# GETTLER-RYAN INC.

# TRANSMITTAL

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Department of Environmental Health
1131 Harbor Bay Parkway, Room 250
Alameda, California 94502-6577

DATE: July 2, 2001
PROJ.#: 240004.02
SUBJECT: Former Unocal #2512
1300 Davis Street
San Leandro, CA

FROM:
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COMMENTS:

We are sending this RMP at the request of Unocal. Please call us at 916.631.1300 if you have questions.

cc: Mr. Nick Nickerson, Unocal Corporation, 8788 Elk Grove Boulevard, Building 3, Suite 15, Elk Grove, CA 95624
Ms. Jill Tracy, Unocal Corporation, 376 South Valencia, Avenue, Brea, CA 92823
Mr Chuck Headlee, Regional Water Quality Control Board, 1515 Clay Street, Suite 1400, Oakland, CA 94612
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Ms Leah Goldberg, Hanson Bridgett, 333 Market Street, Suite 2300, San Francisco, CA 94105

# GETTLER-RYAN INC.

## RISK MANAGEMENT PLAN

Former Unocal Service Station #2512
1300 Davis Street
San Leandro, California

GR Report No. 240004.02-1

**Prepared for:**

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June 28, 2001

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## 1.0 INTRODUCTION

Gettler-Ryan Inc. prepared this Risk Management Plan (RMP) at the request of Unocal Corporation. The subject site was formerly operated as Unocal Service Station #2512, located at 1300 Davis Street, San Leandro, California. An environmental investigation identified petroleum hydrocarbons in the soil and groundwater beneath the site, which were successfully remediated to acceptable levels. With the submittal of this RMP, the environmental investigation at this site will be closed by Alameda County Health Care Services Agency.

As part of the environmental investigation, Unocal requested a corrective action evaluation be performed for the site. The evaluation was completed by Geraghty & Miller (G&M), and concluded that maximum detected soil concentrations at the site are health-protective, and that future remediaton or control measures were not necessary. The exposure scenarios considered in this risk assessment included both adult and child residents and excavation workers. These conclusions are presented in a document titled *Site-Specific Health Risk Assessment for Former Unocal Service Station Facility #2512, San Leandro, California* (dated October 18, 1994). A copy of this document is included in Appendix A.

There is always some level of uncertainty in subsurface environmental investigations. Although highly unlikely, it is possible that the environmental investigation failed to identify some areas of impacted soil, and that future development of the site might encounter this impact. This document provides a Risk Management Plan (RMP) for the site **in the event soil or groundwater are encountered during construction activities that exhibit obvious evidence of petroleum hydrocarbons, such as strong gasoline or oil odors, or obvious staining of the soil.** In Section 2, the compounds of concern (COCs), risk, and sources of risk are summarized. In Section 3, risk management measures are developed. The RBCA evaluation that serves as a basis for this work is given in Appendix A, and figures showing the site location and relevant site features are provided in Appendix B.

## 2.0 RISK SUMMARY

### 2.1 Data

All aboveground and underground facilities have been removed. Delineation of soil and groundwater impact is complete. Impacted soil was excavated and removed. Dissolved fuel hydrocarbon concentrations have decreased to non-detectable levels. Fuel hydrocarbon impact at the site appears to pose very little risk to human health or the environment. Based on this lack of risk, the fuel hydrocarbon case at this site has been closed by ACHCSA.

A summary of the previous environmental investigations at this site was summarized by G&M in their *Site-Specific Health Risk Assessment*. Tables containing chemical analytical data from soil and grab groundwater samples collected during these investigations, copies of the most recent groundwater sampling events and the Site Closure Summary, and figures showing the hydrocarbon-affected areas are provided in Appendix B. Observations regarding the data are listed below.

- The highest hydrocarbon concentrations detected in soil samples were 270 parts per million (ppm) of Total Petroleum Hydrocarbons as gasoline (TPHg), 210 ppm of TPH as diesel (TPHd), 7,200 ppm of Oil and Grease (TOG), and 0.72 ppm of benzene. These samples

were collected in the vicinity of the former underground storage tanks (USTs) and dispenser islands, which have been removed.

- The vertical and lateral extent of hydrocarbons in unsaturated soil has been well defined by soil samples collected at the furthest extent of the excavations, and by the soil borings drilled around the former UST pit and across the site. Therefore, hydrocarbon impact to soil has been adequately delineated.

- Groundwater fluctuates from approximately 10 to 19 feet below ground surface (bgs). Impacted soil remains in the soil outside the zone of groundwater fluctuation (0 to 10 feet bgs), but only at very low concentrations. TPHg concentrations up to 6.8 ppm, benzene concentrations up to 0.013 ppm, and TPHd concentrations up to 5.0 ppm have been detected in soil samples collected at approximately 5 or 10 feet bgs. While natural processes have undoubtedly reduced these concentrations, some level of hydrocarbons likely remain in these areas.

- Groundwater was gauged and analyzed quarterly from November 1993 to January 2000. Groundwater has been observed to flow toward the west-southwest and toward the northeast. TPHg, TPHd, benzene, methyl tert butyl ether (MtBE), and tetrachloroethene (PCE) have been detected in site wells in steadily decreasing concentrations over this time, indicating a stable and decreasing plume. During the most recent monitoring and sampling event conducted January 18, 2000, TPHg, TPHd, benzene, or PCE were not detected in the groundwater beneath the site. MtBE was detected at a concentration of 135 parts per billion by EPA Method 8020 (not confirmed by EPA Method 8260).

- In June 1996, Pacific Environmental Group conducted a survey of water wells immediately southwest of the site. A total of five wells were identified within ¼ mile of the site. The nearest well northeast of the site is an industrial supply well at 1052 Davis Street, approximately 600 feet from the site. The nearest water supply well to the west-southwest is an irrigation well located at 1309 Kelly Avenue, approximately 500 feet west-southwest of the site.

- During the most recent sampling event, monitoring wells MW-8 and MW-9, situated on the eastern boundary of the Unocal site, do not contain detectable concentrations of petroleum hydrocarbons. Monitoring wells MW-3 (southwest corner of the site) and MW-7 (65 feet southwest of the site) did not contain TPHg, TPHd or benzene during the most recent sampling event. These wells contained 135 ppb and 6.10 ppb of MtBE, respectively, by EPA Method 8020. The presence of MtBE in these wells was not confirmed by EPA Method 8260.

- Groundwater beneath the site and in the site vicinity have been impacted by solvents leaking from dry cleaners and manufacturing facilities in the area. Groundwater samples collected

from monitoring wells at the former Unocal site have contained the chlorinated solvents PCE, trichlorethene, 1,1-dicholorethane, 1,1,1-trichloroethane, 1,1-dichloroethene, and 1,2-dichlorobenzene. Chlorinated solvents were not detected in groundwater samples during the most recent monitoring and sampling event.

- During a special sampling event conducted May 31, 2001, a well at a former dry cleaning facility situated approximately 110 feet west-southwest of the former Unocal site (well MW-DC) did not contain any detectable concentrations of petroleum hydrocarbons.

**2.2 Risk Summary**

Risks at the site were evaluated by G&M in their *Site-Specific Health Risk Assessment* (Appendix A). Per agreement with ACHCSA, this risk assessment considered only impacted soil. Groundwater beneath the site was also impacted. While the concentrations of dissolved fuel hydrocarbons in the groundwater has decreased to non-detectable concentrations, groundwater in the vicinity of the site remains impacted by chlorinated hydrocarbon solvents emanating from off-site sources unrelated to the former Unocal station. Risks identified by G&H's evaluation include:

- The *Risk Assessment* performed by G&M indicates that TPHg, TPHd and BTEX compounds in soil beneath the site do not pose a significant risk to occupants of an on-site building. This *Risk Assessment* is based on a conservative residential use scenario. Per agreement between Unocal and Alameda County Health Care Services Agency (ACHCSA), risks associated with impacted groundwater beneath the site were not included in G&M's *Risk Assessment.*

- Complete exposure pathways identified by the *Risk Assessment* include: vapor intrusion into indoor air; incidental ingestion, dermal contact, and inhalation of contaminant-laden dust; and exposure of excavation workers to incidental ingestion, dermal contact, and inhalation of contaminant-laden dust.

- G&M's *Risk Assessment* concluded that "...detected soil concentrations at the site are health-protective assuming exposure under hypothetical exposure scenarios. Therefore, future remediation or control measures are not necessary to protect human health."

- G&M's *Risk Assessment* concluded that "Exposure of environmental receptors to site-related constituents is not likely to occur for several reasons."

As discussed above, the maximum soil concentrations identified at the site are protective of human health, both for future residents of the property and workers engaged in construction activities at the property. And as mentioned above, it is possible (although unlikely) that construction activities might encounter pockets of soil impacted at concentrations above the health-based goals calculated in G&H's *Risk Assessment.*

Possible scenarios where previously unidentified hydrocarbon might be encountered at concentrations above the health-based goals are discussed below.

- Construction workers engaged in subsurface piping or foundation excavation at the site could be exposed to hydrocarbon-impacted soil if excavating in unexplored portions of the site.

- Construction workers engaged in subsurface piping or foundation excavation could be exposed to impacted groundwater. Chlorinated hydrocarbon solvents are known to be present in groundwater in the site vicinity.

- Construction dewatering could take place at or near the site. Untreated groundwater could be inadvertently discharged to the street or storm drain.

- A groundwater extraction well could be installed for the purpose of providing an irrigation supply. Residents at the site could be exposed to untreated groundwater, or the irrigation well could act as a conduit to a deeper groundwater supplies;

- Impacted soil excavated from the site as a result of construction activities could be used as fill for landscaping;

- If previously unidentified pockets of highly impacted soil are intersected by excavations, atmospheric conditions, such as pressure and temperature, could create a situation where vapor phase hydrocarbons accumulate at the bottom of a trench or excavation. Workers might then be exposed to vapor phase hydrocarbons, or the mixture of air and vapor phase hydrocarbons could reach the lower explosive limit, and an ignition source could cause a fire or explosion.

## 3.0 RISK MANAGEMENT

It appears highly unlikely exposure risks identified in Section 2 above will be realized at this site. It is unlikely that petroleum hydrocarbons will be encountered during construction activities at concentrations exceeding the identified health-based goals. All areas of known petroleum usage (USTs, lifts, piping) were investigated and remediated. Soil borings drilled outside these areas did not encounter any hydrocarbon impact. The risk of either resident or construction worker being exposed to hydrocarbon concentrations that exceed the health-based goals identified in G&H's *Risk Assessment* appears very low.

In the unlikely event that construction activities encounter soil is encountered that exhibits a strong odor of gasoline or other petroleum product, has free-flowing oil or other petroleum-like substance, or is obviously stained or discolored relative to surrounding soil, work on that portion of the project should be halted immediately. Unocal should be contacted immediately (916.714.3204). Unocal will dispatch appropriately trained personnel to evaluate the situation and collect samples as appropriate. Unocal will also notify the

appropriate regulatory agency. If petroleum hydrocarbons are present at concentrations that exceed the established health-based goals, Unocal will arrange for appropriate remedial measures to be implemented.

Historical monitoring data indicate that groundwater is not likely to be encountered during routine residential construction activities (foundation trenching, utility trenching). Construction dewatering will probably not be required. Water service is available from a public utility, so a well for either domestic supply or irrigation is not necessary. Because of these facts the risk of resident or construction worker to impacted groundwater appears very low. However, if it becomes necessary to pump groundwater at this site (construction dewatering, for example), Unocal should be contacted prior to initiating any pumping activities. Unocal will contact the appropriate regulatory agency, will assist in obtaining the necessary permits, and will provide assistance with any required remedial equipment or personnel required.

## 4.0 LIMITATIONS

Evaluations of the subsurface conditions at the site that serve as a basis for this RMP are inherently limited due to the limited number of observation points. There may be variations in subsurface conditions in areas away from the sample points. There are no representations, warranties, or guarantees that the points selected for sampling are representative of the entire site. The recommendations provided herein reflect the sample conditions at specific locations at a specific point in time. No other interpretations, representations, warranties, guarantees, express or implied, are included or intended in this RMP. Additional work, including further subsurface investigation, might reduce the inherent uncertainties associated with this RMP.

# APPENDIX A

# SITE-SPECIFIC HEALTH RISK ASSESSMENT FOR FORMER UNOCAL SERVICE STATION FACILITY #2512 SAN LEANDRO, CALIFORNIA

**October 18, 1994**
**RC0286.001**

**Prepared for:**

**UNOCAL CORPORATION**
**2000 Crow Canyon Place, Suite 400**
**San Ramon, California 94583**

Prepared by:

GERAGHTY & MILLER, INC.
*Environmental Services*
1050 Marina Way South
Richmond, California 94804

**SITE-SPECIFIC HEALTH RISK ASSESSMENT FOR**
**FORMER UNOCAL SERVICE STATION FACILITY #2512**
**SAN LEANDRO, CALIFORNIA**

**October 18, 1994**
**RC0286.001**

Geraghty & Miller, Inc. is submitting this report to Unocal Corporation for work performed at the former Unocal Service Station Facility No. 2512 in San Leandro, California. The report was prepared in conformance with Geraghty & Miller's strict quality assurance/quality control procedures to ensure that the report meets industry standards in terms of the methods used and the information presented. If you have any questions or comments concerning this report, please contact one of the individuals listed below.

Respectfully submitted,

**GERAGHTY & MILLER, INC.**

Kathleen Neuber
Project Scientist/Risk Assessment Task Manager

Carol B. Day
Senior Scientist

Gary Keyes, P.E.
Principal Engineer/Project Officer

KN:CD:GK:kn

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GERAGHTY & MILLER, INC.
Environmental Services

Ground Water Engineering Hydrocarbon Remediation Education

October 18, 1994
RC0286.001

Alameda County Health Agency
Department of Environmental Health
1131 Harbor Bay Parkway
Alameda, California 94502

Attention: Ms. Madhulla Logan

Subject: Risk Assessment
Former Unocal Service Station Facility #2512
1300 Davis Street, San Leandro, California

Dear Ms. Logan:

On behalf of Unocal Corporation (Unocal), Geraghty & Miller, Inc. (Geraghty & Miller) is submitting the results of a site-specific health risk assessment for the subject site. The risk assessment has been provided at the request of Alameda County Health Agency to support closure of the subject site. Unocal and Geraghty & Miller are confident that the risk assessment will satisfy any concerns raised by the County of Alameda regarding closure of the site. If you have any questions, please call Kathleen Neuber at (714) 753-0444.

Sincerely,
GERAGHTY & MILLER, INC.

Kathleen Neuber
Project Scientist

Craig Neslage for
Gary Keyes
Principal Engineer
Project Officer

encl: Site-Specific Health Risk Assessment

cc: Mr. Ed Ralston, Unocal Corporation

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# SITE-SPECIFIC HEALTH RISK ASSESSMENT FOR FORMER UNOCAL SERVICE STATION FACILITY #2512 SAN LEANDRO, CALIFORNIA

## EXECUTIVE SUMMARY

The purpose of this risk assessment is to identify potential exposure pathways (both those complete and incomplete) associated with potential future exposure to soil and to develop health-protective soil goals for those potentially complete exposure pathways at the site. The site is the former Unocal service station facility #2512 at 1300 Davis Street in San Leandro, California. The soil health-based goals (HBGs) developed in this risk assessment can be used to determine if further remediation, or control measures should be employed at the site to protect human health.

Previous site investigation at the former Unocal service station indicated the presence of constituents in soil typically associated with a hydrocarbon release: benzene, toluene, ethylbenzene, xylenes (BTEX), and total petroleum hydrocarbons (TPH) as both gasoline (TPH-g) and diesel (TPH-d). The constituents of potential concern (COC) for the risk assessment were BTEX, TPH-g, and TPH-d.

Health-based goals (HBGs) were developed for COC in soil at the site based upon a hypothetical residential land use scenario. The evaluation of a residential scenario is conservative because current land use is commercial. A residential exposure scenario is expected to provide the most conservative (health-protective) HBGs, based upon longer potential exposure duration, the presence of sensitive receptors (i.e., children), and greatest number of potential routes of exposure to COC in soil.

Indoor exposure of hypothetical adult and child residents via inhalation to volatile COC originating from subsurface soil and accumulating in overlying buildings was assumed to occur. The migration pathway from soil beneath the site to indoor air was evaluated using a vapor intrusion model. Outdoor exposure of hypothetical adult and child residents via inhalation of

volatile COC as vapors and nonvolatile COC as fugitive dust, incidental ingestion of surface soil, and dermal contact with surface soil was assumed to occur. The migration pathway from surface soil to outdoor air was evaluated using the volatilization factor (VF) and particulate emission factor (PEF) defined in USEPA guidance (1991b). Exposure of hypothetical excavation workers to subsurface soil via inhalation, incidental ingestion, and dermal contact was also assumed to occur.

HBGs were developed for each complete exposure pathway for all COC. Because TPH-g and TPH-d are complex mixtures of constituents and there are no constituent-specific toxicity values, chemical surrogates of n-hexane and naphthalene, respectively, were used.

To calculate HBGs for carcinogens, acceptable cancer risk levels were targeted. Following USEPA (1991b) guidance, the "target" cancer risk for each potential carcinogen was conservatively set at $1 \times 10^{-6}$. To calculate HBGs for non-carcinogenic health effects, the "target" hazard quotient (HQ) for non-cancer risk for constituents with different critical effects was set at 1. However, ethylbenzene and toluene both exert effects on the liver and kidney, so the target HQ were set at 0.5, for a cumulative hazard index (HI) of 1.

The constituent-specific and media-specific HBGs that were developed for these exposure pathways were compared to maximum detected soil concentrations to evaluate the need for risk management or remedial action for protection of human health and the environment (Table ES-1). The comparison indicated that maximum detected soil concentrations of COC at the site are health-protective under the assumed exposure conditions. Therefore, future remediation or control measures are not necessary to protect human health. The data, as presented herein, indicate that current site conditions would support future residential land use and that closure of this site should be granted.

Table ES-1. Comparison of Constituent Concentrations Detected in Soil to Health Based Goals, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | | MAXIMUM DETECTED CONCENTRATION Cs (mg/kg) | HEALTH-BASED GOALS: Vapor Intrusion Adult Resident HBG (mg/kg) | Vapor Intrusion Child Resident HBG (mg/kg) | Direct Contact Adult Resident HBG (mg/kg) | Direct Contact Child Resident HBG (mg/kg) | Direct Contact Excavation Worker HBG (mg/kg) |
|---|---|---|---|---|---|---|---|
| VOCs | | | | | | | |
| Benzene | | 0.12 | 3.2 | 3.4 | 0.56 | 0.43 | 1 |
| Ethylbenzene | | 0.25 | 42,000 | 8,900 | 1,900 | 500 | 640 |
| Toluene | | 0.21 | 13,000 | 2,800 | 2,000 | 280 | 680 |
| Xylenes (total) | | 1.7 | 3,500,000 [c] | 760,000 | 74,000 | 19,000 | 310,000 |
| TPH | | | | | | | |
| TPH-g | [a] | 20 | 830 | 180 | 700 | 68 | 58 |
| TPH-d | [b] | 13 | 7,000 | 3600 | 320 | 30 | 1,900 |

[a] n-Hexane used as a surrogate for TPH-g.

[b] Naphthalene used as a surrogate for TPH-d.

[c] Value is greater than a million ($10^6$) parts per million (ppm), and therefore is not itself a valid concentration goal, but indicates that concentrations below saturation are health-protective.

Cs Maximum detected constituent concentration in soil.

HBG Health-based goals for soil.

mg/kg Milligrams per kilogram.

TPH Total petroleum hydrocarbons.

VOCs Volatile organic compounds.

# SITE-SPECIFIC HEALTH RISK ASSESSMENT FOR FORMER UNOCAL SERVICE STATION FACILITY #2512 SAN LEANDRO, CALIFORNIA

## 1.0 INTRODUCTION

Geraghty & Miller, Inc., (Geraghty & Miller) has been contracted to identify potential exposure pathways (both those complete and incomplete) associated with exposure to soil and to develop health-protective soil remediation goals for those potentially complete exposure pathways at the subject site. The site is the former Unocal Service Station Facility #2512 at 1300 Davis Street in San Leandro, California. The soil goals will be based on protection of human health assuming reasonable maximum exposure (RME) conditions for a hypothetical future residential land use scenario. This risk assessment was prepared for Unocal Corporation (Unocal) to develop, considering both the magnitude and likelihood of exposure to site-related constituents, appropriate health-based goals (HBGs) for soil that are protective in the event that exposure to impacted soil should occur. This information can be used to determine if additional remediation, remediation in conjunction with institutional or engineering controls, or control measures should be employed at the site to protect human health.

Groundwater is not addressed in this risk assessment due to the presence of the regional Caterpillar solvent flow. It was agreed upon, in a July 1994 meeting with the Alameda County Health Agency, that this risk assessment would only address potential exposure to soil.

Previous site investigation has indicated the presence of constituents in soil typically associated with a hydrocarbon release: benzene, toluene, ethylbenzene, xylenes (BTEX), and total petroleum hydrocarbons (TPH) as both gasoline (TPH-g) and diesel (TPH-d). Analytical results of soil samples collected during previous investigations have been provided in previous reports (Kaprealian Engineering Incorporated [KEI]; 1993a,b,c; 1992; 1989a,b,c,d,e).

The methodologies used in this health risk assessment were designed to be generally consistent with guidelines established by the U.S. Environmental Protection Agency (USEPA)

(1989a; 1991a,b,c) for risk assessments in general and the development of health-protective remedial goals specifically. This health risk assessment was also designed to be consistent with California Environmental Protection Agency (Cal/EPA) guidance for screening of hazardous substance release sites (Cal/EPA, 1994).

The risk assessment report is organized as follows:

- **Section 2: Site and Constituent Characterization,** briefly describes pertinent physical and hydrogeological characteristics of the site and current land use, summarizes previous site investigations, and identifies the constituents of potential concern (COC) at the site.

- **Section 3: Toxicity Assessment,** provides toxicological information and toxicity values for the COC used to evaluate the potential carcinogenic and systemic toxicant effects on exposed receptors.

- **Section 4: Exposure Assessment,** presents the physical and chemical properties relevant to environmental fate and transport for COC; identifies potential migration of COC in environmental media; and discusses potential exposure pathways, routes of exposure, exposure points, and receptors used in the derivation of the soil HBGs.

