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**Soil and Soil Gas Sampling and  
Human Health Risk Assessment Report**

Former Chevron Station No. 9-2444  
803 North Milpas Street  
Santa Barbara, California

*Prepared for:*

**Chevron Environmental Management Company**

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**Geomatrix**

**EXHIBIT I**

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## REVISED SOIL AND SOIL GAS SAMPLING AND HUMAN HEALTH RISK ASSESSMENT REPORT

Former Chevron Station No. 9-2444  
803 North Milpas Street  
Santa Barbara, California

### 1.0 INTRODUCTION

On behalf of Chevron Environmental Management Company (Chevron), Geomatrix Consultants, Inc., (Geomatrix) has prepared this Revised Soil Gas Sampling and Human Health Risk Assessment Report (the Report) for former Chevron Station No. 9-2444 in Santa Barbara, California (the Site, Figure 1). This Revised Risk Assessment addresses comments to the Soil Gas Sampling and Human Health Risk Assessment Report (Geomatrix, 2005c) made by the Santa Barbara County Fire Department, Fire Prevention Division (FPD) in a letter dated June 8, 2006. Specifically, the HHRA has been revised to include the evaluation of gasoline additives identified in groundwater but below detection limits in soil gas samples.

Volatile fuel constituents have been detected in soil and groundwater samples collected at the Site since 1993. Soil and groundwater remediation have occurred at the Site, which removed over 2,000 tons of soil and reduced concentrations of oxygenates in groundwater; however, residual concentrations of volatile constituents remain in the subsurface. Equipment and buildings at the former station have been decommissioned and demolished in preparation for future commercial/residential development. This report documents additional sampling activities and a human health risk assessment conducted for the Site.

Soil and soil gas samples were collected in accordance with the *Revised Soil and Soil Gas Sample Collection and Human Health Risk Assessment Work Plan* (the Revised Work Plan, Geomatrix 2005a). The Revised Work Plan addressed comments to the *Soil and Soil Gas Sample Collection and Human Health Risk Assessment Work Plan* (the Work Plan, Geomatrix, 2005b) from the Santa Barbara County Fire Department (SBCFD), transmitted in a letter from Mr. Tom Rejzek to Mr. Eric Roehl of Chevron dated May 24, 2005. SBCFD approved the Revised Work Plan in a letter from Mr. Tom Rejzek to Mr. Eric Roehl dated August 10, 2005. The Work Plan was prepared to describe the methods to collect necessary data and to conduct a human health risk assessment. Soil gas data had not previously been collected at the Site and are an appropriate measurement for evaluating potential exposure to chemicals migrating from the subsurface to indoor air or ambient air.

The following comments made by SBCFD in their letter dated May 24, 2005, were resolved during a conversation between representatives of Chevron and SBCFD and documented in the Revised Work Plan (Geomatrix, 2005a):

- a) SBCFD required soil gas samples to be collected from a minimum of three locations within the area of the excavation. Geomatrix added or moved sample locations slightly on the grid to target former source areas and provide for three samples in the excavation, as requested by SBCFD.
- b) SBCFD required soil gas sample points on a 50-foot grid to target additional potential source areas and that a sample point be placed near all viable potential sources of volatile organic compounds (VOCs). Following discussion with SBCFD, sampling density was increased on the northern Site boundary in conjunction with the response to Item a.
- c) SBCFD required collection and analysis of shallow soil samples from areas outside the former excavation, specifically the hydraulic lift and clarifier. During the conversation with SBCFD, Ms. Elva Rogers of Holquin Fahan Associates, Inc. (HFA) indicated that required soil sampling at known subsurface features (e.g., USTs, dispensers, and piping) had been conducted; therefore, only the samples at the former hydraulic lift and clarifier were required.

The report is organized as follows:

- Background information for the Site is presented in Section 3.0.
- An overview of the sampling program is provided in Section 4.0.
- Drilling and sample collection methodologies are described in Section 5.0.
- Sampling results are presented in Section 6.0.
- The human health risk calculations are presented in Section 7.0.
- Conclusions and recommendations are presented in Section 8.0.
- References are presented in Section 9.0.

## 2.0 OBJECTIVE

The goal of soil gas sampling was to collect Site-specific information for use in a vapor transport model to conservatively assess potential exposure to chemicals in soil gas that could potentially migrate to indoor air in future residential or commercial buildings at the Site. The goal of soil sampling was to delineate the lateral and vertical extent of petroleum hydrocarbons detected in the vicinity of the former hydraulic lift and clarifier. These data and soil and groundwater data collected previously were used to assess potential human health risk.

### 3.0 BACKGROUND

The Site is a former service station located at 803 North Milpas Street on the corner of North Milpas and De La Guerra Streets in Santa Barbara, California. The former service station consisted of a station building, four dispenser islands, and underground storage tanks (USTs) and associated piping and served as an automobile service station until it was closed and demolished in 2004. The Site is bounded by an apartment complex to the west and southwest; Santa Barbara Junior High School to the south; and commercial and retail properties to the northwest, north, northeast, and east. Leaking underground fuel tank (LUFT) sites are located crossgradient (north/northeast, #90078) and downgradient (east/southeast, #50779) from the Site (Figure 2). A California National Guard Armory is located approximately 400 feet to the west. It is also a former LUFT site.

In March 1993, unleaded-plus fuel was released from a ruptured underground product line that ran from the USTs to the dispenser islands. Total petroleum hydrocarbons as gasoline (TPHg) were present in stockpiled soil (up to 1,900 milligrams per kilogram [mg/kg]) from the product line repair. During renovations in 1994, four USTs (two 10,000-gallon gasoline USTs, one 5,000-gallon gasoline UST, and one 1,000-gallon waste oil UST) were removed and replaced. Groundwater Technology, Inc. (GTI) excavated hydrocarbon-containing soil from the vicinity of the USTs (maximum TPHg concentration of 1,400 mg/kg). The replacement USTs consisted of three 12,000-gallon gasoline USTs and one 1,000-gallon waste oil UST. The replacement gasoline USTs were located in the same area as the original USTs at the northeastern corner of the Site. The replacement waste oil UST was located on the southern portion of the Site, but not in the former location of the previous waste oil UST.

Several additional assessments have been conducted at the Site since 1994. In 1995, seven borings for groundwater monitoring wells (MW-1 to MW-7) and one angle boring for soil samples (B-1) were advanced at the Site by GTI. In 1996, three borings for groundwater monitoring wells (MW-8 to MW-10) and one boring for soil samples (B-2) were advanced at the Site by Fluor Daniel GTI. In 1999, four borings for groundwater monitoring wells were advanced at the Site by Bechtel (MW-11 to MW-14). In 2003, two borings for groundwater monitoring wells (MW-15 and MW-16) were advanced by HFA. In 2004, 64 soil samples were collected as part of remediation activities; 35 samples were considered representative of soil remaining at the Site after excavation.

Groundwater remediation activities at the Site consisted of over-purging wells (i.e., periodic extraction of up to 200 gallons of groundwater from selected wells using a vacuum truck) in

2000 and subsequent continuous operation of a groundwater pump and treat system. The groundwater pump and treat system operated for 323 days between September 2001 and August 2002 and periodically in 2003. Operation of the groundwater treatment system was restarted on June 20, 2003 and has been shut off since March 29, 2005. A total of approximately 450,000 gallons of groundwater was extracted, treated, and discharged to the sanitary sewer during these remediation efforts. Concentrations of methyl tert-butyl ether (MTBE) and tert-butyl alcohol (TBA) in monitoring wells were reduced significantly during this period.

