —	Suspected telecommunications line
— UU —	Undifferentiated utility line
— XJT —	Joint trench
— WL —	Water line

Abbreviation:
UST = underground storage tank

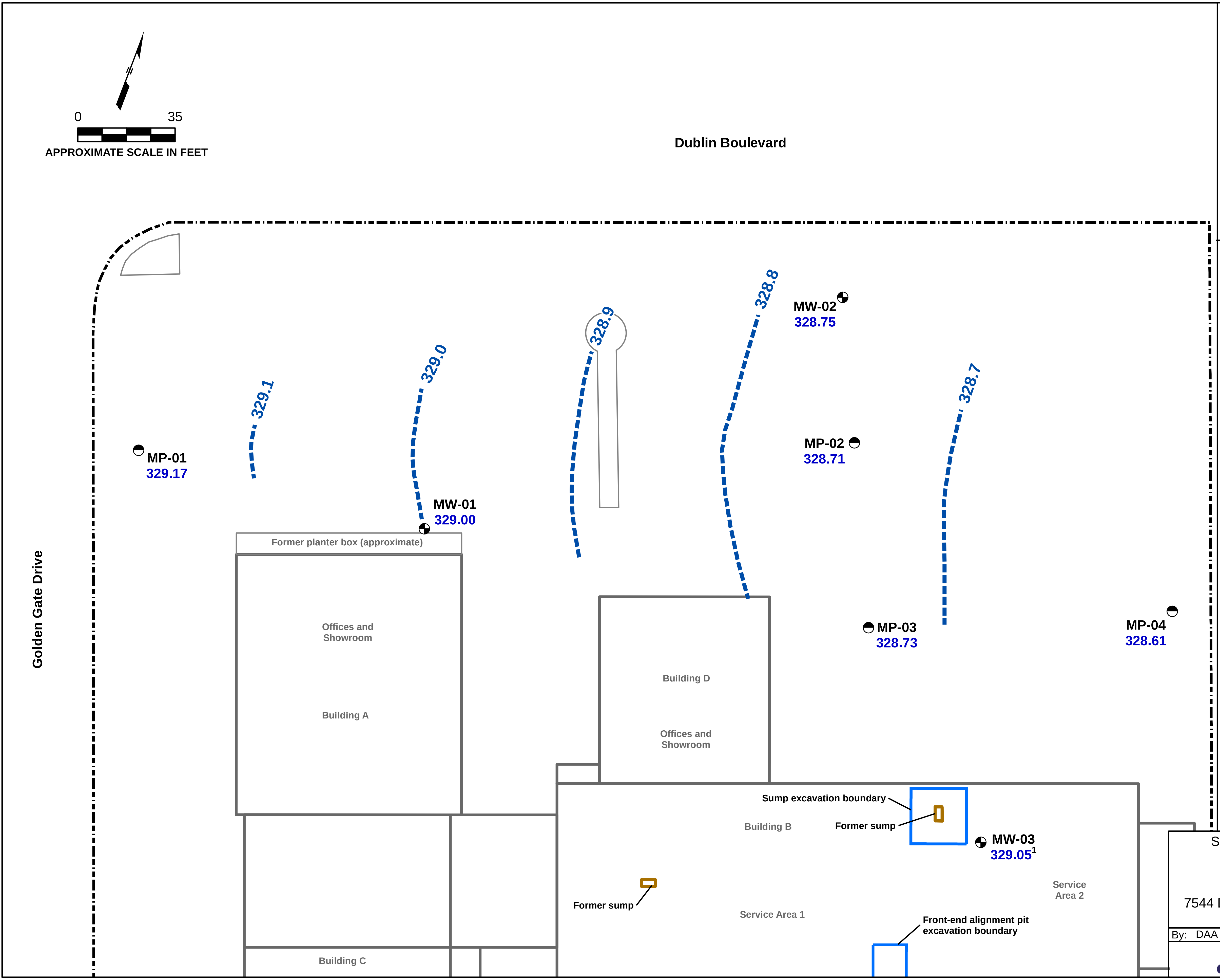
Note:
Locations of utilities in north parking lot provided by NorCal Geophysical Consultants, Inc., in October 2012. Locations of all other utilities provided by Carlson, Barbee, & Gibson, Inc., in July 2012 (locations are approximate).

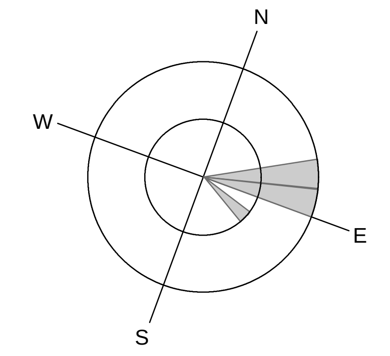
PROPOSED DEVELOPMENT AND
SAMPLE LOCATIONS
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW | Date: 11/08/2013 | Project No. OD10160070

amec

Figure 2b





Rose diagram of
shallow groundwater flow direction

Explanation

◐ AMEC shallow monitoring well location (installed August 2012)

◒ AMEC multi-port monitoring well (3-channel) location (installed August 2012)

329.00 Groundwater elevation in feet above mean sea level (msl), measured on October 28, 2013.

- -329.0- Line of equal groundwater elevation in feet msl. Contours are approximate; contour interval = 0.1 feet.

▭ Approximate excavation boundary (October 2011)

-·-·- Approximate property line

▭ Approximate sump location

Note:
1. The water level measured in MW-03 on October 28, 2013 does not appear to reflect proper equilibration with atmospheric pressure. For this reason, the groundwater elevation measured in MW-03 was not used in the contouring of the potentiometric surface.

SHALLOW POTENTIOMETRIC SURFACE
NORTH PARCEL
OCTOBER 2013
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: DAA	Date: 04/30/2014	Project No.	OD10160070
amec		Figure	3

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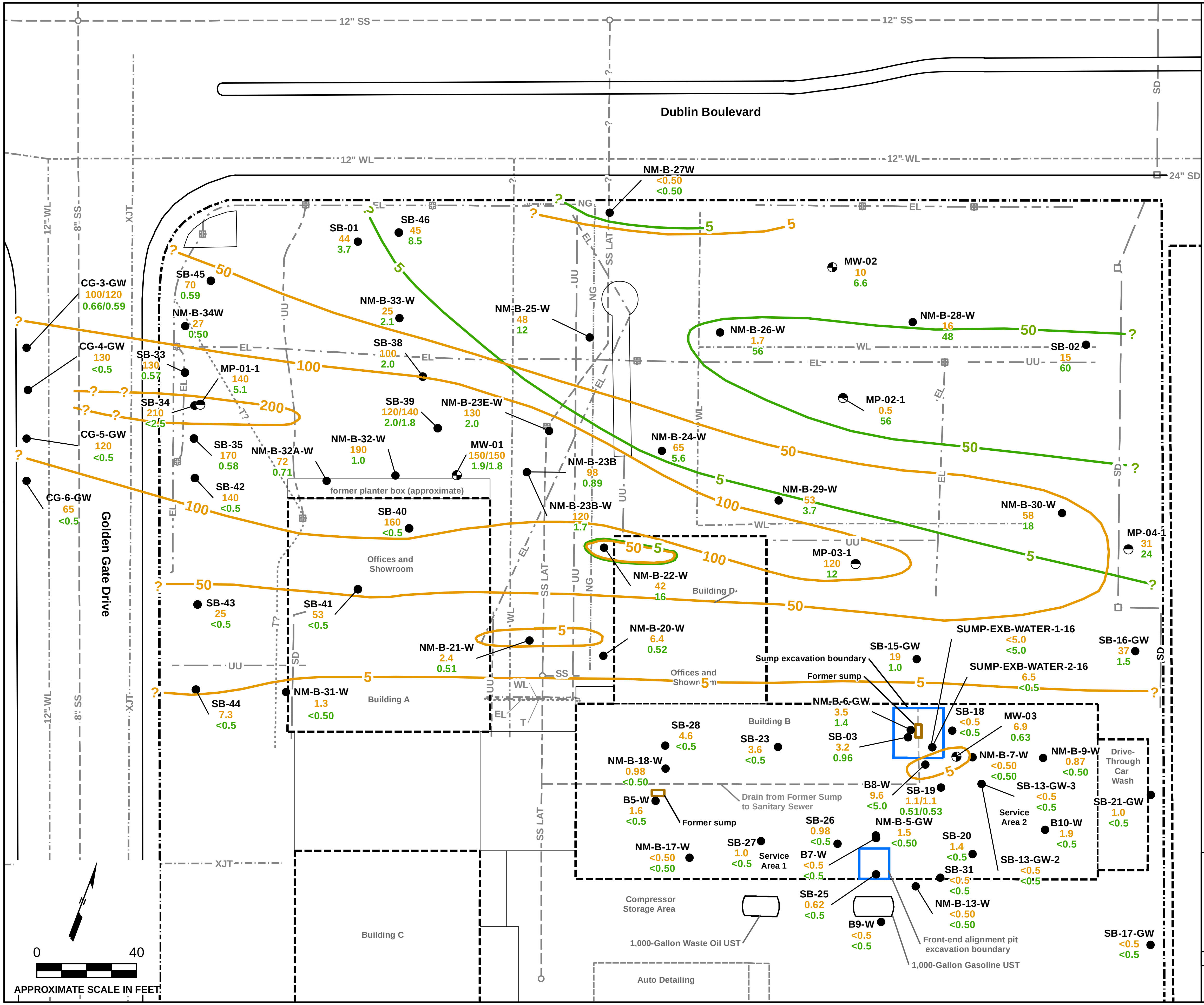

Explanation

—50— Approximate line of equal PCE concentration
—50— Approximate line of equal TCE concentration

MW-01 ← Well/Boring ID
150/150 ← PCE concentration in µg/L
1.9/1.8 ← TCE concentration in µg/L
Duplicate data
Grab groundwater sample

Drinking Water ESLs (µg/L)	
PCE	5.0
TCE	5.0

◕	Shallow monitoring well location (October 2013)
◒	Multi-port monitoring well (3-channel) location (October 2013)
●	Soil and/or grab groundwater location (various dates 2010-2013)
▭	Approximate excavation boundary (October 2011)
—·—·	Approximate property line
▬	Approximate sump location
☐	Storm drain inlet
○	Manhole
⊞	Utility vault
– · EL · –	Electric line
···NG···	Natural gas line
– SS –	Sanitary sewer line
–SS LAT–	Sanitary sewer lateral line
– SD –	Storm drain line
·····T·····	Telecommunications line
····T?····	Suspected telecommunications line
– UU· –	Undifferentiated utility line
·–XJT–·	Joint trench
– · WL · –	Water line

Abbreviations:
ESL = Environmental Screening Level
NS = not sampled
PCE = tetrachloroethene
TCE = trichloroethene
UST = underground storage tank
µg/L = micrograms per liter
< = not detected at or above laboratory reporting limit shown

PCE AND TCE IN SHALLOW GROUNDWATER
NORTH PARCEL
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 03/21/2014	Project No. OD10160070
		Figure 4

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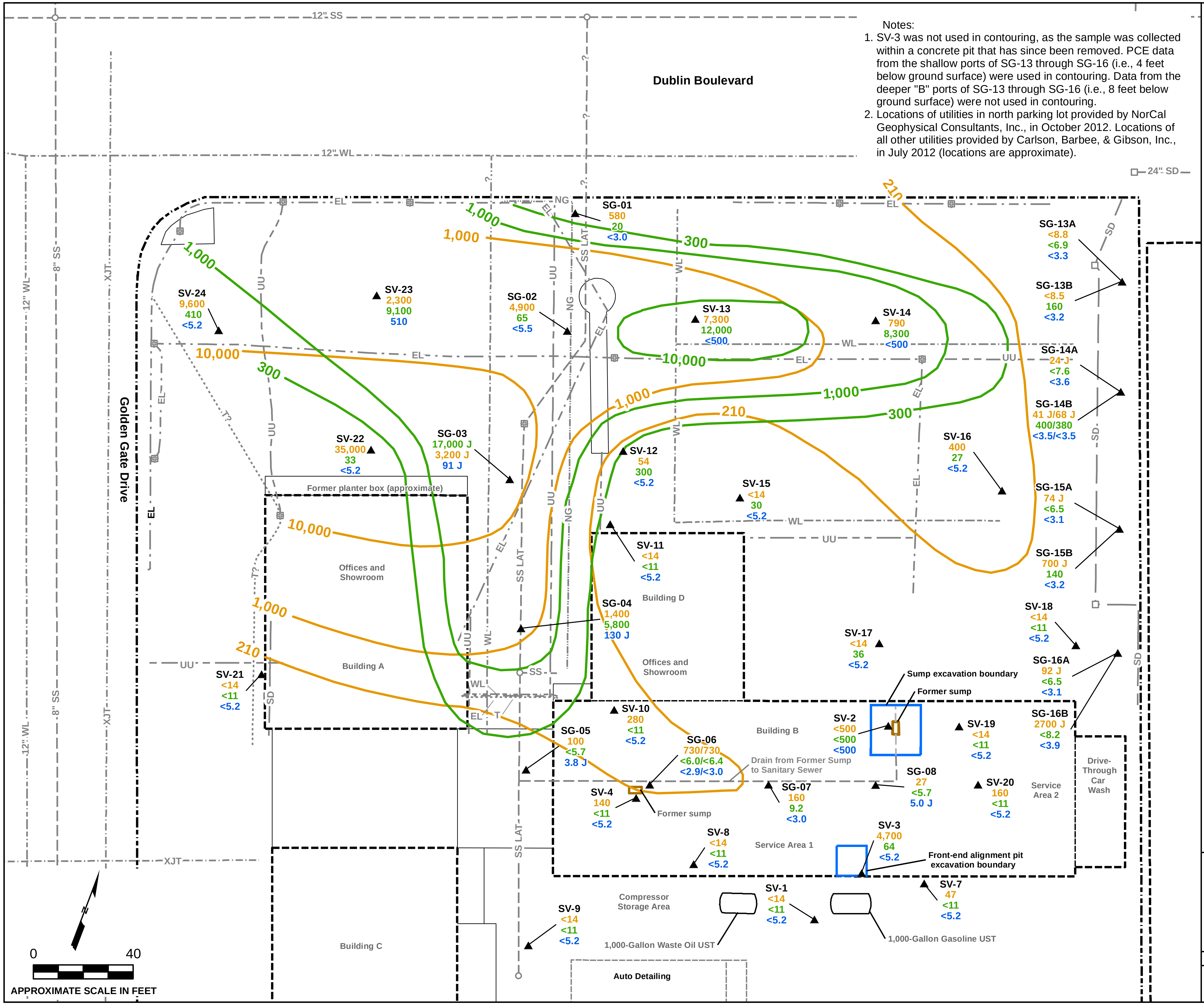


Notes:

1. SV-3 was not used in contouring, as the sample was collected within a concrete pit that has since been removed. PCE data from the shallow ports of SG-13 through SG-16 (i.e., 4 feet below ground surface) were used in contouring. Data from the deeper "B" ports of SG-13 through SG-16 (i.e., 8 feet below ground surface) were not used in contouring.
2. Locations of utilities in north parking lot provided by NorCal Geophysical Consultants, Inc., in October 2012. Locations of all other utilities provided by Carlson, Barbee, & Gibson, Inc., in July 2012 (locations are approximate).

Explanation

—210— Approximate line of equal PCE concentration

—1,000— Approximate line of equal TCE concentration

"A" indicates sample from 4 feet bgs;
"B" indicates sample from 8 feet bgs.

SG-14B	Well/Boring ID
41 J/68 J	PCE concentration in µg/m^3
400/380	TCE concentration in µg/m^3
<3.5/<3.5	VC concentration in µg/m^3

Duplicate data

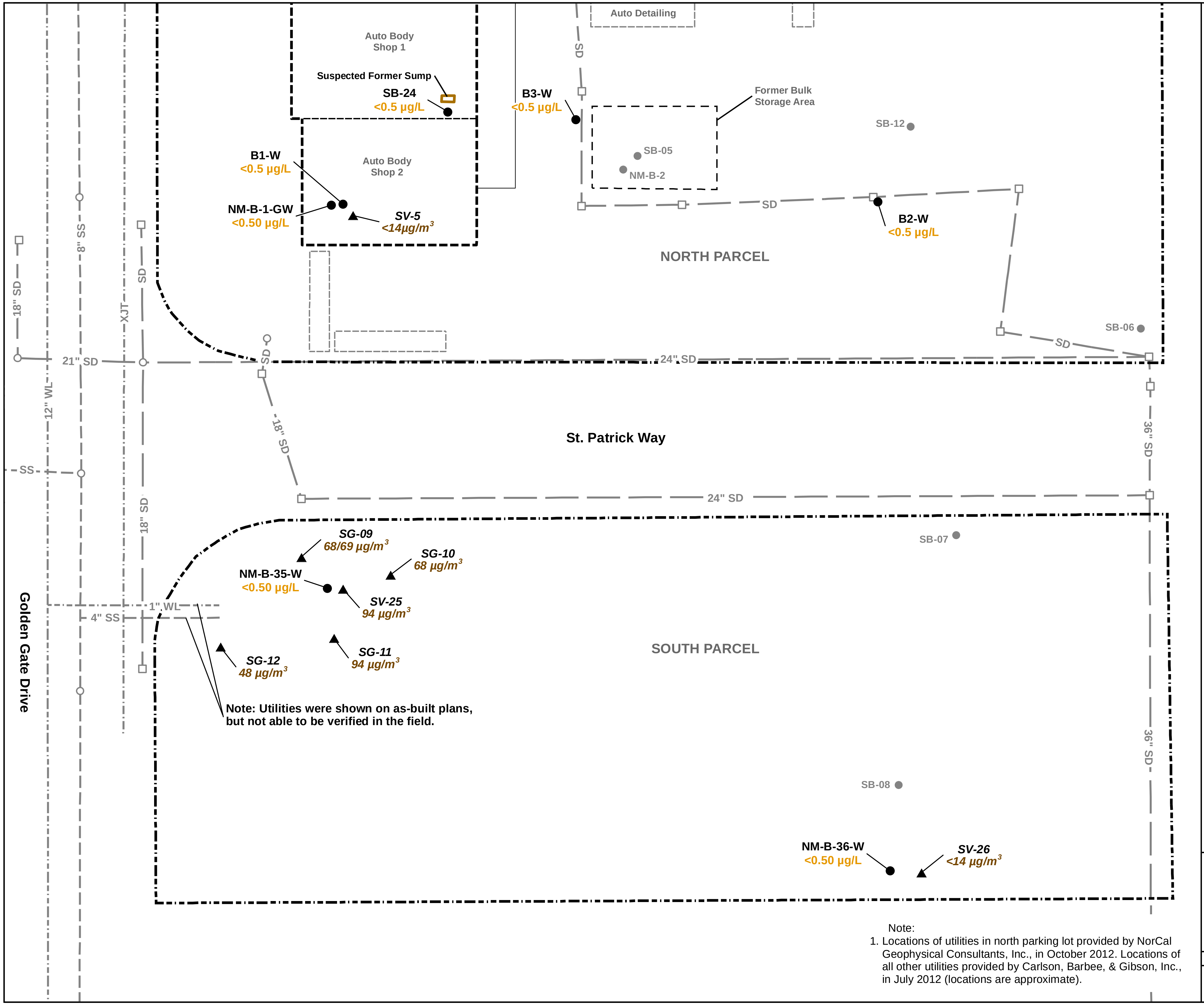
Soil Vapor ESLs (µg/m^3) (Residential Land Use)	
PCE	210
TCE	300
Vinyl chloride	31

▲	Soil vapor sample location
▭	Approximate excavation boundary (October 2011)
·—·—·—	Approximate property line
▬	Approximate sump location
□	Storm drain inlet
○	Manhole
⊞	Utility vault
— · EL · —	Electric line
··— NG —··	Natural gas line
— · SS — —	Sanitary sewer line
— SS LAT —	Sanitary sewer lateral line
— SD —	Storm drain line
·····T·····	Telecommunications line
····T?····	Suspected telecommunications line
— UU · —	Undifferentiated utility line
·—XJT—·	Joint trench
— — WL — ·	Water line

Abbreviations:
bgs = below ground surface
ESL = Environmental Screening Level
PCE = tetrachloroethene
TCE = trichloroethene
UST = underground storage tank
VC = vinyl chloride
µg/m³ = micrograms per cubic meter
< = not detected at or above laboratory reporting limit shown
J = estimated value

PCE, TCE, AND VINYL CHLORIDE IN SOIL VAPOR
NORTH PARCEL
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 04/30/2014	Project No. OD10160070
amec		Figure 5



Note:
1. Locations of utilities in north parking lot provided by NorCal Geophysical Consultants, Inc., in October 2012. Locations of all other utilities provided by Carlson, Barbee, & Gibson, Inc., in July 2012 (locations are approximate).

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Explanation

● Soil and/or grab groundwater sample location

▲ Soil vapor sample location

Soil Vapor Data:
SG-10 ← Well/Boring ID
68 µg/m³ ← PCE concentration in micrograms per cubic meter (µg/m³)

Soil Vapor ESLs (µg/m³) (Residential Land Use)	
PCE	210

Groundwater Data:
NM-B-35-W ← Well/Boring ID
<0.50 µg/L ← PCE concentration in micrograms per liter (µg/L)

Drinking Water ESL (µg/L)	
PCE	5.0

-·-·- Approximate property line

☐ Storm drain inlet

○ Manhole

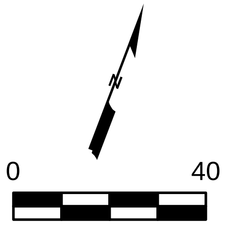
— SS — Sanitary sewer line

— SD — Storm drain line

-·-XJT-·- Joint trench

-- WL -- Water line

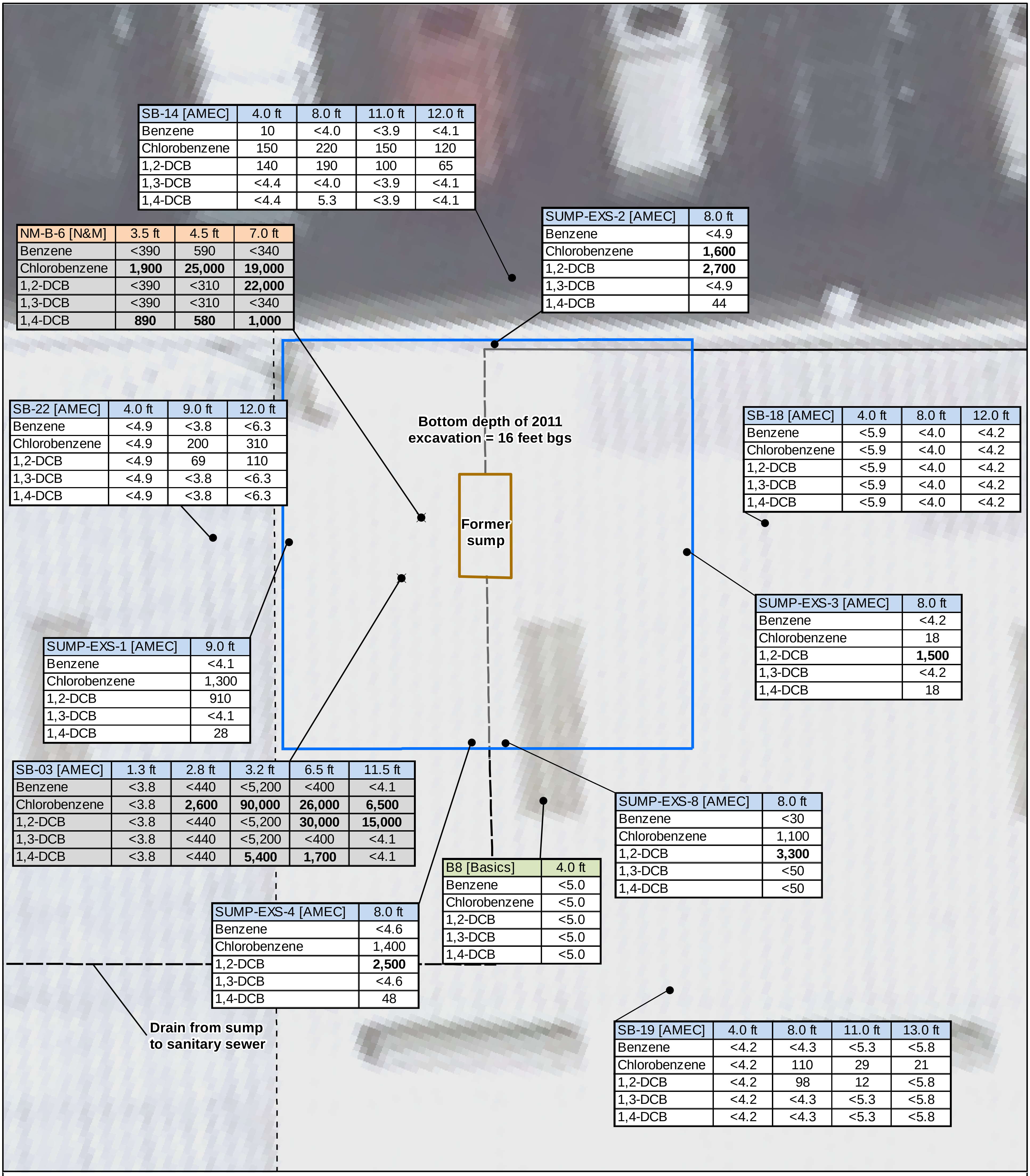
Abbreviations:
ESL = Environmental Screening Level
PCE = tetrachloroethene
µg/L = micrograms per liter
µg/m³ = micrograms per cubic meter
< = not detected at or above laboratory reporting limit shown



APPROXIMATE SCALE IN FEET

PCE IN GROUNDWATER AND SOIL VAPOR
SOUTH PARCEL
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 04/30/2014	Project No. OD10160070
amec		Figure 6



SB-14 [AMEC]	4.0 ft	8.0 ft	11.0 ft	12.0 ft
Benzene	10	<4.0	<3.9	<4.1
Chlorobenzene	150	220	150	120
1,2-DCB	140	190	100	65
1,3-DCB	<4.4	<4.0	<3.9	<4.1
1,4-DCB	<4.4	5.3	<3.9	<4.1

NM-B-6 [N&M]	3.5 ft	4.5 ft	7.0 ft
Benzene	<390	590	<340
Chlorobenzene	**1,900**	**25,000**	**19,000**
1,2-DCB	<390	<310	**22,000**
1,3-DCB	<390	<310	<340
1,4-DCB	**890**	**580**	**1,000**

SUMP-EXS-2 [AMEC]	8.0 ft
Benzene	<4.9
Chlorobenzene	**1,600**
1,2-DCB	**2,700**
1,3-DCB	<4.9
1,4-DCB	44

SB-22 [AMEC]	4.0 ft	9.0 ft	12.0 ft
Benzene	<4.9	<3.8	<6.3
Chlorobenzene	<4.9	200	310
1,2-DCB	<4.9	69	110
1,3-DCB	<4.9	<3.8	<6.3
1,4-DCB	<4.9	<3.8	<6.3

SB-18 [AMEC]	4.0 ft	8.0 ft	12.0 ft
Benzene	<5.9	<4.0	<4.2
Chlorobenzene	<5.9	<4.0	<4.2
1,2-DCB	<5.9	<4.0	<4.2
1,3-DCB	<5.9	<4.0	<4.2
1,4-DCB	<5.9	<4.0	<4.2

SUMP-EXS-3 [AMEC]	8.0 ft
Benzene	<4.2
Chlorobenzene	18
1,2-DCB	**1,500**
1,3-DCB	<4.2
1,4-DCB	18

SUMP-EXS-1 [AMEC]	9.0 ft
Benzene	<4.1
Chlorobenzene	1,300
1,2-DCB	910
1,3-DCB	<4.1
1,4-DCB	28

SB-03 [AMEC]	1.3 ft	2.8 ft	3.2 ft	6.5 ft	11.5 ft
Benzene	<3.8	<440	<5,200	<400	<4.1
Chlorobenzene	<3.8	**2,600**	**90,000**	**26,000**	**6,500**
1,2-DCB	<3.8	<440	<5,200	**30,000**	**15,000**
1,3-DCB	<3.8	<440	<5,200	<400	<4.1
1,4-DCB	<3.8	<440	**5,400**	**1,700**	<4.1

SUMP-EXS-8 [AMEC]	8.0 ft
Benzene	<30
Chlorobenzene	1,100
1,2-DCB	**3,300**
1,3-DCB	<50
1,4-DCB	<50

B8 [Basics]	4.0 ft
Benzene	<5.0
Chlorobenzene	<5.0
1,2-DCB	<5.0
1,3-DCB	<5.0
1,4-DCB	<5.0

SUMP-EXS-4 [AMEC]	8.0 ft
Benzene	<4.6
Chlorobenzene	1,400
1,2-DCB	**2,500**
1,3-DCB	<4.6
1,4-DCB	48

SB-19 [AMEC]	4.0 ft	8.0 ft	11.0 ft	13.0 ft
Benzene	<4.2	<4.3	<5.3	<5.8
Chlorobenzene	<4.2	110	29	21
1,2-DCB	<4.2	98	12	<5.8
1,3-DCB	<4.2	<4.3	<5.3	<5.8
1,4-DCB	<4.2	<4.3	<5.3	<5.8

Explanation

● Soil and/or grab groundwater location

✱ Sample collected from soil that was subsequently removed during excavation

▭ Approximate excavation boundary (2011)

- - - - Interior building wall

——— Approximate location of above-ground drain line

— — — Approximate location of below-ground drain line

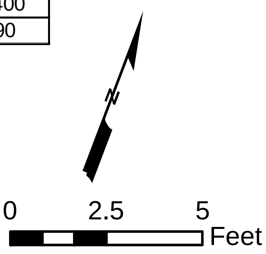
Sampler

Sample ID – Sample depth (bgs)

Constituent – Concentration (µg/kg)

B8 [Basics]	4.0 ft
Benzene	<5.0
Chlorobenzene	<5.0
1,2-DCB	<5.0
1,3-DCB	<5.0
1,4-DCB	<5.0

Shallow Soil ESLs (µg/kg) (Residential Land Use)	
Benzene	44
Chlorobenzene	1,500
1,2-DCB	1,100
1,3-DCB	7,400
1,4-DCB	590



Notes:
1. Analytes shown on this figure were detected in at least one soil sample above their ESLs. Results shown in **bold** exceed their respective ESLs. Although gasoline range organics (GRO) were detected in samples SB-03-3.2 and NM-B-6 above the GRO ESL, the GRO values reported are likely due to the presence of non-gasoline VOCs in the samples; therefore, they are not reported here.
2. Shading indicates that the sample was collected from soil that was subsequently removed during excavation.
3. For clarity, borings not advanced adjacent to the 2011 excavation areas, or with samples not analyzed for target constituents, are not shown on this figure.