- **Section 5: Risk Characterization,** presents the mathematical equations and exposure parameter values used to calculate the soil HBGs for COC based on attainment of an acceptable risk, assuming that individuals contact impacted media under site-specific conditions.

- Section 6: Uncertainties, discusses the inherent uncertainties in the health risk assessment process and in the assumptions used in the HBG derivations.

- **Section 7: Findings and Conclusions**, presents goals based on protection of human health and the environment and summarizes the results and conclusions of the risk assessment.

- **Section 8: References**, presents a list of references used to support the risk assessment.

# 2.0 SITE AND CONSTITUENT CHARACTERIZATION

The following sections provide a concise description of the site, the facility background, previously conducted site investigations, and the hydrogeology of the site and area; and identify COC for the risk assessment.

## 2.1 BACKGROUND

The site is a rectangular 11,393 square foot lot on the northwest corner of the intersection of Davis Street and Douglas Drive in San Leandro, California (PHR, 1991). The site, 1300 Davis Street, was formerly a Unocal service station facility. Facility operations included routine automobile repair and service, and dispensing of gasoline (PHR, 1991). The property was occupied by a Union Oil or Unocal service station facility from 1946 to 1992. In 1966, the service station was renovated and two new 10,000 gallon gasoline underground storage tanks (USTs) and one 280 gallon waste oil UST were installed. The original USTs were probably removed at the time of the rebuild (PHR, 1991). In 1989, routine soil borings that were required one year before lease expiration indicated impacted soil in the vicinity of the original waste oil tank. Groundwater monitoring wells were installed and indicated potential impacts to groundwater beneath the site. The station building, pump islands, and other station equipment were recently demolished and removed from the site (KEI, 1993a).

The site is in an area of commercial and retail land use. Residential areas are located across Virginia Street to the north of the site and across Davis Street to the south (PHR, 1991). The adjacent property to the west (1335 to 1370 Davis Street) is occupied by a strip shopping center containing a bar, a beer and wine supplier, a barber shop and a dry cleaner (PHR, 1991).

In February and March 1990, five test borings were drilled at the adjacent property to the west of the site prior to finalization of the purchase agreement on that property. Unocal's plans to purchase the adjoining property were abandoned after it was determined in 1990 that

the property at 1335 to 1370 Davis Street had been impacted by cleaning solvents beyond the maximum levels stipulated in the purchase option. In May 1991, Unocal notified the lessor, Douglas T. Federighi, of Federighi & Company, of their decision to cease operation of the service station.

The City of San Leandro approved dealer occupancy of the Unocal service station property through March 1992 and Unocal use of the property through June 1993 for the purpose of contamination remediation (PHR, 1991). Federighi & Company, the lessor of the Unocal service station property and owner of the property at 1335 to 1370 Davis Street, has requested that a risk assessment be conducted to evaluate the suitability of the property for future residential development. Therefore, this risk assessment identifies health-based goals for COC detected at the former Unocal service station under a hypothetical residential land use scenario.

## 2.2 PREVIOUS INVESTIGATIVE ACTIVITIES

On January 3, 1989, six exploratory soil borings were drilled at the site as part of Unocal's procedure for site divestment. The six borings (EB1 through EB6) were drilled to depths ranging from 26.5 to 30 feet below ground surface (bgs), and groundwater was encountered at depths ranging from 25 to 26.5 feet bgs (KEI, 1993b). Soil and water samples collected from borings EB2 through EB6 were analyzed for TPH-g, and BTEX. Soil and water samples from EB1 were analyzed for TPH-d, total oil and grease (TOG), and halogenated and aromatic volatile organic compounds. Soil samples collected from boring EB6 were also analyzed for TPH-d and TOG. Analytical results of soil samples collected from borings EB1 through EB6 indicated levels of TPH-g ranging from non-detectable to 73 parts per million (ppm). Benzene was detected only in samples EB5 (20 feet bgs) and EB6 (15 foot bgs) at concentrations of 0.12 ppm and 0.065 ppm, respectively. Analytical results of soil samples collected from boring EB6 indicated levels of TPH-d ranging from 3 ppm to 160 ppm, and levels of TOG ranging from 130 ppm to 7,800 ppm (KEI, 1993b). Toluene was the only volatile organic constituent detected in samples from EB1.

On May 11, 1989, the soil surrounding exploratory boring EB6 was excavated, sampled, and sent off-site for proper disposal (KEI, 1992). Samples collected from the sidewalls of the excavation indicated that detectable levels of TPH-d and TOG were still present and the excavation was extended laterally and to a depth of approximately 17 feet below grade in October 1993 (KEI, 1993a).

On July 28, 1992, the two fuel USTs and one waste oil tank were removed from the site. Four soil samples (A1, A2, B1, B2) were collected from beneath the fuel tanks at depths of about 14 feet bgs. Two soil samples (WO1 and WO1[15]) were collected from beneath the waste oil tank at depths of 10 and 15 feet bgs, respectively. Six soil samples (P1 through P6) were collected from beneath the product pipe trenches and dispensers at depths of about 3.5 feet below grade (KEI, 1993a). Four additional exploratory borings (EB7 through EB10) were drilled at the site on March 22 and 23, 1993. Analytical results indicated that TPH-g, TPH-d, BTEX and TOG were present in EB8 at 5 foot bgs. The area surrounding EB8 was subsequently excavated to a depth of approximately 7 feet bgs (KEI, 1993a).

In October 1993, additional excavation in the vicinity of the former fuel and waste oil tank pits was performed. Soil samples were collected at the bottom and sidewalls of the excavations. Additional soil excavation was performed in November 1993 in the vicinity of the former pump island. Soil was excavated to a depth of approximately 17 feet bgs. Analytical results of sidewall samples indicated the need for additional lateral excavation. Sidewall soil samples (SWBB, SWCC, and SWDD) were collected after the final excavation in the pump island area at depths of about 15.5 feet bgs (KEI, 1993a).

Analytical results of water samples collected from borings EB5 and EB6 prompted the installation of three monitoring wells in April 1989. The three wells were drilled and completed to total depths of 33 feet below grade. Groundwater was encountered at depths ranging from 17.5 to 18.5 feet bgs. A total of seven monitoring wells have been installed at the site since April of 1989 (KEI, 1993a). Although the constituents identified in soil at the site appear to be

present in groundwater as well, this issue is complicated by a regional groundwater problem of intermingled plumes (the San Leandro Plume Site) and groundwater will not be addressed herein.

## 2.3 HYDROGEOLOGY

During the drilling of exploratory borings at the service station property in March 1993, groundwater was encountered at depths ranging from 18 to 24 feet bgs. Based on the water elevation data gathered in December 1991, January 1992, and October 1992, the groundwater flow direction appeared to be predominantly to the west (KEI, 1993b).

The results of subsurface studies at the service station property indicated that the site is underlain by fill materials to a depth of about 1 to 8 feet bgs. The fill is in turn underlain by alluvium to the maximum depth explored (33 feet bgs). The alluvium underlaying the site was observed to consist mainly of clay or silty clay interbedded with thin discontinuous beds or lenses of clayey or sandy silt, and silty sand (KEI, 1993b). The soil boring log for the boring advanced at 1370 Davis Street indicated that alluvium underlaying the adjacent property consists of clay and clayey silt (Hageman-Schank, 1990). Physical properties of site soils were not further characterized during previous site investigations.

## 2.4 CONSTITUENTS OF POTENTIAL CONCERN (COC)

Constituents detected in soil at the service station property during previous investigations included BTEX, TPH-d, TPH-g, and TOG. TPH-g and TPH-d are complex mixtures of petroleum-derived hydrocarbons with 4 to 11 carbon atoms and 9 to 22 carbon atoms, respectively, in their molecular structures (Millner et al., 1992).

When TPH-g or TPH-d enters the soil, changes in its composition, referred to as "weathering", begin immediately. Volatilization of the lighter compounds occurs at a higher rate than heavier compounds, resulting in a shift in the composition of the weathered gasoline toward heavier compounds. The solubilities of the heavier hydrocarbons generally are lower and the

adsorption characteristics are stronger than those of the lighter fuel compounds. Therefore, these heavier compounds tend to remain adsorbed to soil organic matter for longer periods of time, while the more soluble components partition into soil moisture more quickly and/or more completely. Rates of biotransformation also are different; short-chain alkanes generally are biodegraded more readily than aromatics, cycloalkanes, and heavier alkanes (USEPA, 1989b). The net result of these weathering processes with respect to the TPH analytical data is that the TPH concentrations reported will reflect a greater proportion of the heavier TPH components than fresh TPH. These heavier components are comprised largely of cycloalkanes and straight- and branched-chain alkanes (Andrews and Snyder, 1991).

For the purposes of this report, the fate and transport characteristics of TPH-g will at times be compared to those of n-hexane, although n-hexane, a comparatively toxic, short-chained hydrocarbon, only reportedly comprises 0.24 percent to 3.5 percent by weight of fresh gasoline (California LUFT Task Force, 1989). Using n-hexane as a surrogate compound to describe the fate and transport behavior of weathered gasoline in soil represents a conservative approach, because n-hexane is as soluble and volatile, if not more soluble and volatile, than most of the heavier hydrocarbons. It has been shown that the toxicity and mobility of hydrocarbons generally decreases as the chain length increases (Rumack and Lovejoy, 1991). Therefore, n-hexane, a 6-carbon chain hydrocarbon, is expected to be the most toxic and most mobile component of the represented TPH-g mixture.

The fate and transport characteristics of TPH-d will be compared to those of naphthalene which comprises 0.13 percent by weight of fresh diesel (California LUFT Task Force, 1989). Naphthalene is one of the more mobile constituents found in diesel fuel. Therefore, using naphthalene as a surrogate for TPH-d will predict as great or greater mobility of TPH-d than is likely to occur at the site. Thus, naphthalene represents a conservative surrogate for the TPH-d mixture.

TOG may be comprised of a very wide range of hydrocarbon components. The major constituents of TOG that may be present are unknown, therefore, there are no readily available

surrogates for the evaluation of fate, transport or toxicity of TOG. Samples that were analyzed for TOG were also analyzed for BTEX and TPH. TOG is generally used as a potential indicator of impacted soil, and because soil impacts were characterized as BTEX, TPH-g, or TPH-d, TOG was not considered to be a COC for the risk assessment. COC for the site are BTEX, TPH-g evaluated as n-hexane, and TPH-d evaluated as naphthalene.

# 3.0 TOXICITY ASSESSMENT

The risks associated with exposure to constituents detected at the site are a function of the inherent toxicity of the constituents and the exposure dose. There are two general categories of toxic effects evaluated in risk assessments: non-carcinogenic or systemic toxicant health effects and carcinogenic risk. The chemical-specific toxicity values used to evaluate potential non-carcinogenic and carcinogenic effects are determined from available federal databases and from State guidance. Toxicity values for noncarcinogenic effects were first obtained from the USEPA's Integrated Risk Information System (IRIS) (1994), and if not available on IRIS, from USEPA's Health Effects Assessment Summary Tables (HEAST) (USEPA, 1994), in accordance with USEPA guidance (1989a). Toxicity values for carcinogenic effects were obtained from the list of cancer potency factors (CPFs) compiled by the Standards and Criteria Work Group of Cal/EPA (1992). Additional toxicity information regarding potential tumor sites and USEPA cancer classification was obtained from IRIS (1994) and HEAST (USEPA, 1994). A further discussion of the basis for, and nature of, toxicity values used to assess potential risk posed by site-related COC is presented in Appendix A.

## 3.1 NON-CARCINOGENIC EFFECTS

Toxicity values for non-carcinogenic effects are presented as chronic reference doses (RfDs) and subchronic RfDs for oral, dermal and inhalation exposure routes. Chronic RfDs are used to assess exposures greater than seven years duration, subchronic RfDs are used for exposures ranging from two weeks to seven years. The toxicity values for non-carcinogenic effects for COC addressed in this risk assessment are presented in Table 1. Chronic RfDs were used to evaluate potential residential exposure because residents are assumed to be present at the site over a period of time greater than 7 years. Subchronic RfDs were used to evaluate potential excavation worker exposure because excavation workers are assumed to be present at the site for a short period of time. Where toxicity values for the inhalation route were not available for a particular constituent, the toxicity value for the oral route was used to evaluate toxicity via inhalation in compliance with California guidance (Cal/EPA, 1994).

## 3.2 CARCINOGENIC EFFECTS

Toxicity values used for evaluation of carcinogenic risk are cancer potency factors (CPFs) developed for oral and inhalation exposure routes. The toxicity values for carcinogenic risk via ingestion and inhalation used for this risk assessment are presented in Table 2. Neither USEPA nor Cal/EPA develop toxicity values specific to dermal exposure, thus, per USEPA guidance, toxicity values for dermal contact (RfDs and CPFs adjusted) were derived from those toxicity values based on oral exposure routes using the constituent-specific oral absorption efficiencies presented in Table 3.

# 4.0 EXPOSURE ASSESSMENT

This section provides information on the potential for constituent migration and describes the potential human exposure pathways at the site under a hypothetical future residential scenario. Exposure is defined as the actual contact of an organism with a chemical or physical agent (USEPA, 1989a). Exposure is characterized by estimating the type and magnitude of exposures to COC that are present at or migrating from a site. The potential for exposure is evaluated by estimating the way an individual or population may come into contact with constituents originating at a site. Typically this involves projecting concentrations along hypothetical or probable pathways between sources and receptors. The projection usually is accomplished using site-specific data and, when necessary, mathematical modeling. The assessment of exposure includes characterization of the physical environment, identification of exposure pathways (including migration pathways, exposure points, and exposure routes), identification of potentially exposed individuals and populations, and quantification of exposure as an average daily dose, where possible. For this site, because the results of the risk assessment will determine the necessity for further remedial action, once exposure pathways were identified as potentially complete, HBGs protective of those specific receptors were developed. Comparison of reported soil concentrations to the HBGs will identify if further remediation may be required. The following sections describe potential migration pathways and exposure pathways at the site, and identify those exposure pathways that may be complete.

## 4.1 PHYSICAL AND CHEMICAL PROPERTIES INFLUENCING CONSTITUENT MIGRATION

The environmental fate and transport of constituents are dependent on the physical and chemical properties of those constituents, the environmental transformation processes affecting them, and the media through which the constituents are migrating. The primary physical and chemical properties of the constituents that may influence the potential for migration of the COC in groundwater, saturated soil, and the vadose zone are presented in Table 4. A discussion of the key properties of water solubility, specific gravity, volatility, organic-carbon partition

coefficient ($K_{OC}$), soil distribution coefficient ($K_d$), octanol-water partition coefficient ($K_{ow}$), bioconcentration factors (BCFs), and half lives, and the effect of these properties on the migration potential of the COC, is provided in Appendix B.

## 4.2 MECHANISMS OF MIGRATION

COC were detected in subsurface soils at the site. Soil containing residual levels of COC can act as a source of constituents to other environmental media. This section discusses the mechanisms by which migration to other media may occur at the site.

Migration of COC into the air from soil can occur via volatilization, the mass transfer of an organic compound from a specific medium (i.e., water) to the air. Vapors can diffuse from constituents in soil and migrate upwards through soil to the land surface. The ability for this transfer or migration to occur will depend on other competing processes which could hinder this migration. For example, if a constituent is highly soluble and dissolved in water, or strongly sorbed to soil; it will be less likely to volatilize into the air even though it may also have a high vapor pressure. Environmental factors that affect constituent volatilization and transport through soil include the soil temperature, porosity, water content, and the depth to impacted soil (Jury et al., 1983).

Generally, organic constituents with high vapor pressures (greater than 10 mm Hg) or high Henry's Law Constants (greater than $10^{-3}$ atm-$m^3$/mol) and molecular weights less than 200 g/mol are expected to volatilize readily from soil and water. BTEX and n-hexane have Henry's Law Constants greater than $10^{-3}$, with the highest value being 0.77 atm-$m^3$/mol for n-hexane (the surrogate compound used to represent TPH-g). Using this high Henry's Law Constant to assess the volatilization potential of TPH-g is conservative since the TPH-g petroleum mixture at this site is believed to be weathered and composed of mostly heavier, much less volatile compounds.

Vapors that may migrate upward through the soil diffuse into ambient air when they reach the surface. These vapors that may be released into the ambient air are subject to

dispersion by prevailing winds and diffusion into the atmosphere. Vapors originating from subsurface soil can, however, enter on-site buildings through cracks in building foundations. These vapors are subject to limited dispersion and diffusion forces and may accumulate in indoor air. Because hypothetical residential buildings may be built over impacted soil, the potential exists for vapors to migrate up through the subsurface and intrude into the overlying buildings.

The migration of volatile constituents from subsurface soil to indoor air may be predicted mathematically. A description of the vapor intrusion model used to predict COC migration to indoor air is provided in Appendix C. Site-specific environmental factors accounted for in the model include moisture content of soil, bulk density of soil, total soil porosity, and depth to impacted soil beneath the building. Site-specific values for these parameters were obtained from previous investigations at the site and from judgment based on known site conditions, such as soil type.

There are two processes by which COC in surface soil may migrate into outdoor air. Organic constituents may volatilize and migrate into the air. Constituents adsorbed to surface soil may migrate into the air through the generation of dust either through wind erosion in unpaved areas or mechanical means. Constituents released into the atmosphere are subject to transport and dispersion by prevailing winds.

The potential for fugitive dust generation at the site is considered low because the impacted soil is found at depth. However, during potential future construction at the site, dust may be generated by construction and earth-moving equipment. In addition, impacted subsurface soils may be moved to the land surface. Following construction, the majority of the site will likely again be covered by buildings, pavement, or landscaping, thereby reducing the probability of fugitive dust generation.

As discussed above, fugitive dust emissions may occur from wind or vehicle operations during invasive activities conducted at the site. Constituents with relatively low organic carbon partition coefficients ($K_{oc}$ values less than 1,000) and moderate to high water solubility (greater

than 1 mg/L) are more likely to be associated with the water or vapor phases than to remain in soil and therefore are unlikely to be present in emitted dust. BTEX and n-hexane fall into this category; therefore, these constituents are not expected to be emitted in fugitive dust. Naphthalene, used as a surrogate to represent TPH-d, is expected to adsorb to soil and migrate with dust, rather than in vapor form.

## 4.3 EXPOSURE PATHWAYS

Whether a constituent is actually of concern to human health depends on the likelihood of exposure, i.e., whether a complete exposure pathway exists. This section addresses the potential for reasonable maximum exposure (RME) to COC detected in soil under hypothetical future land use. The RME is defined as the highest exposure that is reasonably expected to occur at a site (USEPA, 1989a).

### 4.3.1 Conceptual Site Model

An exposure pathway is defined by four elements: (1) a source and mechanism of constituent release to the environment; (2) an environmental transport medium for the released constituent; (3) a point of potential contact by the receptor with the impacted medium (the exposure point); and (4) an exposure route to the receptor at the exposure point. The objective of the exposure assessment is to estimate the types and magnitudes of exposure to the COC, known through sampling to occur in soil, that are present at or migrating from the facility. Without exposure there is no risk. Thus, the exposure assessment is a key element of the risk assessment.

The conceptual site model is based on a conservative residential land use scenario. The evaluation of a residential scenario is conservative because current land use for the site is commercial. In addition, a residential exposure scenario is expected to provide the most conservative (health-protective) HBGs for the site, based upon potential exposure duration (i.e.,

30 years for adult resident), the presence of sensitive receptors (i.e., children), and greater number of potential pathways of exposure to COC in soil (i.e., direct contact with soil).

The current source of COC in the environment is impacted subsurface soil at 5 foot depth and below. Surface soil at the site was not sampled, but is not expected to have been impacted due to the nature of the primary release mechanisms which were leaks originating from underground storage tanks and associated piping. Small surface spills that may have occurred at the site during normal operations are not expected to have adversely impacted underlaying soils due to the presence of asphalt and concrete paving. For the hypothetical future residential scenario, it was assumed that subsurface soils would be moved to the land surface as part of residential development. This assumption is conservative, given that most residential development involves removal or grading of only the top two feet of soil. The conceptual site model, however, is based upon the assumption that COC are present in surface soil. Potential exposure points therefore include surface soil, indoor air impacted by volatilization of COC from surface and subsurface soil, and outdoor air impacted by volatilization of COC and emission of fugitive dust from surface soil.

Possible exposure pathways for residential land use at the site include direct contact of human receptors with impacted soil outdoors and inhalation of indoor vapors originating from impacted subsurface soil. For each of the possible exposure pathways, a point of potential contact between the receptor and the impacted medium must be determined for the pathway to be considered complete.

It was assumed that impacted subsurface soils would be brought to the land surface during development, and that the resulting impacted surface soil would remain uncovered by vegetation or pavement. This scenario, although unlikely to occur, would result in potential exposure of residents to impacted soil by direct contact. Exposure of residents to COC by direct contact with impacted surface soil may occur via ingestion and dermal contact. Residents may also be exposed via inhalation to volatile COC as vapors and non-volatile COC absorbed to fugitive dust in ambient outdoor air. Indoor exposure of residents via inhalation to volatile COC

originating from subsurface soil may occur if vapors intrude into buildings overlying the impacted area.

If development of the site for residential land use occurs in the near future, then construction workers may also be exposed to COC in subsurface soils. Excavation workers may be exposed to COC by direct contact with impacted subsurface soils via incidental ingestion and dermal contact. Excavation workers may also be exposed via inhalation to volatile COC as vapors and to non-volatile COC adsorbed to fugitive dust.

In summary, potentially complete exposure pathways to soil for the residential land use scenario are as follows:

- Exposure of adult and child residents via inhalation to volatile COC originating from subsurface soil and intruding into overlying buildings.

- Exposure of adult and child residents via incidental ingestion, dermal contact, and inhalation to COC in surface soil.

- Exposure of excavation workers via incidental ingestion, dermal contact, and inhalation to COC in surface and subsurface soil.

### 4.3.2 Human Receptors

Human receptors were identified for a residential land use scenario. Hypothetical residential receptors to the indoor air pathway include both adults and children that may occupy the future residential buildings at the site. Residents were assumed to be present in the residence for 350 days per year and 24 hours per day. Adult residents were assumed to be present at the residence for 30 years and child residents for 6 years. The estimates of RME residential exposure duration were derived from USEPA (1989a) and Cal/EPA (1994) guidance. Other

default exposure parameters for residential exposure were obtained from USEPA (1989a, 1991b) and Cal/EPA guidance (1994).