During demolition of the former service station in 2004, the four replacement USTs were removed from the Site. In 2004, soil was excavated from the vicinity of the gasoline USTs and to the west, as shown on Figure 2 (maximum TPHg concentration in excavated soil of 820 mg/kg). Prior to excavation, on-Site groundwater monitoring wells (MW-1A, MW-2, MW-3, MW-4, MW-5, MW-6, MW-9, and MW-11) were destroyed by HFA. Approximately 2,000 tons of soil was excavated between August and November 2004. Excavation depths ranged from approximately 9 to 12 feet below ground surface (bgs). Groundwater was pumped from the excavation, treated, and discharged to the sanitary sewer in accordance with the City of Santa Barbara Waste Discharge Permit.

The excavation in the northern portion of the Site (the four replacement USTs) was backfilled with materials consisting of angular crushed rock placed from the bottom of the excavation to approximately 6 feet bgs; liquid boot compound was installed; a 4-inch-thick layer of 2-sack slurry concrete mix was placed; and 5 to 6 feet of backfill soil compatible with Site soil to the surface was placed (Geo-Etka, Inc., 2005). Approximately 3000 pounds of ORC Advanced™ was distributed below the groundwater table in the excavation to create a zone of enhanced oxygen supply to accelerate the aerobic bioremediation of the residual hydrocarbon-impacted groundwater beneath and surrounding the excavation.

The following subsections summarize soil and groundwater conditions based on data developed during the assessments described above.

### 3.1 SOIL CONDITIONS

Lithologic logs for the 16 monitoring wells constructed during previous Site assessments were available for review; eight of the wells are located on Site. Shallow Site soil (0 to 10 feet bgs) consists of fine-grained sediment (predominantly clay and silt) across much of the Site. (Lithologic logs for MW-4 and MW-5 represent conditions in the UST backfill to 25 feet bgs

rather than native soil.) A sand unit occurs between approximately 10 and 20 feet bgs and varies in thickness from 3 to 15 feet.

A total of 116 soil samples were collected during the installation of groundwater monitoring wells from 1995 to 2003 and excavation activities in 2004. Only data collected after the initial excavations (1993 and 1994) were considered relevant to current conditions and included in this discussion. Data collected prior to or as part of the 1993 and 1994 excavations are considered more representative of soil removed from the Site during the 1993 or 1994 excavations.

Of the samples collected previously, 97 soil samples represent soil remaining on and off Site once excavation was completed; 52 of these are in the upper 10 feet of soil below ground surface and 35 are also on Site. Appendix A summarizes the data for samples remaining after excavation. Sample locations remaining on Site are presented on Figure 2. The remainder of this discussion focuses on analytical results for on-Site samples representing soil remaining after excavation between the surface and 10 feet bgs because soil between 0 to 10 feet bgs is most likely to be contacted or brought to the surface during redevelopment.

One or more of the following, benzene, toluene, ethylbenzene, and xylenes, was detected in up to four samples at the Site between 0 and 10 feet bgs. Benzene was detected in one sample (MW-2-5) at 0.59 mg/kg. Toluene was detected in three samples from 0.0032 to 0.77 mg/kg. Ethylbenzene was detected in two samples at 0.004 and 0.0099 mg/kg. Total xylenes were detected in two samples at 0.071 and 0.4 mg/kg. Only the concentration of benzene exceeded its Santa Barbara County Fire Department, Fire Prevention Division, Site Investigation Level (SIL; SBCFD, 2004).

Two oxygenates, MTBE and TBA, were detected in nine and ten on-Site samples, respectively, between 0 and 10 feet bgs. Concentrations of MTBE ranged from 0.0067 to 0.15 mg/kg and TBA ranged from 0.12 to 1.5 mg/kg. Concentrations in several of these samples exceeded Santa Barbara County Site Investigation Levels (SILs) for MTBE and TBA.

Lead was detected in three on-Site samples at concentrations between 5 and 20 mg/kg. These concentrations are below SILs and consistent with naturally occurring concentrations of lead in soil (Kearny, 1996).

### 3.2 GROUNDWATER CONDITIONS

Groundwater monitoring wells at the Site have been monitored quarterly since 1995. Many of the on-site groundwater monitoring wells (MW-1A, MW-2, MW-3, MW-4, MW-5, MW-6, MW-9, and MW-11) were abandoned prior to 2005; only MW-11, MW-15 and MW-16 on site continue to be sampled. As a result the discussion of groundwater conditions is based on data collected in 2004 or prior.

Depth to groundwater measured in the wells ranged from approximately 6.5 to 10.5 feet bgs in 2004. However, groundwater was first noted in borings on the northern part of the Site (MW-1, MW-2, MW-3, MW-9, and MW-11) at approximately 13 to 20 feet bgs. On the southern portion of the Site, groundwater was first noted at 5 feet bgs (MW-6) and 12 to 15 feet bgs (MW-15 and MW-16, respectively). Flowing artesian conditions were present at times in MW-1, which was destroyed in March 2000 and replaced by MW-1A. This information together suggests that groundwater beneath at least the northern portion of the Site is present under confined or semi-confined conditions.

Although groundwater data through November 2004 provided by HFA are presented in Appendix A, this discussion of groundwater conditions focuses on data collected in the last few years, August 2002 to November 2004. Up to ten rounds of sampling have been completed during that time, depending on the well. Concentrations of benzene on the Site generally were highest in MW-1A; concentrations ranged from 46 to 340 micrograms per liter ( $\mu\text{g/L}$ ) in groundwater samples from this monitoring well since August 2002. TPH and xylenes were detected in similar wells. 1,2-Dichloroethane concentrations generally were highest off site at MW-13; on Site concentrations were higher in MW-3, MW-4, and MW-5 and have ranged from 62 to 340  $\mu\text{g/L}$  since August 2002 in these wells. MTBE concentrations generally were highest on Site in MW-3, MW-5, and MW-9 and have ranged from  $<1$  to 300  $\mu\text{g/L}$  since August 2002 in these wells. TBA concentrations were highest on the Site in MW-3, MW-4, and MW-5 and ranged from  $<10$  to 6,100  $\mu\text{g/L}$  in these wells. Among the off-Site wells, concentrations of 1,2-dichloroethane and benzene were elevated in MW-13, which is on the north side of Milpas Street, upgradient of the Site and close to another UST site.

### 4.0 SAMPLING PROGRAM OVERVIEW

The sampling program included the following elements:

- Advanced 13 soil borings (SV-1 to SV-13) to approximately 5 feet bgs using direct-push methods.
- Analyzed 13 soil gas samples and two sample duplicates for selected petroleum hydrocarbon constituents using EPA Method 8260B in a mobile laboratory. Eight selected soil gas samples were also analyzed for selected petroleum hydrocarbon constituents by EPA Method TO-15.
- Advanced three soil borings to approximately 10 feet bgs and one boring to 22 feet bgs to further evaluate soil conditions at the former hydraulic hoist and clarifier.
- Analyzed soil samples for total petroleum hydrocarbons as gasoline, diesel, and motor oil (TPHg, -d, -mo, respectively) by EPA Method 8015M and for VOCs by EPA Method 8260B.

## 5.0 METHODOLOGY

Prior to commencing field activities, a Site-specific Health and Safety Plan was prepared and access agreements were obtained. The County of Santa Barbara does not require boring permits for soil borings or soil gas sampling. Prior to conducting drilling activities, HFA notified Underground Service Alert of proposed boring locations so that utilities could be marked by utility owners. Additionally, Goldak Incorporated of Glendale, California, a private underground utility locator, cleared boring locations. After the collection of soil gas or soil samples at each location, the boreholes were grouted to ground surface using bentonite chips and completed at ground surface to match existing surface conditions.