Abbreviations:
1,2-DCB = 1,2-dichlorobenzene
1,3-DCB = 1,3-dichlorobenzene
1,4-DCB = 1,4-dichlorobenzene
Basics = Basics Environmental, Inc.
bgs = below ground surface
ESLs = Environmental Screening Levels
ft. = feet
F.E. Pit = Front-end alignment pit
µg/kg = micrograms per kilogram
N&M = Ninyo & Moore
< = not detected at or above above the laboratory reporting limit shown
VOCs = volatile organic compounds

SELECTED VOCs IN SOIL
FORMER SUMP AREA
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 04/30/2014	Project No.	OD10160070
amec		Figure	7

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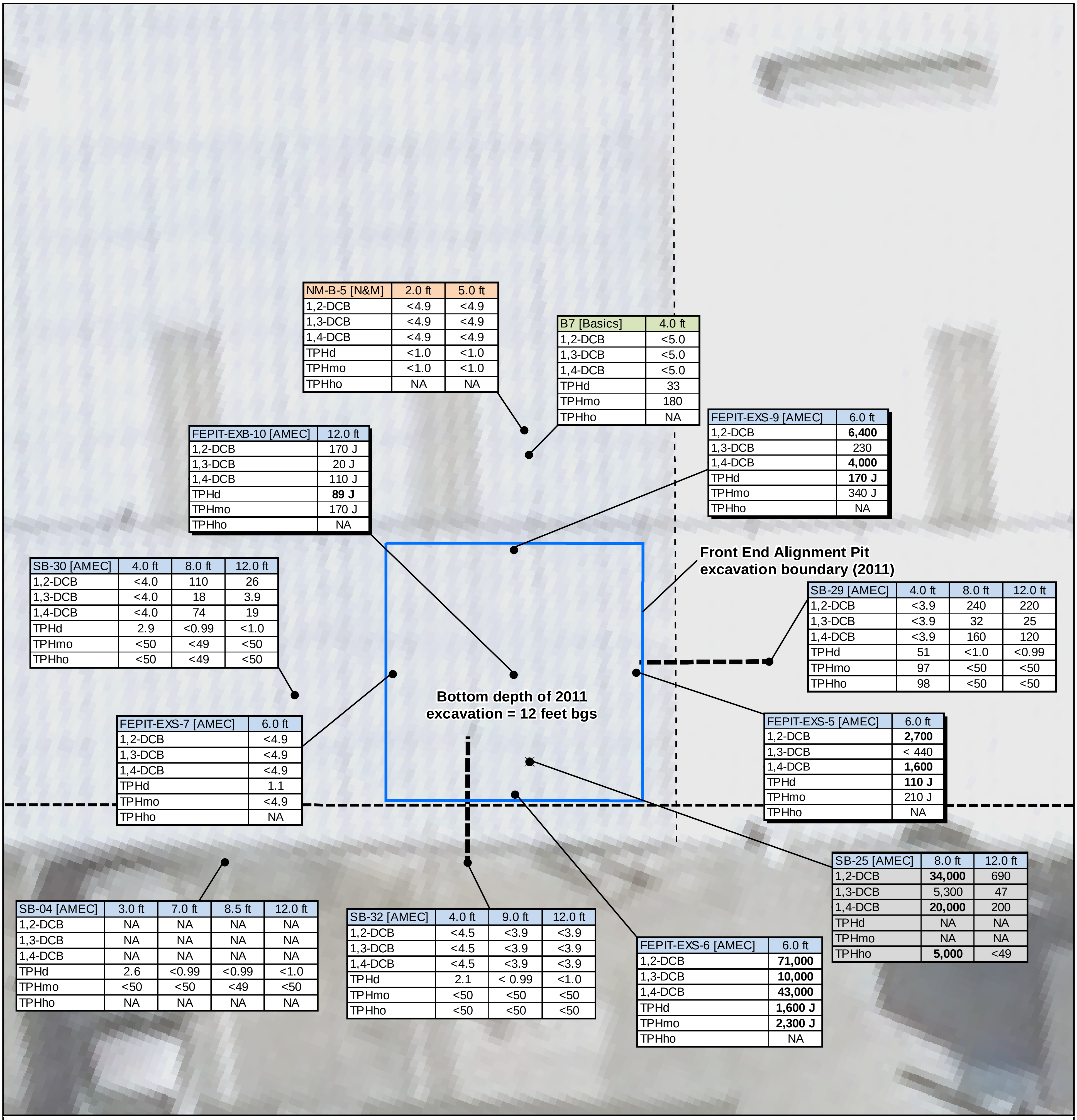


NM-B-5 [N&M]	2.0 ft	5.0 ft
1,2-DCB	<4.9	<4.9
1,3-DCB	<4.9	<4.9
1,4-DCB	<4.9	<4.9
TPHd	<1.0	<1.0
TPHmo	<1.0	<1.0
TPHho	NA	NA

B7 [Basics]	4.0 ft
1,2-DCB	<5.0
1,3-DCB	<5.0
1,4-DCB	<5.0
TPHd	33
TPHmo	180
TPHho	NA

FEPIT-EXB-10 [AMEC]	12.0 ft
1,2-DCB	170 J
1,3-DCB	20 J
1,4-DCB	110 J
TPHd	**89 J**
TPHmo	170 J
TPHho	NA

FEPIT-EXS-9 [AMEC]	6.0 ft
1,2-DCB	**6,400**
1,3-DCB	230
1,4-DCB	**4,000**
TPHd	**170 J**
TPHmo	340 J
TPHho	NA

SB-30 [AMEC]	4.0 ft	8.0 ft	12.0 ft
1,2-DCB	<4.0	110	26
1,3-DCB	<4.0	18	3.9
1,4-DCB	<4.0	74	19
TPHd	2.9	<0.99	<1.0
TPHmo	<50	<49	<50
TPHho	<50	<49	<50

SB-29 [AMEC]	4.0 ft	8.0 ft	12.0 ft
1,2-DCB	<3.9	240	220
1,3-DCB	<3.9	32	25
1,4-DCB	<3.9	160	120
TPHd	51	<1.0	<0.99
TPHmo	97	<50	<50
TPHho	98	<50	<50

FEPIT-EXS-7 [AMEC]	6.0 ft
1,2-DCB	<4.9
1,3-DCB	<4.9
1,4-DCB	<4.9
TPHd	1.1
TPHmo	<4.9
TPHho	NA

FEPIT-EXS-5 [AMEC]	6.0 ft
1,2-DCB	**2,700**
1,3-DCB	< 440
1,4-DCB	**1,600**
TPHd	**110 J**
TPHmo	210 J
TPHho	NA

SB-25 [AMEC]	8.0 ft	12.0 ft
1,2-DCB	**34,000**	690
1,3-DCB	5,300	47
1,4-DCB	**20,000**	200
TPHd	NA	NA
TPHmo	NA	NA
TPHho	**5,000**	<49

SB-04 [AMEC]	3.0 ft	7.0 ft	8.5 ft	12.0 ft
1,2-DCB	NA	NA	NA	NA
1,3-DCB	NA	NA	NA	NA
1,4-DCB	NA	NA	NA	NA
TPHd	2.6	<0.99	<0.99	<1.0
TPHmo	<50	<50	<49	<50
TPHho	NA	NA	NA	NA

SB-32 [AMEC]	4.0 ft	9.0 ft	12.0 ft
1,2-DCB	<4.5	<3.9	<3.9
1,3-DCB	<4.5	<3.9	<3.9
1,4-DCB	<4.5	<3.9	<3.9
TPHd	2.1	< 0.99	<1.0
TPHmo	<50	<50	<50
TPHho	<50	<50	<50

FEPIT-EXS-6 [AMEC]	6.0 ft
1,2-DCB	**71,000**
1,3-DCB	**10,000**
1,4-DCB	**43,000**
TPHd	**1,600 J**
TPHmo	**2,300 J**
TPHho	NA

Explanation

●	Soil and/or grab groundwater location
⊗	Sample collected from soil that was subsequently removed during excavation
▭	Approximate excavation boundary (2011)
▬ ▬ ▬	Approximate path of angled boring
- - - -	Interior building wall

Sampler

Sample ID – | B7 [Basics] | 4.0 ft | – Sample depth (bgs)

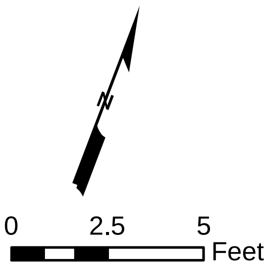
Constituent

B7 [Basics]	4.0 ft
1,2-DCB	<5.0
1,3-DCB	<5.0
1,4-DCB	<5.0
TPHd	33
TPHmo	180
TPHho	NA

Concentration (µg/kg)

Concentration (mg/kg)

Shallow Soil ESLs (Residential Land Use)		
1,2-DCB	1,100	µg/kg
1,3-DCB	7,400	
1,4-DCB	590	
TPHd	83	(mg/kg
TPHmo	500	
TPHho	500	



Abbreviations:

1,2-DCB = 1,2-dichlorobenzene
1,3-DCB = 1,3-dichlorobenzene
1,4-DCB = 1,4-dichlorobenzene
Basics = Basics Environmental, Inc.
bgs = below ground surface
ESLs = Environmental Screening Levels
ft. = feet
FEPIT = Front-end alignment pit
µg/kg = micrograms per kilogram
mg/kg = milligrams per kilogram
N&M = Ninyo & Moore
NA = not analyzed
< = not detected at or above above the laboratory reporting limit shown
J = The analyte was positively identified, and the associated numerical value is the approximate concentration of the analyte in the sample
TPH = total petroleum hydrocarbons
TPHd = TPH quantified as diesel
TPHmo = TPH quantified as motor oil
TPHho = TPH quantified as hydraulic oil
VOCs = volatile organic compounds

Notes:

1. Analytes shown on this figure were detected in at least one soil sample above their ESLs. Results shown in **bold** exceed their respective ESLs.
2. Shading indicates that the sample was collected from soil that was subsequently removed during excavation.
3. The sample chromotographic patterns did not match the laboratory's standards for diesel and motor oil.
4. For clarity, borings not advanced adjacent to the 2011 excavation areas, or with samples not analyzed for target constituents, are not shown on this figure.

TPH AND SELECTED VOCs IN SOIL
FRONT END ALIGNMENT PIT AREA
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW | Date: 04/30/2014 | Project No. OD10160070

amec

Figure **8**

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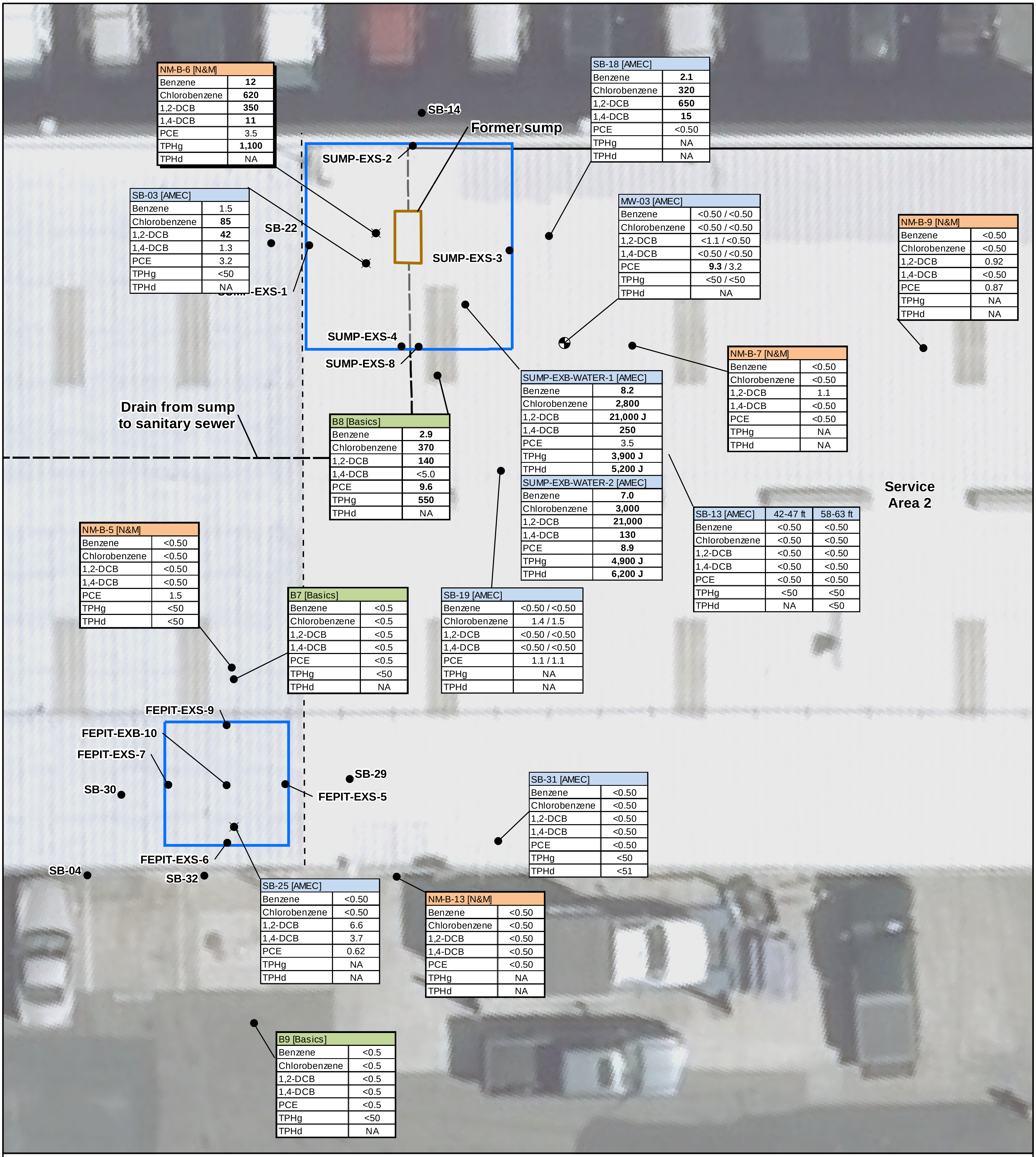


NM-B-6 [N&M]	
Benzene	**12**
Chlorobenzene	**620**
1,2-DCB	**350**
1,4-DCB	**11**
PCE	3.5
TPHg	**1,100**
TPHd	NA

SB-18 [AMEC]	
Benzene	**2.1**
Chlorobenzene	**320**
1,2-DCB	**650**
1,4-DCB	**15**
PCE	<0.50
TPHg	NA
TPHd	NA

SB-03 [AMEC]	
Benzene	1.5
Chlorobenzene	**85**
1,2-DCB	**42**
1,4-DCB	1.3
PCE	3.2
TPHg	<50
TPHd	NA

MW-03 [AMEC]	
Benzene	<0.50 / <0.50
Chlorobenzene	<0.50 / <0.50
1,2-DCB	<1.1 / <0.50
1,4-DCB	<0.50 / <0.50
PCE	**9.3** / 3.2
TPHg	<50 / <50
TPHd	NA

NM-B-9 [N&M]	
Benzene	<0.50
Chlorobenzene	<0.50
1,2-DCB	0.92
1,4-DCB	<0.50
PCE	0.87
TPHg	NA
TPHd	NA

NM-B-7 [N&M]	
Benzene	<0.50
Chlorobenzene	<0.50
1,2-DCB	1.1
1,4-DCB	<0.50
PCE	<0.50
TPHg	NA
TPHd	NA

SUMP-EXB-WATER-1 [AMEC]	
Benzene	**8.2**
Chlorobenzene	**2,800**
1,2-DCB	**21,000 J**
1,4-DCB	**250**
PCE	3.5
TPHg	**3,900 J**
TPHd	**5,200 J**
SUMP-EXB-WATER-2 [AMEC]	
Benzene	**7.0**
Chlorobenzene	**3,000**
1,2-DCB	**21,000**
1,4-DCB	**130**
PCE	**8.9**
TPHg	**4,900 J**
TPHd	**6,200 J**

B8 [Basics]	
Benzene	**2.9**
Chlorobenzene	**370**
1,2-DCB	**140**
1,4-DCB	<5.0
PCE	**9.6**
TPHg	**550**
TPHd	NA

SB-13 [AMEC]	42-47 ft	58-63 ft
Benzene	<0.50	<0.50
Chlorobenzene	<0.50	<0.50
1,2-DCB	<0.50	<0.50
1,4-DCB	<0.50	<0.50
PCE	<0.50	<0.50
TPHg	<50	<50
TPHd	NA	<50

NM-B-5 [N&M]	
Benzene	<0.50
Chlorobenzene	<0.50
1,2-DCB	<0.50
1,4-DCB	<0.50
PCE	1.5
TPHg	<50
TPHd	<50

B7 [Basics]	
Benzene	<0.5
Chlorobenzene	<0.5
1,2-DCB	<0.5
1,4-DCB	<0.5
PCE	<0.5
TPHg	<50
TPHd	NA

SB-19 [AMEC]	
Benzene	<0.50 / <0.50
Chlorobenzene	1.4 / 1.5
1,2-DCB	<0.50 / <0.50
1,4-DCB	<0.50 / <0.50
PCE	1.1 / 1.1
TPHg	NA
TPHd	NA

SB-31 [AMEC]	
Benzene	<0.50
Chlorobenzene	<0.50
1,2-DCB	<0.50
1,4-DCB	<0.50
PCE	<0.50
TPHg	<50
TPHd	<51

SB-25 [AMEC]	
Benzene	<0.50
Chlorobenzene	<0.50
1,2-DCB	6.6
1,4-DCB	3.7
PCE	0.62
TPHg	NA
TPHd	NA

NM-B-13 [N&M]	
Benzene	<0.50
Chlorobenzene	<0.50
1,2-DCB	<0.50
1,4-DCB	<0.50
PCE	<0.50
TPHg	NA
TPHd	NA

B9 [Basics]	
Benzene	<0.5
Chlorobenzene	<0.5
1,2-DCB	<0.5
1,4-DCB	<0.5
PCE	<0.5
TPHg	<50
TPHd	NA

Explanation

◐	Monitoring well location (August 2012 grab groundwater/September 2012 well sample)
●	Soil and/or grab groundwater location (various dates; October 2011 and earlier)
⊗	Sample collected from soil that was subsequently removed during excavation (various dates; prior to October 2011)
▭	Approximate excavation boundary (October 2011)
- - - -	Interior building wall
———	Approximate location of above-ground drain line
— — —	Approximate location of below-ground drain line

Notes:

1. Analytes shown on this figure were detected in at least one sample above their respective ESLs in this portion of the site. Results shown in **bold** exceed their respective ESLs. Although 1,2,4-trichlorobenzene was detected in the two sump excavation water samples (SUMP-EXB-WATER-1 and -2) above the ESL, this constituent was not detected in any other sample and these results are not presented here.
2. Reported TPHd results for samples collected by AMEC are from groundwater samples that were filtered prior to analysis.
3. Reported TPHd results for samples collected by Ninyo & Moore are from groundwater samples that were not filtered prior to analysis.
4. Duplicate samples were analyzed for SUMP-EXB-WATER-1 and SUMP-EXB-WATER-2. The highest detected concentration is reported in the data box.
5. Samples were collected from first-encountered groundwater unless a depth (in feet below ground surface) is indicated.
6. For clarity, borings not advanced adjacent to the 2011 excavation areas, or with samples not analyzed for target constituents, are not shown on this figure.

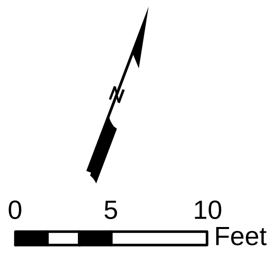
Abbreviations:

1,2-DCB = 1,2-dichlorobenzene
1,4-DCB = 1,4-dichlorobenzene
Basics = Basics Environmental, Inc.
ESLs = Environmental Screening Levels
FEPIT = Front end alignment pit
µg/L = micrograms per liter
N&M = Ninyo & Moore
NA = not analyzed
< = not detected at or above above the laboratory reporting limit shown
PCE = tetrachloroethene
TPH = total petroleum hydrocarbons
TPHg = TPH quantified as diesel
TPHd = TPH quantified as gasoline
J = The analyte was positively identified, and the associated numerical value is the approximate concentration of the analyte in the sample
VOCs = volatile organic compounds

Sampler
Sample ID –
Constituent
Concentration (µg/L)

B8 [Basics]	
Benzene	**2.9**
Chlorobenzene	**370**
1,2-DCB	**140**
1,4-DCB	<5.0
PCE	**9.6**
TPHg	**550**
TPHd	NA

Drinking Water ESLs (µg/L)	
Benzene	1.0
Chlorobenzene	25
1,2-DCB	10
1,4-DCB	5.0
PCE	5.0
TPHg	100
TPHd	100



TPH AND SELECTED VOCs IN GROUNDWATER
FORMER SUMP AND
FRONT END ALIGNMENT PIT AREAS

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 04/30/2014	Project No. OD10160070
amec		Figure 9

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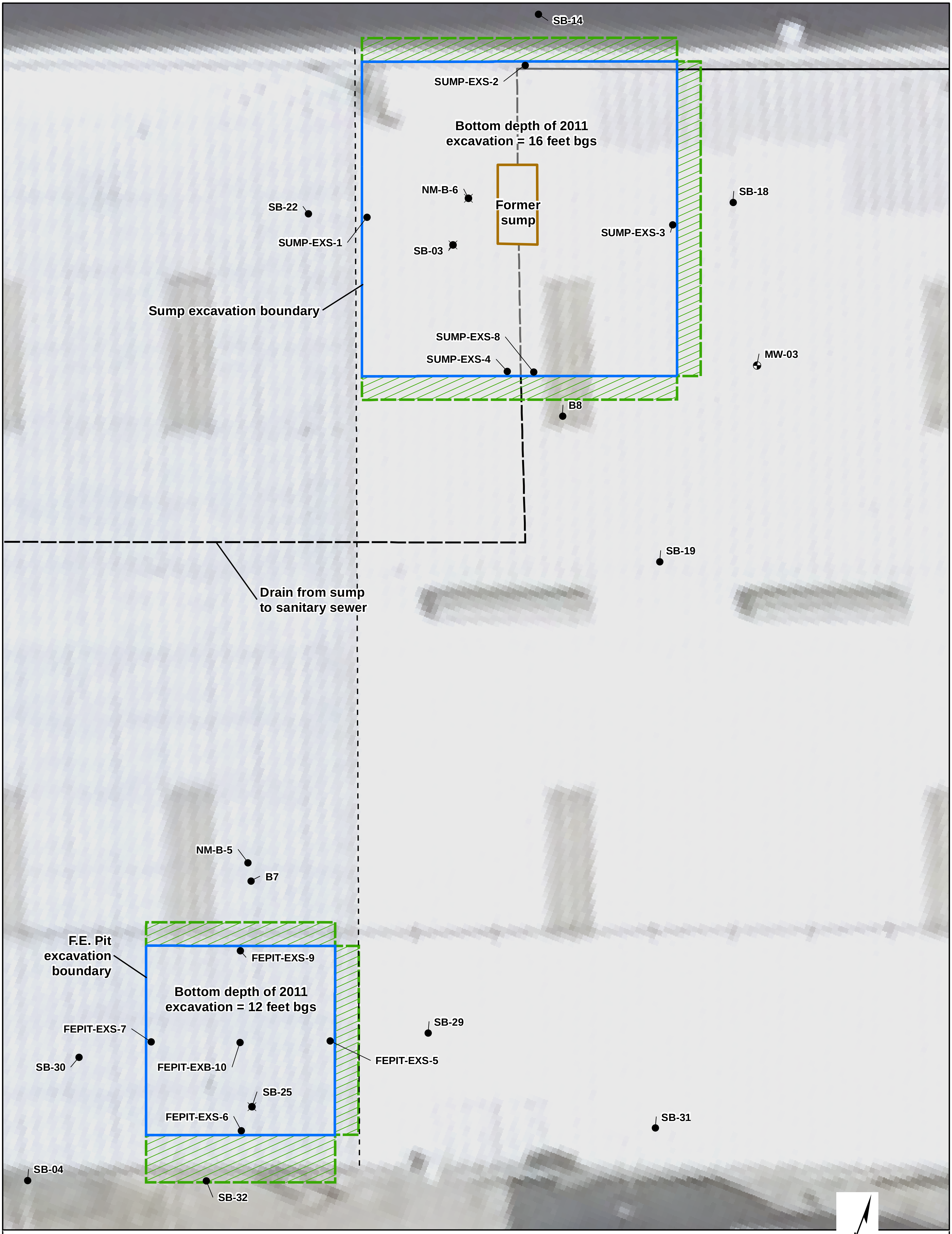


Explanation

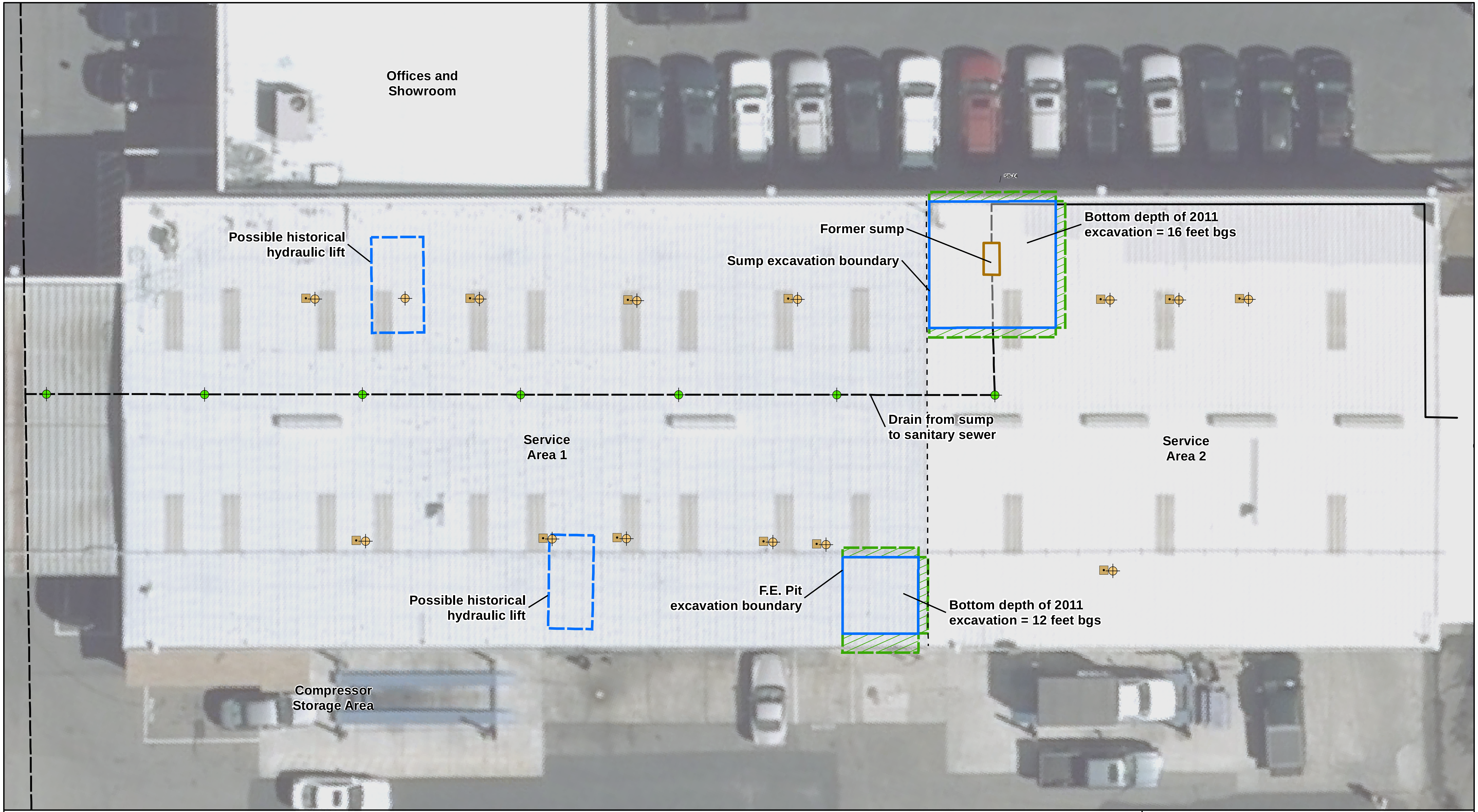
- ⊕ Monitoring well location
- ● Soil and/or grab groundwater location
- ✱ Sample collected from soil that was subsequently removed during excavation
- ▨ Proposed soil excavation area
- ☐ Approximate excavation boundary (2011)
- - - - - Interior building wall
- ——— Approximate location of above-ground drain line
- — — Approximate location of below-ground drain line

Abbreviations:
bgs = below ground surface
F.E. Pit or FEPIT = Front end alignment pit

Notes:
1. Proposed soil excavations are planned to extend to a depth equal to that of the 2011 excavations (i.e., 16 feet bgs at the former sump and 12 feet bgs at the former F.E. Pit).
2. For clarity, borings not advanced adjacent to the 2011 excavation areas, or with samples not analyzed for target constituents, are not shown on this figure.