Hypothetical residents, both adults and children, were also assumed to be potentially exposed to impacted soil via direct contact. Residents were assumed to be present on-site and outdoors for 350 days per year and 16 hours per day. Other default exposure parameters for residential exposure were obtained from USEPA (1989a, 1991b) and Cal/EPA guidance (1994).

Development is expected to occur in the near future at the site, and excavation workers were assumed to be potentially exposed to COC in soils. Workers were assumed to be in direct contact with impacted surface and subsurface soils and outdoor air. Excavation workers were assumed to be at the site for 8 hours/day, 5 days/week, for 12 weeks. Default exposure parameters for evaluation the excavation worker exposure were obtained from USEPA (1990, 1991b) guidance.

### 4.3.3 Environmental Receptors

Exposure of environmental receptors to site-related constituents is not likely to occur for several reasons. The site was 99 percent paved until recently, precluding exposure to soil (PHR, 1991). The commercial nature of the site operations is not conducive to developing or supporting a complex ecosystem. In addition, impacted soil is located at depths that even burrowing animals will not come in contact with under reasonable conditions. As a result, the potential for terrestrial wildlife to be exposed to the COC present in subsurface soils is severely limited or eliminated.

# 5.0 RISK CHARACTERIZATION

Information from the toxicity assessment and characterization of exposure are combined to generate quantitative HBGs. This section discusses the mathematical equations and exposure parameters used to calculate the soil HBGs.

## 5.1 DERIVATION OF HEALTH-BASED GOALS (HBGs)

HBGs were calculated for soil based on hypothetical exposure of receptors under site-specific exposure conditions. Equations presented in USEPA (1991b) guidance for development of preliminary remediation goals were adapted for use here to calculate health-protective medium-specific goals for soil. These goals, protective of the identified receptors, will be used to determine if further remedial action is necessary and to focus any additional remedial action at the site. A residential RME scenario was evaluated for future land use. Potential future receptors evaluated for exposure to COC originating in soil were adult and child residents and excavation workers.

To calculate HBGs, acceptable risk levels must be targeted. Following USEPA (1991) guidance, the "target" cancer risk for each potential carcinogen was conservatively set at $1 \times 10^{-6}$. USEPA has indicated that cumulative risk in the range of $10^{-6}$ to $10^{-4}$ may indicate the need for risk management. Cumulative risk of greater than $10^{-4}$ indicates a need for further investigation or remedial action (Federal Register, March 8, 1990). The "target" hazard quotient (HQ) for non-cancer risk for constituents with different critical effects was set at 1. However, ethylbenzene and toluene both exert effects on the liver and kidney (Table 1), so the target HQ were set at 0.5, for a cumulative hazard index (HI) of 1.

The following sections present the HBG calculations and the resulting constituent-specific HBGs.

### 5.1.1 HBG for Soil Based on Vapor Intrusion

It was assumed that receptors could hypothetically be exposed to vapors diffusing from the soil, migrating upwards, and entering on-site air spaces where the potential exists for the accumulation and inhalation of vapors. A vapor intrusion model was used to calculate soil HBGs for COC. The vapor intrusion model, developed by Daugherty (1991), was modified through the use of site-specific assumptions to more accurately represent site-specific exposure conditions. A discussion of the development of the vapor infiltration model is presented in Appendix C.

The result of the Daugherty (1991) volatilization and vapor diffusion model is a constituent-specific indoor air concentration potentially resulting from soil. This air concentration then can be used in exposure calculations to estimate the potential exposure for hypothetical occupants of the modeled building and subsequently to develop HBGs. Equations and model parameters used to calculate indoor air concentrations from target risk levels are presented in Table 5. Equations and model exposure parameters used to calculate soil HBGs from indoor air concentrations are presented in Table 6. A sample calculation is presented in each table to illustrate the application of the equations. Site-specific information was used whenever possible in place of default assumptions.

Site-specific values used in the model included an assumed residence of 2,000 square feet, with a volume of 454 cubic meters, and environmental factors (i.e., depth to impacted soil). For site-specific parameters for which values were uncertain, such as soil bulk density, conservative estimates were developed using information collected in previous investigations. Building air exchange rates and infiltration rates were estimated based on default values for standard residential buildings. Constituent- and receptor-specific HBGs calculated for COC at the site are presented in Tables 7 and 8 for adult and child residents, respectively.

The HBG for xylenes that is protective of an adult resident is 3,500,000 mg/kg. This value is greater than a million ($10^6$) ppm and, therefore, is not itself a valid concentration goal.

The calculation of a HBG greater than concentrations that are physically possible or probable in soil arises from low toxicity of the constituent and factors governing potential constituent migration. The calculated HBG for xylenes that exceeds a million ppm indicates that concentrations of xylenes below saturation in soil at the site are health-protective.

The HBG for benzene that is protective of human health at a target excess lifetime cancer risk (ELCR) level of $1 \times 10^{-6}$, assuming inhalation of vapors from subsurface soil that intrude into overlying residential buildings in a RME scenario, is 3.2 milligrams per kilogram (mg/kg) in soil based on adult resident exposure. HBGs for systemic toxicants that are protective of child residents are more restrictive than those protective of adult residents. The minimum HBGs for ethylbenzene, toluene, and xylenes in soil are 8,900; 2,800; and 760,000 mg/kg, respectively, based on hypothetical child resident exposure to indoor air. HBGs for TPH-g and TPH-d (using n-hexane and naphthalene as surrogates) are 180 and 3,600 mg/kg (Table 8).

### 5.1.2 HBG for Soil Based on Residential Direct Contact

Equations and exposure parameters used to calculate HBGs protective of outdoor residential exposure are presented in Table 9. A sample calculation is presented in the same table to illustrate the application of the equations. Site-specific information was used whenever possible in place of default assumptions. Receptor-specific default exposure factors, such as skin surface area and body weight were obtained from USEPA (1989a, 1991b) and Cal/EPA (1994) guidance. Soil HBGs, based upon target concentrations of COC at the point of exposure, were calculated based upon physical and chemical parameters derived from USEPA (1990).

There are three potential exposure routes for each residential receptor: inhalation, incidental ingestion, and dermal contact. A HBG for each potential exposure route was calculated for cancer effects and for non-cancer effects. One HBG for cancer effects and one HBG for non-cancer effects were then calculated for each constituent by combining HBGs for the exposure routes (Table 9). The cancer effects HBG and non-cancer effects HBG as indicated in Tables 9, 10 and 11 for adult and child residents, respectively; therefore, take into account

exposure across multiple routes. The lower of the HBGs for cancer and non-cancer effects is considered to be the constituent-specific and receptor-specific soil HBG for the residential direct contact scenario.

The minimum HBG for benzene, protective of child health at a target ELCR level of 1 x $10^{-6}$, assuming direct contact with impacted surface soil in a RME scenario, is 0.43 mg/kg. The minimum HBGs for ethylbenzene, toluene, and xylenes, in soil are 500; 280; and 19,000 mg/kg, respectively, based on hypothetical child resident exposure. Minimum HBGs for TPH-g and TPH-d based upon the use of toxicity surrogates, are 68 and 30 mg/kg, respectively, for protection of child residents exposed to impacted surface soil via direct contact.

### 5.1.3 HBG for Soil Based on Excavation Direct Contact

Equations and exposure parameters used to calculate HBGs protective of hypothetical excavation worker exposure are presented in Tables 12 and 13 for non-carcinogenic and carcinogenic effects, respectively. Sample calculations are presented in the same tables to illustrate the application of the equations. Site-specific information was used whenever possible in place of default assumptions. Receptor-specific default exposure factors, such as skin surface area and body weight were obtained from USEPA (1990) guidance. Soil HBGs, based upon target concentrations of COC at the point of exposure, were calculated based upon physical and chemical parameters derived from USEPA (1990).

The cancer effects HBG and non-cancer effects HBG indicated in Tables 14 and 15 take into account exposure across multiple exposure routes. The lower of the HBGs for cancer and non-cancer effects is considered to be the constituent-specific and receptor-specific soil HBG protective of health under the excavation worker scenario.

The minimum HBG for benzene that is protective of excavation worker health at a target ELCR level of 1 x $10^{-6}$, assuming direct contact with impacted surface soil in a RME scenario, is 1 mg/kg (Table 15). The minimum HBGs for ethylbenzene, toluene, and xylenes in soil are

640; 680; and 310,000 mg/kg, respectively, based on hypothetical excavation worker exposure. Minimum HBGs for TPH-g and TPH-d, using toxicity surrogates, are 58 and 1,900 mg/kg, respectively, for protection of excavation workers directly exposed to impacted soil.

## 5.2 COMPARISON TO CURRENT MEDIA CONCENTRATIONS

The constituent-specific and receptor-specific HBGs may be compared to maximum detected soil concentrations to support a determination that no further remedial action is required. The maximum detected concentrations were obtained from soil samples collected in a judgmental manner (e.g., skewed toward impacted areas), thus, they cannot be considered representative of exposure point concentrations, and instead constitute conservative estimates of exposure point concentrations. Because they are conservative estimates in this case (areas of maximum expected impact were selectively sampled), maximum detected concentrations are appropriate to support the determination that further remediation is unnecessary based upon health concerns.

Site-related concentrations of COC in soil that exceed HBGs based upon RME scenarios and a target ELCR of $1 \times 10^{-6}$ may indicate the need for further investigation, remedial action, or risk management activity if exposure under the identified scenario actually occurs. Site-related concentrations of COC in soil that are less than HBGs based upon RME and a target ELCR of $1 \times 10^{-6}$ or HI of 1 indicate that the site-related concentrations are health-protective under the hypothetical future land use scenario.

Soil HBGs for protection of adult and child resident exposure via inhalation of vapors accumulated in indoor air are presented in Tables 7 and 8, respectively. Soil HBGs protective of adult and child resident RME, via incidental ingestion, dermal contact, and inhalation, to COC in surface soil are presented in Tables 10 and 11, respectively. Soil HBGs protective of excavation worker exposure, via incidental ingestion, dermal contact, and inhalation, to COC in soil are presented in Tables 14 and 15.

A summary of the minimum HBGs for each exposure scenario is presented in Table 16. In general, the child resident exposed to surface soil via direct contact is the critical and most sensitive receptor.

The maximum detected concentration of each constituent across the site is also presented in Table 16. These concentrations were detected in soil samples from depths of 15 to 20 feet bgs. For the purposes of this risk assessment, it was assumed that soils impacted at these concentrations would be brought to the land surface and made available for direct contact by hypothetical future residents. This scenario is unlikely to occur and represents a conservative outlook for the site. Additionally, the volatile organic compounds would not remain in soil at these concentrations for the prolonged exposure durations assumed, especially following exposure to air at land surface. Even given these conservative assumptions, the maximum detected soil concentrations remaining at the site do not exceed the most stringent HBGs for residents or excavation workers.

It should be noted that HBGs in general do not take into account additive/synergistic or antagonistic effects of chemical mixtures. Potential additive effects of toluene and ethylbenzene on the same target organs were addressed in this risk assessment by setting the target HQ for each constituent at 0.5. Recent sampling data indicate that benzene is the only carcinogen currently present in impacted soil; therefore, target ELCR values were not adjusted to address additivity of multiple carcinogens. Comparison of HBGs to individual constituent concentrations at this site is a valid approach to support a recommendation of no further action because of the limited number of COC at the site and the different target organs potentially affected by the COC.

## 6.0 UNCERTAINTIES

Uncertainty is inherent in the risk assessment process, and the potential sources of uncertainty are identified in this section. Each of the three basic building blocks for risk assessment (data evaluation, exposure assessment, and toxicity assessment) contribute uncertainties. Environmental sampling itself introduces uncertainty, largely because of the potential for uneven distribution of constituents in the environment.

Uncertainties in the risk assessment include selection of the exposed receptor population (hypothetical residents), and the assumptions used to calculate HBGs. Exposure scenarios were developed based on site-specific information supplemented by USEPA risk assessment guidance documents, and professional judgment. Although uncertainty is inherent in the exposure assessment, the exposure assumptions were chosen to err on the side of conservatism. The use of conservative exposure assumptions is believed to result in calculations of HBGs below which exposure will not result in adverse health effects.

The toxicity values and other toxicologic (health effects) information used in this report are associated with significant uncertainty. Toxicity values used by the USEPA and Cal/EPA are typically 10 to 10,000 times lower than the lowest concentration documented to produce adverse health effects. Many toxicity values are developed using results of studies in which laboratory animals are exposed to high doses, and the extrapolation to the low exposures for humans is difficult, producing uncertainty. Although species differences in absorption, distribution, metabolism, excretion, and target organ sensitivity are well documented, available data are usually insufficient to allow compensation for these differences. Most laboratory studies strictly control as many factors as possible, yet the human population is genetically diverse and affected by a variety of diets, occupations, pharmaceuticals, and other factors. When human epidemiologic data are available, a different set of uncertainties is present. For instance, exposure dose is seldom well characterized in epidemiologic studies.

Recent research on the mechanisms of carcinogenesis suggests that use of the linearized multistage model to develop CPFs may overestimate the cancer risks associated with exposure to low doses of chemicals. At high doses, many chemicals cause large-scale cell death which stimulates replacement by division. Dividing cells are more subject to mutations than quiescent (non-dividing) cells; thus, there is an increased potential for tumor formation. It is possible that administration of these same chemicals at lower doses would not increase cell division and thus would not increase mutations. This would suggest that the current methodology may overestimate cancer risk.

There is also uncertainty associated with the toxicity of mixtures. For the most part, data about the toxicity of chemical mixtures are unavailable. Rather, toxicity studies generally are performed using a single chemical. Chemicals present in a mixture can interact chemically to yield a new chemical or one can interfere with the absorption, distribution, metabolism, or excretion of another. Chemicals also may act by the same mechanism at the same target organ or can act completely independently. It was assumed that the mixture of constituents present at the site results in neither synergistic nor antagonistic interactions.

As described previously, the constituent composition of TPH varies (especially with weathering) and information in the literature is not always well defined. The TPH at the site is weathered, and is thus expected to be less volatile and less mobile than n-hexane and naphthalene (surrogates used to evaluate fate, transport, and toxicity of TPH-g and TPH-d, respectively). The assumption that n-hexane and naphthalene represent weathered TPH introduces additional uncertainty into the risk assessment.

The vapor intrusion modeling used to calculate the soil HBGs includes parameters for which values must be assumed when site-specific data are not available. While the parameter values for which site-specific data were not available were intentionally chosen to err on the side of conservatism, these assumptions contribute some uncertainty to the results of the vapor intrusion modeling.

The use of upperbound assumptions, focus on a RME scenario, no attenuation in constituent concentrations over the assumed exposure period, and the conservatism built into the RfDs and CPFs are believed to result in an overestimate of human health risk. Therefore, concentrations of COC that are greater than the HBGs estimated in this report may still be health-protective under site-specific conditions.

## 7.0 FINDINGS AND CONCLUSIONS

The health risk assessment was prepared to develop HBGs for soil for exposures and conditions unique to this site. For purposes of assessing potential exposures, it was assumed that the site would be redeveloped as a residential property.

The presence of impacted subsurface soils at the site indicate that it is possible that COC could volatilize and migrate into hypothetical future residential buildings. Exposure of adult and child residents via inhalation to vapors originating from subsurface soil and accumulating in overlying buildings is considered to be a complete exposure pathway for future land use. Direct exposure to COC in soil by adult and child residents via incidental ingestion, inhalation of vapors and dust, and dermal contact was also assumed to be a potentially complete future exposure pathway. Excavation workers could also come into direct contact with impacted soil during redevelopment activities.

HBGs were developed for BTEX, TPH-g, and TPH-d that would be protective of adult and child residents and excavation workers under hypothetical future conditions and the three assumed exposure scenarios. These concentration goals were based on a target ELCR of 1 x $10^{-6}$ (for potential carcinogens) or a target HQ of 1 (for noncancer effects potentially associated with benzene and xylenes) or 0.5 (for noncancer effects potentially associated with ethylbenzene and toluene).

The constituent-specific and media-specific HBGs presented in this report were compared to maximum detected soil concentrations that reflect current conditions (Table 16). Comparison of HBGs to individual constituent concentrations at this site indicate that maximum detected soil concentrations at the site are health-protective assuming exposure under the hypothetical exposure scenarios. Therefore, future remediation or control measures are not necessary to protect human health. The data, as presented herein, indicate that current site conditions would support residential land use and that closure of this site should be granted.

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# TABLES

Table 1 Reference Doses, Target Sites, and Confidence Levels for Constituents of Concern, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | | RfDo (mg/kg/day) Subchronic | RfDo (mg/kg/day) Chronic | RfDi (mg/kg/day) Subchronic | | RfDi (mg/kg/day) Chronic | | Target Sites Oral | Target Sites Inhalation | Confidence Level/ Uncertainty Factor |
|---|---|---|---|---|---|---|---|---|---|---|
| VOCs | | | | | | | | | | |
| Benzene | | NA | NA | NA | | 1.4E-04 | | NA | hematological | medium/100 |
| Ethylbenzene | | 1.0E-01 | 1.0E-01 | 2.9E-01 | | 2.9E-01 | | liver, kidney | developmental | low/1000 |
| Toluene | | 2.0E+00 | 2.0E-01 | 2.9E-01 | | 1.1E-01 | | liver, kidney | CNS | medium/1000 |
| Xylenes | | 4.0E+00 | 2.0E+00 | 4.0E+00 | * | 2.0E+00 | * | hyperactivity | NA | medium/100 |
| Semi-VOCs | | | | | | | | | | |
| n-Hexane | [a] | 6.0E-01 | 6.0E-02 | 5.7E-02 | | 5.7E-02 | | CNS, testicles | CNS | medium/300 |
| Naphthalene | [b] | 4.0E-02 | 4.0E-02 | 4.0E-02 | * | 3.7E-04 | | GI system, anemia | nasal effects | low/1000 |

* Cross-route extrapolation from oral to inhalation route (Cal/EPA, 1994).

[a] n-Hexane used as a surrogate for TPH as gasoline.

[b] Naphthalene used as a surrogate for TPH as diesel.

References. IRIS, 1994, USEPA, 1994; USEPA, provisional values for: naphthalene RfDi; subchronic RfDo for ethylbenzene; RfDi for benzene).

CNS Central nervous system

GI Gastrointestinal

mg/kg/day Milligrams per kilogram per day.

NA Not available

RfDi Inhalation reference dose.

RfDo Oral reference dose

Semi-VOCs Semi-volatile organic compounds.

VOCs Volatile organic compounds.

Table 2 Cancer Potency Factors, Tumor Sites, and USEPA Cancer Classifications for Constituents of Concern, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | Oral CPF (kg-day/mg) | Inhalation CPF (kg-day/mg) | Tumor site | | USEPA Classification |
|---|---|---|---|---|---|
| | | | Oral | Inhalation | |
| VOC | | | | | |
| Benzene | 1.0E-01 | 1.0E-01 | leukemia | leukemia | A |

References Cal/EPA, 1992, IRIS, 1994; USEPA,1994.

CPF Cancer potency factor.
kg-day/mg Kilograms-day per milligram.
VOC Volatile organic compound.

Table 3 Adjusted Toxicity Values Used to Assess Dermal Exposure for Constituents of Concern, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | RfDo (mg/kg/day) Subchronic | RfDo (mg/kg/day) Chronic | CPFo (kg-day/mg) | Oral Absorption Efficiency [a] | Dermal Absorption Efficiency [b] | PC (cm/hour) | RfDa (mg/kg/day) Subchronic | RfDa (mg/kg/day) Chronic | CPFa (kg-day/mg) |
|---|---|---|---|---|---|---|---|---|---|
| VOCs | | | | | | | | | |
| Benzene | NA | NA | 1.0E-01 | 1.00 | 0.25 | 1.00E-01 | NA | NA | 1.0E-01 |
| Ethylbenzene | 1.0E-01 | 1.0E-01 | NC | 1.00 | 0.25 | 1.20E+00 | 1.0E-01 | 1.0E-01 | NC |
| Toluene | 2.0E+00 | 2.0E-01 | NC | 1.00 | 0.25 | 1.00E+00 | 2.0E+00 | 2.0E-01 | NC |
| Xylenes | 4.0E+00 | 2.0E+00 | NC | 1.00 | 0.25 | 8.00E-02 | 4.0E+00 | 2.0E+00 | NC |
| Semi-VOCs | | | | | | | | | |
| n-Hexane | 6.0E-01 | 6.0E-02 | NC | 1.00 | 0.10 | 5.30E-02 | 6.0E-01 | 6.0E-02 | NC |
| Naphthalene | 4.0E-02 | 4.0E-02 | NC | 0.85 | 0.03 [c] | 6.90E-02 | 3.4E-02 | 3.4E-02 | NC |

CPF Cancer potency factor.
mg/kg/day Milligrams per kilogram per day.
NA Not available
NC Not evaluated as a carcinogen.
PC Permeability constant.
RfD Reference dose.
Semi-VOCs Semi-volatile organic compounds.
VOCs Volatile organic compounds.

[a] RfDoral and CPForal are divided by the constituent-specific oral absorption efficency to derive an adjusted RfD and CPF to assess dermal exposure.
[b] Ryan, et al, 1987.
[c] ATSDR (1990) profile for Benzo(a)pyrene.