Prior to and after coring was completed, coring and sampling equipment was cleaned using a pressure washer. Equipment wash water generated during sampling was treated in the on-Site groundwater treatment system.

### 5.1 SOIL GAS SAMPLING

Boreholes were advanced and sampled on September 7 and September 8, 2005, by HFA of Orange, California, a State of California-licensed drilling contractor, using direct-push coring methods to a total depth of approximately 5 feet bgs, above the anticipated depth of shallow groundwater and the vapor barrier installed at the Site. The rods were then pulled back approximately 6 inches for sampling. Hydrated bentonite was used to achieve a seal at the surface of the temporary sampling probe; soil gas samples were collected from the 13 locations as shown on Figure 3.

Three purge volumes were extracted at each sample location prior to sampling. A flow rate of 200 milliliters per minute (ml/min) was used to limit stripping and ambient air dilution. The leak-check compound used during sampling was 1,4-difluoromethane. Soil gas samples were collected in 400-milliliter Summa™ canisters, labeled with a unique sample identifier designating the location and purge volume (SV-11, p132cc for location SV-11 with 132 cubic centimeters purged), and analyzed on Site by H&P Mobile Geochemistry of Lakewood, California.

The soil gas samples were analyzed for a Site-specific list of petroleum hydrocarbon constituents identified in the Revised Work Plan (benzene, toluene, ethylbenzene, xylenes, methyl tert-butyl ether, tert-butyl alcohol, tert-amyl methyl ether, ethyl tert-butyl ether, diisopropyl ether, 1,2-dichloroethane, and 1,2-dibromoethane) by EPA Method 8260B. These soil gas samples were then delivered to H&P Mobile Geochemistry's fixed laboratory in Solano Beach, California, a laboratory certified by the State of California Department of Health Services Environmental Laboratory Accreditation Program (ELAP), under Geomatrix chain-of-custody procedures. Eight soil gas samples where benzene was not detected in on-Site laboratory analyses (SV-1A, SV-2, SV-3, SV-8, SV-9, SV-10, SV-11, and SV-12) were re-analyzed for the subset list of VOCs by EPA Method TO-15 to obtain lower detection limits for these samples. Seven of the eight samples were selected because benzene was not detected in the samples; the eighth sample was selected to compare results of the methods. Laboratory analytical reports for soil gas samples are presented in Appendix B and summarized in Table 1.

## 5.2 SOIL SAMPLING

HFA advanced and sampled four soil borings (B-3, B-4, B-5A, and B-6), which surrounded the former hydraulic hoist and clarifier area, on September 7 and 8, 2005. Sample B-5 was renamed B-5A after the sampling was completed since a previous sample location was identified as B-5. Three borings (B-3, B-4, and B-5A) were cored using a hand auger to a total depth of 10 feet bgs. The fourth boring (B-6) was cored using a hand auger to 10 feet bgs and then advanced using a direct-push rig to 22 feet bgs. Samples were collected at 5 and 10 feet bgs in brass liners into 6-inch-long by 2-inch-diameter brass sleeves. Two samples collected greater than 10 feet bgs were collected between 15 to 17 feet bgs and 20 to 22 feet bgs in 2-foot-long by 1-inch-diameter sample tubes lined with acetate liners using the Geoprobe® LB Soil Sampler (direct-push technology). Samples were capped with Teflon sheets and plastic endcaps, and sealed with silicon tape. Soil samples were stored in Ziploc bags in ice-filled coolers until delivery to Del Mar Analytical of Irvine, California, a laboratory certified by the State of California Department of Health Services Environmental Laboratory Accreditation

Program (ELAP), under HFA chain-of-custody procedures. Lithologic logs were prepared using the Unified Soil Classification System (USCS) visual-manual procedure (ASTM D2488-90) by the field geologist.

Soil samples were analyzed for total petroleum hydrocarbons as gasoline, diesel, and motor oil (TPHg, -d, -mo, respectively) by EPA Method 8015M and for VOCs by EPA Method 8260B. Laboratory results for chemical testing of soil samples are included in Appendix B and summarized in Table 2.

### 5.3 QUALITY ASSURANCE AND QUALITY CONTROL

Geomatrix followed specific, quality assurance/quality control (QA/QC) procedures during the soil gas and soil sampling program. QA/QC samples were analyzed by the laboratory to assess the internal quality, accuracy, and precision of the soil sample analytical results. Both field and laboratory QA/QC samples were collected and analyzed.

#### 5.3.1 Soil Gas Samples

To assess the potential effects of field sampling techniques on analytical results for soil gas samples, two ambient air samples and two field duplicates were collected. One ambient air sample was collected each day (September 7 and 8, 2005) in a 6-liter Summa canister with an 8-hour flow controller and analyzed by Columbia Analytical Services Air Quality Laboratory in Simi Valley, California, a state-certified analytical laboratory. A laboratory-prepared certified-air trip blank accompanied the samples during sample collection and transportation to the laboratory. The laboratory analyzed method blanks, laboratory blanks, matrix spike, and surrogate spike samples as part of the QA/QC process.

The results of the blind field duplicate and laboratory duplicate samples are presented in Table 1. The laboratory duplicate results are consistent with the primary samples. The field duplicate results are sufficiently similar (within 20 percent) to consider the data complete for the purposes of conducting a risk assessment.

The trip blank, method blank, and laboratory blank results were all non-detect. Matrix spike and surrogate spike results were within control limits set by the laboratory.

Toluene (2.6 and 5.6  $\mu\text{g}/\text{m}^3$ ) and xylenes (2.5 and 4.7  $\mu\text{g}/\text{m}^3$ ) were detected in the ambient air samples (Table 3). Maximum detected concentrations of toluene and xylenes in site soil gas samples were at least 100 times higher than these ambient concentrations, suggesting the

ambient concentrations did not significantly affect these results. Also, the leak check compound was not detected in any samples. Sample results quantified at less than five times the ambient air sample concentration are flagged in the summary table.

### 5.3.2 Soil Samples

The laboratory analyzed laboratory blanks, laboratory control spike (LCS) samples, matrix spike/matrix duplicate (MS/MSD) samples, and surrogate spike samples as part of the QA/QC process. The laboratory blank results were all non-detect.

Surrogate spike sample recoveries are used to assess the accuracy of results for each individual sample. The surrogate, 4-bromofluorobenzene (4-BFB), for samples B-5A-10, B-6-9, and B-6-15 for the Volatile Fuel Hydrocarbon analysis (EPA Method 5030/8015M) had recoveries of 137%, 173%, and 330%, respectively, which are above the acceptance limits of 70 to 135%. Therefore, due to a sample matrix effect, the detected target compounds are qualified as estimated concentrations (“J” flagged).

Sample B-6-15 had a detected concentration of TPH of 20 mg/kg, which exceeds the laboratory calibration range. Since this detection is semi-quantitative, it is qualified as an estimated concentration (“J” flagged).

Data accuracy is assessed by the LCS and MS/MSD sample analyses. The MS/MSD was run on sample B-5A-5 for the Hydrocarbon Distribution analysis (EPA Method 8015M) and the data were out of the acceptable range. However, since the sample concentration is greater than four times the spike added, the spike recovery does not apply, and all data are reported without a flag. The MS/MSD for VOC analysis was run using sample B-3-5 and had a MSD percent recovery of TBA at 32%, which is below the acceptance limit of 65 to 140%. Since the LCS, surrogate recoveries, and other MS/MSD results are within criteria, the data are considered acceptable.