PROPOSED SOIL EXCAVATION AREAS
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW
Date: 11/08/2013
Project No. OD10160070
amec
Figure 10a



Explanation

⊕ Proposed drain line confirmation soil sample location

⊕ Proposed hydraulic lift confirmation soil sample location

▪ Approximate location of current or historical hydraulic lift

▨ Proposed soil excavation area

☐ Approximate excavation boundary (2011)

- - - Interior building wall

—— Approximate location of above-ground drain line

— — Approximate location of below-ground drain line

Abbreviations:
bgs = below ground surface
F.E. Pit = Front end alignment pit

0 7.5 15 Feet

PROPOSED HYDRAULIC LIFT AND DRAIN LINE CONFIRMATION SOIL SAMPLING LOCATIONS

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 11/08/2013	Project No. OD10160070
amec		Figure 10b

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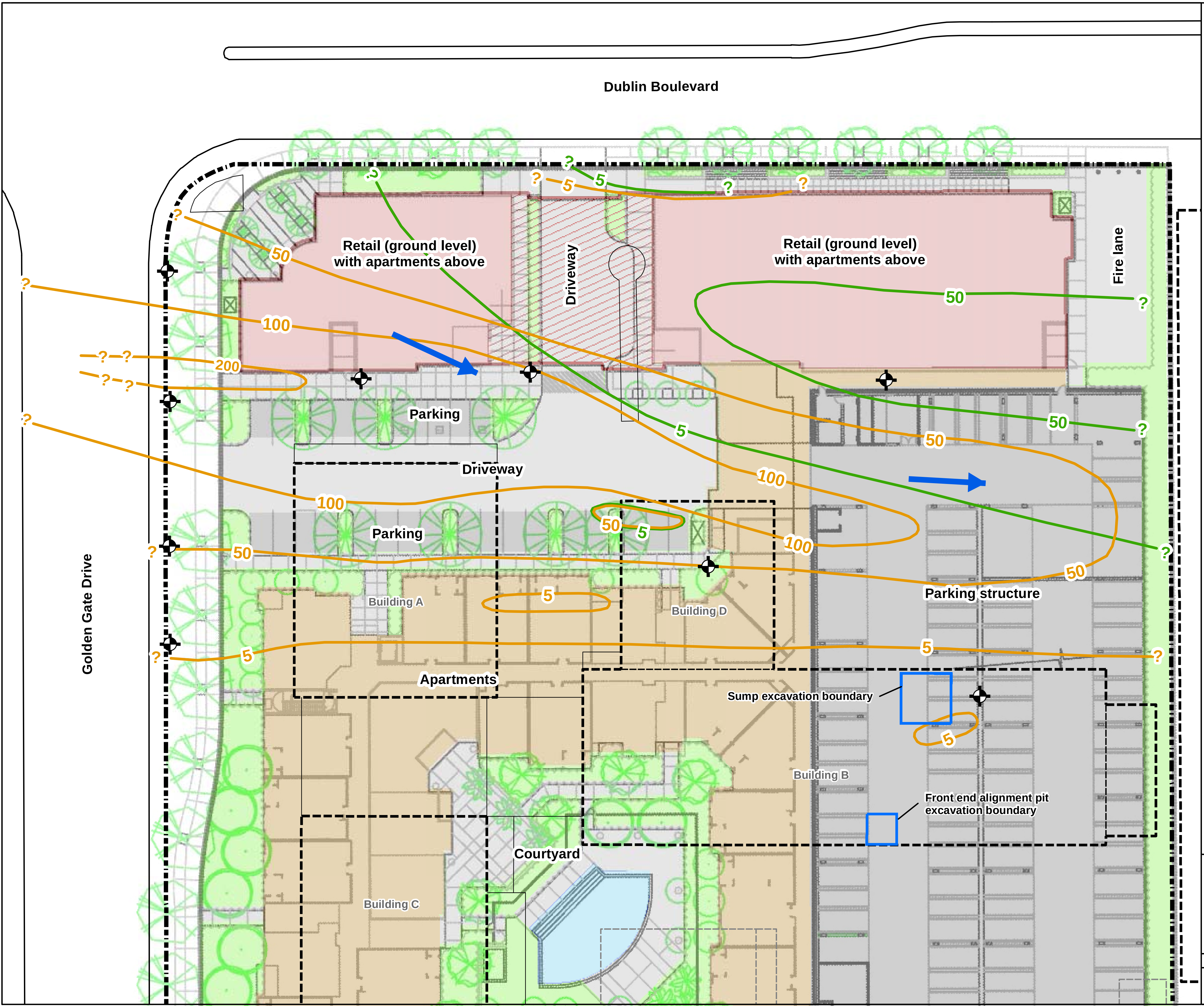

Explanation

⌖ Proposed shallow groundwater monitoring well location

➡ Approximate groundwater flow direction (February 2013)

— Approximate redevelopment property line

☐ Proposed buildings

—50— Approximate line of equal PCE concentration (µg/L)

—50— Approximate line of equal TCE concentration (µg/L)

-·-·- Approximate existing property line

⬚ Existing buildings

☐ Approximate excavation boundary (October 2011)

Abbreviations:
PCE = tetrachloroethene
TCE = trichloroethene
µg/L = micrograms per liter

0 40
APPROXIMATE SCALE IN FEET

Source: Proposed development plans provided by Architects Orange, of Orange, California, on October 19, 2012.

PROPOSED GROUNDWATER MONITORING
WELL LOCATIONS AND
PCE AND TCE IN SHALLOW GROUNDWATER
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 03/21/2014	Project No.	OD10160070
amec		Figure	11

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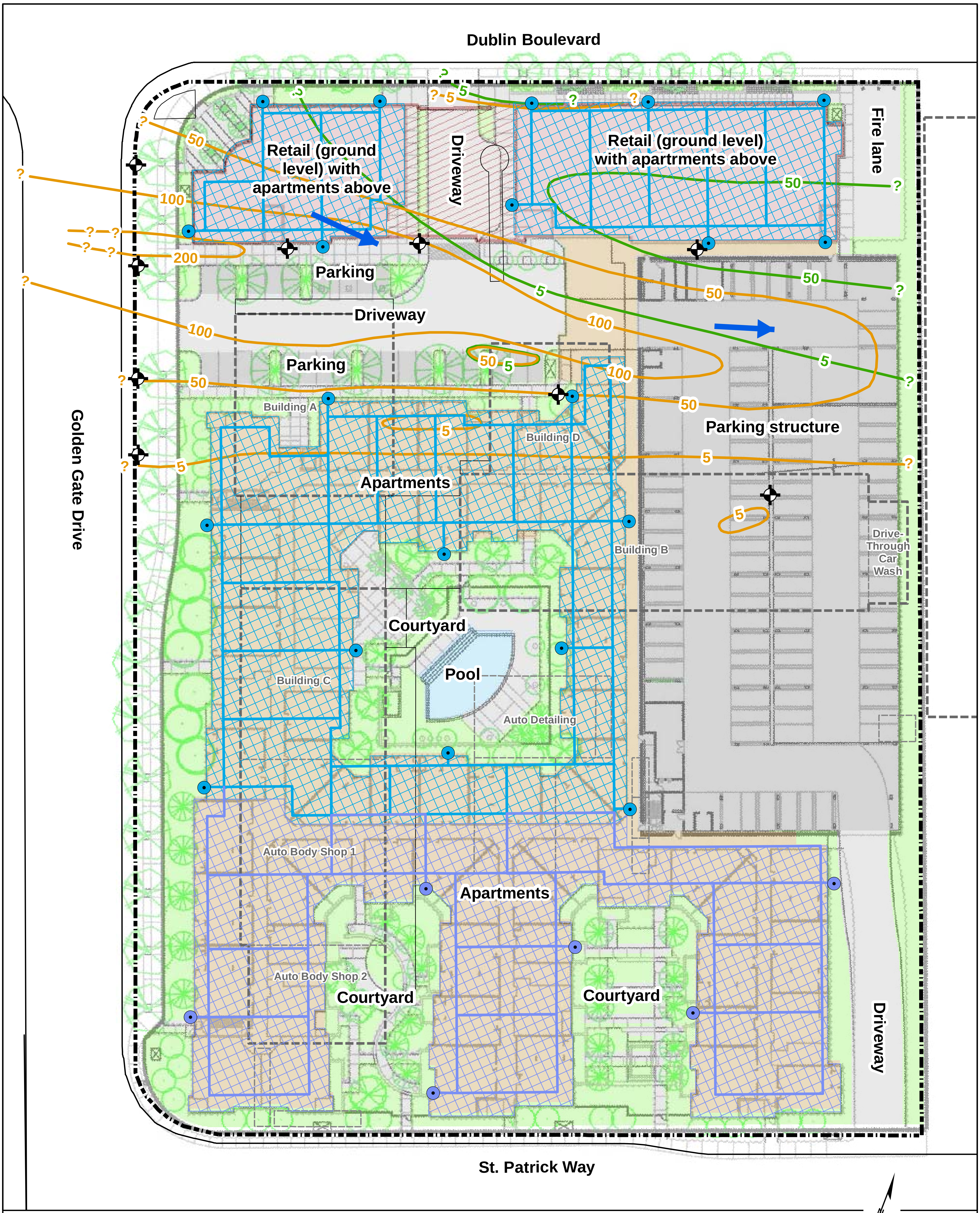

Explanation

▨	Proposed soil vapor barrier
▨	Proposed contingency soil vapor barrier
●	Proposed riser location
●	Proposed contingency riser location
☐	Proposed SSD system layout
☐	Proposed contingency SSD system layout
⊕	Proposed shallow groundwater monitoring well location
➡	Approximate groundwater flow direction (February 2013)
	Approximate redevelopment property line
☐	Proposed buildings
—50—	Approximate line of equal PCE concentration (µg/L)
—50—	Approximate line of equal TCE concentration (µg/L)
—·—·—	Approximate existing property line
☐	Existing buildings

Abbreviations:
PCE = tetrachloroethene
TCE = trichloroethene
SSD = sub-slab depressurization
µg/L = micrograms per liter

0 50
APPROXIMATE SCALE IN FEET

Source: Proposed development plans provided by Architects Orange, of Orange, California, on October 19, 2012.

PROPOSED VAPOR BARRIER AND SSD LOCATIONS AND PCE AND TCE IN SHALLOW GROUNDWATER
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 03/21/2014	Project No.	OD10160070
amec		Figure	12a

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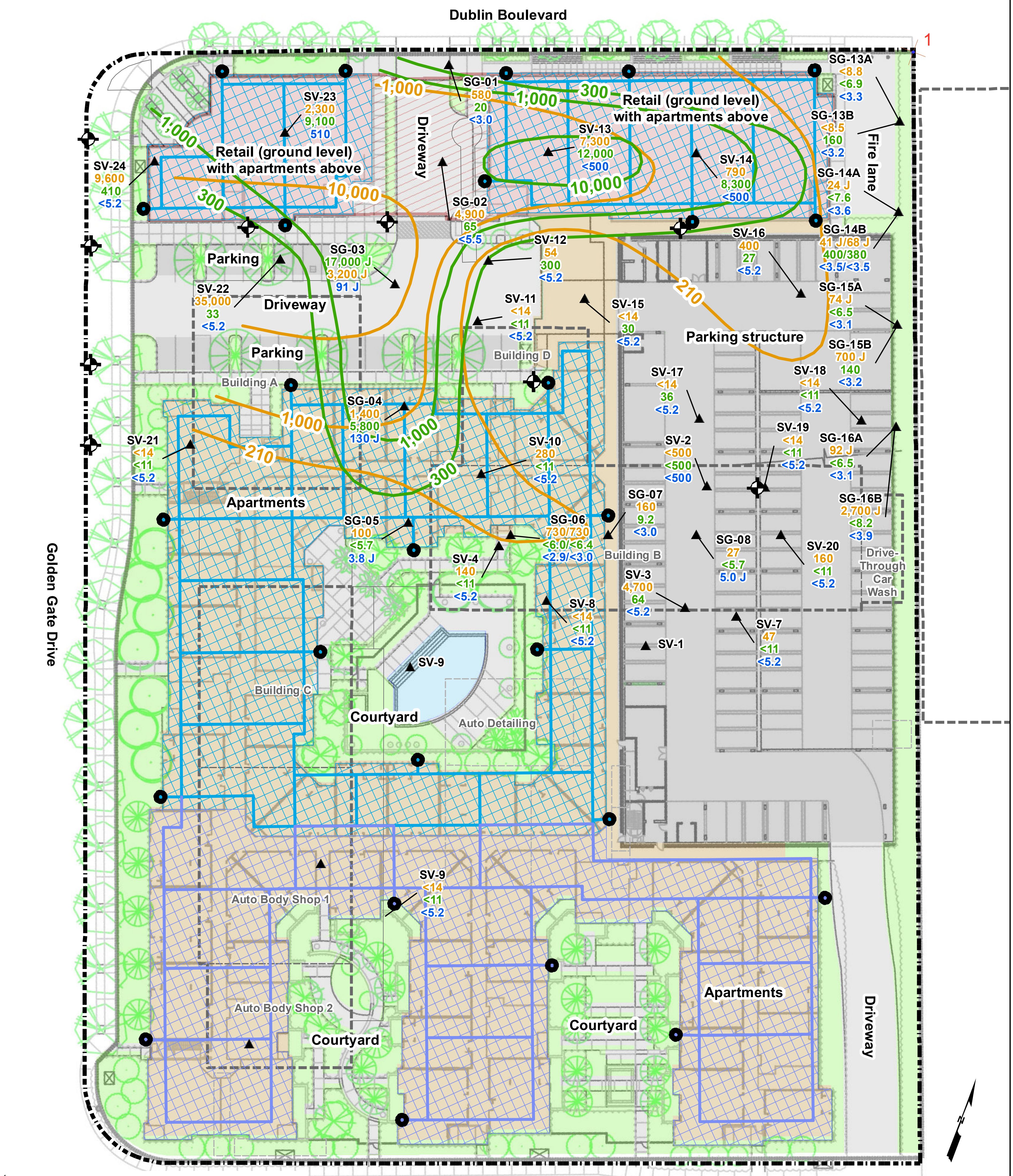


0 50

APPROXIMATE SCALE IN FEET

Note:
SV-3 was not used in contouring, as the sample was collected within a concrete pit that has since been removed. PCE data from the shallow ports of SG-13 through SG-16 (i.e., 4 feet below ground surface) were used in contouring. Data from the deeper "B" ports of SG-13 through SG-16 (i.e., 8 feet below ground surface) were not used in contouring.

Explanation

▨ Proposed soil vapor barrier

▨ Proposed contingency soil vapor barrier

● Proposed riser location

● Proposed contingency riser location

Proposed SSD system layout

Proposed contingency SSD system layout

Proposed shallow groundwater monitoring well location

Approximate redevelopment property line

Proposed buildings

—210— Approximate line of equal PCE concentration (µg/m³)

—1,000— Approximate line of equal TCE concentration (µg/m³)

"A" indicates sample from 4 feet bgs; "B" indicates sample from 8 feet bgs.

SG-14B — Well/Boring ID
41 J/68 J — PCE concentration in µg/m³
400/380 — TCE concentration in µg/m³
<3.5/<3.5 — VC concentration in µg/m³
Duplicate data

▲ Soil vapor sample location

Approximate existing property line

Existing buildings

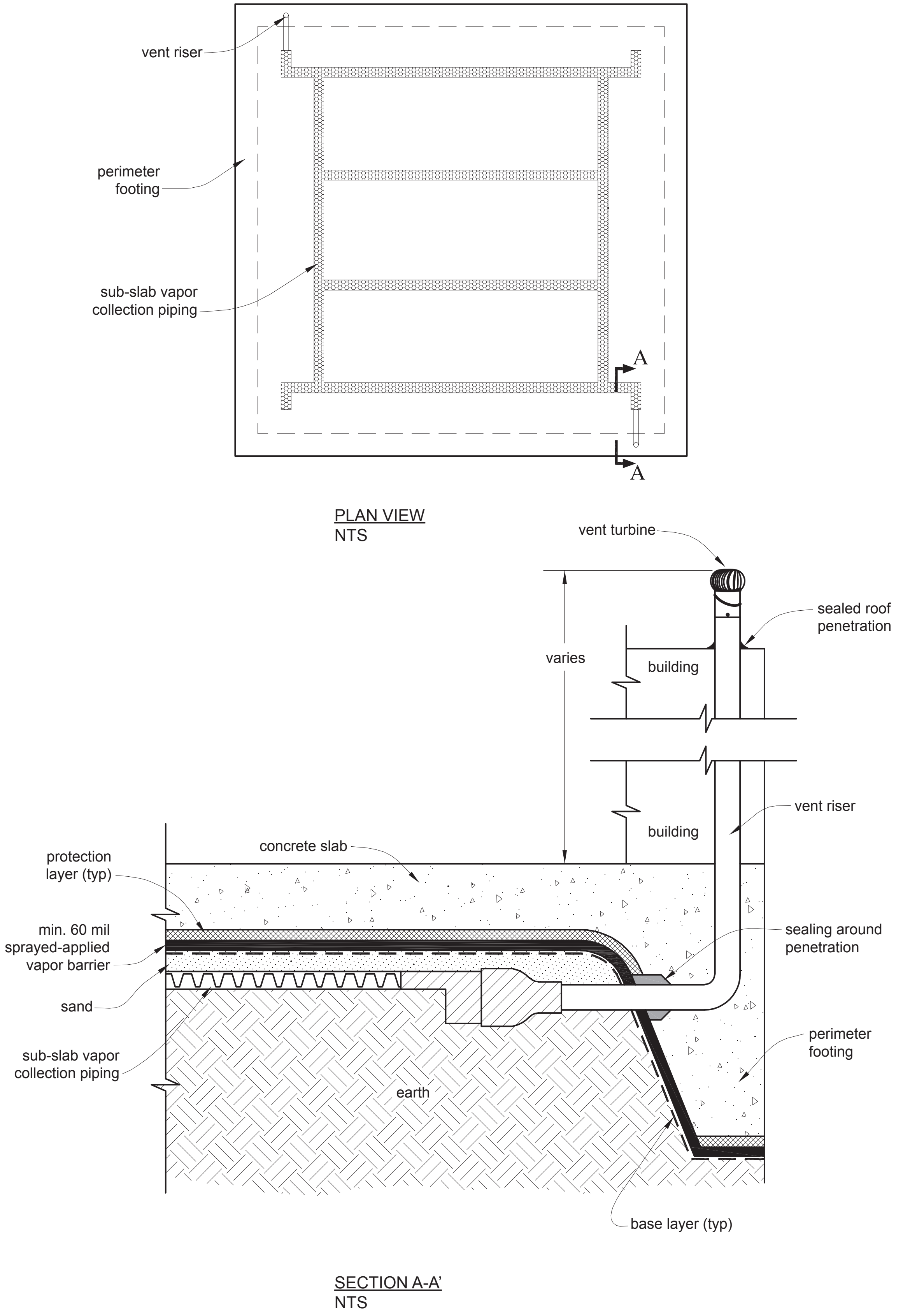
Soil Vapor ESLs (µg/m³)	
PCE	210
TCE	300
Vinyl chloride	31

Abbreviations:
bgs = below ground surface
ESL = Environmental Screening Level
PCE = tetrachloroethene
SSD = sub-slab depressurization
TCE = trichloroethene
UST = underground storage tank
µg/m³ = micrograms per cubic meter
< = not detected at or above laboratory reporting limit shown
J = estimated value

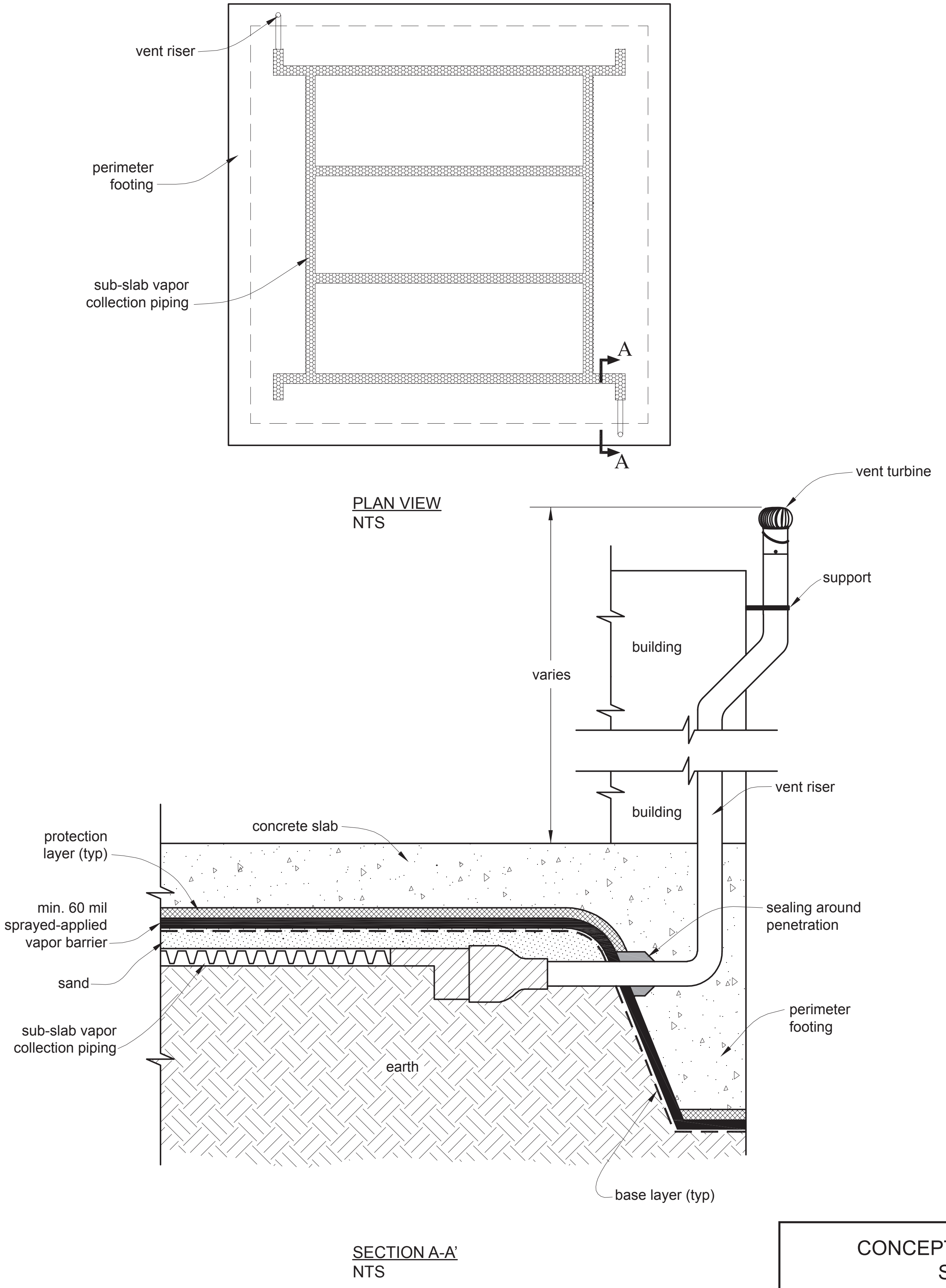
Source: Proposed development plans provided by Architects Orange, of Orange, California, on October 19, 2012.

PROPOSED VAPOR BARRIER AND SSD LOCATIONS AND PCE, TCE, and VINYL CHLORIDE IN SOIL VAPOR
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 11/12/2013	Project No. OD10160070
amec		Figure 12b



VERTICAL VENT OPTION



ANGLED VENT OPTION

Abbreviations:
NTS = not to scale
SSD = sub-slab depressurization system

CONCEPTUAL VAPOR BARRIER AND
SDD COMPONENTS
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: GFS	Date: 03/21/2014	Project No.	OD10160070
amec		Figure	**12c**

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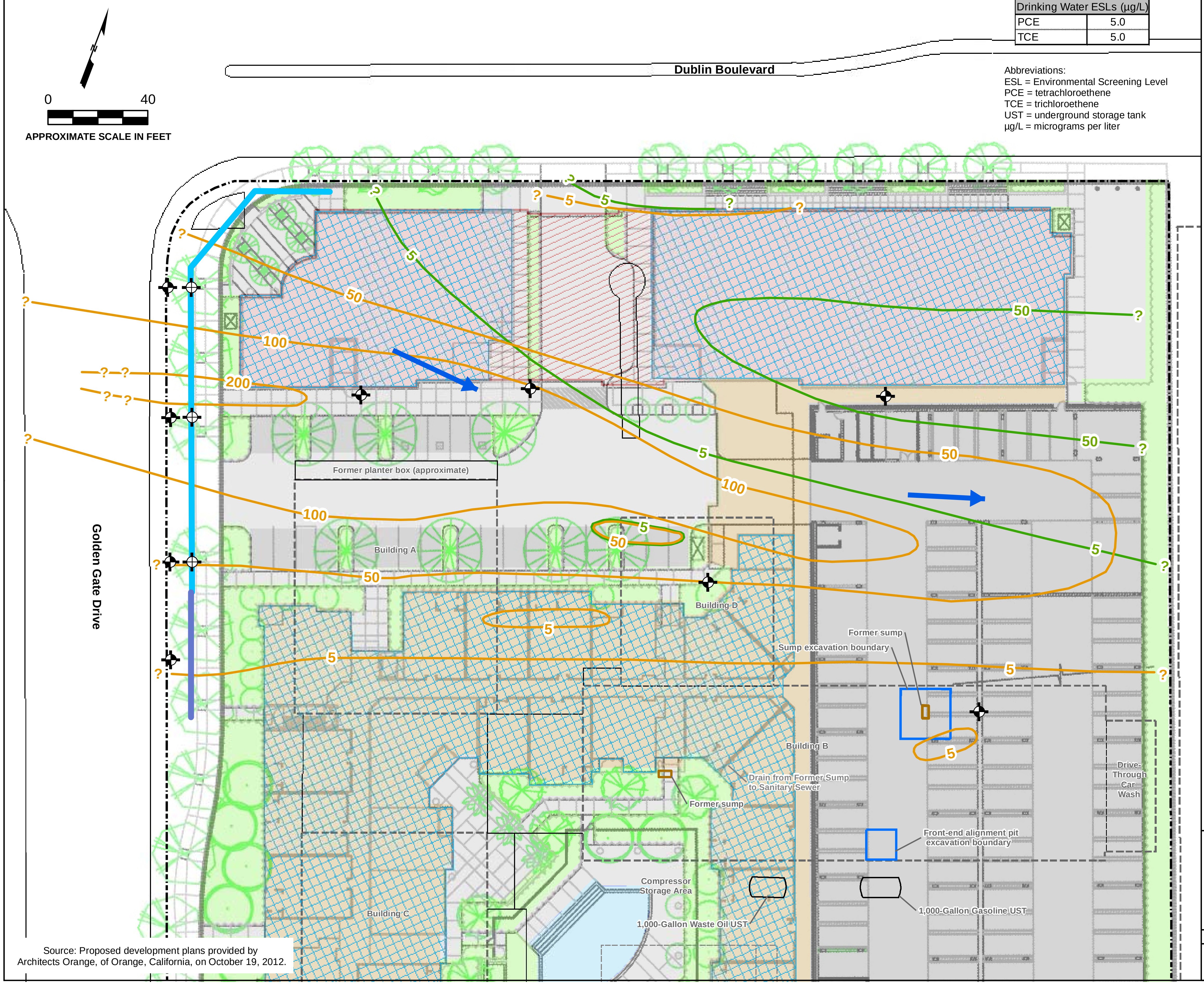
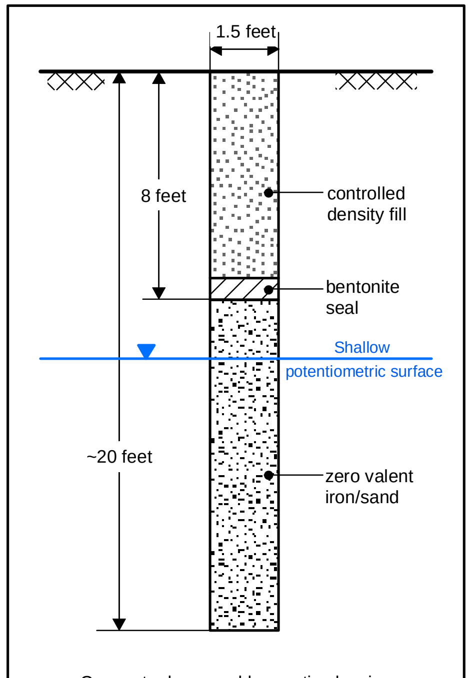


Drinking Water ESLs (µg/L)	
PCE	5.0
TCE	5.0

Abbreviations:
ESL = Environmental Screening Level
PCE = tetrachloroethene
TCE = trichloroethene
UST = underground storage tank
µg/L = micrograms per liter

Source: Proposed development plans provided by Architects Orange, of Orange, California, on October 19, 2012.



