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RISK ASSESSMENT ADDENDUM REPORT

December 31, 1996

2099 Grand Avenue
Alameda, California

Prepared For:
Mr. Curt Bolton
Grand Marina

ACC Project No. 96-6176-1.2

OAKLAND ▪ SACRAMENTO
SEATTLE ▪ LOS ANGELES

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Alameda, California 94501

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1.0 INTRODUCTION

ACC Environmental Consultants, Inc., (ACC) prepared this Addendum to the draft Risk Assessment Report prepared by SECOR International, Inc., (SECOR), dated July 26, 1996, for the Grand Marina facility located at 2099 Grand Avenue, Alameda, California (Figure 1). The Risk Assessment prepared by SECOR included an evaluation of potential human health risk parameters for potential risk of the soil and groundwater impacted by previous site usage. This Risk Assessment Addendum was performed to document the rationale for requesting case closure of the site from the Alameda County Health Care Services Agency (ACHCSA) and from the Regional Water Quality Control Board (RWQCB), San Francisco Bay Region. This Addendum was performed according to the American Society for Testing and Materials (ASTM) *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (E 1739-95) and the United States Environmental Protection Agency's (USEPA) *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual* (USEPA, 1989a).

Based on ACC's conversations with Ms. Madhulla Logan at ACHCSA, soil and groundwater impact from the former gasoline underground storage tank (UST) needs to be evaluated for potential risks posed by onsite commercial workers inside existing Building G located nearest to the former UST. Figure 2 illustrates the locations of the former UST and Building G.

1.1 Background

The Grand Marina facility includes an office located at 2099 Grand Avenue with a marina and associated repair buildings. The 1,000-gallon UST formerly located in the southern portion of the site was used to store gasoline. In May 1988, Uriah, Inc., removed the UST from the property. An aboveground tank (AGT) farm was operated previously on the site and used until 1989. A series of subsurface investigations was conducted at the site regarding the UST and AGT farm. The historic site usage and previous investigation history are summarized in SECOR's report dated June 26, 1996.

Site investigations and remedial activities are under the jurisdiction of the ACHCSA and the RWQCB. Site investigation and remedial activities have been conducted at the site since 1988.

1.2 Purpose

The purpose of this risk assessment Addendum is to:

- identify the constituents of concern;

- provide an analysis of potential health risks to current and future receptors under a range of land use scenarios;

- identify release mechanisms such as wind erosion/vaporization, leaching/percolation, and others;

- determine what levels of constituents are appropriate to remain on site and still be protective of human health; and

- provide required documentation for site regulatory closure that will satisfy the requirements of the ACHCSA and the RWQCB.

1.3 Scope

The focus of this Risk Assessment Addendum is to evaluate potential human health risks associated with exposure to residual petroleum compounds detected in subsurface soil and groundwater in the immediate vicinity of the former UST for current workers located in Building G, located adjacent to the former UST location. This limited evaluation was requested by Ms. Madhulla Logan of ACHCSA. Site history, background data regarding previous investigations, and additional evaluations are presented in the report prepared by SECOR (June 26, 1996). All references regarding site-specific information can be referenced in SECOR's report. Only specific additional information regarding risk evaluation for the UST is included in this Addendum.

The scope is limited to an assessment of complete exposure pathways for Tier 1 Risk-Based Corrective Action (RBCA) using simple analytical models provided by ASTM (1995) and risk assessment techniques outlined by the USEPA (1989a) and using reasonable maximum exposure (RME) default assumptions provided in the ASTM Standard (E 1739-95) and the USEPA (1989a).

The area of focus for this Addendum is in the immediate area around the former UST, as presented on Figure 2. Soil and groundwater analytical results for samples collected from borings and wells adjacent to Building G were used to evaluate potential health and environmental risk. Boring locations used for risk evaluation include MW-2, MW-3, MW-4, MW-5a, MW-6a, TP-3A, borings performed by Zaccor (TP1 through TP8) and SECOR (TP-3), and two samples collected from the tank pit by Uriah. As requested by ACHCSA, the last five quarters of groundwater monitoring results were used for groundwater sample analytical results, however, available data was used for well wells MW-3 and MW-5a. A summary of laboratory results for benzene obtained from soil and groundwater samples collected in the area is presented in Appendix 1 and Appendix 2, respectively.

2.0 CHEMICALS OF POTENTIAL CONCERN

Subsurface soil and groundwater investigations have been conducted at this subject property with regard to the former UST since 1988. This Addendum assumes that the most recent site investigation data provided the most accurate representation of current conditions at the subject site. Data regarding subsurface soil conditions will be based on soil boring activity conducted in 1992 (Zaccor), 1994 (SECOR), and 1994 (ACC). The groundwater evaluation will be based on groundwater samples collected from wells MW-2, MW-4, and MW-6a for the past five quarters (from February 1995 through March 1996) and data collected from wells MW-3 and MW-5a.