Data precision is evaluated by comparing the duplicate laboratory-analyzed MS/MSD samples. The precision is assessed by the calculation of the relative percent difference (RPD) between the pair of duplicate samples. The RPD for the VOC analysis of TBA was 109%, above the method acceptance limit of 30%. Since the RPD is out of range, the data are considered non-reproducible. Therefore, TBA in the corresponding sample, B-3-5, is qualified as an estimated non-detection (“UJ”). All other RPDs were within method control limits, confirming the acceptable precision of the data generated.

### 5.3.3 Conclusions

Overall, the results of the QA/QC review indicate that the analytical results are valid and useable for the purpose of risk assessment. Laboratory results for QA/QC samples are presented in the laboratory reports in Appendix B.

## 6.0 RESULTS

This section presents the results of soil gas and soil sampling and analysis.

### 6.1 LITHOLOGY

The subsurface geologic materials encountered in borings B-3 through B-6 consisted primarily of lean clay with sand, clayey sand, and silty sand. Each boring was advanced to 10 feet bgs, with the exception of B-6, which was advanced to 22 feet bgs. Groundwater was encountered in the borings at depths ranging from 6.5 to 10.0 feet bgs. Boring logs are included in Appendix C.

### 6.2 ANALYTICAL RESULTS

For the purpose of discussing the results for soil gas samples, each sample location where soil gas samples were analyzed multiple times by the same method (e.g., purge volume test or field duplicate) or multiple times by two different methods (e.g., EPA Method 8260 and TO-15) are discussed as one sample location. In the soil gas samples, VOCs that are constituents of petroleum products were detected at 11 soil gas sample locations. Benzene (5.2 to 240  $\mu\text{g}/\text{m}^3$ ), ethylbenzene (6.5 to 9.4  $\mu\text{g}/\text{m}^3$ ), toluene (9.2 to 460  $\mu\text{g}/\text{m}^3$ ), m,p-xylene (5.6 to 20  $\mu\text{g}/\text{m}^3$ ), and o-xylene (6.4 to 18  $\mu\text{g}/\text{m}^3$ ). The highest concentrations of VOCs were detected in SV-4, SV-5, SV-6, SV-7, and SV-9 on the northern portion of the property. Soil gas sample results are presented in Table 1.

Eleven soil samples were analyzed for VOCs and total petroleum hydrocarbons (TPH) as gasoline (TPHg), diesel (TPHd), and motor oil (TPHmo). Fourteen VOCs were detected in at least one sample. VOCs and TPH were not detected in four samples (B-3-5-S, B-4-5-S, B-4-10-S, and B-6-21-S). Only MTBE (0.0078 mg/kg) was detected in sample B-3-10-S. Only TPHd and TPHmo were detected in B-5A-5-S at 22 and 200 mg/kg, respectively, and B-6-5-S at less than 2.5, and 8.4 mg/kg, respectively. The remaining four samples (B-5A-10-S, and B-6-9-S, B-6-10-S, and B-6-15-S) had detections of multiple VOCs and TPH. The highest concentrations of VOCs were in B-6-10-S and B-6-15-S. The highest concentrations of benzene and MTBE were detected in B-6-15-S (0.017 and 0.06 mg/kg, respectively); this

sample was collected below the water table. The deeper sample from the same boring was non-detect for all analytes as mentioned previously. Soil chemical analysis results are presented in Table 2.

## 7.0 HUMAN HEALTH RISK ASSESSMENT

The purpose of this human health risk assessment (HHRA) is to provide an analysis of the potential for adverse human health effects as a result of exposure to chemicals detected at the Site under potential future use for commercial and/or residential purposes. This HHRA presents an assessment of potential adverse human health effects that may result if no further remedial action were to take place, and recognizing that significant remediation efforts have been completed at the Site. The HHRA will be used to identify the need for additional remediation, to develop health-based cleanup criteria, or to support a no further action decision. The risk assessment is presented in the following sections, consistent with U.S. EPA guidance (1989) for risk assessment.

- Section 7.1 – Data Evaluation: presents a summary of the data used in the HHRA and the selection of the chemicals of potential concern that are evaluated in the HHRA.
- Section 7.2 – Exposure Assessment: presents an analysis of the mechanisms by which human receptors may be exposed to chemicals at the Site.
- Section 7.3 – Toxicity Assessment: presents the quantitative criteria developed by U.S. EPA and Cal-EPA to evaluate potential adverse health effects of chemicals.
- Section 7.4 – Risk Characterization: presents the results of the quantitative analysis of potential carcinogenic and non-carcinogenic risks to human health.

### 7.1 DATA EVALUATION

Data evaluation is the process of analyzing Site characteristics and analytical data to identify chemicals of potential concern (COPCs) to be evaluated in the HHRA. This section of the report presents the data that are considered in the risk assessment and the methodologies used to select COPCs. A complete discussion of the data collected from the Site is presented in Sections 3.0 and 6.0.

Several subsurface investigations have been conducted since 1993; these investigations include collection of soil, groundwater, and soil gas samples. The soil and groundwater data are summarized in Appendix A. The soil data in Appendix A-1 is divided into on-Site and off-Site

soil samples. Appendix A-1 presents only samples that remain at the Site after excavation activities; samples collected in areas that were subsequently excavated are not included. For the purpose of the risk assessment, only soil data for the top 10 feet were used to quantitatively estimate potential health risk (Appendix D). Because of the potential for groundwater movement (unlike soil) and the proximity of off-Site monitoring wells to the Site, on-Site and off-Site groundwater data were considered in this risk assessment and presented in Appendix A-2. All groundwater data collected are presented in Appendix A-2; as outlined in the Revised Work Plan, only data collected between August 2002 and November 2004, approximately two years of data, were considered in the HHRA to represent current conditions and to account for the effects of remediation activities (Appendix E). The only soil gas data for the Site were collected in 2005 and are summarized in Table 1.

## 7.2 DATA QUALITY

The data presented in Appendix A and Table 1 are judged to be of sufficient quality to be used in the risk assessment. The sources of the data were documented in previous reports or by previous consultants. Appropriate analytical methods were used for the purpose of risk assessment. A review of the data indicated that adequate data have been collected to characterize conditions at the Site. Data quality for data reported herein is documented; Geomatrix relied on the data quality review performed by previous consultants in reporting their data and has assumed that the data they reported met standard data quality criteria.

## 7.3 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

Tables 4, 5, and 6 present a summary of the data collected in soil, groundwater, and soil gas. Chemicals of potential concern selected for each medium are discussed in this section.

Eighteen chemicals (including TPHg, TPHd, and TPHmo) were detected in at least one soil sample at the Site. Fourteen of the chemicals are classified as VOCs and are considered COPCs. Lead was analyzed and detected in three samples at the Site. Because the concentrations of lead were consistent with background concentrations in California, lead is not considered a COPC for this Site. Measurements of TPH quantified as gasoline or diesel represent a mixture of chemicals that, because of their highly variable composition, do not have descriptive health criteria. Therefore, the toxicity of these mixtures is best described by the aggregate toxicity of key individual chemicals in the mixture, such as BTEX. For the purpose of the HHRA, and as is the practice in California, non-constituent-specific TPH measurements are not considered in the data evaluation process (Cal-EPA, 1999).