Conceptual permeable reactive barrier cross section (not to scale)

Explanation

- Proposed location of permeable reactive barrier
- Proposed contingency location of permeable reactive barrier
- ▨ Proposed soil vapor barrier
- Approximate groundwater flow direction (February 2013)
- —50— Approximate line of equal PCE concentration
- —50— Approximate line of equal TCE concentration
- Proposed shallow groundwater monitoring well location
- Proposed in-barrier groundwater monitoring well location
- ☐ Approximate excavation boundary (October 2011)
- Approximate existing property line
- Approximate redevelopment property line
- ☐ Approximate sump location
- ☐ Existing buildings

APPROXIMATE PROPOSED LOCATION OF
PERMEABLE REACTIVE BARRIER
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 03/21/2014	Project No. OD10160070
amec		Figure 13

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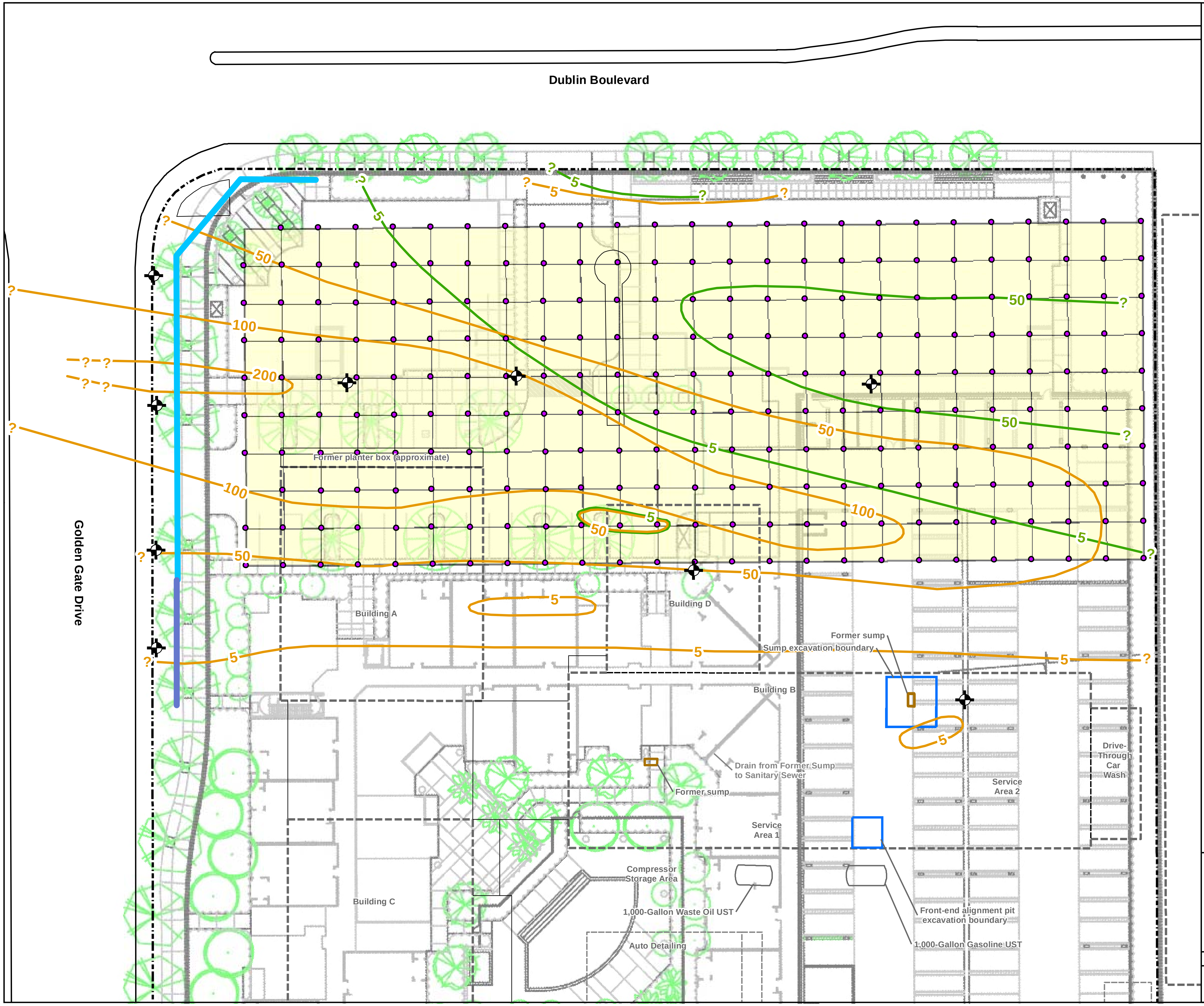

0 40
APPROXIMATE SCALE IN FEET

Explanation

● Proposed bioremediation injection location

⌖ Proposed shallow groundwater monitoring well location

━ Proposed location of permeable reactive barrier

━ Proposed contingency location of permeable reactive barrier

—50— Approximate line of equal PCE concentration

—50— Approximate line of equal TCE concentration

☐ Approximate excavation boundary (October 2011)

-·-·- Approximate property line

▭ Approximate sump location

▭ Existing buildings

Drinking Water ESLs (µg/L)	
PCE	5.0
TCE	5.0

Abbreviations:
ESL = Environmental Screening Level
PCE = tetrachloroethene
TCE = trichloroethene
UST = underground storage tank
µg/L = micrograms per liter

Source: Proposed development plans provided by Architects Orange, of Orange, California, on October 19, 2012.

CONCEPTUAL BIOREMEDIATION INJECTION LOCATIONS
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

By: AWW	Date: 03/21/2014	Project No. OD10160070
amec		Figure 14

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APPENDIX A

Bioremediation Assessment Data

AMEC Geomatrix

WELL SAMPLING RECORD

Well ID: MP-01

Sample ID: MP01-12

Duplicate ID:

Project and Task No.: ~~0014860012.02S.GC &~~ ~~0014860012.02V.GC~~ 0D10160070.00006

Project Name: ~~[illegible]~~ Crown Chevrolet

Date: 10/26/12

Method of Purging: Low flow with peristaltic pump

Method of Sampling: Peristaltic pump

Initial Depth to Water: 13.74

Depth to Water after Sampling:

Total Depth to Well:

Well Diameter: CMT-1

Intake/Sample Depth: 17.5

Total Volume Removed:

Sampled By: RDP

Time	Rate (mL/min)	Temp. (°C)	pH (units)	Specific Electrical Conductance (µS/cm)	Water Level (btoc)	ORP	DO	Remarks (color, turbidity, and sediment)
1530	100	22.36	7.12	1601	-	-145.2	4.18	Clear
1135	"	22.29	6.74	1606		-132.4	1.35	"
1140	60	22.10	6.64	15,84		-126.5	0.58	"
1145	"	21.89	6.65	1537		-114.4	0.44	"
1150	"	21.75	6.66	1487		-111.3	0.37	
1155	"	21.73	6.68	1449		-118.3	0.31	
1200	"	21.71	6.71	1434		-114.0	0.30	
1210	"	21.82	6.77	1421		-112.9	0.22	
1215		21.79	6.77	1416		-103.1	0.22	
1220		21.79	6.77	1414		-104.7	0.21	
		sample						

pH CALIBRATION (choose two)

Buffer Solution	pH 4.0	pH 7.0	pH 10.0	
Temperature C				
Instrument Reading				

Model or Unit No.:

SPECIFIC ELECTRICAL CONDUCTANCE – CALIBRATION

KCL Solution (µS/cm=µmhos/cm)			
Temperature C			
Instrument Reading			

Model or Unit No.:

Notes:

Equipment blank sample taken *PRIOR* to purging & well sample: YES__ NO__

1/4-inch disposable tubing with intake at mid screen level weighted with deconed (alconox and clean water rinse) weight at the end of tubing attached with silicon tape: YES__

YSI with flow through cell used to measure water parameters until stable: YES__

Low flow method (flow rate less than 500mL/min and drawdown does not exceed 1 foot below initial): YES__

AMEC Geomatrix

WELL SAMPLING RECORD

Well ID: MW-02

Sample ID: MW02-102612

Duplicate ID:

Project and Task No.: ~~0014860012.02S.006~~ ~~0014860012.02V.CC~~ 0D10160070.00006

Project Name: ~~NEW~~ Crown Chevrolet

Date: 10/26/12

Method of Purging: Low flow with peristaltic pump

Method of Sampling: Peristaltic pump

Initial Depth to Water: 11.04

Depth to Water after Sampling: 11.04

Total Depth to Well:

Well Diameter: 3/4" pre-pack

Intake/Sample Depth: 17.5

Total Volume Removed: 6½ liters

Sampled By: RDP

Time	Rate (mL/min)	Temp. (°C)	pH (units)	Specific Electrical Conductance (µS/cm)	Water Level (btoc)	ORP	DO	Remarks (color, turbidity, and sediment)
0950	120	21.84	7.11	816	11.61	51.4	1.1	clear
0955	"	21.90	7.13	788	"	41.6	0.69	"
1000	"	21.92	7.12	776	"	25.4	0.41	"
1005	160	21.97	7.11	766	11.89	11.3	0.29	"
1010	175	21.99	7.11	764	11.90	8.5	0.37	"
1015	"	21.96	7.11	759	"	-69.5	0.23	"
1020	"	21.98	7.10	757	"	-49.8	0.23	"
1025	"	21.98	7.10	756	"	-49.6	0.23	
	sample							

pH CALIBRATION (choose two)

Buffer Solution	pH 4.0	pH 7.0	pH 10.0	
Temperature C				
Instrument Reading				

Model or Unit No.:

SPECIFIC ELECTRICAL CONDUCTANCE – CALIBRATION

KCL Solution (µS/cm=µmhos/cm)			
Temperature C			
Instrument Reading			

Model or Unit No.:

Notes:

Equipment blank sample taken *PRIOR* to purging & well sample: YES__ NO__

1/4-inch disposable tubing with intake at mid screen level weighted with deconed (alconox and clean water rinse) weight at the end of tubing attached with silicon tape: YES__

YSI with flow through cell used to measure water parameters until stable: YES__

Low flow method (flow rate less than 500mL/min and drawdown does not exceed 1 foot below initial): YES__

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica Pleasanton
1220 Quarry Lane
Pleasanton, CA 94566
Tel: (925)484-1919

TestAmerica Job ID: 720-45596-1
Client Project/Site: Crown Chevrolet

For:
AMEC Environment & Infrastructure, Inc.
2101 Webster Street, 12th Floor
Oakland, California 94612

Attn: Avery Patton

Onieka Howard

Authorized for release by:
11/2/2012 4:53:08 PM
Onieka Howard
Project Manager I
onieka.howard@testamericainc.com

Designee for

Afsaneh Salimpour
Project Manager I
afsaneh.salimpour@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at:
www.testamericainc.com

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Table of Contents

Definitions/Glossary

Client: AMEC Environment & Infrastructure, Inc.
Project/Site: Crown Chevrolet

TestAmerica Job ID: 720-45596-1

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
☼	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CNF	Contains no Free Liquid
DL, RA, RE, IN	Indicates a Dilution, Reanalysis, Re-extraction, or additional Initial metals/anion analysis of the sample
EDL	Estimated Detection Limit
EPA	United States Environmental Protection Agency
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RL	Reporting Limit
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Case Narrative

Job ID: 720-45596-1

Laboratory: TestAmerica Pleasanton

Narrative

Job Narrative
720-45596-1

Comments
No additional comments.

Receipt
The samples were received on 10/26/2012 2:47 PM; the samples arrived in good condition, properly preserved and, where required, on ice. The temperature of the cooler at receipt was 5.7º C.

Except:

The container label for the following sample(s) did not match the information listed on the Chain-of-Custody (COC):MW02-10261. The container labels list MW01-102612. The COC lists MW02-102612.

General Chemistry
No analytical or quality issues were noted.

Detection Summary

Client: AMEC Environment & Infrastructure, Inc.
Project/Site: Crown Chevrolet

TestAmerica Job ID: 720-45596-1

Client Sample ID: MW02-102612

Lab Sample ID: 720-45596-1

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Sulfate	42		10		mg/L	10		300.0	Total/NA

Client Sample ID: MP01-1-102612

Lab Sample ID: 720-45596-2

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Nitrate as NO3	10		1.0		mg/L	1		300.0	Total/NA
Sulfate	71		10		mg/L	10		300.0	Total/NA

Client Sample Results

Client: AMEC Environment & Infrastructure, Inc.
Project/Site: Crown Chevrolet

TestAmerica Job ID: 720-45596-1

General Chemistry

Client Sample ID: MW02-102612
Date Collected: 10/26/12 10:25
Date Received: 10/26/12 14:47

Lab Sample ID: 720-45596-1
Matrix: Water

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrate as NO3	ND		1.0		mg/L			10/26/12 18:38	1
Sulfate	**42**		10		mg/L			10/26/12 18:56	10

Client Sample ID: MP01-1-102612
Date Collected: 10/26/12 12:20
Date Received: 10/26/12 14:47

Lab Sample ID: 720-45596-2
Matrix: Water

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrate as NO3	**10**		1.0		mg/L			10/26/12 19:13	1
Sulfate	**71**		10		mg/L			10/26/12 19:30	10

QC Sample Results

Client: AMEC Environment & Infrastructure, Inc.
Project/Site: Crown Chevrolet

TestAmerica Job ID: 720-45596-1

Method: 300.0 - Anions, Ion Chromatography

Lab Sample ID: MB 720-124087/4
Matrix: Water
Analysis Batch: 124087

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Sulfate	ND		1.0		mg/L			10/26/12 18:04	1

Lab Sample ID: LCS 720-124087/5
Matrix: Water
Analysis Batch: 124087

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits		
Sulfate			10.0	9.75		mg/L		98	90 - 110		

Lab Sample ID: 720-45596-A-2 MS
Matrix: Water
Analysis Batch: 124087

Client Sample ID: MP01-1-102612
Prep Type: Total/NA

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits		
Sulfate	71		100	170		mg/L		99	80 - 120		

Lab Sample ID: 720-45596-A-2 MSD
Matrix: Water
Analysis Batch: 124087

Client Sample ID: MP01-1-102612
Prep Type: Total/NA

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Sulfate	71		100	170		mg/L		99	80 - 120	0	20

Lab Sample ID: MB 720-124088/4
Matrix: Water
Analysis Batch: 124088

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrate as NO3	ND		1.0		mg/L			10/26/12 18:04	1

Lab Sample ID: LCS 720-124088/5
Matrix: Water
Analysis Batch: 124088

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte			Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits		
Nitrate as NO3			10.0	10.1		mg/L		101	90 - 110		

Lab Sample ID: 720-45596-A-2 MS
Matrix: Water
Analysis Batch: 124088

Client Sample ID: 720-45596-A-2 MS
Prep Type: Total/NA

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits		
Nitrate as NO3	ND		100	112		mg/L		102	80 - 120		

Lab Sample ID: 720-45596-A-2 MSD
Matrix: Water
Analysis Batch: 124088

Client Sample ID: 720-45596-A-2 MSD
Prep Type: Total/NA

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Nitrate as NO3	ND		100	112		mg/L		102	80 - 120	0	20

QC Association Summary

General Chemistry

Analysis Batch: 124087

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
720-45596-1	MW02-102612	Total/NA	Water	300.0	
720-45596-2	MP01-1-102612	Total/NA	Water	300.0	
720-45596-A-2 MS	MP01-1-102612	Total/NA	Water	300.0	
720-45596-A-2 MSD	MP01-1-102612	Total/NA	Water	300.0	
LCS 720-124087/5	Lab Control Sample	Total/NA	Water	300.0	
MB 720-124087/4	Method Blank	Total/NA	Water	300.0	

Analysis Batch: 124088

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
720-45596-1	MW02-102612	Total/NA	Water	300.0	
720-45596-2	MP01-1-102612	Total/NA	Water	300.0	
720-45596-A-2 MS	720-45596-A-2 MS	Total/NA	Water	300.0	
720-45596-A-2 MSD	720-45596-A-2 MSD	Total/NA	Water	300.0	
LCS 720-124088/5	Lab Control Sample	Total/NA	Water	300.0	
MB 720-124088/4	Method Blank	Total/NA	Water	300.0	

Client Sample ID: MW02-102612

Lab Sample ID: 720-45596-1

Date Collected: 10/26/12 10:25

Matrix: Water

Date Received: 10/26/12 14:47

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	300.0		10	124087	10/26/12 18:56	MJK	TAL SF
Total/NA	Analysis	300.0		1	124088	10/26/12 18:38	MJK	TAL SF

Client Sample ID: MP01-1-102612

Lab Sample ID: 720-45596-2

Date Collected: 10/26/12 12:20

Matrix: Water

Date Received: 10/26/12 14:47

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	300.0		10	124087	10/26/12 19:30	MJK	TAL SF
Total/NA	Analysis	300.0		1	124088	10/26/12 19:13	MJK	TAL SF

Laboratory References:

TAL SF = TestAmerica Pleasanton, 1220 Quarry Lane, Pleasanton, CA 94566, TEL (925)484-1919

Certification Summary

Client: AMEC Environment & Infrastructure, Inc.
Project/Site: Crown Chevrolet

TestAmerica Job ID: 720-45596-1

Laboratory: TestAmerica Pleasanton

All certifications held by this laboratory are listed. Not all certifications are applicable to this report.

Authority	Program	EPA Region	Certification ID	Expiration Date
California	State Program	9	2496	01-31-14

Method Summary

Client: AMEC Environment & Infrastructure, Inc.
Project/Site: Crown Chevrolet

TestAmerica Job ID: 720-45596-1

Method	Method Description	Protocol	Laboratory
300.0	Anions, Ion Chromatography	MCAWW	TAL SF

Protocol References:

MCAWW = "Methods For Chemical Analysis Of Water And Wastes", EPA-600/4-79-020, March 1983 And Subsequent Revisions.

Laboratory References:

TAL SF = TestAmerica Pleasanton, 1220 Quarry Lane, Pleasanton, CA 94566, TEL (925)484-1919

Sample Summary

Client: AMEC Environment & Infrastructure, Inc.
Project/Site: Crown Chevrolet

TestAmerica Job ID: 720-45596-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
720-45596-1	MW02-102612	Water	10/26/12 10:25	10/26/12 14:47
720-45596-2	MP01-1-102612	Water	10/26/12 12:20	10/26/12 14:47

CHAIN-OF-CUSTODY RECORD

720-45596

OAK 17605

PROJECT NAME: Crown Chevrolet

PROJECT NUMBER: OD 101600070.0006

RESULTS TO: Avery Patton

TURNAROUND TIME: Standard

SAMPLE SHIPMENT METHOD: hand

LABORATORY NAME: Test America

LABORATORY ADDRESS:

LABORATORY CONTACT:

LABORATORY PHONE NUMBER:

CLIENT INFORMATION:

DATE: 10-26-12 PAGE 1 OF 1

REPORTING REQUIREMENTS: 141877

GEOTRACKER REQUIRED YES [✓ NO]

SITE SPECIFIC GLOBAL ID NO.

SAMPLERS (SIGNATURE): RDavid Pearson

ANALYSES

DATE	TIME	SAMPLE NUMBER	* Sulfate	* Nitrate	CONTAINER TYPE AND SIZE	Soil (S), Water (W), Vapor (V), or Other (O)	Filtered	Preservative Type	Cooled	MS/MSD	No. of Containers	ADDITIONAL COMMENTS
10-26-12	1025	MW02-102612	X	X		W		–	X		1	
1	1220	MP01-1-102612	X	X		W		–	X		1	

RDP

RELINQUISHED BY:

SIGNATURE: RDavid Pearson

PRINTED NAME: RDavid Pearson

COMPANY: Amec

DATE: 10/26/12

TIME: 1447

SIGNATURE:

PRINTED NAME:

COMPANY:

SIGNATURE:

PRINTED NAME:

COMPANY:

RECEIVED BY:

SIGNATURE: John Mullen

PRINTED NAME: Mullen

COMPANY: Test Amer

DATE: 10/26/12

TIME: 1447

SIGNATURE:

PRINTED NAME:

COMPANY:

SIGNATURE:

PRINTED NAME:

COMPANY:

TOTAL NUMBER OF CONTAINERS: 2

SAMPLING COMMENTS: * by EPA 300.0

5.7°C

2101 Webster Street, 12th Floor
Oakland, California 94612-3066
Tel 510.663.4100 Fax 510.663.4141

amec

Login Sample Receipt Checklist

Client: AMEC Environment & Infrastructure, Inc.
Job Number: 720-45596-1

Login Number: 45596
List Source: TestAmerica Pleasanton
List Number: 1
Creator: Apostol, Anita

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	N/A	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	False	
Samples are received within Holding Time.	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

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Certificate of Analysis: Gene-Trac® *Dehalococcoides* Assay

Customer: Avery Patton, AMEC
Project: Crown Chevrolet
Customer Reference: OD10160070.00006

SiREM Reference: S-2653
Report Date: 14-Nov-12
Data Files: iQ5-GBA-QPCR-0042
MyiQ-DHC-QPCR-0951
MyiQ-DB-DHC-QPCR-0325

Table 1: Test Results

Customer Sample ID	SiREM Sample ID	Sample Collection Date	Sample Matrix	Percent Dhc *	*Dehalococcoides* Enumeration/Liter **
MW02	DHC-8714	26-Oct-12	Groundwater	NA	3×10^3 U
MP01-1	DHC-8715	26-Oct-12	Groundwater	NA	3×10^3 U

Notes:

* Percent *Dehalococcoides* (Dhc) in microbial population. This value is calculated by dividing the number of Dhc 16S ribosomal ribonucleic acid (rRNA) gene copies by the total number of bacteria as estimated by the mass of DNA extracted from the sample. Range represents normal variation in Dhc enumeration.

** Based on quantification of Dhc 16S rRNA gene copies. Dhc are generally reported to contain one 16S rRNA gene copy per cell; therefore, this number is often interpreted to represent the number of Dhc cells present in the sample.

J The associated value is an estimated quantity between the method detection limit and quantitation limit.
U Not detected, associated value is the quantification limit.
B Analyte was also detected in the method blank.
NA Not applicable as *Dehalococcoides* not detected and/or quantifiable DNA not extracted from the sample.
I Sample inhibited the test reaction based on inability to PCR amplify extracted DNA with universal primers.
E Extracted genomic DNA was not detected in sample.

Analyst: Kela Bartle
Kela Bartle, B.Sc.
Laboratory Technician

Approved: Ximena Druar
Ximena Druar, B.Sc.
Genetic Testing Coordinator

Table 2: Detailed Test Parameters, Gene-Trac Test Reference S-2653

Customer Sample ID	MW02	MP01-1
SiREM Dhc Sample ID	DHC-8714	DHC-8715
Date Received	31-Oct-12	31-Oct-12
Sample Temperature	4 ºC	4 ºC
Filtration Date	1-Nov-12	1-Nov-12
Volume Used for DNA Extraction	500 mL	500 mL
DNA Extraction Date	9-Nov-12	9-Nov-12
DNA Concentration in Sample (extractable)	1113 ng/L	1391 ng/L
PCR Amplifiable DNA	Detected	Detected
Dhc qPCR Date Analyzed	12-Nov-12	12-Nov-12
Laboratory Controls (see Table 3)	Passed	Passed
Comments	- -	- -

Notes:

Refer to Table 3 for detailed results of controls.

°C = degrees Celsius

DNA = Deoxyribonucleic acid

PCR = polymerase chain reaction

qPCR = quantitative PCR

Dhc = Dehalococcoides

ng/L = nanograms per liter

mL = milliliters

Table 3: Experimental Control Results, Gene-Trac Test Reference S-2653

Laboratory Control	Analysis Date	Control Description	Spiked Dhc 16S rRNA Gene Copies per Liter	Recovered Dhc 16S rRNA Gene Copies per Liter	Comments
Positive Control Low Concentration	12-Nov-12	qPCR with KB1 genomic DNA (CSLD-0588)	8.4×10^4	9.6×10^4	- -
Positive Control High Concentration	12-Nov-12	qPCR with KB1 genomic DNA (CSHD-0588)	1.2×10^7	1.2×10^7	- -
DNA Extraction Blank	12-Nov-12	DNA extraction sterile water (FB-1800)	0	2.6×10^3 U	- -
Negative Control	12-Nov-12	Tris Reagent Blank (TBD-0548)	0	2.6×10^3 U	- -

Notes:

Dhc = *Dehalococcoides*

DNA = Deoxyribonucleic acid

qPCR = quantitative PCR

16S rRNA = 16S ribosomal ribonucleic acid

U Not detected, associated value is the quantification limit.

S-2653

OAK 17606

CHAIN-OF-CUSTODY RECORD

PROJECT NAME: Crown Chevrolet

DATE: 10-26-12 PAGE 1 OF 1

PROJECT NUMBER: 0D 10160070.00006

LABORATORY NAME: SiREm

CLIENT INFORMATION:

REPORTING REQUIREMENTS:

RESULTS TO: Avery Patton

LABORATORY ADDRESS:

TURNAROUND TIME: standard

SAMPLE SHIPMENT METHOD: Fed-Ex

LABORATORY CONTACT: Phil

GEOTRACKER REQUIRED YES [✓ NO]

LABORATORY PHONE NUMBER: 866-251-1747

SITE SPECIFIC GLOBAL ID NO.

SAMPLERS (SIGNATURE): RDavid Pearson

DATE	TIME	SAMPLE NUMBER	ANALYSES *Dhc	CONTAINER TYPE AND SIZE	Soil (S), Water (W), Vapor (V), or Other (O)	Filtered	Preservative Type	Cooled	MS/MSD	No. of Containers	ADDITIONAL COMMENTS
10-26-12	1025	MW02-102612	X	1liter poly	w			X		1	
1	1220	MP01-1-102612	X	1	w			X		1	

RDP

TOTAL NUMBER OF CONTAINERS: 2

RELINQUISHED BY:	DATE	TIME	RECEIVED BY:	DATE	TIME
SIGNATURE: RDavid Pearson PRINTED NAME: RDavid Pearson COMPANY: Amec	10/29/12	0720	SIGNATURE: Kela Bartle PRINTED NAME: Kela Bartle COMPANY: SiREM	10/31/12	14:40
SIGNATURE: PRINTED NAME: COMPANY:			SIGNATURE: PRINTED NAME: COMPANY:		
SIGNATURE: PRINTED NAME: COMPANY:			SIGNATURE: PRINTED NAME: COMPANY:		

SAMPLING COMMENTS:

*Dehalococcoides testing using Gene-Trac

2101 Webster Street, 12th Floor
Oakland, California 94612-3066
Tel 510.663.4100 Fax 510.663.4141

amec

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Guelph ON N1G 5G3
(519) 822-2265

SiREM Technical Note 1.5:

Guidelines for Interpretation of Gene-Trac® Test Results

This document provides technical background information and guidelines for interpreting the results for the following Gene-Trac® assays:

(1) Gene-Trac® Dhc
(2) Gene-Trac® VC
(3) Gene-Trac® Dhb

SiREM Technical Note 1.4 - *Quantitative Gene-Trac® Assay Test Procedure and Reporting Overview* provides detailed information on Gene-Trac® test procedures and reporting. Explanation of data qualifiers and commonly used notes is provided as Appendix A. Table 1 provides a brief interpretation for some common scenarios, more detailed interpretation information is provided in the following sections.