Table 4 Physical and Chemical Properties of Organic Constituents of Concern, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | Molecular Weight (g/mol) | Water Solubility (mg/L 25 °C) | Specific Gravity | Vapor Pressure (mm Hg 25 °C) | Henry's Law Constant (atm-m³/mol) (25 °C) | Diffusivity (cm²/sec) | Koc (mL/g) | Log Kow | Groundwater T ½ Low (days) | Groundwater T ½ High (days) | Soil T ½ Low (days) | Soil T ½ High (days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VOCs | | | | | | | | | | | | |
| Benzene | 78 | 1,780 | 0.88 | 9.5E+01 | 5.48E-03 | 0.09320 | 49 - 100 | 1.56 - 2.15 | 10 - | 720 | 5 - | 16 |
| Ethylbenzene | 106 | 152 - 208 | 0.87 | 9.5E+00 | 8.68E-03 | 0.06667 | 95 - 260 | 3.05 - 3.15 | 6 - | 228 | 3 - | 10 |
| Toluene | 92 | 490 - 627 | 0.87 | 2.8E+01 | 6.74E-03 | 0.07828 | 115 - 150 | 2.11 - 2.80 | 7 - | 28 | 4 - | 22 |
| Xylenes (mixed) | 106 | 162 - 200 | 0.87 | 6.6E+00 - 8.8E+00 | 6.30E-03 | 0.07164 | 128 - 1,580 | 2.77 - 3.20 | 14 - | 360 | 7 - | 28 |
| TPH | | | | | | | | | | | | |
| n-Hexane [a] | 86 | 18 (20 °C) | 0.66 | 1.20E+02 (20 °C) | 7.70E-01 | 0.07461 | 890 | 2.77 | ND | | ND | |
| Naphthalene [b] | 128 | 30 - 34 | 1.16 | 2.3E-01 - 8.7E-01 | 4.60E-04 | 0.08205 | 550 - 3,160 | 3.2 - 4.7 | 1 - | 258 | 16.6 - | 48 |

References: Howard et al., 1991, Howard, 1990 and 1989; Lugg, 1968; Mackay and Shiu, 1981; Montgomery and Welkom, 1990; Research Triangle Institute (RTI), 1987; Shen, 1982, USEPA, 1992; and Verschueren, 1983.

[a] n-Hexane used as a surrogate for TPH as gasoline.

[b] Naphthalene used as a surrogate for TPH as diesel.

atm-m³/mol Atmospheres cubic meters per mole.
BCF Bioconcentration factor.
°C Degrees Celsius
cm²/sec Square centimeters per second.
g/mol Grams per mole
Koc Organic carbon partition coefficient.
Kow Octanol water partition coefficient.
L/kg Liters per kilogram.
mg/L Milligrams per liter.
mL/g Milliliters per gram.
mm Hg Millimeters of mercury.
ND No data.
T ½ Half-life.
TPH Total petroleum hydrocarbons.
VOCs Volatile organic compounds.

Table 5 Equations for Calculation of Indoor Air Concentration for the Daugherty Vapor Intrusion Model, Former Unocal Service Station Facility #2512, San Leandro, California.

For Carcinogenic Effects:

$$C_I\ (mg/m^3) = \frac{TCR \times BW \times AP}{CPFi \times BR \times EF \times ED \times ET}$$

For Non-Carcinogenic Effects:

$$C_I\ (mg/m^3) = \frac{THI \times BW \times AP}{(1/RfDi) \times BR \times EF \times ED \times ET}$$

where:

| | |
|---|---|
| AP | Averaging period (25,550 days [70 yrs × 365 days/yr] for cancer effects; ED [yrs] × 365 days/yr for non-cancer effects). |
| BR | Breathing rate (0.6 m³/hour for reasonable maximum exposure [RME]). |
| BW | Body weight (70 kg for the adult and 15 kg for a child). |
| $C_I$ | Indoor air concentration (mg/m³). |
| CPFi | Cancer potency factor for inhalation (kg-day/mg). |
| ED | Exposure duration (30 years for adult RME and 6 years for a child). |
| EF | Exposure frequency (350 days/year for RME). |
| ET | Exposure time (24 hours/day at home for RME). |
| kg-day/mg | Kilogram-days per milligram. |
| mg/kg/day | Milligrams per kilogram per day. |
| RfDi | Inhalation reference dose (mg/kg/day). |
| TCR | Target carcinogenic risk (1.0E-06) for each constituent. |
| THI | Target hazard index (1) for those constituents without similar critical effects. |

Sample calculation appears on page 2.

Table 5 Equations for Calculation of Indoor Air Concentration for the Daugherty Vapor Intrusion Model, Former Unocal Service Station Facility #2512, San Leandro, California.

Sample calculation for benzene vapors from soil; cancer effects; adult RME:

$$C_I = \frac{1.0E\text{-}06 \times 70\ kg \times 25{,}550\ days}{1.0E\text{-}01\ kg\text{-}day/mg \times 0.60\ m^3/hour \times 350\ days/yr \times 30\ years \times 24\ hours/day} = 1.2E\text{-}04\ mg/m^3$$

Sample calculation for ethylbenzene vapors in soil; non-cancer effects; adult RME:
(THI = 0.5 because ethylbenzene and and toluene may affect the same target organ)

$$C_I = \frac{0.5 \times 70\ kg \times 10{,}950\ days}{(1/0.29\ mg/kg/day) \times 0.60\ m^3/hour \times 350\ days/yr \times 30\ years \times 24\ hours/day} = 7.4E\text{-}01\ mg/m^3$$

Reference Daugherty, 1991.

Table 6 Equations for Calculation of Vapor-Phase Flux and Health-Based Goal for Soil Using the Daugherty Vapor Intrusion Model, Former Unocal Service Station Facility #2512, San Leandro, California.

HBG (mg/kg) = Cpw x Koc x foc

where

$$Cpw\ (mg/L) = \frac{Csg}{UC1 \times Ho}$$

$$Csg\ (mg/cm^3) = \frac{F \times X}{De}$$

$$De\ (cm^2/sec) = \frac{Di \times (Pt - Pw)^{3.33}}{Pt^2}$$

$$F\ (mg/cm^2/sec) = \frac{Ci \times AER \times V}{A \times UC2 \times UC3}$$

where

| | |
|---|---|
| A | Area of infiltration (0.093 $m^2$) (area of apartment foundation [186 $m^2$ ] × infiltration ratio [0.0005]). |
| AER | Building air exchange rate (0.5 volumes per hour). |
| Ci | Indoor air concentration ($mg/m^3$) (see Table 5). |
| $cm^2/m^2$ | Square centimeters per square meter. |
| $cm^2/sec$ | Square centimeters per second. |
| Cpw | Concentration in soil pore water (mg/L). |
| Csg | Concentration in soil gas ($mg/cm^3$). |
| De | Effective diffusion coefficient ($cm^2/sec$). |
| Di | Diffusivity (constituent-specific) ($cm^2/sec$). |
| F | Flux ($mg/cm^2/sec$). |
| foc | Fraction of organic carbon (unitless) (assumed 0.02). |
| HBG | Health-based soil goal (mg/kg). |
| Ho | Unitless Henry's Law Constant (Henry's Law Constant [constituent-specific] /0.02404). (0.02404 is product of ideal gas constant [8.205E-06 atm-$m^3$/mol/K] and absolute temperature [293 K at 20° C] = atm-$m^3$/mol). |
| Koc | Organic carbon partition coefficient (L/kg); midpoint of range in Table 4 was used. |
| $L/cm^3$ | Liters per cubic centimeter. |
| $mg/cm^2/sec$ | Milligrams per square centimeter per second. |
| $mg/cm^3$ | Milligrams per cubic centimeter. |

Example calculation appears on page 2.

Table 6 Equations for Calculation of Vapor-Phase Flux and Health-Based Goal for Soil Using the Daugherty Vapor Intrusion Model, Former Unocal Service Station Facility #2512, San Leandro, California.

| | |
|---|---|
| mg/kg | Milligrams per kilogram. |
| mg/L | Milligrams per liter. |
| $mg/m^3$ | Milligrams per cubic meter. |
| Pt | Total soil porosity (0.35) (unitless) . |
| Pw | Water filled porosity, unitless (assumed 0.10). |
| sec | Second |
| UC1 | Unit conversion (0.001 $L/cm^3$). |
| UC2 | Unit conversion (10,000 $cm^2/m^2$). |
| UC3 | Unit conversion (3,600 sec/hour). |
| V | Volume of the residence (454 $m^3$) (area of foundation [186 $m^2$] x Hr [height of ceiling, 2.44 m]). |
| vph | Volumes per hour. |
| X | Depth to impacted soil (457 cm) (average depth of soil samples, 15 feet). |

Sample calculation of vapor-phase flux and health-based goal for benzene in soil based on carcinogenic effects; adult RME:

$$F\ (mg/cm^2/sec) = \frac{1.2E\text{-}04\ mg/m^3 \times 0.5\ vph \times 454\ m^3}{0.093\ m^2 \times 10{,}000\ cm^2/m^2 \times 3{,}600\ sec/hour} = 8.0E\text{-}09\ mg/cm^2/sec$$

$$De\ (cm^2/sec) = \frac{0.09320\ cm^2/sec \times (0.35 - 0.1)\text{^}3.33}{(0.35)^2} = 0.00752\ cm^2/sec$$

$$Csg\ (mg/cm^3) = \frac{8.0E\text{-}09\ mg/cm^2/sec \times 457\ cm}{0.00752\ cm^2/sec} = 4.9E\text{-}04\ mg/cm^3$$

$$Cpw\ (mg/L) = \frac{4.9E\text{-}04\ mg/cm^3}{0.001\ L/cm^3 \times 0.228} = 2.1\ mg/L$$

$$HBG\ (mg/kg) = 2.1\ mg/L \times 74.5\ L/kg \times 0.02 = 3.2\ mg/kg$$

Reference Daugherty, 1991.

Table 7 Soil Health-Based Goal Calculations Based on Vapor Intrusion for a Hypothetical Adult Resident, Reasonable Maximum Exposure, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | Cancer Effects | | | | Non-Cancer Effects | | | | Minimum HBG* (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|
| | Ci (mg/m³) | CPFi (kg-day/mg) | TCR | HBG (mg/kg) | Ci (mg/m³) | RfDi (mg/kg/day) | THQ | HBG (mg/kg) | |
| VOCs | | | | | | | | | |
| Benzene | 1.2E-04 | 1.0E-01 | 1E-06 | 3.2E+00 | 7.1E-04 | 1.4E-04 | 1 | 1.9E+01 | 3.2 |
| Ethylbenzene | NC | NC | NC | NC | 7.4E-01 | 2.9E-01 | 0.5 | 4.2E+04 | 42,000 |
| Toluene | NC | NC | NC | NC | 2.8E-01 | 1.1E-01 | 0.5 | 1.3E+04 | 13,000 |
| Xylenes | NC | NC | NC | NC | 1.0E+01 | 2.0E+00 | 1 | 3.5E+06 | 3,500,000 [c] |
| TPH | | | | | | | | | |
| n-Hexane [a] | NC | NC | NC | NC | 2.9E-01 | 5.7E-02 | 1 | 8.3E+02 | 830 |
| Naphthalene [b] | NC | NC | NC | NC | 1.9E-03 | 3.7E-04 | 1 | 1.7E+04 | 17,000 |

Goals developed using Daugherty (1991).

* The minimum of the HBGs calculated for cancer and non-cancer effects, rounded to 2 significant figures.

[a] n-Hexane used as a surrogate for TPH as gasoline.

[b] Naphthalene used as a surrogate for TPH as diesel.

[c] Value is greater than a million ($10^6$) parts per million (ppm), and therefore is not itself a valid concentration goal, but indicates that concentrations below saturation are health-protective.

Ci Indoor air concentration (mg/m³).
CPFi Cancer potency factor for inhalation (kg-day/mg).
HBG Health-based soil goal (mg/kg).
NC Not evaluated as a carcinogen.
RfDi Reference dose for inhalation exposure (mg/kg/day).
TCR Target cancer risk.
THQ Target hazard quotient.
TPH Total petroleum hydrocarbons.
VOCs Volatile organic compounds.

Table 8 Soil Health-Based Goal Calculations Based on Vapor Intrusion for a Hypothetical Child Resident, Reasonable Maximum Exposure, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | Cancer Effects Ci (mg/m³) | CPFi (kg-day/mg) | TCR | HBG (mg/kg) | Non-Cancer Effects Ci (mg/m³) | RfDi (mg/kg/day) | THQ | HBG (mg/kg) | Minimum HBG* (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|
| VOCs | | | | | | | | | |
| Benzene | 1.3E-04 | 1.0E-01 | 1E-06 | 3.4E+00 | 1.5E-04 | 1.4E-04 | 1 | 4.1E+00 | 3.4 |
| Ethylbenzene | NC | NC | NC | NC | 1.6E-01 | 2.9E-01 | 0.5 | 8.9E+03 | 8,900 |
| Toluene | NC | NC | NC | NC | 6.0E-02 | 1.1E-01 | 0.5 | 2.8E+03 | 2,800 |
| Xylenes | NC | NC | NC | NC | 2.2E+00 | 2.0E+00 | 1 | 7.6E+05 | 760,000 |
| TPH | | | | | | | | | |
| n-Hexane [a] | NC | NC | NC | NC | 6.2E-02 | 5.7E-02 | 1 | 1.8E+02 | 180 |
| Naphthalene [b] | NC | NC | NC | NC | 4.0E-04 | 3.7E-04 | 1 | 3.6E+03 | 3,600 |

Goals developed using Daugherty (1991).

* The minimum of the HBGs calculated for cancer and non-cancer effects, rounded to 2 significant figures.
[a] n-Hexane used as a surrogate for TPH as gasoline.
[b] Naphthalene used as a surrogate for TPH as diesel.

Ci Indoor air concentration (mg/m³).
CPFi Cancer potency factor for inhalation (kg-day/mg).
HBG Health-based soil goal (mg/kg).
NC Not evaluated as a carcinogen.
RfDi Reference dose for inhalation exposure (mg/kg/day).
TCR Target cancer risk.
THQ Target hazard quotient.
TPH Total petroleum hydrocarbons.
VOCs Volatile organic compounds.

Table 9. Equations for Health-Based Soil Goals for Outdoor Residential Exposure. Former Unocal Service Station Facility #2512, San Leandro, California.

Route-Specific HBGs:

Oral:

$$(HBG_o)_{C\,or\,NC} = \frac{(TCR\ or\ THI) \times BW \times (AP_C\ or\ AP_{NC}) \times (10^6\ mg/kg)}{IR_S \times EP \times EF \times [CPF_o\ or\ (1/RfD_o)]}$$

Dermal:

$$(HBG_d)_{C\,or\,NC} = \frac{(TCR\ or\ THI) \times BW \times (AP_C\ or\ AP_{NC}) \times (10^6\ mg/kg)}{SSA \times SAF \times ABS_d \times EF \times EP \times [CPF_a\ or\ (1/RfD_a)]}$$

Inhalation:

$$(HBG_i)_{C\,or\,NC} = \frac{(TCR\ or\ THI) \times BW \times (AP_C\ or\ AP_{NC}) \times 24\ hrs/day}{[(1/PEF) + (1/VF)] \times BR \times ET \times EF \times EP \times [CPF_i\ or\ (1/RfD_i)]}$$

where:

$$PEF = \frac{LS \times V \times DH}{A} \times \frac{(3{,}600\ sec/hr) \times (1{,}000\ g/kg)}{RF \times (1-G) \times (Um/Ut)^3 \times F_X}$$

$$VF = \frac{LS \times V \times DH}{A \times (10{,}000\ cm^2/m^2)} \times \frac{(3.14 \times \alpha \times T)^{1/2}}{2 \times Dei \times Pt \times Kas \times (10^{-3}\ kg/g)}$$

$$\alpha = \frac{Dei \times Pt}{Pt + [\rho s \times (1 - Pt)/Kas]}$$

$$Dei = Di \times Pt^{0.33}$$

$$Kas = H/(RT \times Kd)$$

Cancer Effects HBG:

$$HBG_C = \frac{1}{\frac{1}{(HBG_o)_C} + \frac{1}{(HBG_d)_C} + \frac{1}{(HBG_i)_C}}$$

Non-Cancer Effects HBG:

$$HBG_{NC} = \frac{1}{\frac{1}{(HBG_o)_{NC}} + \frac{1}{(HBG_d)_{NC}} + \frac{1}{(HBG_i)_{NC}}}$$

Table 9. Equations for Health-Based Soil Goals for Outdoor Residential Exposure, Former Unocal Service Station Facility #2512, San Leandro, California.

HBG = Minimum result of $HBG_C$ and $HBG_{NC}$.

where:

| | |
|---|---|
| $\alpha$ | Alpha; calculation intermediate ($cm^2$/sec). |
| A | Contiguous area of contamination (2,025 $m^2$). |
| $ABS_d$ | Dermal absorption efficiency, constituent-specific. |
| $AP_C$ | Averaging period for cancer effects (25,550 days). |
| $AP_{NC}$ | Averaging period for non-cancer effects (days); EP × 365 days/year. |
| BR | Breathing rate (20 $m^3$/day for adult, 10 $m^3$/day for child). |
| BW | Body weight (70 kg for adult, 15 kg for child). |
| CPF | Cancer potency factor for oral ($CPF_o$), dermal (adjusted to an absorbed dose, $CPF_a$), or inhalation exposure ($CPF_i$) (kg-day/mg; inverse of mg/kg/day) . |
| Dei | Effective diffusivity ($cm^2$/sec). |
| DH | Diffusion height (2 m). |
| Di | Diffusivity in air ($cm^2$/sec); constituent-specific . |
| EF | Exposure frequency (350 days/year) . |
| ET | Exposure time (16 hours/day) . |
| EP | Exposure period (30 years for adult, 6 years for child) . |
| Foc | Fraction organic carbon in soil (0.02), default value used to calculate Kd. |
| $F_X$ | Function of Ut/Um (0.00254) (unitless); $F_X = 0.18 \times [\ 8x^3 + 12x\ ] \times \exp(-x^2)$, where $x = 0.886 \times (Ut/Um)$. |
| G | Fraction of vegetative cover (unitless); conservatively assumed as zero. |
| H | Henry's Law Constant (atm-$m^3$/mol); constituent-specific . |
| HBG | Health-based goal for soil (mg/kg); minimum of the $HBG_C$ (based on cancer effects) and the $HBG_{NC}$ (based on non-cancer effects), which are based on the route-specific HBGs ($HBG_o$ for the oral route, $HBG_d$ for the dermal route, and $HBG_i$ for the inhalation route). |
| $IR_S$ | Ingestion rate of soil (100 mg/day for adult, 200 mg/day for child) . |
| Kas | Soil-air partition coefficient (g soil/$cm^3$ air), constituent-specific. |
| Kd | Soil-water partition coefficient ($cm^3$/g or mL/g); constituent-specific. Kd is calculated as Foc × Koc. |
| Koc | Organic carbon partition coefficient ($cm^3$/g or mL/g); constituent-specific . |
| LS | Length of side (cross-wind) of contaminated area (45 m). |
| PEF | Particulate emission factor ($4.63 \times 10^9$ $m^3$/kg). |
| Pt | Total soil porosity (0.35) (unitless), conservative default value. |
| $\rho s$ | True soil or particle density (2.65 g/$cm^3$), default value. |
| RF | Respirable fraction (0.036 g/$m^2$/hr). |
| RfD | Reference dose for oral ($RfD_o$), dermal (adjusted to an absorbed dose, $RfD_a$), or inhalation ($RfD_i$) intake (mg/kg/day). |
| RT | Product of the ideal gas constant ($8.206 \times 10^{-5}$ atm-$m^3$/mol/K) and the Kelvin temperature (298 K at 25 °C) = 0.02445 atm-$m^3$/mol. |
| SAF | Soil adherence factor (1 mg/$cm^2$/day) |
| SSA | Exposed skin surface area (5800 $cm^2$ for adult, 2000 $cm^2$ for child) |
| T | Exposure interval ($9.5 \times 10^8$ seconds) |
| TCR | Target excess lifetime cancer risk ($1 \times 10^{-6}$ [unitless]) |
| THI | Target hazard index (sum of 1.0 [unitless] for constituents with same critical effect) |
| Um | Wind speed (3.6 m/sec [NOAA, 1974]) |
| Ut | Equivalent threshold value of windspeed at 10 meters (12.8 m/sec). |
| V | Wind speed in the mixing zone (1.8 m/sec), Um/2 |
| VF | Volatilization factor (site- and constituent-specific) ($m^3$/kg) |

Table 9. Equations for Health-Based Soil Goals for Outdoor Residential Exposure, Former Unocal Service Station Facility #2512, San Leandro, California.

Example Calculation: (benzene, adult RME)

$$PEF = \frac{(45\text{ m}) \times (1.8\text{ m/sec}) \times (2\text{ m})}{(2{,}025\text{ m}^2)} \times \frac{(3{,}600\text{ sec/hr}) \times (1{,}000\text{ g/kg})}{(0.036\text{ g/m}^2\text{/hr}) \times (1-0) \times [(3.6\text{ m/sec})/(12.8\text{ m/sec})]^3 \times (0.00254)}$$

$$= 1.4 \times 10^{11}\text{ m}^3\text{/kg}$$

$$Dei = (0.0932\text{ cm}^2\text{/sec}) \times (0.35)^{0.33} = 6.59 \times 10^{-2}\text{ cm}^2\text{/sec}$$

$$Kas = \frac{(5.48 \times 10^{-3}\text{ atm-m}^3\text{/mol})}{(0.02445\text{ atm-m}^3\text{/mol}) \times (74.5\text{ cm}^3\text{/g}) \times (0.02)} = 1.5 \times 10^{-1}\text{ g/cm}^3$$

$$\alpha = \frac{(6.59 \times 10^{-2}\text{ cm}^2\text{/sec}) \times 0.35}{0.35 + [(2.65\text{ g/cm}^3) \times (1-0.35)/(1.5 \times 10^{-1}\text{ g/cm}^3)]} = 1.95 \times 10^{-3}\text{ cm}^2\text{/sec}$$

$$VF = \frac{(45\text{ m}) \times (1.8\text{ m/sec}) \times (2\text{ m})}{(2{,}025\text{ m}^2) \times (10{,}000\text{ cm}^2\text{/m}^2)} \times \frac{[3.14 \times (1.95 \times 10^{-3}\text{ m}^3\text{/kg}) \times (9.5 \times 10^8\text{ sec})]^{1/2}}{2 \times (6.59 \times 10^{-2}\text{ cm}^2\text{/sec}) \times (0.35) \times (1.5 \times 10^{-1}\text{ g/cm}^3) \times (10^{-3}\text{ kg/g})}$$

$$= 8{,}802\text{ m}^3\text{/kg}$$

Cancer Effects HBG:

$$(HBG_o)_c = \frac{(10^{-6}) \times (70\text{ kg}) \times (25{,}550\text{ days}) \times (10^6\text{ mg/kg})}{(100\text{ mg/day}) \times (350\text{ day/yr}) \times (30\text{ yr}) \times (0.1\text{ kg-day/mg})}$$

$$= 17\text{ mg/kg}$$

$$(HBG_d)_c = \frac{(10^{-6}) \times (70\text{ kg}) \times (25{,}550\text{ days}) \times (10^6\text{ mg/kg})}{(5{,}800\text{ cm}^2) \times (1\text{ mg/cm}^2\text{/day}) \times (0.25) \times (350\text{ days/yr}) \times (30\text{ yr}) \times (0.1\text{ kg-day/mg})}$$

$$= 1.2\text{ mg/kg}$$

$$(HBG_i)_c = \frac{(10^{-6}) \times (70\text{ kg}) \times (25{,}550\text{ days}) \times (24\text{ hr/day})}{\left(\frac{1}{1.4 \times 10^{11}\frac{\text{m}^3}{\text{kg}}}\right) + \left(\frac{1}{8{,}802\frac{\text{m}^3}{\text{kg}}}\right) \times 20\frac{\text{m}^3}{\text{day}} \times 16\frac{\text{hr}}{\text{day}} \times 350\frac{\text{day}}{\text{yr}} \times 30\text{ yr} \times (0.1\text{ kg-day/mg})}$$

$$= 1.1\text{ mg/kg}$$

Table 9. Equations for Health-Based Soil Goals for Outdoor Residential Exposure, Former Unocal Service Station Facility #2512, San Leandro, California.

$$HBG_c = \frac{1}{\frac{1}{17\ mg/kg} + \frac{1}{1.2\ mg/kg} + \frac{1}{1.1\ mg/kg}}$$

$$= 0.56\ mg/kg$$

Non-Cancer Effects HBG:

There is no available toxicity value for non-carcinogenic effects of benzene via oral exposure, therefore $(HBG_o)_{NC}$ was not calculated.