Nine chemicals (including TPHg) were detected in at least one groundwater sample collected at the Site. Eight of the chemicals are classified as VOCs and are COPCs. The remaining chemical mixture (TPHg) is not considered a COPC for the reasons described in the previous paragraph.

Four VOCs were detected in at least one soil gas sample and are considered COPCs for the purpose of this HHRA. The data summarized in Table 6 are based on one sample from each soil gas location (Appendix F). In cases where more than one sample was collected at a specific location (e.g., purge volume tests, sample duplicates, and mobile/fixed laboratory analyses), the maximum detected concentration, or the lowest detection limit if the results were non-detect, was used to create the summary.

Consistent with DTSC guidance (2005b), chemicals detected in groundwater that were not detected in soil gas were evaluated further. Four fuel additives (tert-butyl alcohol (TBA), 1,2-dichloroethane (1,2-DCA), di-isopropyl ether (DIPE), and MTBE) were detected in groundwater but not in soil gas samples at the site. The reporting limits in soil gas for MTBE were approximately 10 to 1,000 times lower than screening level ( $8600 \mu\text{g}/\text{m}^3$ ) for soil gas for the vapor intrusion pathway for residential site use published by the Office of Environmental Health Hazard Assessment (OEHHA, 2005b). As such, MTBE was not considered a COPC from a volatilization perspective. The reporting limits in soil gas for 1,2-DCA were approximately the same to 20 times lower than screening levels ( $110 \mu\text{g}/\text{m}^3$ ) for soil gas for the vapor intrusion pathway for residential site use (OEHHA, 2005b). 1,2-DCA was retained as a COPC to consider potential additive effects of exposure to multiple chemicals for the volatilization pathway. Screening levels have not been published by OEHHA for tert-butyl alcohol or di-isopropyl ether so these compounds were retained as COPCs for the volatilization pathway. The remaining additives analyzed in soil gas (1,2-dibromoethane, ethyl tertiary butyl ether, and tertiary amyl methyl ether) were not detected in soil gas or in groundwater during recent sampling events (August 2002 to April 2004) and are not considered COPCs in groundwater at this Site.

#### 7.4 EXPOSURE ASSESSMENT

Exposure assessment is the process of describing, measuring, or estimating the intensity, frequency, and duration of potential human exposure to COPCs in environmental media (e.g., soil, water, and air) at a site. This section of the report discusses the mechanisms by which people (receptors) might come into contact with COPCs. Exposure assessment is best

explained by what is known about the chemical sources, migration pathways, exposure routes, and possible exposure scenarios associated with the Site, as summarized in this section.

Chemicals related to the use of the Site as a former service station are present in soil, shallow groundwater, and soil gas. Many of these chemicals are volatile and may migrate from soil or groundwater through the subsurface to indoor air in future buildings. Thus, future occupants of the Site may be exposed to chemicals in soil, groundwater, and migrating into indoor air.

An exposure assessment is best conducted within the context of a risk-based site conceptual model (SCM). As described in U.S. EPA's guidance for *Conducting Remedial Investigations and Feasibility Studies under CERCLA*, the purpose of the SCM is to describe what is known about chemical sources, migration pathways, exposure routes, and possible exposure scenarios. Figure 4 presents the SCM.

#### **7.4.1 Receptors**

Potential human receptors are identified based on potential development of the Site for residential or commercial/industrial purposes. The Site has been cleared and fenced, so no occupants are currently present. Potential future exposure is evaluated in the HHRA. Potential future receptors at the Site include residents, commercial/industrial workers, construction workers, and trespassers if the site remains undeveloped.

#### **7.4.2 Exposure Pathways**

Soil and groundwater at the Site have been impacted by fuel hydrocarbons that apparently leaked from former USTs. As described in the data summary section, affected soil was removed during tank excavations, and affected groundwater was treated using a groundwater extraction system. Groundwater was approximately 6.5 to 10.5 feet bgs in 2004. Based on the proposed land use for a commercial and/or residential building, potential direct contact with affected soil is a complete exposure pathway. While use of shallow groundwater as a drinking water source is unlikely, this exposure pathway has been included in this analysis. In addition, groundwater is sufficiently shallow to be contacted by construction workers at the Site. Volatile COPCs are present in soil gas and could migrate to ambient air or indoor air, resulting in exposure to building occupants. Physico-chemical properties for the COPCs are presented in Table 7.

The complete exposure pathways applicable to each receptor are as follows:

- Future residents at the Site may be exposed to chemicals in soil via soil ingestion and chemicals in soil gas via inhalation of chemicals that potentially migrate to indoor air. Inhalation of particulates and is not considered a complete pathway since all COPCs are volatile chemicals.
- Future commercial/industrial workers at the Site may be exposed to chemicals in soil via soil ingestion and chemicals in soil gas via inhalation of chemicals that potentially migrate to indoor air. Inhalation of particulates and is not considered a complete pathway since all COPCs are volatile chemicals.
- Future construction workers at the Site may be exposed to chemicals in soil via soil ingestion; chemicals in groundwater via dermal contact and inhalation; and chemicals in soil gas via inhalation of chemicals that migrate to ambient air. Inhalation of particulates and is not considered a complete pathway since all COPCs are volatile chemicals.
- Future trespassers at the Site may be exposed to chemicals in soil via soil ingestion and chemicals in soil gas via inhalation of chemicals that migrate to ambient air. Inhalation of particulates is not considered a complete pathway since all COPCs are volatile chemicals.

Although shallow groundwater at the Site is not a source of drinking water, potential ingestion of groundwater was evaluated based on comparison of concentrations in groundwater to maximum contaminant limits (MCLs) for drinking water or other drinking water criteria if MCLs (e.g., preliminary remediation goals [PRGS]) are not available.

#### 7.4.3 Exposure Point Concentrations

Exposure point concentrations generally are estimated using measured concentrations in environmental media or based on fate and transport models. Depending on a number of factors, including the distribution of the data (normal versus lognormal), the proportion of samples reported as non-detect, and the total number of samples, several statistical parameters may be used to estimate exposure point concentrations. With the exception of soil gas, exposure point concentration was based on the 95% upper confidence limit (95% UCL) of the mean to estimate a reasonable maximum exposure (RME) scenario (U.S. EPA, 2002). U.S. EPA defines the RME scenario as the “highest exposure that is reasonably expected to occur at the site.” COPCs reported below the detection limit were assumed to be present at one-half the practical quantitation limit (PQL). This approach assumes that, on average, any value between zero and the PQL could be present in any given sample. For soil gas, the maximum detected concentration was used, as discussed below. The exposure point concentrations are summarized in Table 8.

For soil, exposure point concentrations were calculated as the 95% UCL using samples in the top 10 feet of on-Site soil (Appendix D). For groundwater, average concentrations in each well since August 2002 were used and compared individually to MCLs or other drinking water criteria where available. For groundwater exposure pathways unrelated to domestic water use (e.g., direct contact by construction workers or vapor intrusion), an average concentration in each well was used to calculate a 95% UCL for groundwater for these Site-wide exposures (Appendix E). For soil gas, the maximum concentration detected in soil gas was used as the representative concentration to account for variability in sampling (Appendix F).

U.S. EPA's ProUCL software (Version 3.0, 2004) was used to develop 95% UCLs based on the distribution of the data for each chemical. ProUCL provides recommendations for 95% UCLs for (1) normally distributed data sets, (2) log normally distributed data sets, and (3) data sets that are neither normal nor lognormal (non-parametric data). The ProUCL calculations are consistent with recommendations in U.S. EPA guidance (U.S. EPA, 2002) for calculating exposure point concentrations at hazardous waste sites. In the event that the calculated 95% UCLs exceed the maximum detected value, the maximum value was used as the exposure point concentration.