Table 1: Common Gene-Trac® Test Result Scenarios and Interpretation

Gene-Trac® Dhc (*Dehalococcoides*)	**Gene-Trac® VC (*vcrA*)**	**Gene-Trac® Dhb (*Dehalobacter*)**	**Interpretation**
>1 x10^7/L	**>1 x10^7/L**	Not Analyzed	Complete dechlorination to ethene likely as Dhc high and *vcrA* high
1 x10^7/L	**Not Detected**	Not Analyzed	VC accumulation possible as *vcrA* negative
Not Detected	**Not Detected**	Not Analyzed	Dhc negative/ lack of dechlorination or *cis*-DCE accumulation likely
Not Analyzed	Not Analyzed	**1 x10^6/L**	Dhb positive,potential for biodegradation of 1,1,1-TCA, 1,2-DCA, carbon tetrachloride and chloroform, PCE and TCE to *cis*-DCE
Not Analyzed	Not Analyzed	**Not Detected**	Biodegradation of 1,1,1-TCA, carbon tetrachloride and chloroform not expected as Dhb negative

Gene-Trac® Dhc -Total *Dehalococcoides* Test

Background:

Gene-Trac® Dhc is a quantitative PCR (qPCR) test for total *Dehalococcoides* (Dhc) microbes that targets Dhc specific sequences of the 16S ribosomal ribonucleic acid (rRNA) gene, a gene commonly used to indentify microbes. Dhc are the only known microorganisms capable of complete dechlorination of chloroethenes (i.e., tetrachloroethene, trichloroethene, cis-1,2-dichloroethene [cis-DCE] and vinyl chloride) to non-toxic ethene. Gene-Trac® Dhc may also be used to assess the in situ growth of Dhc containing bioaugmentation cultures such as KB-1®.

Negative Gene-Trac® Dhc Test Results (U qualified)

A non-detect in the Gene-Trac® Dhc assay (e.g., 4,000U) indicates that Dhc were not detected in the sample. The absence of Dhc is frequently associated with a lack of complete dechlorination or incomplete dechlorination of chlorinated ethenes. Where Dhc are absent the accumulation of cis-DCE is commonly observed, particularly after addition of electron donors. Bioaugmentation with Dhc containing cultures, such as KB-1®, is commonly used to improve bioremediation performance at sites that lack an indigenous Dhc population.

Positive Gene-Trac® Dhc Test Results

The detection of Dhc has been correlated with the complete biological dechlorination of chlorinated ethenes to ethene at contaminated sites (Hendrickson et al., 2002). A positive Gene-Trac® Dhc test indicates that Dhc DNA was detected in the sample and is encouraging for dechlorination of chlorinated ethenes to ethene. Note not all Dhc are capable of conversion of vinyl chloride to ethene; this capability can be determined by the Gene-Trac® VC test (see Section 2) which is commonly performed as a follow-on analysis after positive Gene-Trac® Dhc tests. In most cases Dhc must be present at sufficient concentrations in order for significant dechlorination to be observed, guidelines for expected impacts at various Dhc concentrations are indicated below.

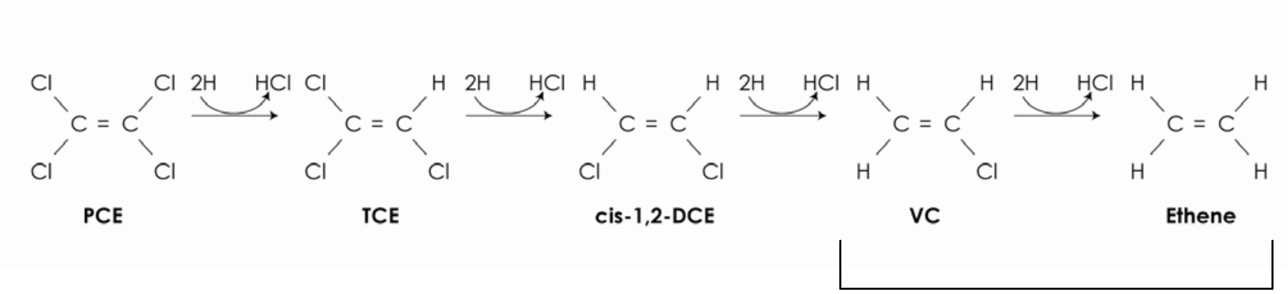
> **Values of 10^4 Dhc gene copies per liter (or lower):** indicates that the sample contains low concentrations of Dhc which may indicate that site conditions are suboptimal for high rates of dechlorination. Increases in Dhc concentrations at the site may be possible if conditions are optimized (e.g., electron donor addition).
>
> **Values of 10^5-10^6 Dhc gene copies per liter:** indicates the sample contains moderate concentrations of Dhc which may, or may not, be associated with observable dechlorination activity (i.e., detectable ethene).
>
> **Values at or above 10^7 Dhc gene copies per liter:** indicates that the sample contains high concentrations of Dhc that are often associated with high rates of dechlorination (Lu et al., 2006) and the production of ethene.
>
> **Values of 10^9 Dhc gene copies per liter** are generally the highest observed for groundwater samples with rare exceptions.

Gene-Trac® VC- Vinyl Chloride Reductase (*vcrA*) Test

Background

Gene-Trac® VC is a qPCR test for the vinyl chloride reductase (*vcrA*) gene that codes for a Dhc enzyme that converts (VC) to ethene, a critical step in reductive dechlorination of chlorinated ethenes. Gene-Trac® VC is commonly used where Gene-Trac® Dhc test results are positive to confirm that the Dhc detected are capable of complete dechlorination to ethene.#

The vinyl chloride reductase gene (*vcrA)* (Müller et al., 2004) produces an enzyme that is found in many (but not all) Dhc and is reported to be the most common identified VC reductase in the environment (van der Zaan et al., 2010).



Key activity of vinyl chloride reductase vcrA gene/enzyme

Interpretation of Gene-Trac® VC Results

Detect in Gene-Trac® VC Test

A detect in the Gene-Trac® VC test indicates that a Dhc population has the *vcrA* gene and the prospects for complete dechlorination to ethene are good. As a minimal requirement, *vcrA* copies exceeding 10^5/L combined with observed increases over time (i.e., cell growth) are required for robust VC dechlorination (van der Zaan et al., 2010). Also the guidelines for detection of ethene provided under Gene-Trac® Dhc are conservative for interpretation of Gene-Trac® VC (i.e., > 1 $x10^7$ gene copies/L indicate a high likelihood of detection of ethene). In one study, more than 90% of samples where *vcrA* enumeration exceeded 1 $x10^7$ gene copies/L had detectable ethene (Dennis, 2009). In cases where *vcrA* gene copies are lower the likelihood of detectable ethene decreases.

Non-Detect in Gene-Trac® VC Test (U qualified)

A non-detect in the Gene-Trac® VC test indicates that *vcrA* gene sequences in the sample are below the detection limit of the assay (typically 4 x 10^3 *vcrA* gene copies/L). This indicates VC accumulation (VC stall) is possible. Note negative Gene-Trac® VC test results do not indicate with 100% certainty that a VC-stall will occur as there are other vinyl chloride reductase genes, such as *bvcA* (van der Zaan et al., 2010) that also convert VC to ethene.

Comparing Gene-Trac® VC and Gene-Trac® Dhc Test Results

Sites may contain different types of Dhc populations. At some sites the Dhc population is homogenous while other sites have Dhc populations that are mixtures of different types of Dhc. This can lead to differing results for Gene-Trac® Dhc and Gene-Trac® VC.

In many cases, the numerical results of Gene-Trac® VC test are identical to those obtained in the Gene-Trac® Dhc test, indicating that the entire Dhc population contains the *vcrA* gene. In other cases, Gene-Trac® VC results may differ significantly (i.e., more than an order or magnitude) from the total Dhc for a number of reasons.

Table 3 provides some common scenarios for Gene-Trac® VC and Gene-Trac® Dhc test results. In general, where Gene-Trac® VC results are non-detect, or significantly lower than Gene-Trac® Dhc, accumulation of VC is more likely.

Table 2: Interpretation of Gene-Trac® VC in Relation to Gene-Trac® Dhc

Gene-Trac® Dhc (16S rRNA gene copies/ L)	Gene-Trac® VC (*vcr*A gene copies/L)	Results Summary	Interpretation	Potential Site Implications
2 x 10^8 /L	3 x 10^8/L	Total Dhc and *vcrA* are ~the same (within 3-fold)	Entire Dhc population has *vcrA* gene	Potential for complete dechlorination high. VC stall unlikely-sites with *vcr*A above 1x10^7/L typically have detectable ethene
1 x 10^8/L	Non-detect	Total Dhc high; *vcrA* non-detect	High concentration of Dhc and entire population lacks the *vcrA* gene	Likelihood for VC accumulation high as *vcrA* non-detect
1 x 10^8/L	1 x 10^6 /L	Total Dhc is significantly higher (100 fold) than *vcrA*	*Dhc* population consists of different types, some with the *vcrA* gene (~1%) and some without (~99%)	VC-accumulation possible; Dhc/*vcrA* proportions may change over course of remediation
1 x 10^6/L	1 x 10^8/L	*vcrA* orders of magnitude higher than Dhc	Significantly higher *vcrA* may indicate the presence of populations of non-Dhc microorganisms with *vcrA* like genes	Potential for VC-stall likely low

Gene-Trac® Dhb-Total *Dehalobacter* Test

Gene-Trac® Dhb is a qPCR test targeting the 16S rRNA gene sequences unique to *Dehalobacter* (Dhb). Dhb are implicated in the biodegradation of 1,1,1-trichloroethane (to chloroethane), 1,1,2-trichloroethane and 1,2-dichloroethane to ethene (Grostern and Edwards, 2006) and chloroform (to dichloromethane) (Grostern et al., 2010) as well as incomplete dechlorination of PCE and TCE to cis-DCE (Holliger et al.,1998). Gene-Trac® Dhb may also be used as a tool to assess the impact of bioaugmentation with the KB-1® Plus cultures which contain high concentrations of Dhb.

Positive Gene-Trac® Dhb Test Results (Detects)

A positive Gene-Trac® Dhb indicates that a member of the *Dehalobacter* (Dhb) genus was detected in the sample. The detection of Dhb indicates that some or all of the dechlorination activities attributed to Dhb may be present at the subject site. Increasing concentrations of Dhb are indicative of increased potential to degrade some or all of these compounds.

Note: the Gene-Trac® Dhb test will not differentiate the type of Dhb*;* therefore, observations of the specific biodegradation pathways and end products based on chemical analytical methods in conjunction with Gene-Trac® Dhb will increase the interpretability of Gene-Trac® Dhb results.

Note: Dhb have been reported to contain multiple copies (up to 4 per cell) of the 16S rRNA gene (Grostern and Edwards, 2008). This means that, unlike Dhc, there is not a 1:1 ratio between the 16S rRNA gene copy and the number of Dhb cells in a sample. Calculating the number of Dhb cells requires dividing the Gene-Trac® Dhb test result by the 16S rRNA gene copy number (often 3-4 copies/cell).

Non-detect Gene-Trac® Dhb Results (U qualified)

In cases where Gene-Trac® Dhb is not detected (e.g., 4,000U) this indicates that *Dehalobacter* species were not identified in the sample and that anaerobic reductive dechlorination of 1,1,1-TCA, 1,1,2-TCA, 1,2-DCA or chloroform, which are dechlorinated by *Dehalobacter*, may not be observed. This activity can be introduced at sites through the addition of bioaugmentation cultures containing *Dehalobacter* such as KB-1® Plus.

Key Elements of Gene-Trac® Data

Gene-Trac® test results include two key values (a) Target Gene Enumeration, an enumeration of target gene sequence by quantitative PCR (e.g. "Dhc Enumeration" "Dhb 16S Gene Copies" or "*vcrA* gene copies") and (b) Target gene percent (e.g. "Percent Dhc"), an estimated percentage of the microbial population comprised by microbes harboring the target gene and other microbes present in sample. Further explanation of these values is provided below.

a) Target Gene Enumeration

This value is the concentration of Dhc or Dhb 16S rRNA or *vcrA* gene copies detected in the sample. Results may be reported as either gene copies per liter (for groundwater) or per gram (for soil). In general, the greater the number of gene copies in a sample the greater the likelihood of related dechlorination activity. Dhc 16S gene copies are typically equivalent to the number of Dhc as they have 1 gene copy per cell this is not necessarily true for Dhb or *vcrA* which have the potential be present in multiple gene copies per cell. Guidelines for relating target gene presence and concentration to observable dechlorination activity for groundwater samples are provided below in previous sections.

b) Target Gene Percent (%Dhc, %Dhb, %*vcrA*)

This value estimates the percentage of the target gene (e.g., %Dhc) relative to other microorganisms in the sample based on the formulas/assumptions presented below. For example, %Dhc is a measure of the predominance of Dhc and, in general, the higher this percentage the better.

$$\%Dhc = \frac{\text{Number Dhc}}{\text{Number Dhc} + \text{Number other Bacteria}}$$

Where:

$$\text{Number other Bacteria} = \frac{\text{Total DNA in sample (ng)} - \text{DNA attributed to Dhc (ng)}}{{}^{*}4.0 \times 10^{-6}\ \text{ng DNA per bacterial cell}}$$

*Paul and Clark, (1996).

Percent Dhc (and % *vcrA*) values can range from very low fractions of percentages, in samples with low numbers of Dhc and a high number of other bacteria (incompletely colonized by Dhc), to greater than 50% in Dhc enriched locations (highly colonized by Dhc).

In addition to determining the predominance of the target gene target gene percent is also useful for interpretation of Dhc counts from different sampling locations, or the same location over time. For example, the %Dhc value can be used to correct Dhc counts where samples are biased due to non-representative sampling. Example 1 illustrates a hypothetical scenario where the %Dhc value improved data interpretation.

Example 1, use of %Dhc to interpret enumeration data

Table 2 presents results from MW-1 sampled in April, May and June. Based on the Dhc enumeration alone one would conclude that the concentration of Dhc held steady between April and May; however, the %Dhc indicates the proportion of Dhc actually increased from April to May and the unchanged count in May could be a case of low biomass recovery during sampling or other losses such as sample degradation in transit. The higher raw count and the higher percentage of Dhc in June confirm the trend of increasing Dhc concentrations over time.

Table 3: Use of % Dhc* Value to Diagnose Sampling Bias

Sample	Dhc Enumeration	%Dhc	Interpretation Based on %Dhc
MW-1, April	1.0 x 10^5/Liter	0.1%	Dhc is a low proportion of total microbial population
MW-1, May	1.0 x 10^5/Liter	1%	Dhc proportion increased 10-fold from April. Dhc enumeration was unchanged possibly due to low biomass recovery from monitoring well, non-biased sample would be [(1.0/0.1) x 1.0 x10^5] = 1.0 x 10^6/Liter
MW-1, June	1.0 x 10^7/Liter	10%	Dhc has increased 100-fold from April and confirms May sample was likely low biased

**Note: the above approach is also applicable to the "%vcrA" and "%Dhb" values provided on their respective test certificates*

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Appendix A: Data Qualifiers

Data Qualification

Data qualifiers and notes are used to clarify Gene-Trac® test results. Additional explanation beyond that provided on the test certificate is provided below.

“**U” Not detected, associated value is the quantitation limit.** Indicates that the target gene (microbe) was not detected in the sample above the quantitation limit of the assay. Note the quantitation limit value can change between samples as the volume filtered can vary; thus, a sample in which 100 ml was tested would have a 5–fold higher quantification limit compared with a sample in which 500 ml was tested.

“J” The associated value is an estimated quantity between the method detection limit and quantitation limit. Indicates that the target gene was conclusively detected but the concentration is below the quantitation limit where it cannot be accurately quantified.

“I” Sample inhibited the test reaction. This means universal primers were incapable of amplifying DNA from this sample. The inability to amplify with universal primers suggests that the sample may be imparting matrix interference. Matrix interference is commonly attributed to humic compounds, polyphenols and metals. Non-detects with an “I” qualifier are more likely to be false negative.

“B” Analyte was also detected in the method blank. Indicates that DNA was detected in a method blank or negative control; detectable contamination of the blanks with microbes or DNA containing the gene of interest is not uncommon as the test reaction is extremely sensitive. In most cases, blank contamination is at a very low level relative to test results (often orders of magnitude lower). In these cases, blank contamination is not relevant to interpretation of test results. The potential of test samples being contaminated (i.e. false positives) should be considered in cases where blank results are within 1 order of magnitude of test results.

APPENDIX B

Remedial Alternative Cost Estimates

TABLE B1

CROWN CHEVROLET CADILLAC ISUZU

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

Remedial Cost Component	Cost
Capital Costs	
1. Excavation (Sump and Pit) Soil Removal and Hydraulic Lift and Drain Line Confirmation Sampling	$140,000
2. On-site and Upgradient Groundwater Monitoring Well Destruction and Installation	$200,000
3. Vapor Barrier and Sub-Slab Depressurization System Installation	$500,000
4. Permeable Reactive Barrier with Zero Valent Iron and In-Barrier Monitoring Wells	$920,000
5. In-Situ Bioremediation Injections	$690,000
O&M Costs	
6. Groundwater Monitoring and Reporting (12 wells for 5 years)	$220,000
7. Institutional Controls (30 years)	$120,000
8. Vapor Barrier and Sub-Slab Depressurization System O&M and Monitoring (5 years)	$150,000
9. Indoor Air Monitoring and Reporting (5 years)	$30,000

	Total Costs			Incremental Costs		
Alternative	**Capital**	**O&M**	**Total**	**Capital**	**O&M**	**Total**
Alternative 1 (1+2+6+7)	**$340,000**	**$340,000**	**$680,000**	**$340,000**	**$340,000**	**$680,000**
Alternative 2 (1+2+3+6+7+8+9)	**$840,000**	**$520,000**	**$1,360,000**	**$500,000**	**$180,000**	**$680,000**
Alternative 3 (1+2+3+4+6+7+8+9)	**$1,760,000**	**$520,000**	**$2,280,000**	**$920,000**	**$0**	**$920,000**
Alternative 4a (1+2+3+4+5+6+7+8+9)	**$2,450,000**	**$520,000**	**$2,970,000**	**$690,000**	**$0**	**$690,000**

Note

1. Costs are for the purpose of feasibility study analysis only. Contractor estimates were not obtained for this
2. All costs are presented in 2012 dollars.

Abbreviation

O&M = operation and maintenance

TABLE B2

CORRECTIVE ALTERNATIVE COST ESTIMATE
Excavation (Sump and Pit) Soil Removal and Hydraulic Lift and Drain Line Confirmation Sampling

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Quantity	Unit	Unit Cost	Amount
1 - Contractor and Equipment Costs - Site Preparation and Excavation				
Mobilization/demobilization	1	lump sum	$2,500	$2,500
Buried utility/obstruction survey	1	lump sum	$1,500	$1,500
Soil excavation and loading	100	CY	$95	$9,500
Dewatering costs	1	lump sum	$4,000	$4,000
Testing of dewatered water	1	test	$400	$400
Disposal of dewatered water	1	lump sum	$1,200	$1,200
Testing of excavated soil	2	test	$400	$800
Transport and disposal of non-hazardous soil to Class II landfill	169	ton	$80	$13,520
Testing of confirmation samples (excavations)	15	test	$150	$2,250
Testing of confirmation samples (hydraulic lifts/drain lines)	23	test	$400	$9,200
Testing of groundwater	4	test	$150	$600
Controlled-density fill (includes placement)	100	CY	$180	$18,000
Grade area to match existing	1	lump sum	$1,500	$1,500
As-built drawings and closeout documents	1	lump sum	$5,000	$5,000
2 - Health and Safety Costs				
H&S supervisor and PPE	1	lump sum	$5,000	$5,000
A - SUBTOTAL (1 + 2)				$74,970
B. Bid Contingencies (% of A)			10%	$7,497
C. Scope Contingencies (% of A)			15%	$11,246
D. Subtotal Capital Costs With Bid and Scope Contingencies (A + B + C)				$93,713
E. Engineering Design (% of D)			20%	$18,743
F. Permitting & Agency Liaison (% of D)			6%	$5,623
G. Construction Oversight (% of D)			15%	$14,057
H. Project Management (% of D)			10%	$9,371
ESTIMATED TOTAL IMPLEMENTATION COST (D + E + F + G + H)				**$140,000**

Notes

1. Estimated soil overexcavation based remaining soil impacts, as presented in the *Remediation Report* (AMEC, 2011).
2. Excavation assumes 100% of the volume to be disposed of as non-hazardous waste to a Class II facility, because material from the 2011 excavation in the same areas (but with likely higher concentrations in soil) was disposed of as non-hazardous Class II waste.
3. Excavation will be conducted per the non-shoring method and CDF backfill used during the 2011 excavation.
4. Excavation duration based on a percentage of the time of completion for the 2011 excavation (i.e., 13 days to remove approximately 302 CY).
5. Unit rates based on the following sources: vendor costs obtained from other projects; engineering judgment to extrapolate appropriate costs from other projects.
6. Contingencies and professional service costs are from *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* , EPA 2000.
7. No costs for contractor performance bonds or insurance are included.
8. Monitoring costs are included in the groundwater monitoring O&M task.
9. Costs are for the purpose of feasibility study analysis only. Contractor estimates were not obtained for this analysis.

Abbreviations

CDF = controlled-density fill
CY = cubic yards
EPA = Environmental Protection Agency
F.E. Pit = front-end alignment pit
H&S = health and safety
O&M = operations and maintenance
PPE = personal protective equipment

TABLE B3

CORRECTIVE ALTERNATIVE COST ESTIMATE
On-site and Upgradient Groundwater Monitoring Well Destruction and Installation

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Quantity	Unit	Unit Cost	Amount
1 - Contractor and Equipment Costs - Initial Well Destruction and Installations				
Well destruction (seven existing wells)	7	each	$3,000	$21,000
Well installation (nine wells, coordinated with development)	9	each	$4,000	$36,000
Well destruction/installation reporting	1	lump sum	$5,000	$5,000
Final well destructions (after 5 years of monitoring)	12	each	$3,000	$36,000
Final well destruction report	1	lump sum	$5,000	$5,000
2 - Health and Safety Costs				
H&S supervisor and PPE	1	lump sum	$2,500	$2,500
A - SUBTOTAL (1 + 2)				$105,500
B. Bid Contingencies (% of A)			10%	$10,550
C. Scope Contingencies (% of A)			15%	$15,825
D. Subtotal Capital Costs With Bid and Scope Contingencies (A + B + C)				$131,875
E. Engineering Design (% of D)			20%	$26,375
F. Permitting & Agency Liaison (% of D)			6%	$7,913
G. Construction Oversight (% of D)			15%	$19,781
H. Project Management (% of D)			10%	$13,188
ESTIMATED TOTAL IMPLEMENTATION COST (D + E + F + G + H)				**$200,000**

Notes

1. Cost assumes destruction of existing wells prior to development.
2. Cost assumes installation of five shallow groundwater monitoring wells for future monitoring. Installation will be coordinated with development.
3. Cost assumes wells to be destroyed after four years of groundwater sampling.
4. Unit rates based on the following sources: vendor costs obtained from other projects; engineering judgment to extrapolate appropriate costs from other projects.
5. Contingencies and professional service costs are from *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* , EPA 2000.
6. No costs for contractor performance bonds or insurance are included.
7. Monitoring costs are included in the groundwater monitoring O&M task.
8. Costs are for the purpose of feasibility study analysis only. Contractor estimates were not obtained for this analysis.

Abbreviations

EPA = Environmental Protection Agency
H&S = health and safety
O&M = operations and maintenance
PPE = personal protective equipment

TABLE B4

CORRECTIVE ALTERNATIVE COST ESTIMATE
Vapor Barrier and Sub-Slab Depressurization System Installation

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Quantity	Unit	Unit Cost	Amount
1 - Contractor and Equipment Costs - SSD and Vapor Intrusion Barrier Installation				
Mobilization/demobilization	3	lump sum	$2,500	$7,500
Install wind-driven turbine fan on roof	20	each	$1,500	$30,000
Install sprayed applied membrane (60 mils, smoke testing) and SSD	55,300	SF	$4	$221,200
System startup and shakedown	1	lump sum	$5,000	$5,000
Site cleanup	1	allow	$1,500	$1,500
2 - Health and Safety Costs				
H&S supervisor and PPE	1	lump sum	$6,000	$6,000
3 - Completion Report				
As-built drawings and closeout documents	3	lump sum	$5,000	$15,000
A - SUBTOTAL (1 + 2 + 3)				$286,200
B. Bid Contingencies (% of A)			10%	$28,620
C. Scope Contingencies (% of A)			15%	$42,930
D. Subtotal Capital Costs With Bid and Scope Contingencies (A + B + C)				$357,750
E. Engineering Design (% of D)			15%	$53,663
F. Permitting & Agency Liaison (% of D)			6%	$21,465
G. Construction Oversight (% of D)			10%	$35,775
H. Project Management (% of D)			8%	$28,620
ESTIMATED TOTAL IMPLEMENTATION COST (D + E + F + G + H)				**$500,000**

Notes

1. Unit rates based on the following sources: vendor costs obtained from other projects; engineering judgment to extrapolate appropriate costs from other projects; recent subcontractor costs for similar projects.
2. Contingencies and professional service costs are from *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* , EPA 2000.
3. Building square footage estimate based on Achitects Orange development plans ("Option B - Ground Level").
4. Cost assumes no active treatment of sub-slab gas venting is necessary.
5. No costs for contractor performance bonds or insurance are included.
6. Costs are for the purpose of feasibility study analysis only. Contractor estimates were not obtained for this analysis.

Abbreviations

EPA = Environmental Protection Agency
H&S = health and safety
mil = approximately 1/1000 inch
LF = linear feet
PPE = personal protective equipment
SSD = sub-slab depressurization system
SF = square feet

TABLE B5

CORRECTIVE ALTERNATIVE COST ESTIMATE

Permeable Reactive Barrier with Zero Valent Iron and In-Barrier Monitoring Wells

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Quantity	Unit	Unit Cost	Amount
1 - Pre-Design Activities				
Pre-installation investigation (soil borings and groundwater sampling)	1	lump sum	$25,000	$25,000
ZVI Column Testing	1	lump sum	$25,000	$25,000
2 - Contractor and Equipment Costs - Site Preparation and PRB Installation				
Mobilization/demobilization	1	lump sum	$50,000	$50,000
Surveying - site preparation - trench alignments - well installations	1	lump sum	$8,000	$8,000
Buried utility/obstruction survey and decommissioning	1	lump sum	$15,000	$15,000
Install ZVI continuous trenching	200	LF	$500	$100,000
Granular ZVI (200 ft x 12 ft x 1.0 ft)	178	ton	$800	$142,400
Granular ZVI Packing and Transportation	178	ton	$185	$32,930
Sand (200 ft x 12 ft x 0.5 ft)	62	ton	$33	$2,046
In-barrier groundwater well installation	3	each	$2,500	$7,500
Controlled-density fill (includes placement)	119	CY	$180	$21,420
License fee for using ZVI	1	lump sum	$36,000	$36,000
Testing of excavated soil	4	test	$850	$3,400
Transport and disposal of non-RCRA hazardous soil to Class I landfill	375	ton	$80	$30,000
General site restoration/cleanup	1	allow	$2,500	$2,500
3 - Health and Safety Costs				
H&S supervisor and PPE	1	lump sum	$11,000	$11,000
Air monitoring	5	days	$850	$4,250
4 - Completion Report				
As-built drawings and closeout documents	1	lump sum	$15,000	$15,000
A - SUBTOTAL (1 + 2 + 3 + 4)				$531,446
B. Bid Contingencies (% of A)			10%	$53,145
C. Scope Contingencies (% of A)			15%	$79,717
D. Subtotal Capital Costs With Bid and Scope Contingencies (A + B + C)				$664,308
E. Engineering Design (% of D)			15%	$99,646
F. Permitting & Agency Liaison (% of D)			6%	$39,858
G. Construction Oversight (% of D)			10%	$66,431
H. Project Management (% of D)			8%	$53,145
ESTIMATED TOTAL IMPLEMENTATION COST (D + E + F + G + H)				**$920,000**

Notes

1. Cost assumes all excavated soil will be disposed of as non-RCRA hazardous waste. Soil is assumed to be non-hazardous based on available VOC data; no data are available for metals or other constituents. Waste characterization will be performed on excavated soil to validate these assumptions. Soil is expected to be classified as a characteristic waste, and not as a listed waste.
2. Cost assumes trenching will be conducted with continuous trenching equipment, and no shoring will be needed.
3. Cost assumes that 66% ZVI will be installed in the bottom 12 feet of the wall with 8 feet of CDF to the top.
4. Cost includes a license fee for the use of ZVI in a PRB.
5. Unit rates based on the following sources: vendor costs obtained from other projects; engineering judgment to extrapolate appropriate costs from other projects.
6. Contingencies and professional service costs are from *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* , EPA 2000.
7. No costs for contractor performance bonds or insurance are included.
8. Monitoring costs are included in the groundwater monitoring O&M task.
9. Costs are for the purpose of feasibility study analysis only. Contractor estimates were not obtained for this analysis.