There is no available toxicity value for non-carcinogenic effects of benzene via dermal exposure, therefore $(HBG_d)_{NC}$ was not calculated.

$$(HBG_i)_{NC} = \frac{(1) \times (70\ kg) \times (10{,}950\ yr) \times (24\ hr/day)}{\left[\left(\frac{1}{1.4 \times 10^{11}\ \frac{m^3}{kg}}\right) + \left(\frac{1}{8{,}802\ \frac{m^3}{kg}}\right)\right] \times 20\ \frac{m^3}{day} \times 16\ \frac{hr}{day} \times 350\ \frac{day}{yr} \times 30\ yr \times \left(\frac{1}{0.00014\ mg/kg\text{-}day}\right)}$$

$$= \mathbf{6.7\ mg/kg}$$

$$HBG_{NC} = \mathbf{6.7\ mg/kg}$$

HBG = Minimum ( 0.56 mg/kg ; 6.7 mg/kg ) = 0.56 mg/kg

Table 10 Health Based Goal Calculations for Outdoor Adult Resident Exposure to Soil, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | | VF ($m^3/kg$) | CANCER EFFECTS: Route-Specific HBGs (mg/kg) Oral (HBGo)c | Dermal (HBGd)c | Inhalation (HBGi)c | Cancer Effects HBG HBGc | NON-CANCER EFFECTS: Route-Specific HBGs (mg/kg) Oral (HBGo)nc | Dermal (HBGd)nc | Inhalation (HBGi)nc | Non-Cancer Effects HBG HBGnc | Minimum HBG * (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VOCs | | | | | | | | | | | |
| Benzene | | 8,802 | 1.7E+01 | 1.2E+00 | 1.1E+00 | 5.6E-01 | NA | NA | 6.7E+00 | 6.7E+00 | 0.56 |
| Ethylbenzene | | 12,828 | NC | NC | NC | NC | 3.7E+04 | 2.5E+03 | 1.0E+04 | 1.9E+03 | 1,900 |
| Toluene | | 11,603 | NC | NC | NC | NC | 7.3E+04 | 5.0E+03 | 3.5E+03 | 2.0E+03 | 2,000 |
| Xylenes | | 32,135 | NC | NC | NC | NC | 1.5E+06 | 1.0E+05 | 3.5E+05 | 7.4E+04 | 74,000 |
| TPH | | | | | | | | | | | |
| n-Hexane | [a] | 2.50E+03 | NC | NC | NC | NC | 4.4E+04 | 7.6E+03 | 7.8E+02 | 7.0E+02 | 700 |
| Naphthalene | [b] | 1.64E+05 | NC | NC | NC | NC | 2.9E+04 | 1.4E+04 | 3.3E+02 | 3.2E+02 | 320 |

* The minimum of the HBGs calculated for cancer and non-cancer effects, rounded to 2 significant figures.

[a] n-Hexane used as a surrogate for TPH as gasoline.

[b] Naphthalene used as a surrogate for TPH as diesel.

mg/kg Milligram per kilogram

$m^3/kg$ Cubic meters per kilogram.

NA Not available, insufficient toxicity data.

NC Not a suspected carcinogen.

HBG Health based goal for soil (mg/kg).

VF Soil to air volatilization factor ($m^3/kg$).

VOCs Volatile organic compounds.

Table 11 Health Based Goal Calculations for Outdoor Child Resident Exposure to Soil, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | | VF ($m^3$/kg) | CANCER EFFECTS: Route-Specific HBGs (mg/kg) Oral (HBGo)c | Dermal (HBGd)c | Inhalation (HBGi)c | Cancer Effects HBG HBGc | NON-CANCER EFFECTS: Route-Specific HBGs (mg/kg) Oral (HBGo)nc | Dermal (HBGd)nc | Inhalation (HBGi)nc | Non-Cancer Effects HBG HBGnc | Minimum HBG * (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VOCs | | | | | | | | | | | |
| Benzene | | 2,784 | 9.1E+00 | 3.7E+00 | 5.1E-01 | 4.3E-01 | NA | NA | 6.1E-01 | 6.1E-01 | 0.43 |
| Ethylbenzene | | 4,057 | NC | NC | NC | NC | 3.9E+03 | 1.6E+03 | 9.2E+02 | 5.0E+02 | 500 |
| Toluene | | 3,669 | NC | NC | NC | NC | 7.8E+03 | 3.1E+03 | 3.2E+02 | 2.8E+02 | 280 |
| Xylenes | | 10,162 | NC | NC | NC | NC | 1.6E+05 | 6.3E+04 | 3.2E+04 | 1.9E+04 | 19,000 |
| TPH | | | | | | | | | | | |
| n-Hexane | [a] | 7.90E+02 | NC | NC | NC | NC | 4.7E+03 | 4.7E+03 | 7.0E+01 | 6.8E+01 | 68 |
| Naphthalene | [b] | 5.19E+04 | NC | NC | NC | NC | 3.1E+03 | 8.9E+03 | 3.0E+01 | 3.0E+01 | 30 |

* The minimum of the HBGs calculated for cancer and non-cancer effects, rounded to 2 significant figures.

[a] n-Hexane used as a surrogate for TPH as gasoline.

[b] Naphthalene used as a surrogate for TPH as diesel.

mg/kg Milligram per kilogram

$m^3$/kg Cubic meters per kilogram.

NA Not available, insufficient toxicity data.

NC Not a suspected carcinogen.

HBG Health-based goal for soil (mg/kg).

VF Soil-to-air volatilization factor ($m^3$/kg).

VOCs Volatile organic compounds.

Table 12 Equation for Soil Human Health-Based Goals for a Hypothetical Excavation Worker, Non-Carcinogenic Effects, Former Unocal Service Station Facility #2512, San Leandro, California.

Non-Carcinogens

$$HBG\ (mg/kg) = \frac{THI \times BW \times AT}{EF \times ED \times ([1/RfDo \times UCF \times IRsoil]+[1/RfDa \times SSA \times SA \times ABS \times UCF]+[1/RfDi \times IRair \times ([1/VF]+[1/PEF]))}$$

where

| | |
|---|---|
| ABS | Dermal adsorption efficiency (Table 3). |
| AT | Averaging time for non-carcinogenic effects, (84 days [12 weeks x 7 days/week] for excavation worker). |
| BW | Adult body weight (70 kg). |
| ED | Exposure duration (1 year for excavation worker). |
| EF | Exposure frequency (60 days/year for excavation worker). |
| HBG | Health-based soil goal (mg/kg). |
| IRair | Workday inhalation rate (6.6 $m^3$/day [0.83 $m^3$/hour x 8 hours/day] for excavation worker). |
| IRsoil | Soil ingestion rate (480 mg/day for excavation worker). |
| PEF | Particulate emission factor (1.4E+11 $m^3$/kg) (USEPA, 1991b). |
| RfDa | Reference dose adjusted for subchronic dermal exposure (Table 1). |
| RfDi | Reference dose for subchronic inhalation exposure (Table 1). |
| RfDo | Reference dose for subchronic oral exposure (Table 1). |
| SA | Soil adherence rate (1 mg/$cm^2$/day). |
| SSA | Skin surface area (3160 $cm^2$ ; adult head, hands, and lower arms) (USEPA,1990). |
| THI | Target hazard index |
| UCF | Unit conversion factor (1E-06 kg/mg). |
| VF | Soil-to-air volatilization factor ($m^3$/kg) (area-specific; constituent-specific; from Table 9). |

Sample calculation of HBG for an excavation worker for toluene in soil (units omitted):

$$HBG = \frac{0.5 \times 70 \times 84}{60 \times 1 \times ([1/2 \times 1E\text{-}6 \times 480] + [1/2 \times 3{,}160 \times 1 \times 0.25 \times 1E\text{-}6] + [1/0.29 \times 6.6 \times ([1/321] + [1/1.4E+11])])}$$

$$= 680\ mg/kg$$

| | | | |
|---|---|---|---|
| Reference | USEPA (1991b) | mg/day | milligram per day |
| kg | kilogram | $m^3$/kg | cubic meters per day |
| mg/kg | milligram per kilogram | mg/$cm^2$-day | milligram per square centimeter times day |
| $m^3$/day | cubic meters per day | $cm^2$ | square centimeter |
| kg/mg | kilogram per milligram | | |

Table 13 Equation for Soil Human Health-Based Goals for a Hypothetical Excavation Worker, Carcinogenic Effects, Former Unocal Service Station Facility #2512, San Leandro, California.

Carcinogens

$$HBG\ (mg/kg) = \frac{TCR \times BW \times AT}{EF \times ED \times ([CPFo \times UCF \times IRsoil]+[CPFa \times SSA \times SA \times ABS \times UCF]+[CPFi \times IRair \times ([1/VF]+[1/PEF])])}$$

where:

| | |
|---|---|
| ABS | Dermal absorption efficiency (Table 3). |
| AT | Averaging time for carcinogenic effects, 84 days [12 weeks x 7 days/week] for excavation worker). |
| BW | Adult body weight (70 kg). |
| CPFa | Adjusted dermal cancer potency factor (Table 3). |
| CPFi | Inhalation cancer potency factor (Table 2). |
| CPFo | Oral cancer potency factor (Table 2). |
| ED | Exposure duration (1 year for excavation worker). |
| EF | Exposure frequency (60 days/year for excavation worker). |
| IRair | Workday inhalation rate (6.6 $m^3$/day [0.83 $m^3$/hour x 8 hours/day] for excavation worker). |
| IRsoil | Soil ingestion rate (480 mg/day for excavation worker). |
| PEF | Particulate emission factor (1.4E+11 $m^3$/kg) (USEPA, 1991a). |
| SA | Soil adherence rate (1 mg/$cm^2$/day). |
| HBG | Health-based soil goal (mg/kg). |
| SSA | Skin surface area (3160 $cm^2$ ; adult head, hands and lower arms) (USEPA, 1990). |
| TCR | Target excess individual lifetime cancer risk (1E-06). |
| UCF | Unit conversion factor (1E-06 kg/mg). |
| VF | Soil-to-air volatilization factor ($m^3$/kg) (area-specific; constituent-specific; from Table 9). |

Sample calculation of HBG for an excavation worker for benzene in soil (units omitted):

$$HBG = \frac{1E\text{-}6 \times 70 \times 25550}{60 \times 1 \times ([0.1 \times 1E\text{-}6 \times 480] + [0.01 \times 3{,}160 \times 1 \times 0.25 \times 1E\text{-}6] + [0.1 \times 6.6 \times ([1/244] + [1/1.4E+11])])}$$

$$= 11\ mg/kg$$

| | | | |
|---|---|---|---|
| Reference | USEPA (1991b) | mg/day | milligram per day. |
| kg | kilogram | $m^3$/kg | cubic meters per day |
| mg/kg | milligram per kilogram | mg/$cm^2$-day | milligram per square centimeter times day |
| $m^3$/day | cubic meters per day | $cm^2$ | square centimeter |
| kg/mg | kilogram per milligram | | |

Table 14. Health-Based Soil Goals for a Hypothetical Future Excavation Worker, Non-Carcinogenic Effects, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | VF ($m^3/kg$) | Subchronic Toxicity Values (mg/kg-day) RfDo | RfDa | RfDi | THI | Non-Cancer Effects HBG (mg/kg) |
|---|---|---|---|---|---|---|
| VOCs | | | | | | |
| Benzene | 243 | NA | NA | 1.4E-04 | 1 | 1 |
| Ethylbenzene | 354 | 1.0E-01 | 1.0E-01 | 2.9E-01 | 0.5 | 640 |
| Toluene | 321 | 2.0E+00 | 2.0E+00 | 2.9E-01 | 0.5 | 680 |
| Xylenes | 888 | 4.0E+00 | 4.0E+00 | 4.0E+00 | 1 | 310,000 |
| TPH | | | | | | |
| n-Hexane [a] | 69 | 6.0E-01 | 6.0E-01 | 5.7E-02 | 1 | 58 |
| Naphthalene [b] | 4,533 | 4.0E-02 | 3.4E-02 | 4.0E-02 | 1 | 1,900 |

[a] n-Hexane used as a surrogate for TPH as gasoline.
[b] Naphthalene used as a surrogate for TPH as diesel.
$m^3/kg$ Cubic meters per kilogram.
mg/kg Milligrams per kilogram.
mg/kg-day Milligrams per kilogram per day.
NA Not available.
RfDa Adjusted reference dose, subchronic.
RfDi Inhalation reference dose, subchronic.
RfDo Oral reference dose, subchronic.
HBG Health-based soil goal.
THI Target hazard index.
TPH Total petroleum hydrocarbons.
VF Soil-to-air volatilization factor.
VOCs Volatile organic compounds.

Table 15. Soil Health-Based Goal for a Hypothetical Future Excavation Worker, Carcinogenic Effects, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | VF ($m^3/kg$) | Toxicity Values (kg-day/mg) | | | TCR | Cancer Effects HBG (mg/kg) |
|---|---|---|---|---|---|---|
| | | CPFo | CPFa | CPFi | | |
| Benzene | 244 | 1.0E-01 | 1.0E-01 | 1.0E-01 | 1.0E-06 | 11 |

| | |
|---|---|
| CPFa | Adjusted dermal cancer potency factor, kg-day/mg. |
| CPFi | Inhalation cancer potency factor, kg-day/mg. |
| CPFo | Oral cancer potency factor, kg-day/mg. |
| $m^3/kg$ | Cubic meters per kilogram. |
| mg/kg | Milligrams per kilogram. |
| HBG | Health-based soil goal, mg/kg. |
| kg-day/mg | Kilogram times day per milligram. |
| TCR | Target excess lifetime cancer risk. |
| VF | Soil-to-air volatilization factor, $m^3/kg$. |

Table 16. Comparison of Constituent Concentrations Detected in Soil to Health Based Goals, Former Unocal Service Station Facility #2512, San Leandro, California.

| Constituent | MAXIMUM DETECTED CONCENTRATION Cs (mg/kg) | HEALTH-BASED GOALS: Vapor Intrusion Adult Resident HBG (mg/kg) | Vapor Intrusion Child Resident HBG (mg/kg) | Direct Contact Adult Resident HBG (mg/kg) | Direct Contact Child Resident HBG (mg/kg) | Direct Contact Excavation Worker HBG (mg/kg) |
|---|---|---|---|---|---|---|
| VOCs | | | | | | |
| Benzene | 0.12 | 3.2 | 3.4 | 0.56 | 0.43 | 1 |
| Ethylbenzene | 0.25 | 42,000 | 8,900 | 1,900 | 500 | 640 |
| Toluene | 0.21 | 13,000 | 2,800 | 2,000 | 280 | 680 |
| Xylenes (total) | 1.7 | 3,500,000 [c] | 760,000 | 74,000 | 19,000 | 310,000 |
| TPH | | | | | | |
| TPH-g [a] | 20 | 830 | 180 | 700 | 68 | 58 |
| TPH-d [b] | 13 | 7,000 | 3600 | 320 | 30 | 1,900 |

[a] n-Hexane used as a surrogate for TPH-g.

[b] Naphthalene used as a surrogate for TPH-d.

[c] Value is greater than a million ($10^6$) parts per million (ppm), and therefore is not itself a valid concentration goal, but indicates that concentrations below saturation are health-protective.

Cs Maximum detected constituent concentration in soil.

HBG Health-based goals for soil.

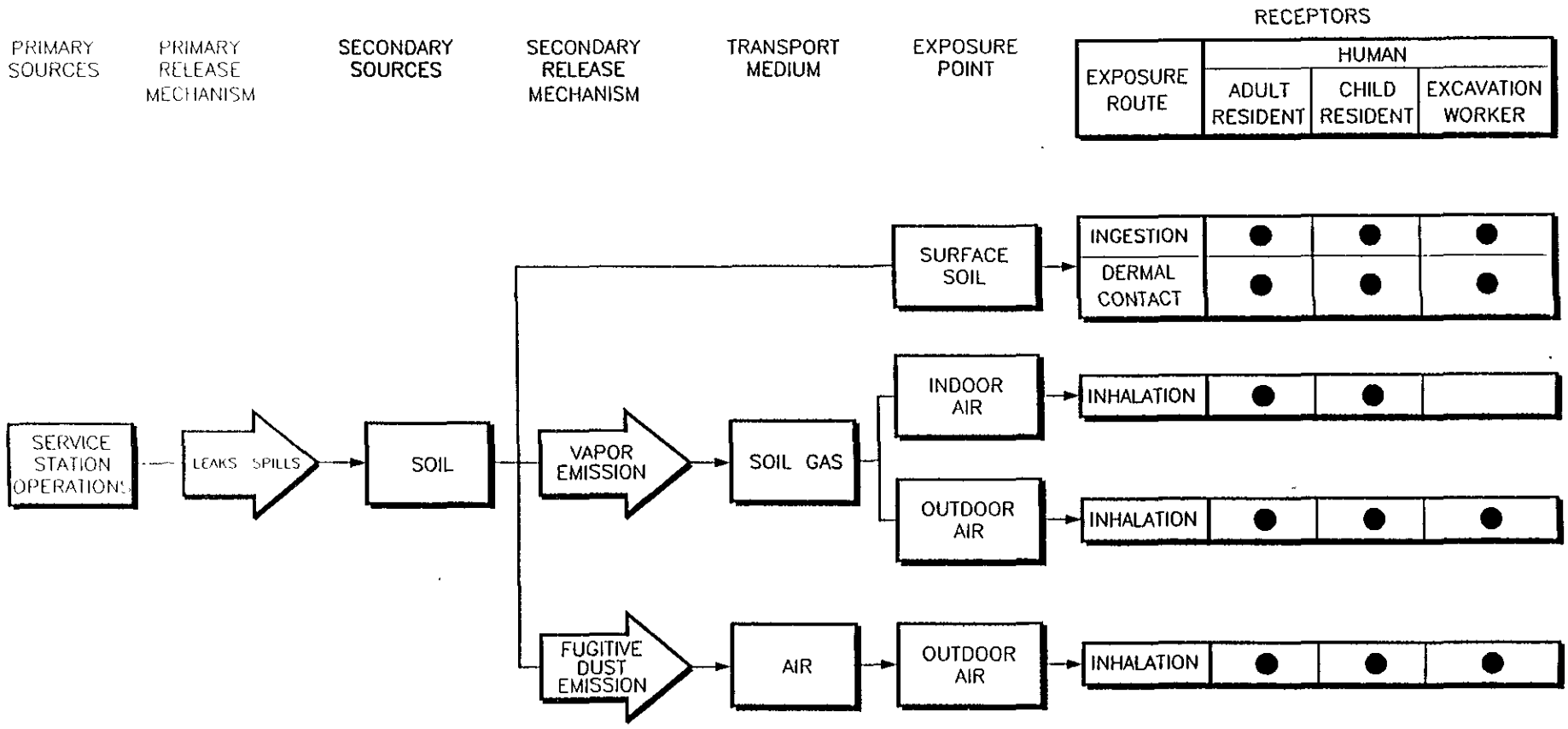
mg/kg Milligrams per kilogram.

TPH Total petroleum hydrocarbons.

VOCs Volatile organic compounds.

# FIGURES

| DWG DATE 10 11 94 | PROJ NO RC0286.001 | FILE 4IR0415 | DRAWING: SANL-CSM | CHECKED: KN | APPROVED: KN | DRAFTER: SKP |
|---|---|---|---|---|---|---|




LEGEND

● COMPLETE PATHWAY TO RECEPTOR

GERAGHTY & MILLER, INC.
*Environmental Services*

# CONCEPTUAL SITE MODEL FOR POTENTIAL EXPOSURE

FORMER UNOCAL SERVICE STATION #2512
SAN LEANDRO, CALIFORNIA

FIGURE
1

# APPENDIX A

# TOXICITY ASSESSMENT

This section discusses the two general categories of toxic effects (non-carcinogenic or systemic toxicant and carcinogenic) evaluated in risk assessments and the toxicity values used to calculate risk. Toxicity values for non-carcinogenic effects were determined from available databases. For this risk assessment, this included the USEPA's Integrated Risk Information System (IRIS), (1994); and when not available on IRIS, USEPA's Health Effects Assessment Summary Tables (HEAST) (USEPA, 1994). Toxicity values for carcinogenic effects were obtained from the list of cancer potency factors (CPFs) compiled by the Standards and Criteria Work Group of Cal/EPA (1992).