Modeling was used to estimate the concentration of COPCs in indoor air based on soil gas concentrations. COPC concentrations in indoor air were estimated using the Johnson and Ettinger model as parameterized by U.S. EPA (2003) and adopted by Cal-EPA. The model incorporates both advective and diffusive mechanisms for estimating the transport of chemical vapors emanating from the subsurface into indoor spaces located directly above or in close proximity to a source of chemicals. The model is a one-dimensional analytical solution to advective and diffusive vapor transport into indoor spaces and provides an estimated attenuation coefficient that relates the vapor concentration in the indoor space to the vapor concentration at the source. Inputs to the model include chemical properties, building properties, and exposure assumptions. Physical properties for evaluated chemicals were based on defaults provided by U.S. EPA; building properties were also based on default assumptions provided by the U.S. EPA. Soil properties were based on the average of Site-specific data that are presented in Appendix G. All COPCs in soil gas were evaluated for vapor intrusion into indoor air using the version of the Johnson & Ettinger model appropriate to soil gas measurements. COPCs in groundwater for the vapor intrusion pathway (TBA, 1,2-DCA, and DIPE) were evaluated for vapor intrusion from groundwater into indoor air using the version of the Johnson and Ettinger model appropriate for groundwater measurements.

Modeling was also used to estimate the concentrations of COPCs in ambient air based on soil gas and groundwater concentrations. The Volatilization Factor model adjusted to accommodate soil gas data and groundwater data was used to estimate an emission rate resulting from volatilization of COPCs through the vadose zone. The Quiescent Surface Impoundment model was used to estimate an emission rate resulting from COPCs in exposed groundwater in a trench during construction (i.e., the vadose zone soil has been removed and groundwater is exposed). In both cases, a dispersion factor was used to estimate concentrations in air based on the emission rates predicted by the models. A more detailed description of the models and assumptions is presented in Appendix G.

#### **7.4.4 Exposure Quantification**

The “Annual Average Daily Dose” (AADD) or “Lifetime Average Daily Dose” (LADD) is used to quantify exposure in the HHRA. The AADD is used as a standard measure for characterizing long-term noncarcinogenic effects. The LADD, which addresses exposures that may occur over varying durations from a single event to an average 70-year human lifetime, is used to estimate potential carcinogenic risks. Exposure assumptions used in the daily intake calculations are based on information contained in U.S. EPA and Cal-EPA risk guidance, Site-specific information, and professional judgment, and represent upper-bound values under an RME scenario. The exposure assumptions for the future resident, commercial/industrial worker, construction worker, and trespasser are presented in Tables 9 through 12, respectively. The calculation of exposures and risk is presented in Appendix H.

#### **7.5 TOXICITY ASSESSMENT**

A toxicity assessment evaluates the potential for a chemical to cause adverse health effects in exposed individuals (hazard identification) and characterizes the relationship between the extent of exposure to a chemical and the anticipated response (dose-response assessment). The result of the hazard identification is a summary of the available toxicological information and its relevance to human exposure. The result of the dose-response assessment is a set of toxicity criteria (i.e., a reference dose [RfD] for noncarcinogenic effects and a slope factor [SF] for carcinogenic effects) that are used in the risk characterization to estimate the likelihood of adverse effects occurring in exposed individuals at different exposure levels.

Toxicity criteria used in the HHRA were selected according to the following hierarchy:

1. Cal-EPA Office of Environmental Health Hazard Assessment (OEHHA), California Cancer Potency Factors, Standards and Criteria Work Group (on-line database);
2. Cal-EPA OEHHA, Chronic Reference Exposure Levels (on-line database);
3. U.S. EPA, Integrated Risk Information System (IRIS) (on-line database);
4. U.S. EPA, Health Effects Summary Tables, FY-1997 Annual (1997b); and
5. U.S. EPA, Region 9 Preliminary Remediation Goals (PRGs) (2004).

Toxicity criteria used in this assessment are summarized in Tables 13 and 14. In the event that an RfD or SF is not available for the inhalation route of exposure, the RfD or SF for the oral route was used in the calculations unless clear toxicological evidence indicates this extrapolation is inappropriate for a specific chemical. In addition, toxicity criteria are not available for chemicals for evaluating dermal exposure. In this case, the oral RfDs or SFs were used considering absorption factors when available. For COPCs that do not have appropriate toxicity criteria from any of the above sources, where relevant and appropriate, surrogate toxicity criteria were used based on similarities in chemical structure and toxicity. For this evaluation, toluene was used as a surrogate for cymene (p-isopropyl toluene), and 1,2,4-trimethylbenzene was used as a surrogate for 1,3,5-trimethylbenzene.

## 7.6 RISK CHARACTERIZATION

Risk characterization represents the final step in the risk assessment process. In this step, the results of the exposure and toxicity assessments are integrated into quantitative or qualitative estimates of potential health risks. Potential noncarcinogenic health effects and carcinogenic health risks are characterized separately.

### 7.6.1 Noncarcinogenic Effects

Potential adverse noncarcinogenic health effects were evaluated using the hazard index (also called HI) approach as recommended by U.S. EPA (1989). The first step in this approach is to compare the annual average daily dose (AADD) for each chemical to the appropriate RfD. This comparison is expressed in terms of a "hazard quotient," which is calculated as follows:

$$\text{Hazard Quotient}_i = \frac{\text{AADD}_i}{\text{RfD}_i}$$

A hazard quotient less than or equal to 1 indicates that the predicted exposure to that chemical should not result in an adverse noncarcinogenic health effect (U.S. EPA, 1989). In cases where individual chemicals potentially act on the same organs or result in the same health endpoint

(e.g., respiratory irritants), potential additive effects may be addressed by calculating a hazard index as follows:

$$\text{Hazard Index} = \sum_{i=1}^n \text{Hazard Quotient}_i$$

A hazard index of less than or equal to 1 indicates acceptable levels of exposure for chemicals having an additive effect. In this risk assessment, a screening-level hazard index was calculated by summing the hazard quotients for all chemicals, regardless of toxic endpoint (U.S. EPA, 1989). This approach is generally believed to overestimate the potential for noncarcinogenic health effects due to simultaneous exposure to multiple chemicals because it does not account for different toxic endpoints. (U.S. EPA, 1989; NRC, 1988; Risk Commission, 1997; Seed, et al., 1995) However, it can be used as a screening tool to rapidly identify those exposure scenarios for which exposure to multiple chemicals does not pose a noncarcinogenic health risk. If the screening hazard index is greater than 1, a target organ-specific hazard index may be calculated to more accurately assess the potential for noncarcinogenic effects to specific target organs based on target organs for each chemical identified by OEHHA.

The hazard indices calculated in this manner for this risk assessment are summarized in Tables 15 through 18. The hazard indices ranged from  $4 \times 10^{-6}$  (trespasser) to 0.03 (resident). Therefore, the hazard indices for all exposure scenarios in the SCM are approximately two orders of magnitude below a level that can be considered to be without adverse health effects with a substantial margin of safety. These hazard indices are so low that potential health risks to off-site receptors are also considered insignificant.

#### 7.6.2 Carcinogenic Health Effects

Carcinogenic health risks are defined in terms of the increased probability of an individual developing cancer as the result of exposure to a given chemical at a given concentration. Incremental lifetime excess cancer risks are estimated as follows:

$$\text{Lifetime Excess Cancer Risk}_i = \text{LADD}_i \times \text{SF}_i$$

As with hazard indices, the estimated excess cancer risks for each chemical were summed regardless of toxic endpoint to estimate the total excess cancer risk for the exposed individual.