Abbreviations

CDF = controlled-density fill
CY = cubic yards
EPA = Environmental Protection Agency
ft = feet
H&S = health and safety
LF = linear feet
O&M = operations and maintenance
PPE = personal protective equipment
PRB = permeable reactive barrier
RCRA = Resource Conservation and Recovery Act
VOC = volatile organic compound
ZVI = zero-valent iron

TABLE B6

CORRECTIVE ALTERNATIVE COST ESTIMATE
In-Situ Bioremediation Injections

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Quantity	Unit	Unit Cost	Amount
1 - Contractor and Equipment Costs - Site Preparation and Injection				
Mobilization/demobilization	2	lump sum	$ 5,000	$ 10,000
Surveying - site preparation	2	lump sum	$ 1,000	$ 2,000
Buried utility/obstruction survey	2	lump sum	$ 5,000	$ 10,000
Organic substrate cost (total for two events, delivered)	24,000	lb	$ 3	$ 72,000
Organic substrate injection costs (single event)	30	days	$ 4,000	$ 120,000
Bioaugmentation substrate cost (total for one event, delivered)	800	liter	$ 120	$ 96,000
Bioaugmentation substrate injection costs (single event)	6	days	$ 4,000	$ 24,000
Water costs for dilution of substrate (1 unit = 748 gallons)	39	unit	$ 1	$ 57
De-oxygenating amendment for dilution water (delivered)	720	lbs	$ 5	$ 3,600
Closed top, vented tank to hold dilution water while de-oxygenating	1	month	$ 3,500	$ 3,500
Labor related to de-oxygenating dilution water	1	lump sum	$ 10,000	$ 10,000
2 - Health and Safety Costs				
H&S supervisor and PPE	2	lump sum	$ 9,000	$ 18,000
3 - Completion Report				
As-built drawings and closeout documents	1	lump sum	$ 30,000	$ 30,000
A - SUBTOTAL (1 + 2 + 3)				$399,157
B. Bid Contingencies (% of A)			10%	$39,916
C. Scope Contingencies (% of A)			15%	$59,873
D. Subtotal Capital Costs With Bid and Scope Contingencies (A + B + C)				$498,946
E. Engineering Design (% of D)			15%	$74,842
F. Permitting & Agency Liaison (% of D)			6%	$29,937
G. Construction Oversight (% of D)			10%	$49,895
H. Project Management (% of D)			8%	$39,916
ESTIMATED TOTAL IMPLEMENTATION COST (D + E + F + G + H)				**$690,000**

Notes
1. Estimate assumes 240 injection points will be installed; injection points will be installed on a 15-foot grid.
2. Unit rates based on the following sources: vendor costs obtained from other projects; engineering judgment to extrapolate appropriate costs from other projects.
3. Contingencies and professional service costs are from *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* , EPA 2000.
4. No costs for contractor performance bonds or insurance are included.
5. Monitoring costs are included in the groundwater monitoring task.
6. Costs are for the purpose of feasibility study analysis only. Contractor estimates were not obtained for this analysis.

Abbreviations
EPA = Environmental Protection Agency
H&S = health and safety
lbs = pounds
PPE = personal protective equipment

TABLE B7

CORRECTIVE ALTERNATIVE COST ESTIMATE
Groundwater Monitoring and Reporting (12 wells for 5 years)

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Quantity	Unit	Unit Cost	Yearly Amount	# of Years	Amount
1 - Maintenance and Repair						
Yearly maintenance	1	each	$ 2,000	$ 2,000	3	$ 6,000
2 - Groundwater Sampling						
First quarterly event (12 wells, including analysis)	1	each	$ 9,600	$ 9,600	1	$ 9,600
Quarterly events - first 2 years	3.5	each	$ 9,600	$ 33,600	2	$ 67,200
Annual event - year 3	1	each	$ 9,600	$ 9,600	1	$ 9,600
Annual event - year 4	1	each	$ 9,600	$ 9,600	1	$ 9,600
Annual event - year 5	1	each	$ 9,600	$ 9,600	1	$ 9,600
3 - Groundwater Monitoring Reporting						
First quarterly report	1	each	$ 5,000	$ 5,000	1	$ 5,000
Quarterly reports - first 2 years	3.5	each	$ 2,500	$ 8,750	2	$ 17,500
Annual report - year 3	1	each	$ 2,500	$ 2,500	1	$ 2,500
Annual report - year 4	1	each	$ 2,500	$ 2,500	1	$ 2,500
Closure request report	1	each	$ 21,000	$ 21,000	1	$ 21,000
4 - Agency Oversight						
Review (first quarterly event)	1	each	$ 2,976	$ 2,976	1	$ 2,976
Review (quarterly events - first 2 years)	3.5	each	$ 1,488	$ 5,208	2	$ 10,416
Review (annual event - years 3 and 4)	1	each	$ 1,488	$ 1,488	2	$ 2,976
Review (annual event - year 4)	1	each	$ 4,464	$ 4,464	1	$ 4,464
A. SUBTOTAL COSTS (1 + 2 + 3 + 4)						$ 181,000
B. Scope Contingencies (% of A)					10%	$ 18,000
C. Project Management (% of A)					10%	$ 18,000
ESTIMATED TOTAL COST (A + B + C)						**$ 220,000**

Notes
1. Cost assumes five years of groundwater monitoring.
2. Cost assumes quarterly sampling and reporting for years 1 and 2, and annual sampling and reporting for years 3 through 5.
3. Cost assumes the groundwater monitoring program will be used for any groundwater remedy installed (e.g., PRB, etc.).
4. Unit rates based on the following sources: vendor costs obtained from other projects; engineering judgment to extrapolate appropriate costs from other projects.
5. Well destruction costs are included in the capital costs in the groundwater monitoring task.
6. Costs are for the purpose of feasibility study analysis only. Contractor estimates were not obtained for this analysis.

Abbreviations
O&M = operations and maintenance
PRB = permeable reactive barrier

TABLE B8

CORRECTIVE ALTERNATIVE COST ESTIMATE
Institutional Controls (30 years)
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Quantity	Unit	Unit Cost	Yearly Amount	# of Years	Amount
1 - Plans						
Intitutional Control Plan	1	each	$ 50,000	$ 50,000	1	$ 50,000
Site Management Plan	1	each	$ 20,000	$ 20,000	1	$ 20,000
2 - Annual Site Inspections						
Site inspection (Y1-Y2, semiannual)	2	each	$ 1,200	$ 2,400	2	$ 4,800
Site inspection (Y3-Y4, annual)	1	each	$ 1,200	$ 1,200	2	$ 2,400
Site inspection (Y5-Y20, every five years)	1	each	$ 1,200	$ 1,200	4	$ 4,800
3 - Site Inspection Reporting						
Reporting (Y1-Y2, semiannual)	2	each	$ 2,000	$ 4,000	2	$ 8,000
Reporting (Y3-Y4, annual)	1	each	$ 1,500	$ 1,500	2	$ 3,000
Reporting (Y5-Y20, every five years)	1	each	$ 1,500	$ 1,500	4	$ 6,000
4 - Agency Oversight						
Review (Y1-Y2, semiannual)	2	report	$ 372	$ 744	2	$ 1,488
Review (Y3-Y4, annual)	1	report	$ 372	$ 372	2	$ 744
Review (Y5-Y20, every five years)	1	report	$ 372	$ 372	4	$ 1,488
A. SUBTOTAL COSTS (1 + 2 + 3 + 4)						$ 103,000
B. Scope Contingencies (% of A)					10%	$ 10,000
C. Project Management (% of A)					10%	$ 10,000
ESTIMATED TOTAL COST (A + B + C)						**$ 120,000**

Notes
1. Cost assumes periodical site visits to inspect for compliance with institutional land use controls and integrity of remedy.
2. Cost assumes a period of 20 years; inspection frequencies over this period are outlined in the above table.
3. Cost assumes a letter report for each inspection.
4. Unit rates based on the following sources: vendor costs obtained from other projects; engineering judgment to extrapolate appropriate costs from other projects.
5. Costs are for the purpose of feasibility study analysis only. Contractor estimates were not obtained for this analysis.

TABLE B9

CORRECTIVE ALTERNATIVE COST ESTIMATE
Vapor Barrier and Sub-Slab Depressurization System O&M and Monitoring (5 years)
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Quantity	Unit	Unit Cost	Yearly Amount	# of Years	Amount
1 - Maintenance and Repair						
Yearly maintenance of conveyance piping and turbines	1	each	$ 2,500	$ 2,500	5	$ 12,500
2 - System Operation & Maintenance						
Passive SSD labor costs, year 1	12	mo	$ 1,500	$ 18,000	1	$ 18,000
Passive SSD analytical costs, year 1	88	each	$ 200	$ 17,600	1	$ 17,600
Passive SSD labor costs, years 2-5	4	mo	$ 1,500	$ 6,000	4	$ 24,000
Passive SSD analytical costs, years 2-5	44	each	$ 200	$ 8,800	4	$ 35,200
3 - System O&M Reporting						
Reporting (semi-annual), year 1	2	report	$ 2,000	$ 4,000	1	$ 4,000
Reporting (annual), years 2-5	1	report	$ 2,000	$ 2,000	4	$ 8,000
4 - Agency Oversight						
Review (Y1-Y5, annual)	1	report	$ 744	$ 744	5	$ 3,720
A. SUBTOTAL COSTS (1 + 2 + 3 + 4)						$ 123,000
B. Scope Contingencies (% of A)					10%	$ 12,000
C. Project Management (% of A)					10%	$ 12,000
ESTIMATED TOTAL COST (A + B + C)						**$ 150,000**

Notes
1. Cost assumes five years of O&M.
2. Cost assumes O&M of SSD system will decrease over time.
3. Cost assumes risers will remain in place until building removal.
4. Cost assumes SSD system is exempt from BAAQMD requirements/fees.
5. Unit rates based on the following sources: vendor costs obtained from other projects; engineering judgment to extrapolate appropriate costs from other projects.
6. Costs are for the purpose of feasibility study analysis only. Contractor estimates were not obtained for this analysis.

Abbreviations
BAAQMD = Bay Area Air Quality Management District
mo = month
O&M = operations and maintenance
SSD = sub-slab depressurization system

TABLE B10

CORRECTIVE ALTERNATIVE COST ESTIMATE
Indoor Air Monitoring and Reporting (5 years)
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Quantity	Unit	Unit Cost	Yearly Amount	# of Years	Amount
1 - Indoor Air Sampling						
Indoor air labor costs, (Y2 and Y4)	1	mo	$ 3,000	$ 3,000	2	$ 6,000
Indoor air sampling equipment costs, (Y2 and Y4)	14	each	$ 75	$ 1,050	2	$ 2,100
Indoor air laboratory costs, (Y2 and Y4)	14	each	$ 175	$ 2,450	2	$ 4,900
2 - Indoor Air Monitoring Reporting						
Reporting (Y1 and Y4)	1	each	$ 3,500	$ 3,500	2	$ 7,000
3 - Agency Oversight						
Review (Y1 and Y4)	1	report	$ 372	$ 372	2	$ 744
A. SUBTOTAL COSTS (1 + 2 + 3)						$ 21,000
B. Scope Contingencies (% of A)					10%	$ 2,000
C. Project Management (% of A)					10%	$ 2,000
ESTIMATED TOTAL COST (A + B + C)						**$ 30,000**

Notes
1. Cost assumes collection of 1 sample for up to approximately 5,000 sf of floor plan during initial semiannual sampling (12 primary samples), as well as collection of 2 QA/QC samples during each sampling event.
2. Cost assumes a total of two indoor air monitoring event within the first five years post SSD installation.
3. Cost assumes risers will remain in place until building removal.
4. Unit rates based on the following sources: vendor costs obtained from other projects; engineering judgment to extrapolate appropriate costs from other projects.
5. Costs are for the purpose of feasibility study analysis only. Contractor estimates were not obtained for this analysis.

Abbreviations
mo = months
QA/QC = quality assurance/quality control
sf = square feet

APPENDIX C

Development of Risk-Based Screening Levels for Groundwater

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APPENDIX C

DEVELOPMENT OF RISK-BASED SCREENING LEVELS FOR GROUNDWATER

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

1.0 INTRODUCTION

This appendix presents risk-based screening levels (RBSLs) that were developed by AMEC Environment & Infrastructure, Inc. (AMEC) to evaluate potential human health risks associated with exposure to tetrachloroethene (PCE) and trichloroethene (TCE) present in groundwater at the Crown Chevrolet Cadillac Isuzu located at 7544 Dublin Boulevard and 6707 Golden Gate Drive in Dublin, California (the site). The RBSLs were developed using the methodology presented by the United States Environmental Protection Agency (U.S. EPA) for Regional Screening Levels (RSLs) (U.S. EPA, 2012) and the more protective toxicity criteria from either Office of Environmental Health Hazard Assessment (OEHHA) or U.S. EPA, consistent with California Department of Toxic Substances Control (DTSC) guidance on the use of RSLs and conducting screening-level human health risk assessments (HHRAs) in California (DTSC, 2011a, 2012). The following three-step process was applied to develop these RBSLs:

1. Calculation of target indoor air concentrations. Target indoor air concentrations, were developed for PCE and TCE for both cancer risks and noncancer hazards using U.S. EPA's equations for residential air RSLs (U.S. EPA, 2012). These target indoor air concentrations are equivalent to Environmental Screening Levels developed by the California Regional Water Quality Control Board, San Francisco Bay Region (Regional Water Board, 2013), and were derived in accordance with the ESL guidance document.
2. Use of the Johnson and Ettinger vapor intrusion model to calculate chemical- and depth-specific, groundwater–to–indoor air attenuation factors using DTSC/OEHHA protocols for estimating groundwater-to-indoor air attenuation (DTSC, 2011b; OEHHA, 2005).
3. Calculation of the groundwater RBSLs.

This appendix presents the toxicity criteria (Table C-1), equations and assumptions (Tables C-2 through C-4), and vapor intrusion model spreadsheets (Attachment C-1) used to derive the RBSLs for indoor air hypothetical future residents, and the resulting depth-specific RBSLs for groundwater. Evaluation of the hypothetical future residents was selected because the redevelopment plans for site is tentatively planned for mixed-use with retail space at ground level and apartments located above.

2.0 CALCULATION OF TARGET INDOOR AIR CONCENTRATIONS

The equations used to develop the target indoor air concentrations (indoor air RBSLs) are presented below, as provided in Appendix B of the CHHSL guidance document (OEHHA, 2005). As noted above, the indoor air RBSLs are equivalent to the current residential indoor air ESLs. Indoor air RBSLs were developed for both cancer risks (Equation 1) and noncancer hazards (Equation 2):

$$\mathrm{RBSL}_{ia-c} = \frac{\mathrm{TR\ x\ AT_c\ x\ 365\ days/year}}{\mathrm{EF\ x\ ED} \times \mathrm{URF}} \qquad (1)$$

Where:

$\mathrm{RBSL}_{ia\text{-}c}$ = indoor air RBSL for cancer risks (micrograms per cubic meter [$\mu g/m^3$])
TR = target risk level ($1x10^{-6}$)
AT_c = averaging time for carcinogens (years)
EF = exposure frequency (days/year)
ED = exposure duration (years)
URF = unit risk factor [$(\mu g/m^3)^{-1}$], chemical-specific

$$\mathrm{RBSL}_{ia-nc} = \frac{\mathrm{THQ\ x\ AT_{nc}\ x\ 365\ days/year\ x\ CF_{mg\text{-}ug}}}{\mathrm{EF\ x\ ED\ x\ \ 1/REL(RfC)}} \qquad (2)$$

Where:

$\mathrm{RBSL}_{ia\text{-}nc}$ = indoor air RBSL for noncancer hazards ($\mu g/m^3$)
THQ = target hazard quotient (1)
AT_{nc} = averaging time for noncarcinogens (years)
$\mathrm{CF}_{mg\text{-}ug}$ = unit conversion from milligrams to micrograms (1000 µg/mg)
REL (RfC) = reference exposure level (or reference concentration) (milligrams per cubic meter [mg/m^3])
All other terms previously defined

The cancer and noncancer toxicity criteria selected to derive the indoor air RBSLs are presented in Table C-1. Unit risk factors (URFs) were selected from the OEHHA Toxicity Criteria Database (OEHHA, 2013) and the U.S. EPA Integrated Risk Information System (IRIS) on-line database (U.S. EPA, 2013). Similarly, the reference exposure levels (RELs) and reference concentrations (RfCs) were selected from the OEHHA Toxicity Criteria Database (OEHHA, 2013), OEHHA Chronic Reference Exposure Levels Table (OEHHA, 2012), and IRIS on-line database (U.S. EPA, 2013).

U.S. EPA published revised toxicity criteria for PCE on February 10, 2012 and for TCE on September 28, 2011 (U.S. EPA, 2013); however, OEHHA has not revised the toxicity criteria for either PCE or TCE. For comparative purposes, both the U.S. EPA and OEHHA toxicity criteria for PCE and TCE are presented in Table C-1, but the proposed RBSLs are based on the more conservative toxicity criteria for both PCE and TCE. Specifically, the RBSLs derived for PCE are based on the more conservative OEHHA URF and REL. For TCE, the RBSLs derived to evaluate TCE are based on the more conservative U.S. EPA URF and RfC.

3.0 CALCULATION OF GROUNDWATER-TO-INDOOR AIR ATTENUATION FACTORS

Attenuation factors provided by the Johnson and Ettinger (1991) vapor intrusion model (J&E model) relate vapor concentrations in indoor air to groundwater concentrations in the subsurface by accounting for the one-dimensional convective and diffusive mechanisms of vapor transport from the subsurface to indoor air. Consistent with OEHHA's methodology for calculating CHHSLs for soil gas (OEHHA, 2005), the advanced J&E model spreadsheets for groundwater, parameterized by the U.S. EPA (2004) and adopted and republished by the DTSC (2004), were used to calculate groundwater–to–indoor air attenuation factors.

Inputs to the advanced groundwater model spreadsheets used for this assessment include chemical properties, site-specific vadose zone soil properties, and conservative default assumptions regarding the structural properties of the hypothetical future buildings at the site. Exposure and toxicity assumptions presented in the model spreadsheets were not actually used in the RBSL development; the model spreadsheets were used only to estimate chemical- and depth-specific attenuation factors. For the future residential scenario, attenuation factors were estimated for the approximate depth to groundwater at the site, 10 feet bgs (Table C-3).

Consistent with OEHHA guidance for future buildings (OEHHA, 2005), the subsurface for the residential scenario was modeled as a concrete slab with a mixture of crushed rock (or gravel) and sand below the slab (Stratum A), and a layer of engineered fill material used to stabilize the building (Stratum B). The default physical soil parameters for sandy soil were selected to represent Strata A and B.

Stratum C was selected to represent the interval between the bottom of the layer of engineered fill and the depth of ground water; sandy clay was selected to represent Stratum C. The lithology at this site consist primarily of finer-grained deposits (clays, sandy clays, silts, and sandy silts) with interbedded sand lenses from ground surface to approximately 20 feet bgs (AMEC, 2012). The default values for Soil Conservation Service (SCS; now Natural Resources Conservation Service) soil type "sandy clay (SC)" provided by OEHHA (2005), as recommended by U.S. EPA (2004), for dry bulk density, total porosity, and water-filled porosity were selected as inputs for Stratum C.

All input parameters to the J&E models are presented in Table C-3. The J&E model spreadsheets used to estimate the chemical- and depth-specific attenuation factors for the residential scenarios are presented in Attachment C-1.

4.0 CALCULATION OF GROUNDWATER RISK-BASED SCREENING LEVELS

The groundwater RBSLs were calculated from the indoor air RBSLs using the following equation (Equation 3):

$$RBSL_{gw} = \frac{RBSL_{ia}}{\alpha_{gw-ia} \times H'} \qquad (3)$$

Where:

$RBSL_{gw}$ = groundwater RBSL (µg/m^3)
$RBSL_{ia}$ = indoor air RBSL (µg/m^3)
α_{gw-ia} = groundwater-to-indoor air attenuation factor (unitless)
H' = Henry's Law Constant (unitless)

The chemical-specific Henry's Law Constant was used to calculate the indoor air RBSLs and groundwater RBSLs. Henry's Law states that the amount of the chemical present in soil vapor is directly proportional to its equilibrium concentration in groundwater. Table C-4 presents the RBSL calculations and resulting depth-specific RBSLs for future residents for PCE and TCE in groundwater at a depth of 10 feet bgs.

5.0 REFERENCES

AMEC Environment & Infrastructure, Inc., 2012, Soil, Groundwater, and Soil Vapor Investigation Report, Crown Chevrolet Cadillac Isuzu, 7544 Dublin Boulevard and 6707 Golden Gate Drive, Dublin, California, October 19.

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United States Environmental Protection Agency (U.S. EPA), 2004, User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings: Office of Emergency and Remedial Response, February 22.

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TABLES

TABLE C-1

TOXICITY CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Current Toxicity Criteria Available				
	Carcinogenic Toxicity Criteria		Noncarcinogenic Toxicity Criteria		
	Unit Risk Factor (URF)		Reference Concentration (RfC)		
Chemical	**Value ($\mu g/m^3$)$^{-1}$**	**Source**	**Value (mg/m^3)**	**Source**	**Notes**
Tetrachloroethene	5.9E-06	OEHHA TCDB	3.5E-02	OEHHA REL	Selected Toxicity Criteria
	2.6E-07	IRIS [1]	4.0E-02	IRIS [1]	Comparative
Trichloroethene	4.1E-06	IRIS	2.0E-03	IRIS	Selected Toxicity Criteria
	2.0E-06	OEHHA TCDB [2]	0.6	OEHHA REL	Comparative

Notes

1. U.S. EPA published revised noncarcinogenic and carcinogenic toxicity criteria for tetrachloroethene (PCE) on February 10, 2012 (IRIS, 2012); OEHHA has not published a revision to its toxicity criteria. For comparative purposes, both the U.S. EPA and OEHHA RfCs and URFs for PCE are presented, but the OEHHA toxicity criteria for PCE was conservatively selected to evaluate noncarcinogenic and carcinogenic health effects.
2. U.S. EPA published revised carcinogenic toxicity criteria for trichloroethylene (TCE) on September 28, 2011 (IRIS, 2011); OEHHA has not published a revision to its toxicity criteria. For comparative purposes, both the U.S. EPA and OEHHA URFs for TCE are presented, but the U.S. EPA toxicity criteria for TCE was conservatively selected to evaluate carcinogenic health effects.

Toxicity Criteria Sources

IRIS = USEPA, 2013, Integrated Risk Information System (IRIS) database.
OEHHA REL = Chronic Reference Exposure Level, from OEHHA, 2013, Toxicity Criteria Database
OEHHA TCDB = OEHHA, 2013, Toxicity Criteria Database

Abbreviations

-- = not available
mg/kg-day = milligrams per kilogram per day
mg/m^3 = milligrams per cubic meter
µg/m^3 = micrograms per cubic meter
RfC = Reference Concentration
URF = unit risk factor

TABLE C-2

TARGET INDOOR AIR CONCENTRATIONS—FUTURE RESIDENTIAL SCENARIO

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

	Toxicity Criteria		**Target Indoor Air Concentrations**	
	Cancer	**Noncancer**	**Cancer**	**Noncancer**
Compound	**Unit Risk Factor (URF) ($\mu g/m^3)^{-1}$**	**Reference Exposure Level (or Reference Concentration) (REL/RfC) (mg/m^3)**	**Residential ($C_{ia\text{-}c,\ res}$) ($\mu g/m^3$)**	**Residential ($C_{ia\text{-}nc,\ res}$) ($\mu g/m^3$)**
Tetrachloroethene	5.9E-06	3.5E-02	0.4	40
	2.6E-07	4.0E-02	9.4	40
Trichloroethene	4.1E-06	2.0E-03	0.6	2.1
	2.0E-06	6.0E-01	1.22	630

Note
Rows shaded gray are for comparison purposes only.

Abbreviations
-- = not applicable
NC = no unit risk factor available (not an established carcinogen)
mg/m^3 = milligrams per cubic meter
$\mu g/m^3$ = micrograms per cubic meter

Exposure Parameters (OEHHA, 2005)

Parameter	**Value**
ATc (years)	70
ATnc (years)	30
EF (days/year)	350
ED (years)	30

Constants

Constant	**Value**
TR (unitless)	1E-06
THQ (unitless)	1
$CF_{mg\text{-}\mu g}$ (µg/mg)	1E+03

Equations

$$C_{ia\text{-}c,\ c/i} = \frac{TR \times AT_c \times 365\ \text{days/year}}{EF \times ED \times URF}$$

$$C_{ia\text{-}nc,\ c/i} = \frac{THQ \times AT_{nc} \times 365\ \text{days/year} \times CF_{mg\text{-}\mu g}}{EF \times ED \times 1/REL(RfC)}$$

TABLE C-3

SUMMARY OF JOHNSON AND ETTINGER MODEL ASSUMPTIONS

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

Parameter	Symbol	Units	Future Residential Scenario	Rationale
Depth below grade to bottom of enclosed space floor	L_F	cm	9	Default value for slab-on-grade construction (OEHHA, 2005).
Depth to groundwater	L_t	cm	**305 (10 feet)**	Depth to groundwater at the site is approximately 10 feet below ground surface.
Average soil temperature	Ts	C^o	24	Average temperature recommended by DTSC (2011).
Thickness of soil stratum A	h_A	cm	19	Default thickness (9 cm) of concrete slab for typical future building construction, combined with default thickness (10 cm) of crushed rock or gravel, and sand mixture installed below the slab (OEHHA, 2005).
Thickness of soil stratum B	h_B	cm	30	Default thickness of engineered fill used to stabilize the building (OEHHA, 2005).
Thickness of soil stratum C	h_C	cm	**259**	Depth to groundwater minus thickness of soil strata A and B
Stratum A SCS soil type	--	--	S (Sand)	Stratum A represents the concrete slab and a layer of crushed rock, gravel, and sand beneath the slab. Both layers are modeled as sand, per OEHHA (2005).
Stratum A soil dry bulk density	$\rho_{b, A}$	g/cm^3	1.66	Default value for sand SCS soil type provided by OEHHA (2005), as recommended by USEPA (2004).
Stratum A soil total porosity	$P_{T, A}$	cm^3/cm^3	0.375	Default value for sand SCS soil type provided by OEHHA (2005), as recommended by USEPA (2004).
Stratum A soil water-filled porosity	$P_{w, A}$	cm^3/cm^3	0.054	Default value for sand SCS soil type provided by OEHHA (2005), as recommended by USEPA (2004).
Stratum B SCS soil type	--	--	SIC (Engineered fill)	Engineered fill used to stabilize the building (OEHHA, 2005).
Stratum B soil dry bulk density	$\rho_{b, B}$	g/cm^3	1.8	Bulk density of engineered fill provided by OEHHA (2005).
Stratum B soil total porosity	$P_{T, B}$	cm^3/cm^3	0.3	Total porosity of engineered fill provided by OEHHA (2005).
Stratum B soil water-filled porosity	$P_{w, B}$	cm^3/cm^3	0.15	Water-filled porosity of engineered fill provided by OEHHA (2005).
Stratum C SCS soil type	--	--	**SC (Sandy Clay)**	Subsurface investigation findings for the site indicate that subsurface materials consist primarily of finer-grained deposits (clays, sandy clays, silts, and sandy silts) with interbedded sand lenses from ground surface to approximately 20 feet bgs. Stratum C soil type was assumed to be sandy clay due to the finer-grained deposits. Default values for dry bulk density, total porosity, and water-filled porosity provided by OEHHA (2005), as recommended by USEPA (2004), were used in the model as presented below.
Stratum C soil dry bulk density	$\rho_{b, C}$	g/cm^3	**1.63**	Default value for sandy clay SCS soil type provided by OEHHA (2005), as recommended by USEPA (2004).
Stratum C soil total porosity	$P_{T, C}$	cm^3/cm^3	**0.385**	Default value for sandy clay SCS soil type provided by OEHHA (2005), as recommended by USEPA (2004).
Stratum C soil water-filled porosity	$P_{w, C}$	cm^3/cm^3	**0.197**	Default value for sandy clay SCS soil type provided by OEHHA (2005), as recommended by USEPA (2004).
Enclosed space floor thickness	L_{crack}	cm	9	Default thickness of concrete slab for typical current building construction (OEHHA, 2005).

TABLE C-3

SUMMARY OF JOHNSON AND ETTINGER MODEL ASSUMPTIONS

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

Parameter	Symbol	Units	Future Residential Scenario	Rationale
Enclosed space floor length	L_B	cm / ft	1000 / 33	Default value provided by OEHHA (2005), as recommended by USEPA (2004)
Enclosed space floor width	W_B	cm / ft	1000 / 33	Default value provided by OEHHA (2005), as recommended by USEPA (2004)
Enclosed space floor height	H_B	cm / ft	244 / 8	Default value provided by OEHHA (2005), as recommended by USEPA (2004)
Floor-wall seam crack width	w	cm	0.1	Default value provided by OEHHA (2005), as recommended by USEPA (2004)
Indoor air exchange rate	ER	1/hr	0.5	Default value for residential and commercial/industrial buildings, provided by DTSC (2011b) and OEHHA (2005).
Average vapor flow rate into building	Q_{soil}	L/min	5	The default value for a 10 m x 10 m building (DTSC, 2011b; USEPA, 2004).
Crack-to-Total Area Ratio	η	-	0.005	Default value recommended by DTSC (2011b).