## NON-CARCINOGENIC EFFECTS

For many systemic toxicant or non-carcinogenic effects, protective mechanisms must be overcome before the effect is manifested. Therefore, a finite dose (threshold), below which adverse effects will not occur, can be identified for non-carcinogens. A single compound might elicit several adverse effects depending on the dose, the exposure route, and the duration of exposure. For a given chemical, the dose that elicits no effect, the no observed effect level (NOEL), when evaluating the most sensitive response in the most sensitive species tested is used to establish a reference dose (RfD) for systemic toxicant effects.

The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level that is unlikely to cause non-carcinogenic health effects. Thus, exposure levels below the RfD are unlikely to produce toxic effects in even sensitive subpopulations. These values are calculated by the USEPA. Chronic RfDs are used to assess long-term exposures ranging from 7 years to a lifetime; subchronic RfDs evaluate the potential of adverse health effects associated with exposure to chemicals during a period of a few days to 7 years. RfDs are derived by the USEPA by dividing the NOELs by uncertainty factors typically ranging from 10 to 10,000 depending on the suitability and quality of the available database. RfDs that are sanctioned by the USEPA are called verified reference doses for oral exposure ($RfD_o$s) or reference concentrations (RfCs) for inhalation exposure. In this risk assessment, RfCs have been converted to reference doses for inhalation exposure ($RfD_i$s) by

assuming an adult breathing rate of 20 cubic meters per day ($m^3$/day) and a body weight of 70 kilograms (kg) (USEPA, 1993). RfCs or RfDs for inhalation have not been established for many volatile organic compounds (VOCs). When they were not available, as with toluene, the oral RfD was substituted as an inhalation RfD. Table 1 in the text of this report presents the RfDs used in this risk assessment. Target sites affected by each constituent are shown in the table for both inhalation and oral exposures. The confidence value and uncertainty factors associated with the RfDs also are listed. The uncertainty factor represents a specific area of uncertainty inherent in the extrapolation from the available data. The confidence levels (low, medium, high) assess the degree of confidence the USEPA has in the extrapolation of available data.

Toxicity values (i.e., RfDs and CPFs) for dermal exposure are rarely available because appropriate toxicity data are scarce. Therefore, the oral RfD and CPF are adjusted to an absorbed dose, using the constituent-specific oral absorption efficiency, as recommended by the USEPA (1989a). In calculating a dermal RfD from an oral RfD, the oral RfD is multiplied by the oral absorption efficiency (1.0 for VOCs); therefore, the dermal RfDs are equal to the oral RfDs for VOCs.

## CARCINOGENIC EFFECTS

Constituents are classified as known, probable, or possible human carcinogens based on a USEPA weight-of-evidence classification scheme in which chemicals are systematically evaluated for their ability to cause cancer in mammalian species and conclusions are reached about the potential to cause cancer in humans. The USEPA classification scheme (USEPA, 1989a) contains six classes, based on the weight of available evidence, as follows:

A known human carcinogen;

B1 probable human carcinogen -- limited evidence in humans;

B2 probable human carcinogen -- sufficient evidence in animals and inadequate data in humans;

C possible human carcinogen -- limited evidence in animals;

D inadequate evidence to classify; and

E evidence of non-carcinogenicity.

Constituents in Classes A, B1, B2 and C generally are included in risk assessments as potential human carcinogens; however, Class C carcinogens may be evaluated on a case-by-case basis (USEPA, 1989a). The only carcinogen at this site was benzene, a Class A, known human carcinogen.

The toxicity value used to evaluate cancer risk is called the cancer slope factor (CSF) by USEPA and the cancer potency factor (CPF) by Cal/EPA. The CSF is generated by the USEPA using a linearized (multistage) model for extrapolating cancer risk from high doses associated with occupational exposure or laboratory animal studies to the low doses typically associated with environmental exposures. The multistage model is based on a non-threshold theory in which any exposure to a carcinogen may result in tumor formation. The model provides a 95 percent upperbound estimate of cancer incidence at a given dose. The slope of the extrapolated curve, called the CSF, is used to calculate the probability of cancer associated with the exposure dose.

CPFs used in this risk assessment are taken from Cal/EPA (1994). The CPFs developed by Cal/EPA are generated using various models for extrapolating cancer risk from high doses associated with occupational exposure or laboratory animal studies to the low doses typically associated with environmental exposures. CPFs are derived from the assumption that any dose level has a probability of causing cancer. The cumulative dose regardless of the exposure period determines the risk; therefore, separate CPFs are not derived for subchronic and chronic exposure periods. CPFs are derived for oral and inhalation exposures. Dermal effects also are evaluated by calculating a dermal CPF from the oral CPF. This is done by dividing the oral CPF by the oral absorption efficiency (1.0 for VOCs). Therefore, dermal CPFs are equal to oral CPFs for VOCs. Table 2 in the text of this report presents the CPFs used in the risk

assessment. Target sites affected by each constituent are shown in the table for both the oral and inhalation routes. USEPA cancer classifications also are listed.

# APPENDIX B

# PHYSICAL AND CHEMICAL PROPERTIES

The water solubility of a substance is an important property affecting environmental fate. Solubility is expressed in terms of the number of milligrams of a constituent that can dissolve in one liter of water (mg/L) under standard conditions of 25 degrees Centigrade ($^0$C) and one atmosphere of pressure (atm). In general, solubilities range from less than 1 mg/L to totally miscible, with most common organic chemicals falling between 1 mg/L and 1,000,000 mg/L (Lyman et al., 1990). The higher the value of the solubility, the greater the tendency of a constituent to dissolve in water. Thus, highly soluble constituents generally are more mobile in groundwater and surface water and are more likely to leach in soil than a constituent with a lower solubility. Benzene is the most soluble of the COC, with a reported solubility of 1,780 mg/L at 25 $^0$C (Table 4) (constituents with solubilities greater than 1,000 mg/L are considered highly soluble [Ney, 1990]). n-Hexane is the least soluble, having a low reported solubility of 18 mg/L at 20 $^0$C.

The specific gravity is the ratio of the density of a chemical in its pure state to the density of water. Non-aqueous phase liquids with a specific gravity greater than one are denser than water and will sink through the water table, whereas constituents with a specific gravity less than one will float on the water table. The volatile BTEX compounds have specific gravities of approximately 0.9 (Table 4), n-hexane has a specific gravity of 0.66 and the semi-volatile naphthalene has a specific gravity of 1.2. Constituents that are completely dissolved in water will not form a separate phase regardless of the specific gravity.

Volatilization of a constituent from an environmental medium will depend on its vapor pressure, water solubility, and diffusion coefficient. Highly water-soluble compounds generally have lower volatilization rates from water than do compounds with lower solubilities unless the constituents also have high vapor pressures. Vapor pressure, a relative measure of the volatility of constituents in their pure state, ranges from about 0.001 to 760 millimeters of mercury (mm Hg) for liquids, with solids ranging down to less than $10^{-10}$mm Hg. The vapor pressures of the COC at this site range from a high of 120 mm Hg at 20 $^0$C for n-hexane to 0.23 to 0.87 mm Hg at 25 $^0$C for naphthalene.

The Henry's Law Constant, combining vapor pressure with solubility and molecular weight, can be used to estimate releases from water to air. The Henry's Law Constant is a partition coefficient used to predict the tendency of an organic constituent to volatilize or "partition" from the aqueous or water phase to the vapor phase and may be experimentally determined or calculated from vapor pressure and solubility. Organic compounds with Henry's Law Constants in the range of $10^{-3}$ atmospheres-cubic meters per mole (atm-$m^3$/mol) and larger and molecular weights equal to or less than 200 grams per mole (g/mol) can be expected to volatilize readily from water; those with values ranging from $10^{-3}$ to $10^{-5}$ atm-$m^3$/mol are associated with possibly significant, but not facile, volatilization; while compounds with values less than $10^{-5}$ atm-$m^3$/mol will only volatilize from water slowly and to a limited extent (Howard, 1989; Lyman et al., 1990). All of the COC, with the exception of naphthalene, have Henry's Law Constants greater than $10^{-3}$ atm-$m^3$/mol (Table 4), indicating the tendency to volatilize. Although n-hexane and naphthalene are used as surrogates, TPH-g and TPH-d are mixtures of compounds and as such do not have unique Henry's Law Constants. Much of the hydrocarbons comprising the TPH at the site are likely to be longer-chain hydrocarbons, which are not considered as volatile as BTEX compounds, and are more likely to remain sorbed to soil.

The diffusion coefficient can be used as a means to predict the rate at which a compound moves through the environment. Molecular diffusion is determined by both molecular properties (e.g., size and weight) and by the presence of a concentration gradient, which means that molecules of a chemical will migrate from areas of higher concentration to areas deficient in molecules of that compound.

A partition coefficient is the ratio of the concentration of adsorbed constituent to the concentration of aqueous phase constituent and is expressed in units of milliliters per gram (ML/g). The octanol-water partition coefficient ($K_{ow}$) often is used to estimate the extent to which a chemical will partition from water into lipophilic or water-containing parts of organisms, for example, animal fat. The organic carbon partition coefficient ($K_{oc}$), used to determine the adsorption potential of a constituent, may be determined empirically or may be estimated using constituent-specific and soil-specific parameters. $K_{oc}$ reflects the propensity of a compound to

adsorb to the organic matter found in the soil or sediments. The normal range of $K_{oc}$ values is from 1 to $10^7$, with higher values indicating greater adsorption potential. The potential for a constituent to absorb to soil particles will affect migration through soil and aquifer materials. When a constituent enters the soil/sediment environment, some of it will bind with particles through the process of sorption and some will dissolve in the water contained in the spaces between soil particles (pore water). The term "sorption" includes adsorption (constituent bound to the outside of soil particles) and absorption (constituent distributed throughout the particle matrix). Sorption to soil reduces volatilization, leaching, and biodegradation. A chemical that is absorbed is less mobile because it is not easily released from the particle. Conversely, a chemical that is adsorbed is released more easily and, therefore, may be mobile. The $K_{oc}$s for the COC at this site range from 49 mL/g (minimum value provided for benzene) to 3,160 mL/g (maximum provided for naphthalene) (Table 4). The $K_{oc}$ indicates that naphthalene has the greatest tendency to adsorb to soil, and benzene is least likely to become and remain sorbed to soil. In general, $K_{oc}$ increases with molecular weight. As a result, the longer chain, heavier components of TPH are more likely to adsorb to soil than to volatilize or leach. The COC for this site generally have low $K_{ow}$s and $K_{oc}$s indicating a tendency not to partition into media other than water.

The COC at this site do not tend to adsorb readily to soil or aquifer materials, and thus are characterized by relatively high mobility in the environment. The components of the weathered TPH are not expected to be as volatile or mobile as BTEX.

Constituent partitioning between soil and water generally is represented by the soil-water distribution coefficient, $K_d$. The $K_d$, like the $K_{oc}$, may be determined empirically or may be estimated using constituent-specific and soil-specific parameters. In the absence of site-specific data, the parameters most often used to calculate $K_d$ for organic constituents are the $K_{oc}$ and the fraction of organic carbon in soil ($f_{oc}$), since $K_d$ commonly is expressed as the product of the $K_{oc}$ and $f_{oc}$ (USEPA, 1989b). As with the $K_{oc}$, higher $K_d$ values indicate that a larger percentage of the constituent is associated with the soil solids, and the constituent therefore is less mobile in the subsurface environment. Low values of $K_{oc}$ (i.e., less than 1,000) and $f_{oc}$, coupled with high

solubility, characterize constituents with a higher potential to migrate through soils or aquifer materials (Ney, 1990).

Biodegradation is the biological process by which microorganisms break down organic chemicals. Environmental factors such as moisture, pH, temperature, and available nutrients will affect the rate of biodegradation. Constituents with high water solubility, low $K_{oc}$, and low $K_{ow}$ values likely will biodegrade (Ney, 1990). The COC at the site have these properties. Persistence is the "lasting power" of constituents and is commonly expressed in terms of half-lives (T1/2) for specific environmental media. The half-life of a constituent is the period of time required for one-half of the original mass of a compound to be transformed into other constituents from the time of its introduction to the environment. Soil and groundwater half-lives obtained from literature of the COC are presented in Table 4. Ranges are shown because the rate of degradation varies according to environmental conditions and concentration. Half-lives may be used to characterize the relative persistence of a constituent in various environmental media.

# APPENDIX C

# VAPOR INTRUSION MODEL

A vapor intrusion model was used to calculate indoor exposure to BTEX, TPH-g and TPH-d, assuming the COC volatilize from soil and enter into an occupied building. The conceptual model consists of estimating the concentration of the constituent in soil air and the subsequent movement of the vapor phase constituent upward to the atmosphere, and then estimating concentrations of the constituent in outdoor and indoor air. The calculation follows the mathematical model developed by Daugherty (1991).

The vapor intrusion model is based on several assumptions (Daugherty, 1991). The model considers only diffusive flux, not pressure or convection driven flow. The constituent is assumed to be present as a nondiminishing steady state source. Biodegradation and other attenuation forces are expected to occur in subsurface soils over time, therefore, this is a conservative assumption. The system is assumed to be at equilibrium and exposure to COC above equilibrium levels due to shutdown of the building ventilation system is assumed to be trivial in terms of lifetime exposure. It is assumed that flux occurs only through infiltration areas such as cracks in the building slab and that flux through the building slab itself is insignificant.

The vapor intrusion model was proposed as a method to calculate concentrations of constituents in indoor air based upon specified constituent concentrations in soil gas (Daugherty, 1991). For the analysis at this site, an acceptable constituent concentration in indoor air was determined based upon target risk levels. The model was then applied in a backward direction and the acceptable indoor air concentration was used to derive the target concentration in soil gas and then the soil HBG.

The equations and parameter values used to calculate the soil HBGs are presented in Section 5 of this report. Physical parameters such as moisture content, dry soil density, porosity, and effective air permeability affect the rate at which the vapors from a volatile compound may migrate through the soils. Site-specific values for these soil parameters were used where available. Conservative default values were identified based upon known site characteristics for parameters that were not measured directly. Assumed parameters of the

hypothetical building were also used to apply the model (i.e., building dimensions). In cases where site-specific values for model parameters were not readily available, conservative default values were identified based upon known site conditions (i.e., moisture content of soil).

A maximum acceptable vapor phase flux ($mg/cm^2/sec$), given the indoor air concentration derived from target risk levels, was calculated by dividing the product of the indoor air concentration, building air exchange rate and building volume, by the area of infiltration:

$$F = \frac{Ci \times AER \times V}{A \times UC2 \times UC3}$$

where:

A Area of infiltration ($m^2$)

AER Building air exchange rate (volumes/hour)

Ci Indoor air concentration ($mg/m^3$)

UC2 Unit conversion (10,000 $cm^2/m^2$)

UC3 Unit conversion (3,600 sec/hour)

V Volume of building ($m^3$)

The volatilized constituent diffuses upward through the soil. The rate of diffusion through soil is determined by the soil characteristics and the constituent characteristics. If it is assumed that diffusion through the soil is primarily vapor-phase diffusion (neglecting diffusion through the soil moisture), then effective diffusivity (De) can be approximated as:

$$De = \frac{Di \times (Pt-[M \times B])^{3.33}}{Pt^2}$$

where:

B Bulk density of soil ($g/cm^3$)

De Effective diffusion coefficient ($cm^2/sec$)

Di Diffusivity ($cm^2/sec$)

M Moisture content of soil ($cm^3/g$)

Pt Total soil porosity (unitless).

The target concentration of constituent in soil gas was calculated by dividing the product of the maximum acceptable flux and depth to groundwater by the effective diffusion coefficient:

$$Csg = \frac{F \times X}{De}$$

where:

Csg Concentration in soil gas ($mg/cm^3$)

De Effective diffusion coefficient ($cm^2/sec$)

F Flux ($mg/cm^2/sec$)

X Depth to groundwater (cm).

Detected concentrations of COC at the site were relatively low; therefore, it was assumed that volatile COC were dissolved in soil pore water. Thus, the target concentration of constituent in soil gas was used to determine the target concentration in soil pore water based upon the Henry's Law Constant for the constituent dissolved in water:

$$Cpw = \frac{Csg}{UC1 \times Ho}$$

where:

Cpw Concentration in soil pore water (mg/L)

Csg Concentration in soil gas ($mg/cm^3$)

Ho Unitless Henry's Law Constant

UC1 Unit conversion (0.001 $L/cm^3$)

The target concentration of constituent in soil pore water was then used to determine the soil HBG:

$$HBG = Cpw \times K_{OC} \times f_{OC}$$

where:

Cpw Concentration in soil pore water (mg/L)

$f_{oc}$ Fraction of organic carbon (unitless)

HBG Health-based goal (mg/L)

$K_{oc}$ Organic carbon partition coefficient (L/kg)

The result of this application of the vapor intrusion model is a concentration of constituent in soil that is expected to result in exposure of receptors at or below the target risk levels. This concentration in soil is a medium-, constituent-, and receptor-specific HBG.

# APPENDIX B

# SITE CLOSURE SUMMARY

## I. AGENCY INFORMATION

Date: 11/7/00

| | |
|---|---|
| Agency Name: Alameda County Health Care Services | Address: 1131 Harbor Bay Parkway, Suite 250 |
| City/State/Zip: Alameda, CA 94502- 6577 | Phone: (510) 622-2300 |
| Responsible Staff Person: Amir K. Gholami | Title: Hazardous Materials Specialist |

## II. SITE INFORMATION

| | | |
|---|---|---|
| Site Facility Name: Former Unocal #2512 | | |
| Site Facility Address: 1300 Davis Street, San Leandro | | |
| RB/SMS Case No.: | Local or LOP Case No.: 2480 | Priority: |
| URF Filing Date: | SWEEPS No.: | |
| Responsible Parties (include addresses and phone numbers): Mr. Nick Nickerson | | |
| Unocal Corporation, 8788 Elk Grove Blvd, Bldg 3, Suite 15, Elk Grove, CA 95624 916.714.3205 | | |

| Tank No. | Size in Gallons | Contents | Closed In—Place/Removed? | Date |
|---|---|---|---|---|
| A | 10,000 | regular unleaded gasoline | removed | 7/28/92 |
| B | 10,000 | super unleaded gasoline | removed | 7/28/92 |
| C | 280 | waste oil | removed | 7/28/92 |

## III. RELEASE AND SITE CHARACTERIZATION INFORMATION

| | | |
|---|---|---|
| Cause and Type of Release: unknown | | |
| Site characterization complete? Yes | Date Approved By Oversight Agency: | |
| Monitoring wells installed? Yes | Number: 9 | Proper screened interval? Yes |
| Highest GW Depth below top of well casing: 10.41' 1/97 Well MW-7 | Lowest:18.75' MW-2 10/91 | Flow Direction: W-SW and NE |
| Most Sensitive Current Use: Domestic supply | | |
| Most Sensitive Potential Use: Domestic or municipal supply and Probability of Use: Possibly none. Apparently site is within the San Leandro Plume Superfund Site. | | |
| Are drinking water wells affected? No | Aquifer Name: | |
| Is surface water affected? No | Nearest SW Name: San Leandro Creek | |
| Off-Site Beneficial Use Impacts (Addresses/Locations): None | | |
| Report(s) on file? Yes | Where is report(s) filed? ACHCSA and RWQCB | |

| TREATMENT AND DISPOSAL OF AFFECTED MATERIAL | | | |
|---|---|---|---|
| **Material** | **Amount (Include Units)** | **Action (Treatment or Disposal w/Destination)** | **Date** |
| Tank | 20,280 gallons | Not identified; assumed destroyed. | 7/28/92 |
| Piping | unknown | Not identified; assumed destroyed | 7/28/92 |
| Free Product | amount unknown | Not identified | |
| Soil | 250 cubic yards<br>1,044 cubic yards<br>12 drums<br>2 tons | Not identified<br>Approved landfill (BFI, Forward)<br>Approved landfill (Forward)<br>Approved landfill (BFI) | 6/89<br>2, 3/94<br>1/27, 30/95<br>10/28/95 |
| Groundwater | 4,200 gallons | Removed by H&H Services, dest. not identified | 11/10/93 |
| Barrels | 12 | Approved landfill or destroyed | 1/27, 30/95 |

| MAXIMUM DOCUMENTED POLLUTANT CONCENTRATIONS--BEFORE AND AFTER CLEANUP | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Soil (ppm) | | Water (ppb) | | | Soil (ppm) | | Water (ppb) | |
| POLLUTANT | Before | After | Before | After | POLLUTANT | Before | After | Before | After |
| TPH (Gas) | 270<br>P6@11' | 73<br>EB6@10' | 1,300,000<br>MW-3, 5/92 | 100,000<br>MW-3, 1/96 | Xylenes | 12 | 0.045 | 160,000<br>MW-3, 5/92 | 16,000<br>MW-3, 1/96 |
| TPH (Diesel) | 210<br>WO1@5' | 160<br>EB6@10' | 2,400,000<br>MW-3, 1/96 | 5,300<br>MW-3, 1/96 | Oil & Grease | 7,800<br>EB6@5' | 850 | 880,000 | NA |
| Benzene | 0.72<br>P6@5' | 0.12<br>EB5@20' | 5,100<br>MW-3, 5/92 | 950<br>MW-3, 1/96 | PCE | NA | NA | 4.8<br>MW-1, 11/90 | 120<br>MW-9, 4/98 |
| Toluene | 3.3 | 0.040 | 66,000<br>MW-3, 5/92 | 3,300<br>MW-3, 1/96 | MTBE (8260) | NA | NA | NA | 6.4<br>MW-9, 4/99 |
| Ethylbenzene | 1.8 | 0.062 | 20,000<br>MW-3, 5/92 | 2,500<br>MW-3, 1/96 | Heavy Metal | NA | NA | NA | NA |

**Comments (Depth of Remediation, etc.):**

1. **Impacted soil was limited to vicinity of former USTs, product lines, and boring EB-6. Impacted soil was excavated** in 10/95. Dissolved fuel hydrocarbons appear restricted to the vicinity of well MW-3. Downgradient of the site dissolved fuel hydrocarbons (TPHg, BTEX compounds) are delineated by wells MW-8 and MW-9, and upgradient by well MW-7. MTBE is detected in well MW-3 (middle of the plume) and MW-9 (downgradient edge of plume).