The result is an incremental lifetime excess cancer risk related to exposure to chemicals at the Site.

Regulatory agencies such as U.S. EPA and Cal-EPA have defined what is considered an acceptable level of risk. The U.S. EPA considers cancer risks of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$  to be the target range for acceptable risks at sites where remediation is considered (U.S. EPA, 1990a and 1990b). Estimates of lifetime excess cancer risk associated with exposure to chemicals of less than one-in-one-million ( $1 \times 10^{-6}$ ) are considered to be so low as to not warrant any further investigation or analysis (U.S. EPA, 1990a). Within the State of California, Cal-EPA also tends to agree with the same target range for acceptable risks; however, pursuant to the California Safe Drinking Water & Toxic Enforcement Act of 1986, the Office of Environmental Health Hazard Assessment has established a no significant risk level at  $1 \times 10^{-5}$  (CCR Division 21.5, Title 22, Section 12703). Many air management districts also consider  $1 \times 10^{-5}$  to be an acceptable risk level for managing air emissions under the Toxics Hot Spots program.

The risk estimates for the scenarios evaluated in this risk assessment are substantially below the one-in-one million benchmark (Tables 19 to 22). The excess lifetime cancer risks range from  $3 \times 10^{-10}$  (trespasser) to  $9 \times 10^{-7}$  (resident).

### 7.6.3 Groundwater Evaluation

As described in the Work Plan, concentrations of chemicals in groundwater were compared to maximum contaminant levels (MCLs), or to environmental screening levels (ESLs) (ESLs; RWQCB, 2005) or preliminary remediation goals for tap water (U.S. EPA, 2005) when an MCL was not available. Drinking water criteria were not available from these sources for tertiary butyl alcohol and di-isopropyl ether. As shown in Table 5, maximum concentrations of benzene, 1,2-dichloroethane, methyl tert-butyl ether, toluene, and TPH (gasoline) exceed the drinking water standard. Further evaluation on a well-specific basis was conducted using the information in Appendix E. The average concentration in each well since August 2002 was compared to the drinking water standard. Chemicals detected at least once since August 2002 where the average concentration exceeds the drinking water standard include:

- Benzene in MW-1A, MW-2, MW-3, MW-8, and MW-13;
- TPH (gasoline) in MW-1A, MW-2, MW-3, MW-4, MW-8, and MW-13 (data presented in Appendix A);

- MTBE in MW-2, MW-3, MW-5, MW-7, and MW-9; and
- 1,2-Dichloroethane in MW-1 to MW-11, MW-13, and MW-16.

Although the maximum detection of toluene exceeded the drinking water standard, the average concentrations by well did not. MTBE and 1,2-dichloroethane exceedances occurred over a larger portion of the site than the petroleum hydrocarbons. The petroleum hydrocarbons exceedances are on the northern part of the site near the former USTs and in wells on Milpas Street. MTBE exceedances are on the northwestern portion of the site. 1,2-Dichloroethane exceedances are present throughout the site and in wells on Milpas and De La Guerra Streets, with the exception of the upgradient well (MW-12), a cross gradient well (MW-15), and a downgradient well (MW-14). The prevalence of 1,2-dichloroethane above the drinking water standard is partially related to the low level of the standard (0.5 µg/L).

#### 7.6.4 Uncertainty Analysis

Uncertainty is inherent in many aspects of the risk assessment process, and generally arises from a lack of knowledge of: (1) Site conditions, (2) the extent to which an individual will be exposed to COPCs, and (3) the toxicity and dose-response of the COPCs. This lack of knowledge means that assumptions must be made based on information presented in the scientific literature or on professional judgment. While some assumptions have significant scientific basis, others have much less. In general, assumptions were selected in a manner that purposefully biases the process toward health conservatism. For example, the maximum concentration was used as the exposure point concentration.

##### 7.6.4.1 Data Evaluation and Selection of Chemicals of Potential Concern

The selection of Site-related COPCs was based upon the results of the sampling and analytical program established for the Site. The factors that contribute to the uncertainties associated with the identification of COPCs are inherent in the data collection and data evaluation processes, including appropriate sample locations, adequate sample quantities, laboratory analyses, data validation, and treatment of validated samples.

The predominant sources of uncertainty and potential bias associated with site characterization are based on the procedures used for site investigation (including sampling plan design and the methods used for sample collection, handling, and analysis) and from the procedures used for data evaluation. In general, a relatively comprehensive sampling program was implemented to

account for the chemicals most likely to be present at the Site as a result of past Site history and activities.

For purposes of this HHRA, all organic chemicals detected in soil, groundwater and soil gas were considered COPCs, regardless of their frequency of detection. As shown in Tables 4, 5, and 6, 1,2-dichlorethane and styrene in soil and di-isopropyl ether in groundwater were detected in fewer than 5 percent of the samples analyzed. Nonetheless, these chemicals were selected as a COPCs, potentially over-estimating the potential health risks posed by the site.

To be conservative, and as described in DTSC's Vapor Intrusion Guidance (DTSC, 2005b), chemicals that were not detected in soil gas, but were detected in groundwater were included as COPCs with the exception of MTBE. The detection limits for MTBE in soil gas were sufficiently low to conclude that MTBE in soil gas would not result in health effects exceeding acceptable levels for vapor migration to indoor air. Based on conservatism in the volatilization model, use of groundwater concentrations to estimate indoor air concentrations may overestimate the contribution of these chemicals to overall risk. However, use of groundwater data to predict vapor intrusion did not result in estimated health effects exceeding acceptable levels.

#### **7.6.4.2 Exposure Assessment**

##### **Exposure Point Concentrations**

For chemicals that were not detected in individual samples, it was assumed that one-half the sample quantitation limit (SQL) was representative of the concentration that may be present in soil or groundwater for purposes of calculating the arithmetic average and 95% UCL concentrations. The current default position of U.S. EPA (1989) is to substitute one-half the SQL for all non-detects. U.S. EPA guidance (2002) indicates that substitution of one-half the SQL is adequate when the proportion of non-detects is less than 10 to 15 percent. If the fraction of non-detects becomes large, then assuming that the value of each non-detect is equal to one-half the SQL will generally overestimate the expected true mean concentrations, with the degree of overestimation increasing with increasing proportions of non-detects. In some cases, chemicals were detected in only 1 or 2 samples, meaning that the majority of the data used to calculate representative concentrations was hypothetical.

Exposure point concentrations for soil gas are based on one round of samples. This may not adequately account for temporal variation. However, the samples were collected across the site

to provide adequate spatial representation, and the maximum concentration detected was used for each chemical to minimize the potential effect of this uncertainty.

### **Environmental Fate and Transport**

Fate and transport models were used to estimate indoor and ambient air concentrations of COPCs volatilized from soil and groundwater. While some site-specific conditions were incorporated into the analysis, the models are screening-level models which typically are conservative and predict concentrations that overestimate risk. For example, biodegradation of petroleum constituents in the vadose zone is not considered. In addition, assumptions about future building design have been incorporated into the indoor air model (e.g., slab-on-grade foundations). The conclusions of the risk assessment are therefore dependent on future building conditions being consistent with those included in the model.