Abbreviations

Bold indicates site-specific value
-- = not applicable
VOCs = volatile organic compounds

References

Department of Toxic Substances Control (DTSC), 2011, Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air (Vapor Intrusion Guidance), Final, October.

Office of Environmental Health Hazard Assessment (OEHHA), 2005, Human-Exposure-Based Screening Numbers Developed to Aid Estimation of Cleanup Costs for Contaminated Soil, California Environmental Protection Agency, January.

United States Environmental Protection Agency (USEPA), 2004, User’s Guide for Evaluating Subsurface Vapor Intrusion Into Buildings, Office of Emergency and Remedial Response, February 22.

TABLE C-4

RISK-BASED SCREENING LEVELS FOR TETRACHLOROETHENE AND TRICHLOROETHENE, 10 FEET BELOW GROUND SURFACE—FUTURE RESIDENTIAL SCENARIO

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

			Carcinogenic RBSL		Noncarcinogenic RBSL		
Compound	**Residential Attenuation Factor ($\alpha_{res, 10\ feet\ bgs}$) (unitless)**	**Henry's Law Constant (H'_{TS}) (unitless)**	**Target Indoor Air Concentration ($C_{ia\text{-}c,\ res}$) (µg/m^3)**	**Residential Groundwater RBSL, 10 feet bgs ($RBSL_{sg\text{-}c,\ res\text{-}10}$) (µg/L)**	**Target Indoor Air Concentration ($C_{ia\text{-}nc,\ res}$) (µg/m^3)**	**Residential RBSL, 10 feet bgs ($RBSL_{sg\text{-}nc,\ res\text{-}10}$) (µg/L)**	**Final RBSL (µg/L)**
Tetrachloroethene	6.57E-06	6.45E-01	0.4	94	40	9,400	94
	6.57E-06	6.45E-01	9.4	2220	40	9,400	--
Trichloroethene	9.31E-06	3.67E-01	0.6	176	2.1	610	176
	9.31E-06	3.67E-01	1.2	357	630.0	184,320	--

Note

Rows shaded gray are for comparison purposes only.

Abbreviations

-- = not applicable
α = attenuation factor
bgs = below ground surface
$CF_{m3\text{-}L}$ = unit conversion from cubic meters to liters (1000)
µg/L = micrograms per liter
µg/m^3 = micrograms per cubic meter
RBSL = risk-based screening level

Equation

$$RBSL_{gw} = \frac{Cia}{(H'_{TS} \times CF_{m3\text{-}L} \times \alpha)}$$

ATTACHMENT C-1

Attenuation Factors for Vapor Intrusion – Future Resident

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

Reset to Defaults

AMEC
modified by PJS; 03/10
Mult. Chemical; version 3.1.3

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES X

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES ☐

ENTER
U.S. EPA or Cal-EPA
Cal-EPA

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
127184	1.00E+00	Tetrachloroethylene
79016	1.00E+00	Trichloroethylene

MORE ↓

			Totals must add up to value of L_{WT} (cell G28)							
ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
22	9	305	19	30	256	C	SC	S		

MORE ↓

ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-fillec porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.66	0.375	0.054	SIC	1.8	0.3	0.15	SC	1.63	0.385	0.197

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
9	40	1000	1000	244	0.1	0.5	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based groundwater concentration.

END

CHEMICAL PROPERTIES SHEET

	Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^{o}C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v.b}$ (cal/mol)	Normal boiling point, T_B (^{o}K)	Critical temperature, T_C (^{o}K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (μg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
Tetrachloroethylene	7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02
Trichloroethylene	7.90E-02	9.10E-06	1.03E-02	25	7,505	360.36	544.20	1.66E+02	1.47E+03	4.1E-06	2.0E-03

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
9.46E+08	296	0.321	0.150	0.188	0.003	1.01E-07	0.998	1.01E-07	30.00	0.385	0.030	0.355	4,000
9.46E+08	296	0.321	0.150	0.188	0.003	1.01E-07	0.998	1.01E-07	30.00	0.385	0.030	0.355	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
3.39E+04	1.00E+06	4.00E-04	9	9,431	1.56E-02	6.45E-01	1.79E-04	1.16E-02	1.44E-03	1.86E-03	6.92E-06	6.61E-05	296
3.39E+04	1.00E+06	4.00E-04	9	8,407	8.89E-03	3.67E-01	1.79E-04	1.28E-02	1.58E-03	2.04E-03	9.91E-06	9.37E-05	296

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)
9	6.45E+02	0.10	8.33E+01	1.16E-02	4.00E+02	9.13E+69	6.57E-06	4.23E-03	5.9E-06	3.5E-02
9	3.67E+02	0.10	8.33E+01	1.28E-02	4.00E+02	5.78E+63	9.31E-06	3.42E-03	4.1E-06	2.0E-03

END

APPENDIX D

Estimation of PCE Attenuation Time Frame

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TABLE

APPENDIX D

ESTIMATION OF PCE ATTENUATION TIME FRAME
Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

1.0 INTRODUCTION

This appendix has been prepared by AMEC Environment & Infrastructure, Inc. to present an attenuation time frame analysis for the Crown Chevrolet Cadillac Isuzu facility located at 7544 Dublin Boulevard and 6707 Golden Gate Drive in Dublin, California (the site). The attenuation time frame considers the effects of natural groundwater flow on tetrachloroethene (PCE) concentration dilution. The methods, calculations, and results associated with the predicted time for PCE concentrations in groundwater to reach a cleanup goal of 94 µg/L (a site-specific risk-based screening level [RBSL] that accounts for potential vapor intrusion risk; derived in Appendix C) across the site are presented below. No calculations were performed to assess the predicted time for trichloroethene (TCE) concentrations in groundwater to reach a cleanup goal of 176 µg/L (Appendix C), as all site concentrations are already below the cleanup goal.

2.0 PRELIMINARY ASSESSMENT OF CURRENT SITE CONDITIONS

There is currently an incomplete understanding of contaminant fate and transport at the site based on the currently available data. However, the time for attenuation of PCE concentrations to below a cleanup goal of 94 µg/L can be estimated using predictive simulations (i.e., numerical models and analytical calculations). While the types of reaction and transport processes (i.e., attenuation mechanisms) controlling chemical concentrations and distribution at the site are not currently known, typical attenuation mechanisms include diffusion, dispersion and biodegradation. In order to estimate the time for attenuation of PCE concentrations, several assumptions have been made regarding attenuation mechanisms and site conditions.

The following assumptions were made when modeling the PCE attenuation time frame:

- The site lithology in the first water-bearing zone is modeled as clays interbedded with some clayey sands.
- As the specific source of PCE is not known, for simplification of the modeling process, a PCE source is assumed in the vicinity of the highest concentrations measured at the upgradient edge of the site.
- No biodegradation or other reaction processes are occurring at the site.

- A permeable reactive barrier (PRB), once installed down gradient of the modeled source location, will cut off the existing plume from the source, with clean water (PCE concentration of zero) exiting the downstream edge of the PRB.

Grab groundwater samples show a maximum concentration of 210 micrograms per liter (µg/L) at the upgradient site boundary and lower concentrations at downgradient locations. Based on this assumed initial condition, and the assumptions outlined above, two models were developed to aid in estimation of possible times for attenuation of on-site PCE concentrations due to diffusion, dispersion, and advection processes.

3.0 ATTENUATION TIME FRAME ESTIMATION METHODS

The two models used to evaluate PCE attenuation time frames are discussed in the following sections.

3.1 FLOW AND TRANSPORT MODEL

A three-dimensional (3D) MODFLOW-MT3D flow and transport model has been utilized to simulate diffusion, dispersion, sorption, and advection processes in a multi-layer aquifer consisting of alternating high- and low-conductivity layers. Model dimensions and layering are shown in Figure A, below. The conceptual model is 500 feet in length, 250 feet in width, and consists of 5 layers, each 10 feet thick.

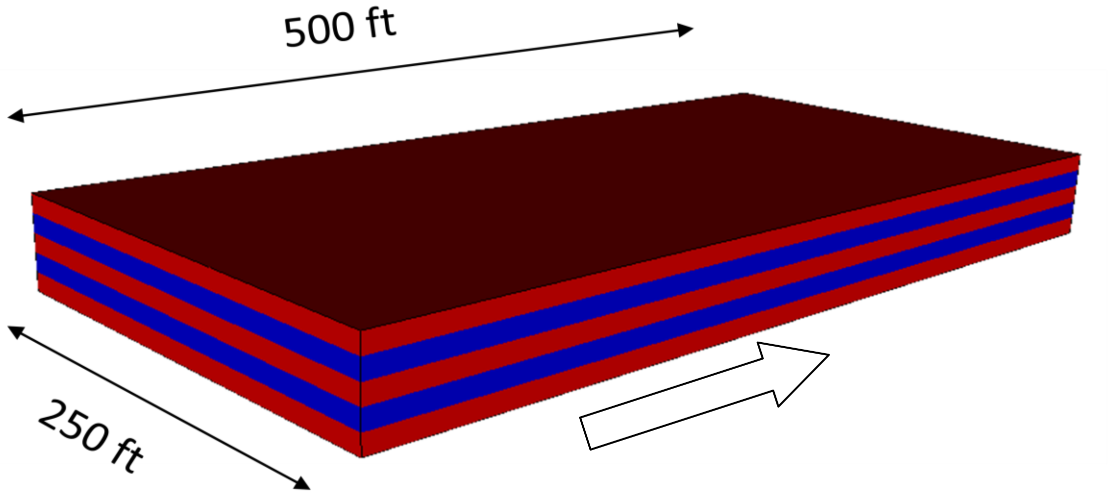

Figure A. Model Domain

The layers shown in red represent high-conductivity material and those in blue represent low-conductivity material. Since site-specific data are not available, the model utilizes typical values of flow and transport parameters (i.e., conductivity, porosity, soil bulk density, and distribution coefficient) taken from textbook and software manuals (Domenico and Schwartz, 1990; EPA, 2000; Zheng and Wang, 1999). Key hydrogeologic parameter inputs for the low- and high-conductivity layers are listed in Table D-1.

A hydraulic gradient of 0.003 foot/foot has been applied across the site and the block arrow in Figure A represents the modeled horizontal flow direction. A source zone is modeled at the upgradient side of the model in the middle three layers. The model is set up to simulate a continuous release from this source area for a specified period of time, followed by another time period during which the source is disabled, to simulate the effect of the PRB. The source release time period and source strength inputs to the model were designed to obtain a spatial distribution of PCE concentration that is similar to the measured PCE concentrations at the site.

The flow and transport model simulations indicate that, once the source is disabled, the time required for PCE concentrations in all the layers to attenuate to less than 94 µg/L is approximately 33 years.

3.2 BATCH MIXING MODEL

An alternative calculation was performed utilizing a simple batch reactor type of model for the mixing of clean water and contaminated groundwater and for PCE dilution downstream of the PRB. In this type of calculation, the attenuation processes are not explicitly modeled but considered to occur as part of the simulation (i.e., in a completely mixed tank). Sorption is assumed to be an instantaneous process that retards the plume movement. The mathematical equation for this type of model can be derived from a one-dimensional contaminant transport equation:

$$(\theta + \rho_b K_d)\frac{\partial C}{\partial t} = -q\frac{\partial C}{\partial x}$$

$$(\theta + \rho_b K_d)\frac{dC}{dt} = -\left(\frac{K \cdot i}{L}\right)C$$

$$C = C_0 \exp\left[-\frac{K\ \cdot i \cdot t}{L(\theta + \rho_b K_d)}\right]$$

Where:

C is the concentration in the tank at time *t,* and C_0 is the initial concentration

q is the Darcy flux

K and *i* represent the effective hydraulic conductivity and gradient, respectively

θ is the porosity

ρ_b and K_d are soil bulk density and sorption coefficient, respectively

L is a length representative of the extent of the 94 µg/L contour.

Effective conductivity is estimated as the geometric mean of the hydraulic conductivities of high and low conductive layers used in the MT3D model. Soil bulk density and the sorption coefficient values are the same as those used in the MT3D model. Other parameter values are listed in Table D-1.

Based on the parameter values in the table above, the batch reactor model predicts an attenuation time period of approximately 80 years.

4.0 CONCLUSION

The two models discussed above were used to estimate PCE attenuation time frames at the site. The MT3D model emphasizes the relative importance of different mechanisms that control attenuation, while the analytical model implicitly groups the different mechanisms and approximates the attenuation process as a fully mixed tank. The estimated attenuation time frames of 33 years and 80 years, respectively, represent a possible range of the likely time to achieve a cleanup goal of 94 µg/L, but reflect the uncertainty due to limited site data.

5.0 REFERENCES

AMEC Environment & Infrastructure, Inc., 2012, Soil, Groundwater, and Soil Vapor Investigation Report, Crown Chevrolet Cadillac Isuzu, 7544 Dublin Boulevard and 6707 Golden Gate Drive, Dublin, California, October 19.

Domenico, P.A. and F.W. Schwartz,1998. Physical and Chemical Hydrogeology, 2nd Edition. John Wiley and Sons, Section 17.2, pp. 352-360

U.S. EPA, 2000. BIOCHLOR Natural Attenuation Decision Support System. User’s Manual Version 1.0, EPA/600/R-00/008. Washington, DC: US EPA, Office of Research and Development.

Zheng, C and P. P. Wang, 1999. MT3DMS: A modular three-dimensional multispecies transport model for simulation of advection, dispersion, and chemical reactions of contaminants in groundwater systems : documentation and user’s guide, US Army Corps of Engineers, Engineering Research and Development Center.

TABLE D-1

NUMERICAL MODEL PREDICTIONS OF PCE ATTENUATION TIME

Crown Chevrolet Cadillac Isuzu
7544 Dublin Boulevard and 6707 Golden Gate Drive
Dublin, California

Hydrogeologic Properties and Conditions - MT3D Numerical Model		
Hydraulic Conductivity Value for high conductive Layers (feet/day)	Hydraulic Gradient in high conductive Layer (foot/foot)	Porosity
15	0.003	0.2
Hydraulic Conductivity Value for low conductive Layers (feet/day)	Hydraulic Gradient in low conductive Layer (foot/foot)	Porosity
0.1	0.003	0.20
Soil Bulk Density (ρ_b) in gm/cc	Distribution Coefficient (K_d) in cc/gm	Calculated Retardation Coefficient
1.6	0.76	7
Source Zone Concentration (µg/L)	Release Time Frame (Years)	Model Simulated Time for Attenuation to 94 µg/L
600 µg/L	50	~ 33 years

Hydrogeologic Properties and Conditions - Analytical Calculation for Completely Stirred Batch Reactor		
Effective Hydraulic Conductivity K (feet/day)	Average Hydraulic Gradient i (foot/foot)	Effective Mobile Porosity (θ)
1.2	0.003	0.20
Mixing Zone Concentration C0 (µg/L)	Length of Mixing Zone Along Plume Centerline L (feet)	Model Calculated Time for Attenuation to 94 µg/L
200 µg/L	150	~ 80 years

APPENDIX E

Case Studies – Vapor Barriers

Taube-Koret Campus
901 San Antonio Road
Palo Alto, California

Background

The site is currently owned by the Taube-Koret Campus for Jewish Life, which purchased the property from Sun Microsystems in 2002. The site was formerly part of a larger Ford Aerospace facility that operated from 1959 to 1990, and has been redeveloped as an “intergenerational facility” (a mixed-use development). Site investigations and groundwater monitoring have been performed at the Site beginning in 1987. Tetrachloroethene (PCE), trichloroethene (TCE), and breakdown products, including vinyl chloride, are present in groundwater and soil vapor beneath the site; the impacted groundwater is migrating onto the site from an upgradient source. The pathway for the upgradient source has been cut off with a permeable reactive barrier (see the Former Ford Aerospace permeable reactive barrier case study in Appendix F). Methane also has been detected in soil vapor.

A total of 39 soil gas samples were collected at the site in 2004 and 2005. PCE, TCE, and/or vinyl chloride were detected in one or more of the soil gas samples. A site-specific human health risk assessment determined that PCE and vinyl chloride posed an unacceptable risk to human health absent any further remedial actions.

Site mitigation for the redevelopment includes a vapor barrier and sub slab depressurization system (SSD).

Geology

The site is located in the San Jose sub-area of the South Bay Groundwater Basin. This area is characterized by a thick alluvial sequence, formed through deposition by streams descending from the Santa Cruz Mountains to the west and south, and is underlain by sediments from the Santa Clara Formation. Depth to first groundwater is approximately 6 to 8 feet below ground surface (bgs).

Constituents of Concern and Maximum Concentrations

PCE has been found in shallow groundwater at concentrations up to 480 micrograms per liter (µg/L). TCE and vinyl chloride also have been found in groundwater at concentrations up to 1,090 µg/L and 530 µg/L, respectively.

In soil vapor, PCE, TCE, and vinyl chloride have been detected at concentrations of 37,000 micrograms per cubic meter ($\mu g/m^3$), 23,000 $\mu g/m^3$, and 26,000 $\mu g/m^3$, respectively.

Oversight Agency

California Regional Water Quality Control Board, San Francisco Bay Region (Water Board) regulates the Site under site cleanup requirements Order No. R2- 2007-0023 (Order). The general redevelopment and monitoring requirements for the site are outlined in the Order; there have been many documents developed that include, but are not limited to, a Risk Management Plan (2006, followed by addenda), Construction Completion Reports (starting in 2009, with others to document different construction phases), and Operations, Maintenance, and Monitoring Plan (Geosyntec, 2011).

Remedial Action Objectives
The remedial action objective for the site is a risk level less than 1 x 10^{-6}, as specified in the Risk Management Plan. Action levels for commercial and residential scenarios were developed for various volatile organic compounds and presented in the risk management plan.

Remedial Action
Remedial actions specific to mitigating soil vapor intrusion to buildings on Parcel 2 (where higher concentrations of VOCs are present in groundwater/vapor) include a sub-slab vapor mitigation beneath all occupied residential and commercial spaces at the site (residential units are podium-style, above slab-on-grade parking). The subs-slab mitigation system includes an active depressurization system (with a motorized blower) beneath all slab-on-grade commercial areas, and a passive depressurization system (relying on a wind-driven turbine) is present in other areas.

The 2007 Site Cleanup Requirements Order indicates that the following must continuously operate:

- mechanical ventilation systems beneath residential units and day care facilities,
- sub-slab vapor barriers beneath all occupied buildings,
- passive vapor extraction beneath all podium parking areas,
- active vapor extraction beneath slab-on-grade commercial areas, and
- vapor mitigation reduction elements in elevator shafts and utility trenches.

Compliance Monitoring
The 2007 Site Cleanup requirements order indicated that the following would occur:

- ongoing sub-slab vapor monitoring beneath both podium parking/residential areas and slab-on-grade residential areas,
- quarterly indoor air sampling in the podium parking garage for the first year following development,
- ongoing groundwater monitoring,
- a contingency plan for active vapor extraction system, if necessary, and
- a deed restriction for land use.

Initially, sub-slab vapor was monitored monthly following installation for a period of one year. Following the initial year, which indicated no exceedances to site-specific criteria, sub-slab monitoring converted to quarterly. Because sub-slab vapor levels were below actions levels from 2009 to 2011, the Water Board approved converting the sub-slab depressurization system from active to passive extraction on December 16, 2011. Because sub-slab vapor concentrations were stable, on November 20, 2012 the Water board approved switching from quarterly to annual sub-slab vapor monitoring.

First floor (garage) air sampling was conducted quarterly only during the first year following development and then was ceased, based on agreement with the Water Board (Geosyntec, 2011). There is no indication in available documents that indoor air sampling was conducted in the residential or commercial areas.

Administrative
Institutional Control: There is a 2009 deed restriction for the site that documents site requirements and includes the Risk Management Plan and Addenda by reference.

“Certificates of Completion”: Each Construction Completion Report was followed by an acknowledgement letter; this letter documented the work completed and the Water Board commented: “The CCR satisfies the requirements of RMP and RMP Addendum. We have no further comments.”

Sources

California Regional Water Quality Control Board, 2012, Approval of Request for Reduction in Frequency of Vapor Monitoring and Reporting Taube-Koret Campus for Jewish Life, 901 San Antonio Road, Parcel 2, Palo Alto, Santa Clara County, November 20.

California Regional Water Quality Control Board, 2007, Site Cleanup Requirements and Rescission of Order No.99-043 and Order No. R2-2003-0071 for Taube-Koret Campus for Jewish Life, 901 San Antonio Road, Parcel 2, Palo Alto, Santa Clara County, March 14.

Geosyntec Consultants, 2006, Risk Management Plan, Taube-Koret Campus for Jewish Life, 901 San Antonio Road, Parcel 2, Palo Alto, California, June 16.

Geosyntec Consultants, 2007, Engineering Design Report Sub-Slab Vapor Mitigation System , Taube-Koret Campus for Jewish Life, 901 San Antonio Road, Parcel 2, Palo Alto, California, May 21.

Geosyntec Consultants, 2011, Operation, Maintenance, and Monitoring Plan, Sub-Slab Vapor Mitigation System, Taube-Koret Campus for Jewish Life, 901 San Antonio Road, Palo Alto, California, May.

Former General Electric Facility
175 Curtner Avenue
San Jose, California

A former General Electric (GE) industrial site has been redeveloped into a commercial retail property.

Background

GE operated at the approximately 55-acre site beginning in 1948. GE operations included the manufacture and repair of large motors and the manufacture of components for commercial nuclear power plants. The site was licensed as a fuel development and manufacturing operation for commercial nuclear power plants in the 1950s by the AEC (now the NRC). Manufacturing operations associated with these licenses were terminated in the early 1970s. While there are various chemical impacts at the site, trichloroethene (TCE) is the main constituent of concern.

In 2005, General Electric Company (GE) sold the property to a developer, who built an approximately 630,000-square-foot retail shopping center (residential development is not permitted at the site), which was completed in 2008. Soil remediation and soil vapor extraction were conducted to treat site impacts. Groundwater remediation is ongoing.

Geology

First groundwater (the A zone) is reportedly present at a depth of approximately 23 feet below ground surface (bgs). The B zone begins at the bottom of the A zone and extends to a depth of 50 feet below the ground surface and consists of a low-permeability upper portion, which contributes to semi-confined conditions in the somewhat more permeable sediments in the remainder of the B zone (LECG, 2005). The soils within the A and B zones consist of relatively lower permeability clays and silts, with occasional thin sand layers (LECG, 2005).

Constituents of Concern and Maximum Concentrations

Following multiple site investigations, the following constituents of concern were identified at the Site (LECG, 2005):

Shallow soil:

- TCE up to 4.5 mg/kg

Groundwater:

- 1,1,1-Trichloroethane (1,1,1-TCA) up to 420 µg/L
- 1,1-Dichloroethane (1,1-DCA) up to 590 µg/L
- 1,1-Dichloroethene (1,1-DCE) up to 1,400 µg/L
- Carbon tetrachloride up to 48 µg/L
- Cis-1,2-dichloroethene (cis-1,2-DCE) up to 2,100 µg/L
- Tetrachloroethene (PCE) up to 380 µg/L
- Trans-1,2-dichloroethene up to 130 µg/L

- TCE up to 83,000 µg/L
- Vinyl chloride 3.7 up to µg/L

Shallow soil vapor (to 5 feet bgs):

- 1,1,1-TCA up to 29,000 µg/m3
- 1,1-DCE up to 51,000 µg/m3
- Cis-1,2-DCE up to 12,000 µg/m3
- 1,1-DCA up to 2,300 µg/m3
- TCE up to 1,000,000 µg/m3
- PCE up to 41,000 µg/m3

Oversight Agency
Regional Water Quality Control Board, San Francisco Bay Region (Water Board)

Remedial Action Objectives
Remedial action objectives (RAOs) were presented in a Remediation and Risk Management Plan (RRMP; LECG, 2005). The RAOs for shallow soil were chosen to provide a degree of protection from direct contact (i.e., incidental ingestion and dermal contact); the RAOs for deeper vadose zone soil were chosen to (a) actively remove VOC source areas and (b) support long-term protection of water resources by eliminating sources of groundwater; the remedial actions for groundwater were chosen to (a) actively remove VOC source areas in groundwater and (b) restore groundwater to levels acceptable for use as drinking water.

Although several COCs were detected in soil and groundwater, TCE was considered the primary COC. The TCE groundwater RAO was 5 µg/L, and the TCE soil RAO was 460 µg/kg (LECG, 2005). No RAO for TCE in soil vapor was provided in the Remediation and Risk Management Plan.

Remedial Action
In addition to the soil and groundwater remediation occurring at the site, a vapor mitigation system was installed beneath each of the 27 buildings at the site, consisting of the following (ARCADIS, 2012): “a low-permeability liner sandwiched between protective layers of either sand or geotextile fabric. Beneath the low-permeability liner is a Sub-Slab Depressurization System (SSDS) consisting of a minimum of 1 foot of permeable sand, gravel or crushed rock installed with geotextile-wrapped, horizontal, perforated piping within it. The piping is connected to a solid, vertical pipe located up the side of each structure in order to vent any collected vapors to the atmosphere at least 2 feet above the roof line. Sample ports are installed within each vertical pipe at roof level.”

Compliance Monitoring
Following installation of the vapor mitigation systems, quarterly vent riser monitoring (at roof-top sampling ports) commenced in 2008. Available documents do not indicate that indoor air samples have been collected at the site. Discontinuation or reductions in monitoring frequency for 13 of the site buildings was approved in 2010 and 2011, and a recommendation to discontinue monitoring in the remaining 14 buildings was accepted in 2012. According to a September 26, 2012 letter from the Water Board to GE:

“Based on the results of the March 2012 semi-annual sampling and the provisions in Appendix D of the RRMP, the recommendation to discontinue monitoring in the remaining 14 buildings is based on the following reasons:

- Since August 2008, no TCE concentrations have been detected which would have required changing the VMS system to a more aggressive design;
- TCE concentrations have remained stable, decreasing or below reporting limits;
- Soil vapor extraction successfully removed TCE from the vadose zone in the source area, and the system was shut down in 2011; and
- Ongoing groundwater remediation is reducing groundwater concentrations and residual mass in the subsurface.”

Operations and maintenance activities were described as follows in the RRMP (LECG, 2005):

- After structure construction and prior to occupancy, each SSD system was to be tested to measure pressure differentials and could include flow rates and collecting samples. The testing results and conclusions were to be submitted to the Water Board.
- Maintenance was to consist of inspecting the visible components of the vapor management systems monthly or more frequently if required. The owner was not required to maintain the system once the Water Board no longer requires the vapor management system to be maintained.
- Proper operation of the vapor management system was to be determined through continuous monitoring of the air pressure differential within each system to ensure that the pressure within the vent pipe was a minimum of 0.1 inch water column less than atmospheric pressure.
- If a foundation or utility retrofit or repair is necessary after construction, all reasonable efforts are taken to avoid disturbing the liner. If disturbing the liner is unavoidable, then the liner is to be repaired so that it functions as it was intended in the original design.

Sources

ARCADIS, 2012, 2011 Remediation Performance and Annual Groundwater Monitoring Report, 2153 Monterey Highway, San Jose, California, December 13.

LECG, LLC, Brown and Caldwell, RTI International, Geomatrix Consultants, Inc., and Mara Feeney & Associates (2005), Remediation and Risk Management Plan for General Electric San Jose Site, October 7.

Regional Water Quality Control Board, 2012, Modifications to the Vapor Management System Monitoring Requirements for the former General Electric facility, 175 Curtner Avenue, San Jose, Santa Clara County, September 26.

Hookston Station
Hookston and Bancroft Roads
Pleasant Hill, California

Background
Hookston Station is an approximately 8-acre site occupied by mixed commercial and light industrial businesses. The site was owned and operated by Southern Pacific from 1891 to 1983. Between 1965 and 1983, the site was developed into a light industrial business complex. During this time, a former tenant used trichloroethene (TCE). Investigations conducted between 1990 and 1996 discovered the presence of volatile organic compounds (VOCs) in shallow groundwater beneath the site.

Geology
Shallow soil consists of silts and clays interspersed with lenses of sands to 30 to 50 feet bgs. Depth to first groundwater is approximately 15 feet bgs.

Constituents of Concern and Maximum Concentrations
Maximum detected concentrations of constituents of concern in groundwater are as follows: 1,400 µg/L of tetrachloroethene (PCE); 8,860 µg/L of TCE; 670 µg/L of cis-1,2-dichloroethene (cis-1,2-DCE); and 341 µg/L of 1,1-dichloroethene (1,1-DCE).

The maximum detected TCE concentration in soil vapor is 64,000 µg/m^3.

Oversight Agency
California Regional Water Quality Control Board, San Francisco Bay Region (Regional Water Board).

Remedial Action Objectives
Cleanup goals were set at the maximum contaminant levels (MCLs) for TCE (5 µg/L), cis-1,2-DCE (6 µg/L), trans-1,2,-DCE (10 µg/L), 1,1-DCE (6 µg/L), and vinyl chloride (0.5 µg/L), as specified in RWQCB Order R2-2007-0009. Indoor air data is compared to Environmental Screening Levels (ESLs) published by the Regional Water Board.