2. The PCE detected in groundwater comes from a former dry cleaners located upgradient of the former Unocal station. PCE impact has been documented at the former dry cleaners, and from the regional Caterpillar solvent plume. A September 20, 1996 letter from the State Division of Clean Water Programs indicates that the solvent tank at the former cleaners was transferred to the City of San Leandro for further oversight, while the petroleum tank problem at the former Unocal station remained under Alameda County oversight. This information was discussed with Mr. Chuck Headlee of the Regional Water Quality Control Board on January 9, 2001. Mr. Headlee indicated that because of the confirmed upgradient PCE source, sampling soil at the former Unocal site for PCE was not necessary.

3. Concentrations of hydrocarbons listed in the "After" column above reflect the highest concentrations reported for groundwater samples after completion of remedial activities (10/95). Groundwater at this site was monitored and

benzene, toluene, ethylbenzene, or xylenes were not detected at concentrations above the laboratory reporting limits in any of the wells sampled (MW-3, MW-7, MW-8 or MW-9). MTBE was not reported in wells MW-8 or MW-9. MTBE by EPA Method 8020 was reported in wells MW-3 (135 ppb) and MW-7 (6.10 ppb), but EPA Method 8260 confirmation of these results was not performed. The wells were last analyzed for MTBE by EPA Method 8260 in April 1999. At that time, MTBE was confirmed only in wells MW-3 (4.7 ppb) and MW-9 (6.4 ppb). Wells MW-1, MW-2, MW-4, MW-5 and MW-7 were destroyed in January 1995 to accommodate remedial activities.

## IV. CLOSURE

| | | |
|---|---|---|
| Does completed corrective action protect existing beneficial uses per the Regional Board Basin Plan? Yes | | |
| Does completed corrective action protect potential beneficial uses per the Regional Board Basin Plan? Yes | | |
| Does corrective action protect public health for current land use? Yes | | |
| Site Management Requirements: None | | |
| | | |
| Monitoring Wells Decommissioned: Yes | Number Decommissioned: 5 | Number Retained: 4 |
| List Enforcement Actions Taken: None | | |
| | | |
| List Enforcement Actions Rescinded: NA | | |
| | | |

## V. TECHNICAL REPORTS, CORRESPONDENCE ETC., THAT THIS CLOSURE RECOMMENDATION WAS BASED UPON

| Title: | Date: |
|---|---|
| Preliminary Subsurface Investigation (KEI #P88-1204.R1) | 2/3/89 |
| Preliminary Ground Water Investigation (KEI #P88-1204.R2) | 5/16/89 |
| Stockpiled Soil Sampling (KEI #P88-1204.R3) | 6/19/89 |
| Soil Sampling Report (KEI #J88-1204.R4) | 6/15/89 |
| Ground Water Investigation (KEI #P88-1204.QR1) | 9/27/89 |
| Report of Subsurface Environmental Conditions, 1335 to 1370 Davis Street, San Leandro (Hageman-Schank, Inc.) | 10/9/90 |
| Continuing Ground Water Investigation (KEI #P88-1204.R5) | 4/9/92 |
| Continuing Subsurface Investigation (KEI #P88-1204.R8) | 4/26/93 |
| Soil Sampling Report (KEI #P88-1204.R9) | 12/21/93 |
| Stockpiled Soil Sampling (KEI #P88-1204.R10) | 3/24/94 |
| Drill Cutting Sampling and Disposal Report (KEI #P88-1204.R12) | 2/13/95 |
| Drill Cutting Sampling and Disposal Report (KEI #P88-1204.R13) | 11/20/95 |
| Continuing Subsurface Investigation (KEI #P88-1204.R14) | 1/10/96 |
| First Quarter 2000 Groundwater Monitoring and Sampling Report (GR #280039) | 2/17/00 |

## VI. ADDITIONAL COMMENTS, DATA, ETC.

PLEASE INCLUDE/ATTACH THE FOLLOWING AS APPROPRIATE:

1) SITE MAP INDICATING TANK PIT LOCATION, MONITORING WELL LOCATION, GROUNDWATER GRADIENT, ETC.; AND,

2) SITE COMMENTS WORTHY OF NOTICE (E.G., AREA OF RESIDUAL POLLUTION LEFT IN PLACE, DEED NOTICES ETC.)

This document and the related CASE CLOSURE LETTER, shall be retained by the lead agency as part of the official site file.

KEI-P88-1204.R14
January 10, 1996

TABLE 4

SUMMARY OF LABORATORY ANALYSES
SOIL

| Sample Number | TPH as Diesel | TPH as Gasoline | Benzene | Toluene | Ethylbenzene | Xylenes | TOG |
|---|---|---|---|---|---|---|---|
| | | | (Collected on April 17, 1989) | | | | |
| MW1(5) | ND | 4.0 | ND | ND | ND | ND | ND |
| MW1(10) | ND | ND | ND | ND | ND | ND | ND |
| MW1(15) | ND | ND | ND | ND | ND | ND | ND |
| MW1(17) | ND | ND | ND | ND | ND | ND | 31 |
| MW2(5)* | ND | ND | ND | ND | ND | ND | 31 |
| MW2(10)* | ND | 1.1 | ND | ND | ND | ND | 60 |
| MW2(15)* | ND | ND | ND | ND | ND | ND | 71 |
| MW3(5) | ND | ND | ND | ND | ND | ND | ND |
| MW3(10) | ND | 1.1 | ND | ND | ND | ND | ND |
| MW3(15) | ND | 1.2 | ND | ND | ND | ND | 32 |
| MW3(17) | ND | 6.2 | ND | 0.21 | ND | 0.42 | 180 |
| | | | (Collected on August 16, 1989) | | | | |
| MW4(5) | -- | 3.3 | ND | ND | ND | 0.11 | ND |
| MW4(10) | -- | ND | ND | ND | ND | ND | ND |
| MW4(15) | -- | ND | ND | ND | ND | ND | ND |
| MW4(19) | -- | ND | ND | ND | ND | ND | ND |
| MW5(5) | -- | ND | MD | ND | ND | ND | ND |
| MW5(10) | -- | ND | ND | ND | ND | ND | ND |
| MW5(15) | -- | ND | ND | ND | ND | ND | ND |
| MW5(20) | -- | 20 | ND | ND | ND | ND | ND |
| MW5(22) | -- | ND | ND | ND | ND | ND | ND |
| MW6(5) | -- | ND | ND | ND | ND | ND | ND |
| MW6(10) | -- | ND | ND | ND | ND | ND | ND |
| MW6(15) | -- | ND | ND | ND | ND | ND | ND |
| MW6(20) | -- | ND | ND | ND | ND | ND | ND |

TABLE 4 (Continued)

SUMMARY OF LABORATORY ANALYSES
SOIL

| Sample Number | TPH as Diesel | TPH as Gasoline | Benzene | Toluene | Ethylbenzene | Xylenes | TOG |
|---|---|---|---|---|---|---|---|
| | | | (Collected on February 11, 1992) | | | | |
| MW7(5) | ND | ND | ND | ND | ND | ND | -- |
| MW7(9.5) | ND | ND | ND | ND | ND | ND | -- |
| MW7(15) | ND | ND | ND | ND | ND | ND | -- |
| MW7(16.5) | ND | ND | ND | ND | ND | ND | -- |

-- Indicates analysis not performed.

ND = Non-detectable.

* EPA method 8010 constituents were non-detectable.

Results are in milligrams per kilogram (mg/kg), unless otherwise indicated.

TABLE 5

SUMMARY OF LABORATORY ANALYSES
SOIL

| Sample Number | TPH as Diesel | TPH as Gasoline | Benzene | Toluene | Ethyl-benzene | Xylenes | TOG |
|---|---|---|---|---|---|---|---|
| | | | (Collected on January 3, 1989) | | | | |
| EB1(5)* | 5.0 | -- | ND | 0.05 | ND | ND | ND |
| EB1(10)* | 1.0 | -- | ND | ND | ND | ND | ND |
| EB1(15)* | 1.0 | -- | ND | ND | ND | ND | ND |
| EB1(25)* | 2.0 | -- | -- | -- | -- | -- | ND |
| EB2(10) | -- | ND | ND | ND | ND | ND | -- |
| EB2(15) | -- | ND | ND | ND | ND | ND | -- |
| EB2(20) | -- | ND | ND | ND | ND | ND | -- |
| EB2(25) | -- | 1.9 | ND | ND | ND | ND | -- |
| EB3(5) | -- | ND | ND | ND | ND | ND | -- |
| EB3(10) | -- | ND | ND | ND | ND | ND | -- |
| EB3(15) | -- | 2.7 | ND | ND | ND | ND | -- |
| EB3(20) | -- | 2.2 | ND | ND | ND | ND | -- |
| EB3(25) | -- | ND | ND | ND | ND | ND | -- |
| EB4(5) | -- | ND | ND | ND | ND | ND | -- |
| EB4(10) | -- | ND | ND | ND | ND | ND | -- |
| EB4(15) | -- | ND | ND | ND | ND | ND | -- |
| EB4(20) | -- | ND | ND | ND | ND | ND | -- |
| EB4(25) | -- | ND | ND | ND | ND | ND | -- |
| EB5(5) | -- | ND | ND | ND | ND | ND | -- |
| EB5(10) | -- | ND | ND | ND | ND | ND | -- |
| EB5(15) | -- | 2.0 | ND | ND | ND | ND | -- |
| EB5(20) | -- | 17 | 0.12 | 0.15 | 0.25 | 1.4 | -- |
| EB5(25) | -- | 3.9 | ND | ND | ND | 0.17 | -- |
| EB6(5) | 10 | 1.8 | ND | ND | ND | ND | 7,800 |
| EB6(10) | 160 | 73 | ND | ND | ND | ND | 1,200 |
| EB6(15) | 40 | 17 | 0.065 | ND | ND | 0.21 | 900 |
| EB6(25) | 3.0 | ND | ND | ND | ND | ND | 130 |

TABLE 5 (Continued)

SUMMARY OF LABORATORY ANALYSES
SOIL

| Sample Number | TPH as Diesel | TPH as Gasoline | Benzene | Toluene | Ethyl-benzene | Xylenes | TOG |
|---|---|---|---|---|---|---|---|
| **(Collected on March 22 and 23, 1993)** | | | | | | | |
| EB7(5)* | ND | ND | 0.018 | ND | ND | ND | ND |
| EB7(10)* | 1.3♦ | 3.2♦♦ | ND | ND | ND | ND | 140 |
| EB7(15)* | 6.4♦ | 17♦♦ | ND | 0.011 | 0.0090 | 0.025 | 340 |
| EB7(19.5)* | 3.5♦ | 4.4♦♦ | ND | ND | ND | ND | 80 |
| EB7(23.5)* | ND | ND | ND | ND | ND | ND | 60 |
| EB8(5)*+ | 12♦ | 50♦♦ | 0.020 | 0.040 | 0.062 | 0.045 | 1,700 |
| EB8(10)*+ | 1.2 | ND | ND | ND | ND | ND | ND |
| EB8(15)*+ | 7.6 | 5.0♦♦ | ND | ND | 0.015 | 0.0070 | ND |
| EB8(20)*+ | ND | ND | ND | ND | ND | ND | ND |
| EB8(23)*+ | ND | ND | ND | ND | ND | ND | ND |
| EB9(5)*+ | ND | ND | ND | ND | ND | ND | ND |
| EB9(10)*+ | ND | 2.0 | ND | ND | ND | ND | ND |
| EB9(14.5)*+ | ND | ND | ND | ND | ND | ND | ND |
| EB10(5)* | ND | ND | ND | ND | ND | ND | ND |
| EB10(9.5)* | ND | 1.6 | ND | ND | ND | ND | ND |
| EB10(15)* | ND | ND | ND | ND | ND | ND | ND |
| EB10(20)* | ND | ND | ND | ND | ND | ND | ND |
| EB10(23)* | ND | ND | ND | ND | ND | ND | ND |

**NOTE:** The soil samples were collected at the depths (below grade) indicated in the ( ) of the respective sample number.

* All EPA method 8010 constituents were non-detectable.
\+ TPH as Hydraulic Fluid was non-detectable, except in sample EB8(5), where it was detected at a concentration of 470 mg/kg.
♦ Sequoia Analytical Laboratory reported that the hydrocarbons detected appeared to be a diesel and non-diesel mixture.
♦♦ Sequoia Analytical Laboratory reported that the hydrocarbons detected appeared to be a gasoline and non-gasoline mixture.
ND = Non-detectable.
-- Indicates analysis was not performed.
Results are in milligrams per kilogram (mg/kg), unless otherwise indicated.

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TABLE 6

SUMMARY OF LABORATORY ANALYSES
WATER

| Sample Number | TPH as Diesel | TPH as Gasoline | Benzene | Toluene | Ethyl-benzene | Xylenes | TOG (mg/L) |
|---|---|---|---|---|---|---|---|
| | | | (Collected on January 3, 1989) | | | | |
| EB1 | ND | -- | ND | 3.5 | ND | ND | -- |
| EB2 | -- | ND | 8.2 | 7.4 | 0.67 | 3.3 | -- |
| EB3 | -- | ND | ND | ND | ND | ND | -- |
| EB4 | -- | ND | ND | ND | 0.73 | ND | -- |
| EB5 | -- | 340 | ND | ND | 0.63 | ND | -- |
| EB6 | -- | 1,500 | 1.5 | 1.4 | 8.1 | 12 | -- |
| | | | (Collected on March 22 and 23, 1993) | | | | |
| EB7* | 320++ | 1,000♦ | 19 | ND | 6.8 | ND | ND |
| EB8*+ | 120++ | 510♦♦ | ND | ND | ND | ND | ND |
| EB9*+ | 480++ | 2,600 | ND | 5.1 | 8.3 | 8.8 | ND |
| EB10 | *ND | 180♦♦ | ND | ND | ND | ND | ND |

* All EPA method 8010 constituents were non-detectable, except for tetrachloroethene, which was detected in samples EB9 and EB10 at concentrations of 12 µg/L and 250 µg/L, respectively. Trichloroethene was also detected in sample EB9 at a concentration of 0.63 µg/L.

\+ TPH as hydraulic fluid was non-detectable.

++ Sequoia Analytical Laboratory reported that the hydrocarbons detected appeared to be a diesel and non-diesel mixture.

♦ Sequoia Analytical Laboratory reported that the hydrocarbons detected appeared to be a gasoline and non-gasoline mixture.

♦♦ Sequoia Analytical Laboratory reported that the hydrocarbons detected did not appear to be gasoline.

ND = Non-detectable.

-- Indicates analysis was not performed.

Results are in micrograms per liter (µg/L), unless otherwise indicated.

TABLE 7

SUMMARY OF LABORATORY ANALYSES
SOIL

| Date | Sample | Depth (feet) | TOG | TPH as Diesel | EPA Method 8010 Constituents* | EPA Method 8270 Constituents* |
|---|---|---|---|---|---|---|
| 10/27/93 | A1(15.5) | 15.5 | 200 | 13♦ | ND | ND |
| | WO1(16.75) | 16.75 | ND | 6.7♦ | ND | ND |
| | WOSW1 | 15.0 | ND | ND | ND | ND |
| | WOSW2 | 15.0 | ND | ND | ND | ND |
| | WOSW3 | 15.0 | ND | ND | ND | ND |
| | SWA(4) | 15.5 | ND | -- | -- | -- |
| | SWB(3) | 15.0 | 450 | -- | -- | -- |
| | SWC(3) | 15.5 | 240 | -- | -- | -- |
| | SWD(3.5) | 15.5 | 460 | -- | -- | -- |
| 11/15/93 | SWBB | 15.5 | ND | -- | -- | -- |
| | SWCC | 15.5 | ND | -- | -- | -- |
| | SWDD | 15.5 | ND | -- | -- | -- |

♦ Sequoia Analytical Laboratory reported that the hydrocarbons detected appeared to be a diesel and non-diesel mixture.

* Results are in micrograms per kilogram (mg/kg), unless otherwise indicated.

ND = Non-detectable.

-- Indicates analysis was not performed.

Results are in milligrams per kilogram (mg/kg), unless otherwise indicated.

KEI-P88-1204.R14
January 10, 1996

TABLE 8

SUMMARY OF LABORATORY ANALYSES
SOIL

| Date | Sample | Depth (feet) | TPH as Gasoline | Benzene | Toluene | Ethyl-benzene | Xylenes |
|---|---|---|---|---|---|---|---|
| 10/27/93 | A1(15.5) | 15.5 | 17* | ND | 0.017 | 0.040 | 0.088 |
| | P6(11) | 11.0 | 270 | 0.71 | 12 | 6.3 | 38 |
| | WO1(16.75) | 16.75 | 2.6 | 0.0059 | 0.0063 | 0.013 | 0.0095 |
| | WOSW1 | 15.0 | ND | ND | ND | ND | ND |
| | WOSW2 | 15.0 | ND | ND | ND | ND | ND |
| | WOSW3 | 15.0 | ND | ND | ND | ND | ND |
| 11/15/93 | P6SW1 | 15.5 | ND | ND | ND | ND | ND |
| | P6SW2 | 15.5 | ND | ND | ND | ND | ND |
| | P6SW3 | 15.5 | ND | ND | ND | ND | 0.078 |
| | P6SW4 | 15.5 | ND | ND | ND | ND | ND |

* Sequoia Analytical Laboratory reported that the hydrocarbons detected did not appear to be gasoline.

ND = Non-detectable.

Results are in milligrams per kilogram (mg/kg), unless otherwise indicated.

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## TABLE 9

### SUMMARY OF LABORATORY ANALYSES
### WATER

| Date | Sample | Depth to Water (feet) | TPH as Diesel | TPH as Gasoline | Benzene | Toluene | Ethyl-benzene | Xylenes | TOG (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 11/10/93 | Water 1 | 16.5 | 410♦ | 1,500 | 67 | 10 | 33 | 45 | 7.4 |
| 11/19/93 | Water 2 | 16.0 | 3,200♦ | 2,500 | 68 | 370 | 87 | 560 | 6.3 |
| | Water 3 | 16.0 | -- | 11,000 | 120 | 19 | 870 | 2,700 | -- |

| Sample | Cadmium★ | Chromium★ | Lead★ | Nickel★ | Zinc★ | EPA Method 8270 Constituents | EPA Method 8010 Constituents |
|---|---|---|---|---|---|---|---|
| Water 1 | ND | 0.14 | 0.064 | 0.18 | 0.22 | ND* | ND*** |
| Water 2 | ND | ND | ND | ND | 0.035 | ND** | ND |

-- Indicates analysis was not performed.

ND = Non-detectable.

♦ Sequoia Analytical Laboratory reported that the hydrocarbons detected appeared to be a diesel and non-diesel mixture.

★ EPA method 8270 constituents were all non-detectable, except for 2-methylnaphthalene and naphthalene, which were detected at concentrations of 16 µg/L and 22 µg/L, respectively.

** EPA Method 8270 constituents were all non-detectable, except for 2,4-dimethylphenol and naphthalene, which were detected at concentrations of 110 µg/L and 2.2 µg/L, respectively.

TABLE 9 (Continued)

SUMMARY OF LABORATORY ANALYSES
WATER

*** All EPA method 8010 constituents were non-detectable, except for 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, 1,1-dichloroethane, 1,1-dichloroethene, tetrachloroethene, and 1,1,1-trichloroethane, which were detected at concentrations of 1.8 µg/L, 1.2 µg/L, 1.9 ppb, 24 µg/L 9.3 µg/L, 4.1 µg/L, and 24 µg/L, respectively.

★ Results in milligrams per liter (mg/L), unless otherwise indicated.

Results are in micrograms per liter (µg/L), unless otherwise indicated.

TABLE 10

SUMMARY OF LABORATORY ANALYSES
SOIL

| Date | Sample | Depth (feet) | TPH as Gasoline | Benzene | Toluene | Ethylbenzene | Xylenes | TOG |
|---|---|---|---|---|---|---|---|---|
| 7/28/92 | A1 | 14.0 | 23 | 0.078 | 0.093 | 0.061 | 0.16 | -- |
| | A2 | 14.0 | ND | ND | ND | ND | ND | -- |
| | B1 | 14.0 | 3.2 | 0.0056 | ND | ND | 0.023 | -- |
| | B2 | 14.0 | 8.4 | 0.0086 | 0.019 | 0.069 | 0.054 | -- |
| | P1 | 3.5 | ND | 0.013 | ND | ND | 0.0060 | -- |
| | P2 | 3.5 | 5.8 | 0.042 | 0.022 | 0.024 | 0.11 | -- |
| | P3 | 3.5 | ND | ND | 0.012 | ND | 0.025 | -- |
| | P4 | 3.5 | ND | ND | ND | ND | 0.0067 | -- |
| | P5 | 3.5 | 6.8 | ND | ND | 0.21 | 1.7 | -- |
| | P6 | 3.5 | 91 | 0.72 | 0.32 | 0.34 | 1.4 | -- |
| | WO1* | 10.0 | 150 | 0.61 | 3.3 | 1.8 | 12 | 3,00 |
| | WO1(15) | 15.0 | -- | -- | -- | -- | -- | 210 |

-- Indicates analysis was not performed.

ND = Non-detectable.

* EPA method 8010 constituents were all non-detectable, except for 1-1-Dichloroethane at 120 µg/kg, tetrachloroethene at 86 µg/kg, and 1,1,1-trichloroethane at 260 µg/kg. Cadmium, chromium, lead, nickel, and zinc were detected at concentrations of 0.95 mg/kg, 45 mg/kg, 5.8 mg/kg, 42 mg/kg, and 40 mg/kg, respectively. TPH as diesel was detected at a concentration of 210 mg/kg.

Results are in milligrams per kilogram (mg/kg), unless otherwise indicated.