### **Exposure Assumptions and Parameters**

The exposure assessment is based on an RME scenario, which is defined by U.S. EPA as the highest exposure that could reasonably be expected to occur for a given exposure pathway at a site (U.S. EPA, 1989). To achieve this goal, the RME is based on highly conservative exposure assumptions. For example, the evaluation assumes that a commercial worker will be present on site for 250 days/year for 25 years. This and other upper-bound estimates of exposure most likely overestimate the potential health risks associated with exposure to the COPCs in soil.

### **Exposure Pathways**

Potential exposures to future residents and future industrial/commercial workers from inhalation of VOCs in ambient air were evaluated in this HHRA as if they occurred concurrently with indoor air exposures. This is likely to overestimate risk because a receptor is either inside or outside at any given time. Because the predicted hazard indexes and risks were so low, this assumption did not significantly affect the conclusions.

#### **7.6.4.3 Toxicity Assessment**

##### **Uncertainty in Toxicity Criteria**

One of the largest sources of uncertainty in any risk assessment is associated with the scientific community's limited understanding of the toxicity of most chemicals in humans following exposure to the low concentrations generally encountered in the environment. The majority of available toxicity data are from animal studies, which are then extrapolated using mathematical models or multiple uncertainty factors to generate toxicity criteria used to predict what might

occur in humans. Sources of conservatism in the toxicity criteria used in this evaluation include:

- The use of conservative methods and assumptions to extrapolate from high-dose animal studies to predict the possible response in humans at exposure levels far below those administered to animals;
- The assumption that chemicals considered to be carcinogens do not have thresholds (i.e., for all doses greater than zero, some risk is assumed to be present); and
- The fact that epidemiological studies (i.e., human exposure studies) are limited and are not generally considered in a quantitative manner in deriving toxicity values.

The toxicity criteria used in the HHRA are based on an evaluation of noncarcinogenic and carcinogenic health risks, which were developed using different methods. The noncarcinogenic criteria (i.e., oral and inhalation RfDs) incorporate multiple uncertainty factors to account for limitations in the quality or quantity of available data (e.g., animal data in lieu of human data). These uncertainty factors are applied without regard to available data on the true likelihood of a variation in human response. Therefore, RfDs may be hundreds of times smaller than doses that would actually cause adverse health effects. This purposeful bias in the development of RfDs overestimates the actual potential for noncarcinogenic health risks for these chemicals.

The carcinogenic toxicity criteria (i.e., oral and inhalation SFs) also are developed using techniques that purposefully bias the criteria toward health conservatism. For example, most SFs are based on the premise that cancer data from high-dose animal studies will predict cancer response in humans at dose levels thousands of times lower. The process also assumes that the carcinogenicity of a chemical in an animal model is representative of the response in humans. Finally, the statistical techniques used by regulatory agencies to extrapolate data from animals to human exposures generally assume that the dose-response curve is linear and that the 95% UCL of the slope is representative of the chemical's carcinogenic potency. In aggregate, these assumptions overestimate the actual risk estimates such that they are unlikely to be higher, but could be considerably lower and, in fact, could be non-existent.

#### **Lack of Route-Specific Toxicity Criteria**

In the absence of data for the inhalation route of exposure, the SF or RfD for the oral route was used in the evaluation. As a result, the health risk estimates for these chemicals may be over- or underestimated.

### ***Weight of Evidence of Carcinogenicity***

As shown in Table 14, U.S. EPA assigns weight-of-evidence classifications to potential carcinogens although they have not done this for all chemicals detected at the site. Constituents evaluated quantitatively in this assessment are classified as Group A, Group B1, Group B2, or Group C, defined as follows.

- Group A constituents (known human carcinogens) are agents for which there is sufficient evidence to support a causal association between exposure to the agents in humans and cancer.
- Group B1 constituents (probable human carcinogens) are agents for which there is limited evidence of carcinogenicity in humans.
- Group B2 constituents (probable human carcinogens) are agents for which there is sufficient evidence of carcinogenicity in animals but inadequate or no evidence in humans.
- Group C constituents (possible human carcinogens) are agents for which there is limited evidence of carcinogenicity in animals and inadequate or no human data.

One of the chemicals evaluated was identified in Group A, one was identified in Group B2, one was identified in Group C, and two are not currently assigned to a group by U.S. EPA.

Quantitative cancer risk characterization is generally performed for all Group A, B1, and B2 carcinogens identified at a site. A quantitative evaluation of Group C carcinogens and other chemicals identified as carcinogens is typically performed on a case-by-case basis because the weight of evidence in support of an association between constituent exposure and cancer is not as strong as for Groups A, B1, and B2. To be conservative, all five of these chemicals were evaluated quantitatively as carcinogens.

#### ***7.6.4.4 Uncertainty Associated with Risk Characterization***

One source of uncertainty that is unique to risk characterization is the assumption that the total risk associated with exposure to multiple chemicals is equal to the sum of the individual risks for each chemical (i.e., the risks are additive). Other possible interactions include synergism, where the total risk is higher than the sum of the individual risks, and antagonism, where the total risk is lower than the sum of the individual risks. Relatively little data are available regarding potential chemical interactions following environmental exposure to chemical mixtures. Some studies have been conducted in rodents given simultaneous doses of multiple chemicals. The results of these studies indicated that no interactive effects were observed for mixtures of chemicals affecting different target organs (i.e., each chemical acted).

independently), whereas antagonism was observed for mixtures of chemicals affecting the same target organ, but by different mechanisms (Risk Commission, 1997).

While there are no data on chemical interactions in humans to chemical mixtures at the dose levels typically observed in environmental exposures, animal studies suggest that synergistic effects will not occur at levels of exposure below their individual effect levels (Seed, et al., 1995). As exposure levels approach the individual effect levels, a variety of interactions may occur, including additive, synergistic, and antagonistic (Seed, et al., 1995).

Current U.S. EPA guidance for risk assessment of chemical mixtures (U.S. EPA, 1989) recommends assuming an additive effect following exposure to multiple chemicals. Subsequent recommendations by other parties, such as the National Academy of Sciences (NRC, 1988) and the Presidential/Congressional Commission on Risk Assessment and Risk Management (Risk Commission, 1997) have also advocated a default assumption of additivity. As currently practiced, risk assessments of chemical mixtures generally sum cancer risks regardless of tumor type and sum non-cancer hazard indices regardless of toxic endpoint or mode of action. Given the available experimental data, this approach likely overestimates potential risks associated with simultaneous exposure to multiple chemicals.

## 7.7 CONCLUSIONS OF UNCERTAINTY ANALYSIS

In summary, these and other assumptions contribute to the overall uncertainty in the development of risk-based cleanup goals. However, given that the largest sources of uncertainty generally result in overestimates of exposure or risk, it is believed that results presented in this document are based on conservative estimates.

## 8.0 CONCLUSIONS

Soil gas and soil samples were collected to provide data to evaluate potential human health risks associated with future use of the Site for commercial/residential development. The results of the risk assessment (Table 23) show that potential human health risks are below levels considered acceptable by regulatory agencies and do not represent a potential public health risk. Chemicals in groundwater exceed drinking water standards in several wells, but shallow groundwater is not a source of drinking water. Therefore, future land use at the site is not restricted by the presence of chemicals at the concentrations under the conditions evaluated in this assessment.

The conclusions presented herein are professional opinions based solely upon the data described in this report. Results reported herein are based on conditions at the Site at that time; changes in Site conditions may change the assumption under which the assessment was done. If further remedial or construction excavations occur on Site, non-native backfill or engineered fill should have similar properties to the native fill. In the event that a significant amount of pea gravel or other fill with higher permeability than native materials is used, a re-evaluation of health risks to on-Site occupants may be required based on potential changes in vapor emissions.

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