Remedial Action(s)
According to the Feasibility Study prepared for the site in July 2006, the following remedial technologies were selected, approved, and have been implemented at the site:

- Installation of a permeable reactive barrier (PRB) with zero valent iron (ZVI) in the A-Zone to remediate A-Zone ground water (from site impacts and off-site impacts as well);
- Implementation of in situ chemical oxidation (ISCO) in the B-Zone to remediate B-Zone ground water;
- Installation of engineering controls in the form of vapor intrusion prevention (VIP) systems at eight residences within the Colony Park neighborhood where TCE was detected above the ESL to address potential migration of VOCs that may be present in soil vapor to indoor air in residences;
- Removal of identified private wells, which were reportedly used for irrigation and filling swimming pools, from residences that overlie the impacted A-Zone ground water in the Colony Park neighborhood;

- Adoption of an institutional control by Contra Costa County regarding new well installations within the impacted area until ground water cleanup goals are achieved; and
- Development of an institutional control in the form of a Soil Management Plan (SMP) to address the management of arsenic-impacted, subsurface soil at a small portion of the site.

The VIP was installed in eight homes with TCE concentrations greater than the ESL, and where the homeowners allowed access, between 2004 and 2007. The VIP systems consist of a plastic vapor barrier on the soil surface within the crawl space to prevent potential migration of vapor that may be present in the subsurface. Under the vapor barrier, low flow vapor extraction is performed as an enhancement to the vapor barrier. Vapor is collected through a perforated pipe located underneath the plastic barrier, and is discharged above the roof through the use of a low-power fan mounted on the exterior of the building structure.

Monitoring

The 2012 Status Report on Remedy Effectiveness indicates the following (ERM, 2012):

“The VIP systems are currently being inspected quarterly, where access is granted, to verify that the systems have not been disturbed and are operating properly. During the inspections, the vapor barriers and system discharge pipes are examined for defects, and airflow through the discharge pipes is measured. Any deficiencies in system operation and equipment are repaired during the inspections, if possible, or shortly thereafter.

Currently, ERM conducts annual indoor air monitoring in accordance with the SMP described in the Order. The SMP requires indoor air sampling at 38 homes, but typically fewer homes allow access for sampling (e.g., 19 homes were sampled in 2012).”

Issues

Concentrations of TCE in one home have been above the screening level. Concentrations have been attributed to indoor sources, but rodent damage to the vapor barrier was also noted and was repaired in 2012.

Sources

Environmental Resources Management (ERM), 2004, Remedial Investigation Report, Hookston Station Site, Pleasant Hill, California, August.

ERM, 2009, Final Construction Report, A-Zone aquifer ZVI Permeable Reactive Barrier Project, Hookston Station Site, Pleasant Hill, California, September.

ERM, 2012, Status Report on Remedy Effectiveness, Hookston Station, Pleasant Hill, California, December 28.

John Swett High School
1098 Pomona Street
Crockett, California

A new music classroom building is being constructed at John Swett High School. Construction commenced in 2012, and occupancy is planned for August 2013 (DTSC, 2013). The new building is located within an area that was formerly occupied by a maintenance garage, where chlorinated solvents and petroleum hydrocarbons were released to the subsurface.

Background

The site is located at 1098 Pomona Street in Crockett, California. Previous investigations concluded that on-site chlorinated solvent impacts are likely the result of degreasing fluids being discharged to floor drains within the former garage. A chlorinated solvent plume, consisting primarily of PCE, and an aromatic hydrocarbon plume, consisting primarily of benzene, are present in the area of the maintenance garage, former underground storage tanks (USTs) and dispenser house at the site. There are also elevated concentrations of PCE, trichloroethene (TCE), and benzene in soil gas in the vicinity of the groundwater plume that pose a potential health risk to future occupants of the music building.

Geology

Regional geologic maps indicate the site and surrounding areas are underlain by stream-deposited sediments generally comprised of gravel, sand, silt, and clay. Sedimentary bedrock of the Panoche Formation, generally comprised of claystone and sandstone, underlies the Quaternary alluvium. Near-surface claystone and sandstone bedrock units have been encountered in portions of the site. The depth to first encountered groundwater beneath the site ranges from 10 to 20 feet below ground surface (J House Environmental, 2011).

Constituents of Concern and Maximum Concentrations

Three constituents of concern have been identified in soil gas (benzene, PCE, TCE), and three COCs have been identified in groundwater (benzene, PCE, cis-1,2-DCE) in the maintenance garage and former fuel storage tank and dispenser area (J House Environmental, 2011).

Maximum detected soil gas concentrations are as follows:

- Benzene at 68,000 µg/m^3;
- PCE at 190,000 µg/m^3;
- TCE at 4,200 µg/m^3.

Maximum detected groundwater concentrations are as follows:

- Benzene at 3.3 µg/L;
- Cis-1,2-DCE at 13 µg/L;
- PCE at 77 µg/L..

Oversight Agency

Cleanup is being conducted under a Voluntary Cleanup Agreement with the California Department of Toxic Substances Control (DTSC).

Remedial Action Objectives
Risk based cleanup goals for soil gas were calculated using the DTSC-modified Johnson and Ettinger (J&E) model with site specific input parameters for unrestricted land use. The final cleanup goals are 150 µg/m^3 for benzene, 860 µg/m^3 for PCE, and 2,400 µg/m^3 for TCE (DTSC, 2011).

The planned approach to address groundwater impacts is to follow the State Water Resources Control Board protocol for closure pursuant to guidance set forth for low risk fuel sites. The remedial action objectives (RAOs) for VOC-impacted groundwater will be met by demonstrating that residual “pollutants” in subsurface materials at the Site will not adversely affect present and anticipated land and water uses (J House Environmental, 2011).

Remedial Action
Soil remediation was conducted in 2012 and involved the excavation of approximately 800 cubic yards of impacted soil. In addition to the soil removal, in-situ injections of food-grade substances were performed to promote enhanced biodegradation of groundwater impacts via reductive de-chlorination (DTSC, 2013).

The recommended vapor mitigation measures include a passive vapor intrusion mitigation system for the new school building. The vapor mitigation system consists of the following elements (Gelfand, 2011):

- Geo-Seal® Base layer consisting of a 5 mil HDPE membrane that is thermally bonded to a 18 mil polypropylene geotextile. Installed with HDPE facing up.
- Geo-Seal® Core layer consisting of an elastic asphaltic membrane spray applied to a minimum dry thickness of 60 mils.
- Geo-Seal® Bond layer consisting of a 5 mil HDPE membrane that is thermally bonded to a 18 mil polypropylene geotextile. Installed with geotextile facing down to provide a friction surface for the concrete to adhere to.
- Gas Venting Materials: Geo-Seal Vapor-Vent HD or Geo-Seal Vapor-Vent Poly, and associated fittings.

Installation and smoke testing of the sub slab depressurization (SSD) commenced in 2012 (DTSC, 2013).

Compliance Monitoring
The established compliance monitoring protocols are as follows (DTSC, 2013):

- A soil vapor monitoring well has been installed within the footprint of the new building to a depth of 5 feet bgs. Four additional soil vapor monitoring wells are to be installed around the building. A minimum of three pre-occupancy sample events are to be completed at two- to three-month intervals, and a total of four to six quarterly sampling events are to be completed.
- At grade sample ports are to be installed on the SSD collection piping. A minimum of two pre-occupancy sampling events are to be completed at two-month intervals.
- Above ground components of the SSD are to be installed, including: vent risers, riser sampling access panels and sampling ports, and roof top terminations with wind turbines. A minimum of two pre-occupancy sampling events are to be completed at two-month intervals. Vent riser wind speeds are to be recorded for each sampling event.

According to the DTSC's EnviroStor website, if monitoring of soil vapor and/or groundwater is needed for more than 1.5 years, an Operation and Maintenance (O&M) Plan will be developed to set forth requirements for ongoing monitoring.

Sources

DTSC, 2013, Removal Action Project Status Update, John Swett High School, 1098 Pomona Street, Crockett, California, January 13.

DTSC, 2011, Approval of Removal Action Workplan, John Swett High School, 1098 Pomona Street, Crockett, California, June 21.

Gelfand Partners Architects, 2011, Section 07136, Vapor Barrier Design, May 27.

J House Environmental Inc., 2011, Removal Action Workplan, John Swett High School, Crockett, California, May 13.

MEW Superfund Study Area
Mountain View, California

Background
The MEW site is named after the three streets that generally bound the source area (Middlefield, Ellis, and Whisman). The Site encompasses a large area extending from the source area in the south, to Moffett Field in the north. During the 1960s and 1970s, several industrial companies conducted semiconductor, electronics, and other manufacturing activities in the MEW area, resulting in soil and groundwater contamination by volatile organic compounds (VOCs), primarily trichloroethene (TCE). North of Highway 101, Moffett Field was operated by the Navy from the 1930s to 1994.

In June 1989, the U.S. Environmental Protection Agency (U.S. EPA) selected soil and groundwater remedies for the site. Soil cleanup has been completed and groundwater remediation is ongoing. During 2003 through 2008, over 3,000 air samples were collected from 47 commercial buildings and 20 residences overlying shallow groundwater affected by TCE.

Geology
The site is underlain by alluvial sediments. Depth to first groundwater is ranges from 10 to 20 feet bgs in the MEW area and from 5 to 10 feet bgs in the Moffett Field area.

Constituents of Concern and Maximum Concentrations
The maximum concentration of TCE in shallow groundwater was 40,000 micrograms per liter (µg/L) in the MEW source area and 3,600 µg/L in the Moffett Field area.

Oversight Agency
The U.S. EPA is the lead regulatory agency responsible for directing the cleanup process under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The California Regional Water Quality Control Board, San Francisco Bay Region is the support regulatory agency.

Remedial Action Objectives
The cleanup goal is a risk level less than 1×10^{-6}. This corresponds to an indoor air vapor concentration of TCE of 1 $\mu g/m^3$ under a residential scenario, and 5 $\mu g/m^3$ under a commercial scenario.

Remedial Action
The selected engineered remedy for existing buildings is the installation of an appropriate sub-slab/sub-membrane and ventilation system. The selected remedy is applicable to existing buildings requiring a response action. For all future buildings where lines of evidence indicate the for potential vapor intrusion, EPA’s selected engineered remedy is the installation of a vapor barrier and passive sub-slab ventilation system (with the ability to be made active).

Compliance Monitoring
Monitoring will be performed in accordance with a long term monitoring plan. The specifics of this plan have not been developed to date. However, indoor air monitoring is currently occurring.

Issues

Recently, TCE has been detected in indoor air at two buildings (369 and 379 North Whisman) at concentrations exceeding the 5 µg/m^3 commercial limit, as noted in various news articles (e.g., San Francisco Chronicle, 2013). It should be noted that neither of these buildings has a true vapor barrier and neither has a sub-slab depressurization system. According to the Bay Citizen article, the heating, ventilation, and air conditioning (HVAC) system was intended to be on at all times to create a positive pressure and prevent vapor intrusion, but was turned to a manual mode recently, allowing vapor intrusion to occur. Following returning the system to automatic mode, TCE concentrations were reduced to below the screening level.

Sources

San Francisco Chronicle, 2013, "Google workers at Superfund site exposed," Susanne Rust and Matt Drange, Center for Investigative Reporting, http://www.sfgate.com/business/article/Google-workers-at-Superfund-site-exposed-4368421.php#ixzz2OD1i3ym4, March 19.

Lenny Seigel, Center For Public Environmental Oversight, 2013, *Air-sampling results for Google-occupied buildings*, February 22.

United States Environmental Protection Agency Region 9, 2010, *Record of Decision Amendment for the Vapor Intrusion Pathway, Middlefield-Ellis-Whisman (MEW) Superfund Study Area, Mountain View and Moffett Field, California*, August 16.

Shinsei Gardens
410 Stargell Ave.
Alameda, California

Shinsei Gardens is a former Navy facility where a 39-unit affordable senior housing facility was constructed over an existing plume of benzene in groundwater.

Background

Previously existing marshland and tidal areas in the vicinity of the site were filled between 1900 and 1939. In 1928 and 1929, the San Francisco Bay Area Airdrome, an airline passenger facility, was constructed at the site and operated until 1941. In the 1950s, the U.S. Navy purchased the area of the site and converted the site area into a screening and scrap yard. Todd Shipyard Corporation operated along the Alameda shore of the Oakland Inner Channel from 1947 to 1952. Between 1930 and the 1990s, the U.S. Navy purchased and operated the Naval Air Station (NAS) Alameda in the area to the west, north, and south of the site.

A 39-unit senior housing facility has since been constructed at the site, which is impacted by benzene and naphthalene from an off-site source. A vapor barrier and passive sub-slab depressurization system covering 22,000 square feet were installed at the site to mitigate the vapor intrusion risk associated with the property.

Geology

The site lithology includes artificial fill and marine and fluvial sedimentary formations. The artificial fill, found within the uppermost 10 to 20 feet, contains dredged material overlying the sedimentary formations. Bay Mud is underlies the fill materials at the site and reportedly ranges from approximately 10 to 95 feet in thickness. A discontinuous layer (generally less than 1 foot thick) of organic peat (marsh crust) is present at the interface of the artificial fill with the Bay Mud, between 10 and 20 feet below the ground surface (Northgate, 2006). Groundwater is found within the fill materials at an approximate average depth of 9 feet below ground surface (Northgate, 2006).

Constituents of Concern and Maximum Concentrations

Following multiple site investigations, soil gas sampling was conducted at the site in 2001 that identified the following chemicals of concern; the main chemical of concern is benzene (Northgate, 2006):

- Benzene up to 2.4 µg/m^3;
- Toluene up to 22 µg/m^3;
- Ethylbenzene up to 7.6 µg/m^3;
- Xylene(s) up to 33.7 µg/m^3;
- Trichlorotrifluoroethane up to 2.2 µg/m^3;
- Methylene chloride up to 4.6 µg/m^3;
- PCE up to 9.7 µg/m^3; and
- 1,2,4-trimethylbenzene up to 2.3 µg/m^3.

Groundwater sampling performed in 2002 identified the following (Northgate, 2006):

- Benzene up to 480 µg/L;
- Toluene up to 170 µg/L;
- Ethylbenzene up to 230 µg/L; and
- Xylene(s) up to 410 µg/L.

Oversight Agency
California Department of Toxic Substances Control (DTSC). The work at the Shinsei Gardens site was conducted under a Voluntary Cleanup Agreement that outlines the general requirements.

Remedial Action Objectives
The overall removal action goal for the site is to prevent exposure of future residents to elevated levels of VOCs, primarily benzene and naphthalene, in indoor air (Northgate, 2006). The Removal Action Workplan indicated that indoor air results could be compared to Environmental Screening Levels (ESLs) published by the California Regional Water Quality Control Board, San Francisco Bay Region or numbers published in the U.S. EPA's 2002 Draft Vapor Intrusion Guidance (Northgate, 2006).

Remedial Action
A vapor mitigation system was installed at the site and consists of a vapor barrier and passive sub-slab depressurization system with the following elements (Northgate, 2009a):

- A lower membrane (membrane-on-grade) consisting of a 15 mil thick Stego Wrap, which was overlapped and taped with Stego tape. The membrane was also taped at all pipe penetrations.
- A 6-inch thick gravel blanket consisting of an open graded gravel with low fines content made from recycled concrete materials. A vent pipe network was installed within the gravel layer; these lead to a riser pipe and turbine system.
- A non-structural concrete slab generally several inches thick and conformed to the shape of the underlying gravel blanket.
- A Geo-Seal composite system consisting of a 5-mil HDPE sheet, a 60 mil asphalt/latex spray applied membrane (core material), and a second 5-mil HDPE sheet. Penetrations, overlaps and edges were sealed using additional 5-mil HDPE/geotextile sheet and asphalt/latex core material.

Compliance Monitoring
The venting system air flow is monitored, but no chemical analysis is performed. No indoor air sampling was required post construction and no formal long term monitoring plan has been established.

Below is a timeline for project documentation to the O&M stage. A certificate of completion was issued for Shinsei shortly after the completion of the vapor barrier/SSD installation.

- On October 3, 2006, DTSC approved the RAW which requires the construction of a passive SSD for new buildings at FISCA Western One-Third of IR02.
- On October 6, 2006, the City of Alameda and DTSC recorded the “Covenant to Restrict Use of Property, Environmental Restriction” to permit residential land use of the site with implementation of Removal Action Alternative 3 (i.e., passive SSD or equivalent) specified in the RAW. A SSDS was necessary before DTSC could release the July 20, 2000 Interim Covenant.
- From June 2008 through August 2009, RCD installed the SSDS. During this period, DTSC oversaw installation and testing of the SSDS and approved specific procedural modifications.
- On September 3, 2009, DTSC approved the Implementation Report and concluded that the City of Alameda and RCD have implemented the removal action pursuant to the RAW for FISCA Western One-Third of IR02. DTSC also approved the O&M Plan on September 3, 2009.
- On January 12, 2010, the City of Alameda, RCD, and DTSC executed an O&M Agreement for periodic maintenance, annual inspection and reporting, five-year reviews, and DTSC oversight cost reimbursement.

Operations and maintenance activities include the following (Northgate, 2009b):

- *Annual Inspections* - In accordance with the Covenant to Restrict Use of Property, Environmental Restriction, dated October 6, 2006; the Owner shall perform annual inspections of the property and the sub-slab depressurization system.
- *Property* - The annual inspection shall verify that no additional buildings of any kind have been constructed on-site without the Owner certifying to the DTSC that a sub-slab depressurization system, approved by DTSC has been installed and has proven to be operating properly. The annual inspection shall also verify that the sub-slab depressurization system has not been disabled, altered, or removed except for routine maintenance and repair.
- *Wind Turbines* - An annual inspection of the terminations of the outlet pipes within the bases of the wind turbines shall be performed. The purpose of these inspections is to verify that the seals around the pipes at the roof line are maintained. The system relies on these seals to draw air from under the buildings. If seals are weathered or leaking they shall be repaired. These annual inspections shall be performed prior to the winter rainy season, preferably during the September/October time frame. In addition, a one-time inspection shall be performed during the winter of 2009 after a major storm event to verify that water does not pond in the wind turbines and drain into the sub-slab depressurization system.
- *Inlet Pipes* - An annual inspection of the terminations of the inlet pipes shall be performed to verify that there are no leaks in the seals at the roof line. Air flow monitoring shall be performed on the inlet pipes at 2.5 year intervals. Air flow will be monitored in each of the inlet pipes when the wind turbines are turning. The monitoring instrument shall have a minimum sensitivity to measure air flow in the range of 0.1 cubic feet per minute.

- Rep*orting* - An annual report will be submitted to the DTSC presenting the results of the annual inspection and summarizing any actions taken during the previous year. The report must be submitted to the DTSC by the December 1 each year.
- *Maintenance Schedule* - There is no specific maintenance scheduled, however, it is anticipated that annual or bi-annual maintenance/repair will be required to maintain the seals around the outlet pipes beneath the wind turbines and possibly the inlet pipes. Based on the measurements taken in the inlet pipes, other additional maintenance activities may be carried out as-needed to maintain the flow of clean air through the sub-slab depressurization system.

Sources

Northgate Environmental Management, Inc. (2006), Removal Action Workplan, 39-Unit Apartments, Western One-Third of Installation Restoration site 02, Former Fleet and Industrial Supply Center Oakland Alameda Facility/Alameda Annex, Alameda, California, October 3.

Northgate Environmental Management, Inc. (2009a), Implementation Report, Sub-Slab Depressurization System, Shinsei Gardens, Alameda, California, Project: 1127.02, August 26.

Northgate Environmental Management, Inc. (2009b), Operations and Maintenance Plan, Sub-Slab Depressurization System, Shinsei Gardens, Alameda, California, Project: 1127.02, August 26.

APPENDIX F

Case Studies – Permeable Reactive Barriers

Cinema Place
22695 Foothill Boulevard
Hayward, California

Background

The 2.54-acre Cinema Place property is located in downtown Hayward. Dry cleaning operations occurred at the site from 1965 to 1982. Environmental investigations conducted since 2002 indicated the presence of volatile organic compounds (VOCs), primarily tetrachloroethene (PCE) and trichloroethene (TCE), in groundwater. The site has since been redeveloped for commercial and retail use, including a movie theater. A 2006 land use covenant restricts site use to prohibit residential or other sensitive land uses.

Geology

A coarse-grained water-bearing unit is present at depths of 14 to 28 feet below ground surface (bgs). Below this unit, the soil becomes increasingly fine grained and bedrock is encountered at 45 feet bgs. The depth to first groundwater ranges from 11 to 18 feet bgs.

Constituents of Concern and Maximum Concentrations

PCE is the main constituent of concern, with a maximum concentration of 7,300 micrograms per liter (µg/L). TCE has been detected at a maximum concentration of 14 µg/L.

Oversight Agency

California Regional Water Quality Control Board, San Francisco Bay Region

Remedial Action(s)

In 2011, a total of 20 iron-filled borings were installed at the site to treat VOC-impacted groundwater. Six rows of 18-inch-diameter soil borings were advanced to 30 feet bgs, spaced approximately 3 to 8 feet apart. The borings were backfilled with 100% iron from 10 to 30 feet bgs to intersect the impacted A zone groundwater. The top 10 feet of each boring was filled with bentonite and neat cement grout.

Cleanup Goals

The cleanup goals for the site were to reduce PCE concentrations in ground by one order of magnitude and demonstrate a decreasing trend in PCE concentrations in groundwater.

Compliance Monitoring

Three groundwater monitoring wells are located within the iron filled borings and two additional wells are located hydraulically downgradient. Groundwater data collected from the in-boring wells is compared to grab groundwater data collected in 2008 (the 2008 grab groundwater data indicated PCE concentrations up to 7,300 µg/L). The most recent data (from September 2012) indicates PCE concentrations ranging from <0.5 µg/L to 4.6 µg/L in groundwater within the iron filled borings. These results are an acceptable reduction from the 2008 concentrations.

Sources

AMEC Geomatrix, Inc., Remedial Action report, Cinema Place Property, 22695 Foothill Boulevard, Hayward, California, August 30.

AMEC Environment & Infrastructure, 2013, Semiannual Groundwater Monitoring Report, July through December 2012, Cinema Place Property, 22695 Foothill Boulevard, Hayward, California, January 22.

Former Ford Aerospace
3825 Fabian Way
Palo Alto, California

Background
The Site is currently owned by Far Western Land and Investment, Inc., which leased the property from 1959 to 1990 to the former Ford Aerospace Corporation (Ford), which operated a research and development facility at the site. Operations included the use of chlorinated solvents in and around two buildings, resulting in volatile organic compound (VOC) impacts to soil and groundwater, primarily tetrachloroethene (PCE) and trichloroethene (TCE). Space Systems/Loral currently uses the property for research and development of communication equipment.

Geology
The shallow groundwater zone is subdivided into four distinct depth intervals based on the current understanding of conditions: less than 20 feet below ground surface (bgs), 20-30 feet bgs, 30-40 feet bgs, and 40-60 feet bgs. First groundwater is encountered at approximately 5 feet bgs.

Constituents of Concern and Maximum Concentrations
PCE has been detected at a maximum concentration of 850 micrograms per liter (µg/L) and TCE at a maximum of 1,100 µg/L in the vicinity of the PRB.

Oversight Agency
California Regional Water Quality Control Board, San Francisco Bay Region. The site has been subject to the following Board orders:

- Site Cleanup Requirements (Order No. 89-137) adopted August 16, 1989.
- Waste Discharge Requirements, NPDES Permit (Order No. 90-109) adopted August 15,
- 1990.
- Amendment to Site Cleanup Requirements (Order No. 93-091) adopted August 18, 1993.
- Site Cleanup Requirements (Order No. 96-023) adopted February 28, 1996.
- Revised Site Cleanup Requirements (Order No. 99-043) adopted June 16, 1999.
- Amendment to Site Cleanup Requirements (Order No. R2-2003-0071) issued August 8,
- 2003.
- Final Site Cleanup Requirements and Recission for Order No. 99-043 and Order No. R2-2003-0071

Remedial Action(s)
In 2007, a permeable reactive barrier (PRB) was installed to treat the PCE and TCE groundwater impacts. The first phase of construction was to construct a 6-inch thick slurry wall along the entire length of the PRB to depths of 48 to 60 feet bgs. The total length of the slurry

wall was 371 feet, with the length of the PRB approximately 210 feet. Following construction of the slurry wall, thirty-nine 36-inch-diameter borings were advanced at 6- to 9-foot centers along and through the slurry wall. The borings were backfilled with a mixture of sand and zero-valent iron. The combination of the borings and slurry wall form the “funnel and gate” structure of the PRB. Additionally, a series of 18-inch diameter borings backfilled with zero-valent iron were installed 200 feet upgradient of the PRB to provide supplemental treatment immediately downgradient of the former source area. The borings were installed to depths of 37 to 41 feet bgs on 3-foot centers along an approximately 75-foot transect.

Cleanup Goals
The objective was to minimize the downgradient migration of PCE in groundwater that exceeds 100 µg/L.

Compliance Monitoring
Seven transects of three multi-depth monitoring wells (upgradient, within, and downgradient) are located at the PRB. The percent reduction of PCE in wells installed within the PRB recently ranged from 63% to 100%. The percent reduction of PCE ranged from 41% to 100% in most of the downgradient wells, with three downgradient wells showing no reduction in PCE (AMEC, 2012).

The average upgradient PCE concentration was 70 µg/L (with a maximum of 320 µg/L) and the average downgradient concentration was 26 µg/L. For TCE, the average upgradient concentration was 254 µg/L and the average downgradient concentration was 102 µg/L.

Issues
Downgradient concentrations have not dropped significantly in some wells. It is believed that back-diffusion processes are the cause of the higher concentrations PCE in these three wells.

Sources

AMEC Environment & Infrastructure, 2012, Proposed Modifications to Permeable Reactive Barrier Monitoring Program and Self Monitoring Program, 3963 and 3977 Fabian Way, Palo Alto, California, August.

AMEC Environment & Infrastructure, 2012, Semiannual Groundwater Self-Monitoring and Permeable Reactive Barrier (PRB) Monitoring Report, 3963 and 3977 Fabian Way, Palo Alto, California, November.

Intersil Corporation
1276 Hammerwood Avenue
Sunnyvale, California

Background
Intersil manufactured semiconductors at the site beginning in the 1970s. Operations included use of an acid neutralization system, and results of sampling in 1982 indicated that volatile organic compounds (VOCs), including trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), vinyl chloride, and Freon 113, had been released to groundwater.

Geology
The shallow groundwater zone, consisting of fine to coarse sands and gravels, begins from 10 to 15 feet below ground surface (bgs) and extends down to a low-permeability clay layer located at 20 feet bgs.

Constituents of Concern and Maximum Concentrations
The main constituents of concern are TCE, with a historical maximum concentration of approximately 3,000 micrograms per liter (µg/L), cis-1,2-DCE, and vinyl chloride. Maximum concentrations in the vicinity of the source area at the time of installation of the permeable reactive barrier (PRB) were 170 µg/L for TCE, 3,200 µg/L for cis-1,2-DCE, and 2,200 µg/L for vinyl chloride.

Oversight Agency
California Regional Water Quality Control Board, San Francisco Bay Region

Remedial Action(s)
A groundwater pump-and-treat system was installed at the site in 1987 and reduced TCE concentrations from a high of approximately 3,000 µg/L to 170 µg/L in 1994.

In 1995, a 40-foot-wide PRB was installed using trenching and metal sheet piles. The PRB consists of a 4-foot-thick zone of 100% iron with 2 feet of pea gravel on the upgradient and downgradient sides to even out groundwater flow through the PRB. The iron was installed from 6 to 20 feet bgs, with the base of the iron at the top of the low-permeability zone. Adjacent to the PRB are two slurry walls (300 feet and 235 feet long) used to funnel VOC-impacted groundwater through the PRB.

Cleanup Goals
Cleanup goals are as follows: 5 µg/L for TCE, 6 µg/L for cis-1,2-DCE, 0.5 µg/L for vinyl chloride, and 1,200 µg/L for Freon 113.

Monitoring
A total of six monitoring wells are installed within the PRB. The wells were monitored quarterly until 1999, when the frequency changed to semiannually. Groundwater monitoring results from samples collected from the wells from 1996 through 2006 indicate that, with the exception of anomalous results from two wells, the cleanup goals have been consistently met throughout the 18 years the PRB has been in place.

Issues

Concentrations of TCE, cis-1,2-DCE, and vinyl chloride in groundwater samples collected approximately 140 feet downgradient of the treatment area continue to contain relatively high concentrations of VOCs, but reflect VOC concentrations from sources at multiple sites that were present prior to the installation of the treatment zone, and are influenced by the biological and geochemical changes at these sites (AMEC, 2013). The PRB is still viewed as successful in treating groundwater from the upgradient source zone it was designed to treat.

Sources

AMEC Environment & Infrastructure, Inc., 2013, Technical Status and 2013 Annual Self-Monitoring Summary, 1276 Hammerwood Avenue, Sunnyvale, California, January 31.

California Department of Toxic Substances Control, 2008, An Assessment of Zero Valence Iron Permeable Reactive Barrier Project in California, April.