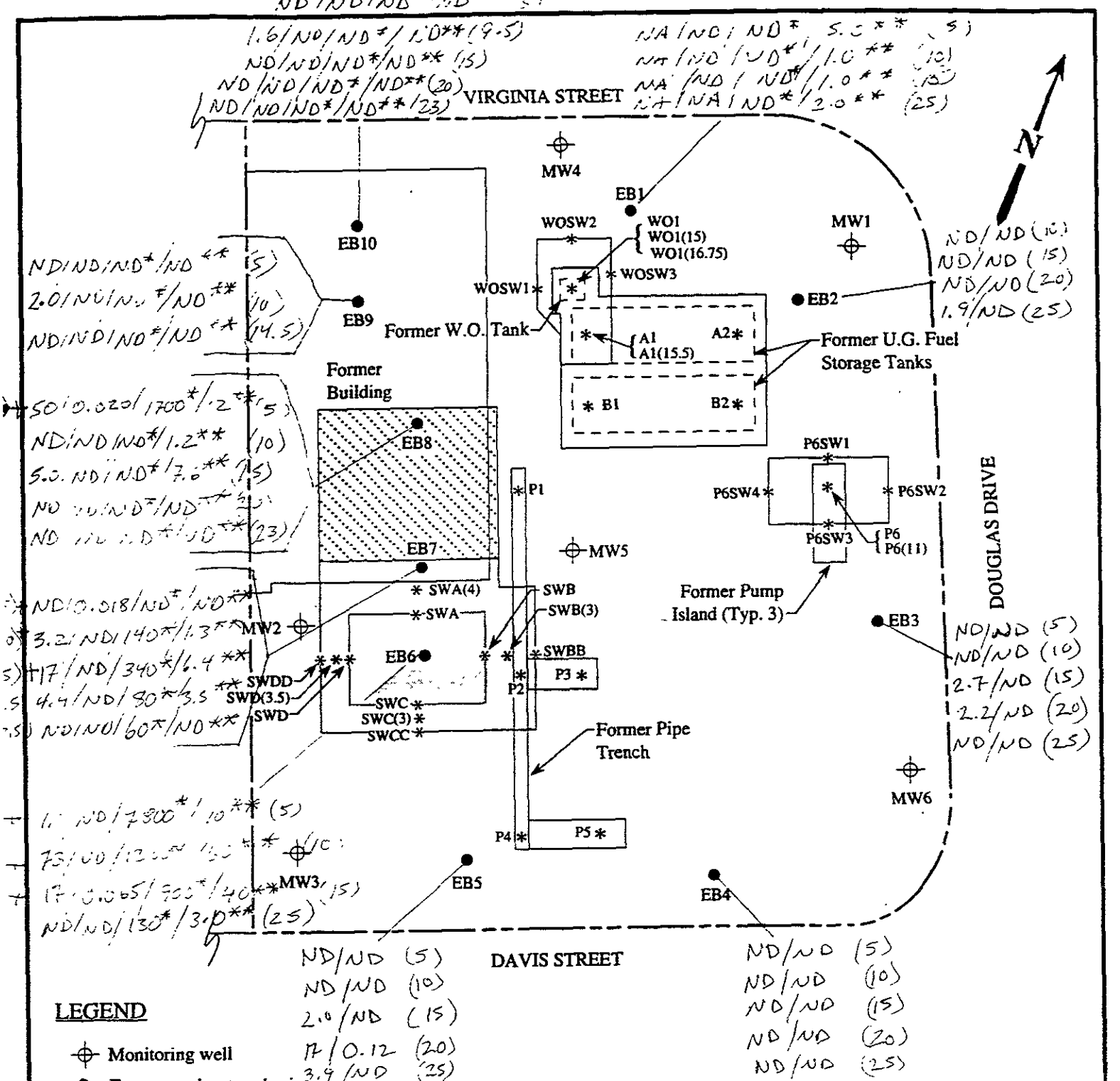
TABLE 11

SUMMARY OF LABORATORY ANALYSES
SOIL

| Sample Number | Depth (feet) | TPH as Diesel | TPH as Gasoline | Benzene | Toluene | Ethyl-benzene | Xylenes | TOG |
|---|---|---|---|---|---|---|---|---|
| | | | (Collected on May 11, 1989) | | | | | |
| SWA | 16.5 | 21 | -- | -- | -- | -- | -- | 850 |
| SWB | 16.5 | 18 | -- | -- | -- | -- | -- | 580 |
| SWC | 16.5 | 26 | -- | -- | -- | -- | -- | 680 |
| SWD | 16.5 | 16 | -- | -- | -- | -- | -- | 170 |

-- Indicates analysis was not performed.

Results are in milligrams per kilogram (mg/kg), unless otherwise indicated.



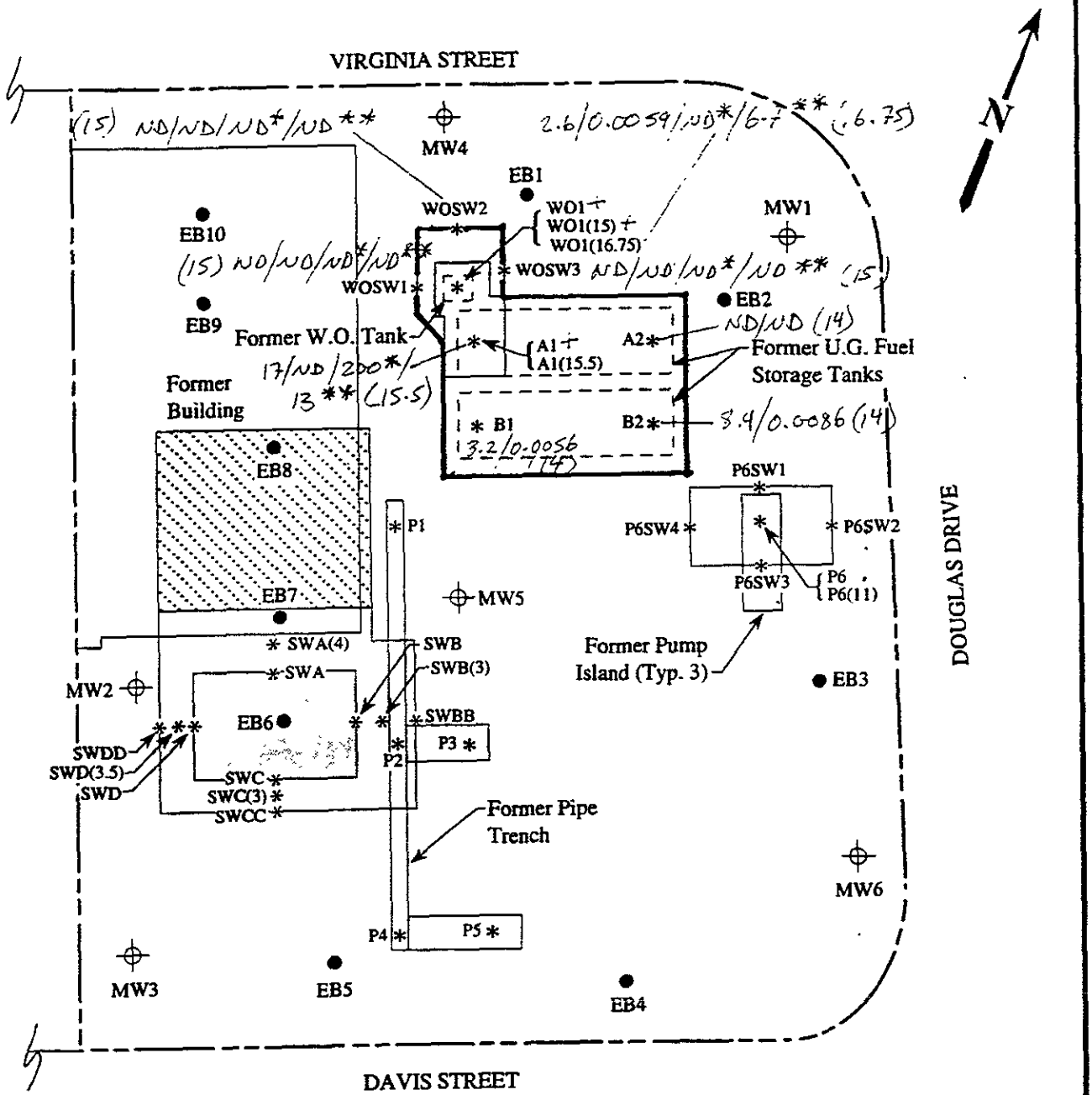

MONITORING WELL, BORING LOG, AND SAMPLE POINT LOCATION MAP

KAPREALIAN ENGINEERING INCORPORATED

UNOCAL SERVICE STATION #2512
1300 DAVIS STREET
SAN LEANDRO, CALIFORNIA

FIGURE 1

Concentrations Remaining in Place




## LEGEND

- Monitoring well
- Former exploratory boring
- * Sample point location
- Area excavated to a depth of about 17 feet below grade.
- Area excavated to a depth of about 7 feet below grade.
- Area of previous excavation (May 11, 1989)

TPHg/Benzene = Concentrations in ppm
(15) = Depth in feet
ND = None Detected
* = TOG in ppm
** = PID in ppm
+ = Sample excavated

0 20 40
Approx. scale feet

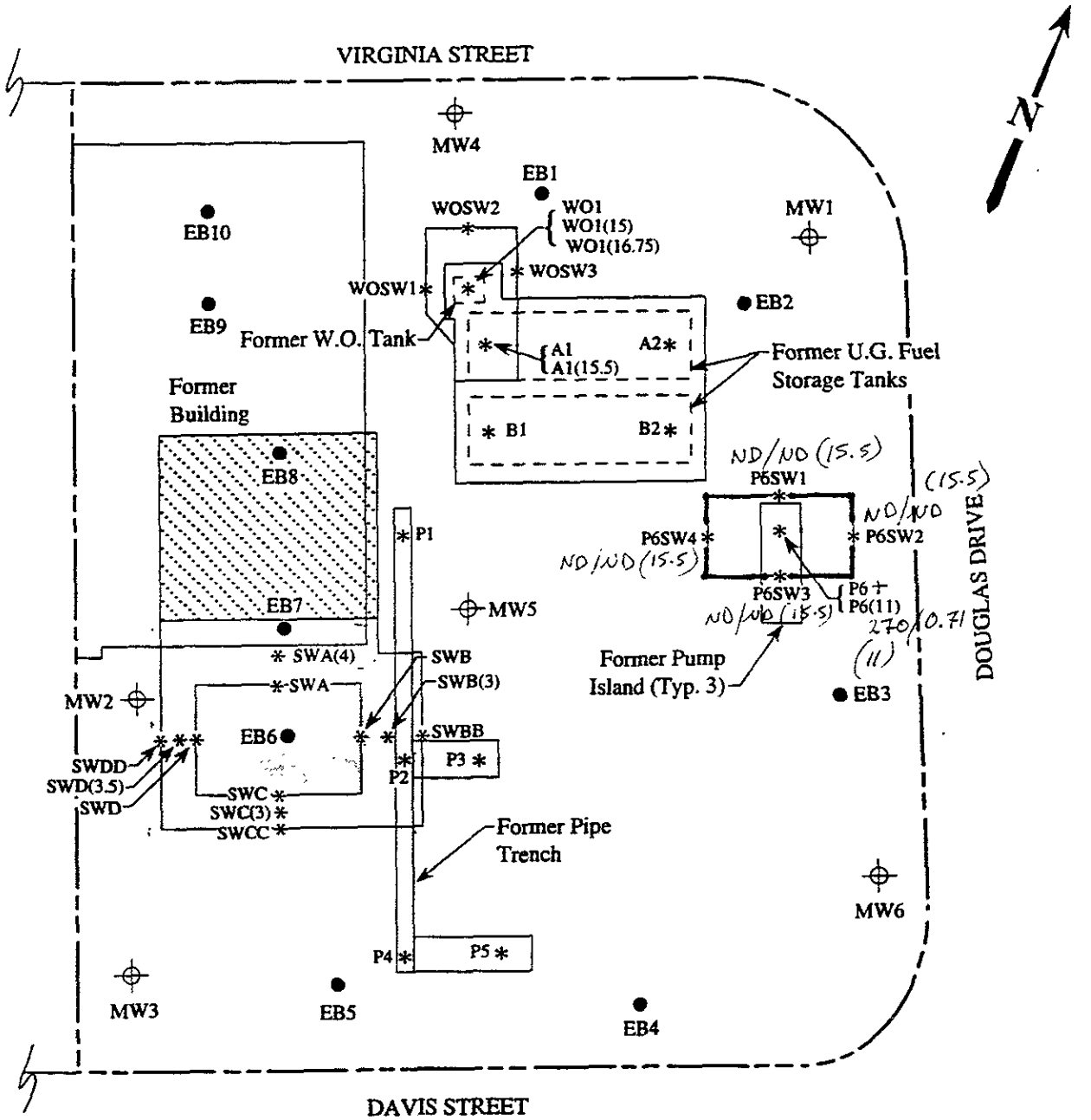
MONITORING WELL, BORING LOG, AND SAMPLE POINT LOCATION MAP

KAPREALIAN ENGINEERING INCORPORATED

UNOCAL SERVICE STATION #2512
1300 DAVIS STREET
SAN LEANDRO, CALIFORNIA

FIGURE 1

Concentrations Remaining in Place




## LEGEND

- Monitoring well
- Former exploratory boring
- * Sample point location
- Area excavated to a depth of about 17 feet below grade.
- Area excavated to a depth of about 7 feet below grade.
- Area of previous excavation (May 11, 1989)

TPHg/Benzene = Concentrations in ppm
(15) = Depth in feet
ND = None Detected
+ = Sample area excavated

0 20 40
Approx. scale feet

MONITORING WELL, BORING LOG, AND SAMPLE POINT LOCATION MAP

KAPREALIAN ENGINEERING INCORPORATED

UNOCAL SERVICE STATION #2512
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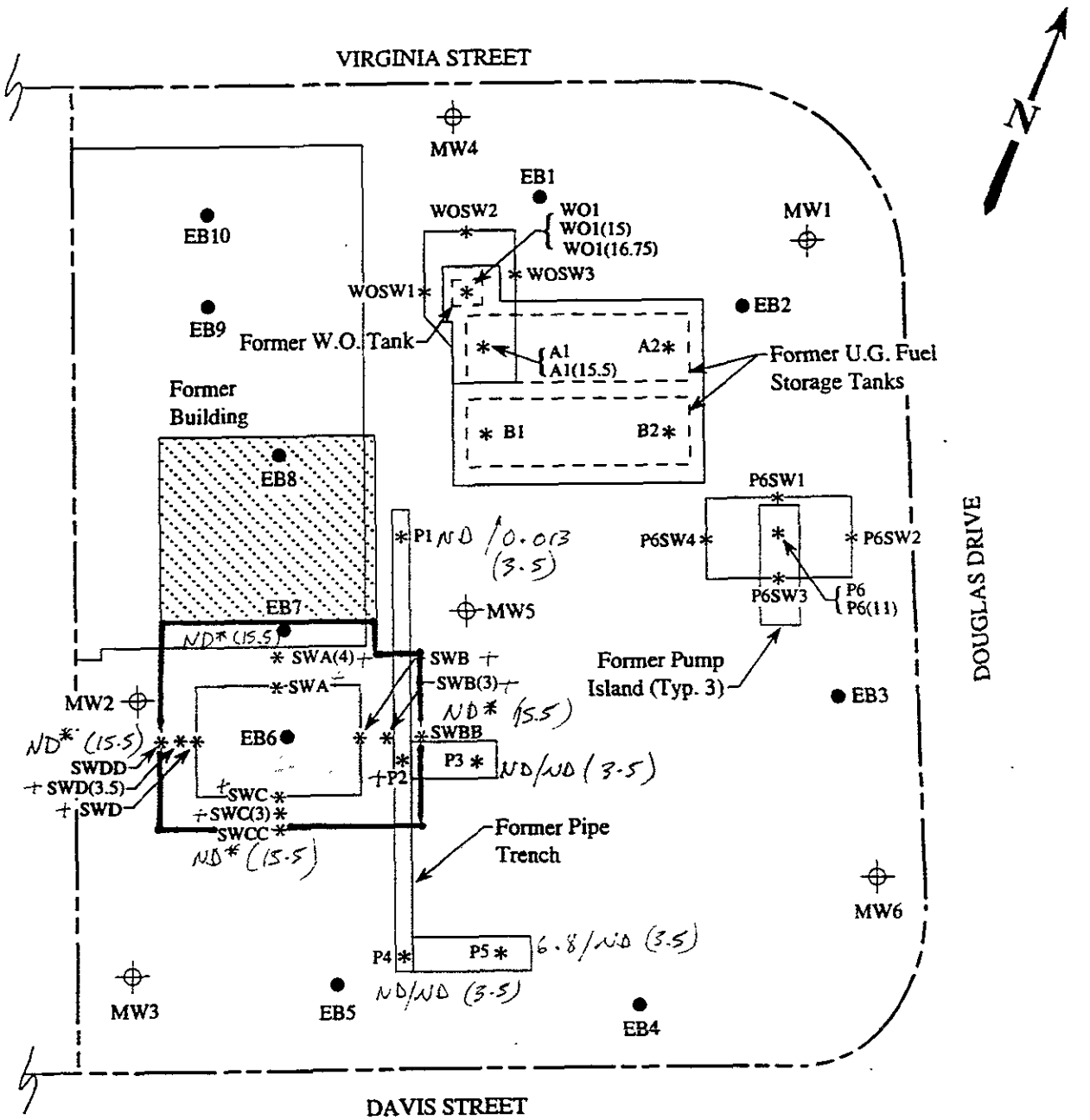
SAN LEANDRO, CALIFORNIA

FIGURE 1

Concentrations Remaining in Place




## LEGEND

- Monitoring well
- Former exploratory boring
- * Sample point location
- Area excavated to a depth of about 17 feet below grade.
- Area excavated to a depth of about 7 feet below grade.
- Area of previous excavation (May 11, 1989)

TPHg/Benzene = Concentrations in ppm
(15) = Depth in feet
ND = None Detected
** = TPHd in ppm
+ = TOG in ppm
+ = Sample Excavated

0 20 40
Approx. scale feet

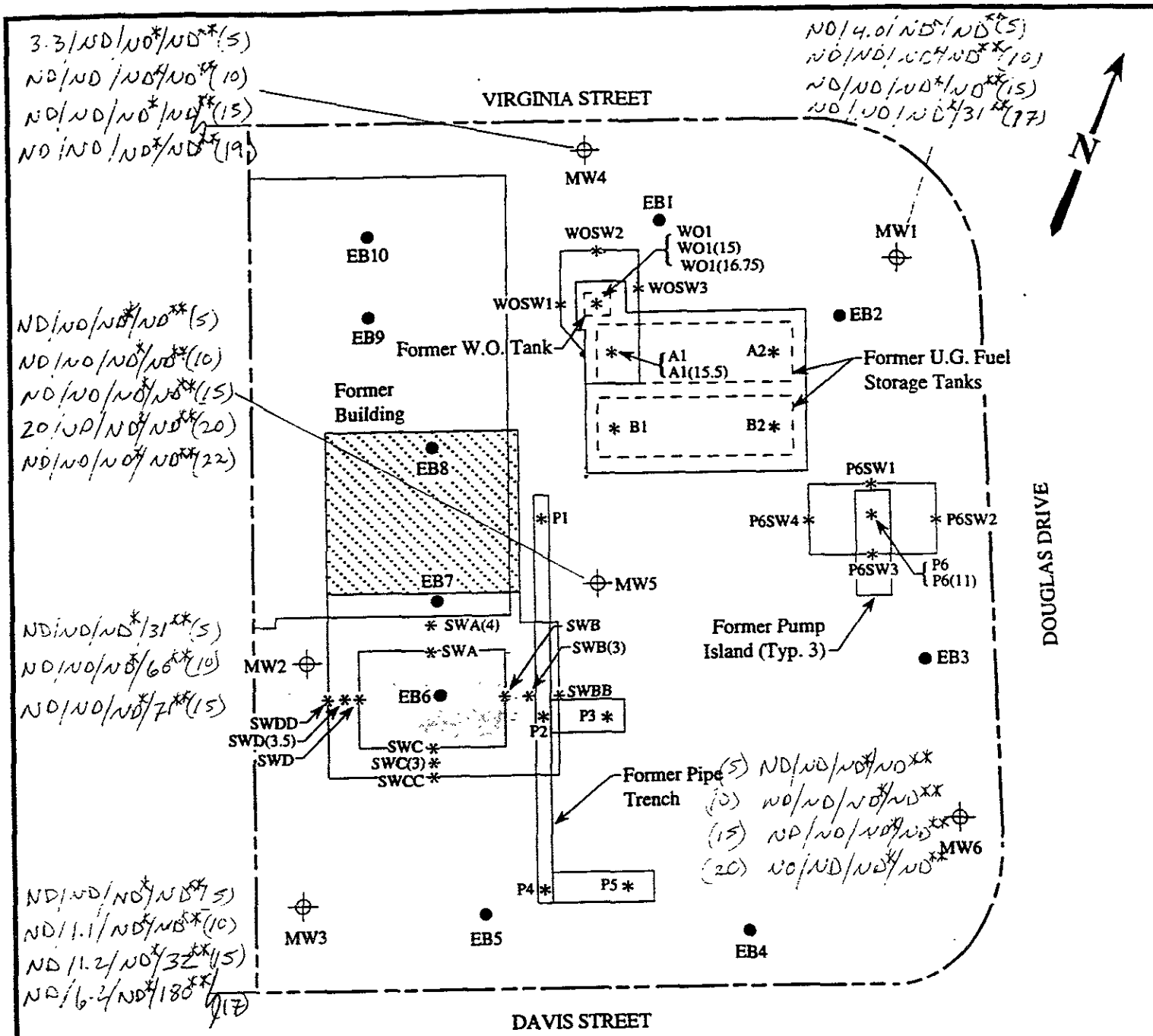
MONITORING WELL, BORING LOG, AND SAMPLE POINT LOCATION MAP

KAPREALIAN ENGINEERING INCORPORATED

UNOCAL SERVICE STATION #2512
1300 DAVIS STREET
SAN LEANDRO, CALIFORNIA

FIGURE 1

Concentrations Remaining in Place




## LEGEND

- Monitoring well
- Former exploratory boring
- Sample point location
- Area excavated to a depth of about 17 feet below grade.
- Area excavated to a depth of about 7 feet below grade.
- Area of previous excavation (May 11, 1989)

TPHg / Benzene = Concentrations in ppm
(15) = Depth in feet
ND = None detected
** = TPHd in ppm
* = TOG in ppm

0 20 40
Approx. scale feet

MONITORING WELL, BORING LOG, AND SAMPLE POINT LOCATION MAP

KAPREALIAN ENGINEERING INCORPORATED

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FIGURE 1