Historically, soil and groundwater samples collected at the site have been analyzed for total petroleum hydrocarbons as gasoline (TPHg), benzene, toluene, ethylbenzene, and total xylenes (BTEX). Of these constituents, only benzene has been identified as a Class A carcinogen by the USEPA. Therefore, according to the ASTM *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (E1739-95), the use of TPHg as an individual constituent is not appropriate because "in general, TPH should not be used for 'individual constituent' risk assessments because the general measure of TPH provides insufficient information about the amounts of individual compounds present" (Appendix X1.5.4).

2.1 Identification of Chemicals of Potential Concern

The purpose of identifying a COPC is to focus the risk assessment of chemicals that contribute most significantly to potential risks existing at the subject property. The chemical of potential concern (COPC) has been identified as benzene. Concentrations of benzene at the subject property are compared with risk-based screening levels (RBSLs) to determine whether the risk posed at the evaluation area is due to the presence of this chemical that exceeds acceptable levels of risk. This Addendum assumes a level of risk equal to 1×10^{-5} (equivalent to one death per 100,000 exposed). This level of risk was chosen based on the current and potential future use of the area of concern as a commercial property and accepted practices by the RWQCB for potential risk at similar scenarios. ACC's Site Conceptual Model (SCM) identifies potentially complete exposure/receptor pathways for the area of evaluation (Figure 3).

The SCM makes the following assumptions:

- primary sources are subsurface soils;
- release mechanisms are wind erosion/vaporization leaching/percolation to upper groundwater,
- secondary sources are air vapors from wind erosion/vaporization and upper groundwater from leaching/percolation; and

- receptor/exposure routes are identified as inhalation and ingestion for onsite workers within Building G.

2.1.1 *Subsurface Soil COPC*

Tier 1 soil RBSLs have been calculated by ASTM for the following potential routes of exposure from chemicals in subsurface soil:

- indoor inhalation of vapor originating from soil beneath the building;
- outdoor inhalation of vapor originating from soil; and.
- ingestion of soil (which also considers dermal contact with soil and inhalation of airborne particles).

Table 2-1 presents a comparison of averaged detected concentrations of benzene in soil against Tier 1 RBSLs for these exposure pathways.

2.1.2 *Groundwater COPC*

Tier 1 groundwater RBSLs have been calculated by ASTM for the following potential routes of exposure from chemicals in groundwater:

- indoor inhalation of vapor originating from groundwater;
- outdoor inhalation of vapor originating from groundwater; and
- ingestion of groundwater.

Table 2-2 presents a comparison of averaged detected concentrations of benzene in groundwater against Tier 1 RBSLs for these exposure pathways.

3.0 EXPOSURE ASSESSMENT

The purpose of the exposure assessment is to estimate the type and magnitude of exposures to current and potential future receptors from the COPCs that are present at the area of evaluation and those COPCs that may be migrating from the site. The results of the exposure assessment are combined with chemical specific toxicity information (Section 4.0) to characterize potential risks (Section 5.0).

The exposure assessment consists of the following three components:

- characterize potentially exposed human populations (receptors) under expected land use conditions;
- identify actual or potential exposure pathways; and
- quantitatively determine the extent of exposure (quantitatively estimate relevant receptor point concentration using data, models, or combination and estimate the uptake of each chemical by each receptor for each route of exposure).

3.1 Characterization of Potentially Exposed Human Receptors

Potentially exposed human receptors are selected for evaluation under current and hypothetical future land use conditions. Land use at and surrounding the subject property is currently commercial/service and industrial. The current use of the subject property is commercial/industrial. There is no anticipated change in the current use of the subject property. Commercial/industrial land use is considered representative of future conditions.

Because of current and anticipated land use conditions, onsite exposures will be limited to onsite worker exposures. The onsite worker is assumed to work indoors at the same location for a period of 8 hours per day (time), 5 days per week, 50 weeks per year (frequency), for a total of 25 years (duration).

The total area of evaluation for this Addendum is estimated to be 7,000 square feet (located in the immediate vicinity of the former UST) which is paved with asphalt or concrete. No landscaped areas exist within the area of evaluation; therefore, potential exposure through landscape work is not evaluated for this area

Potential risks to the onsite worker are conservatively estimated assuming current detected levels of benzene remain at a steady state. Biodegradation will not be considered.

3.2 Identification of Exposure Pathways

An exposure pathway describes a specific environmental pathway by which a receptor can be exposed to COPCs present at the subject property. Elements which comprise the pathway consist of:

- a primary chemical source (e.g., surface, subsurface soils);
- a secondary chemical source (e.g., groundwater, air vapors);
- a release mechanism (e.g., leaching, wind erosion/vaporization); and
- receptors and exposure routes (e.g., offsite worker, resident, and inhalation, ingestion).

Information concerning sources, release and transport mechanisms, locations of potential receptors, and potential exposure routes was used to develop a SCM for the subject property. The schematic model is Figure 3. The purpose of the SCM is to provide a framework for problem definition, identify exposure pathways that may result in human health risks, aid in identifying data gaps, and aid in identifying effective cleanup methodologies that target specific contaminant sources. The SCM was submitted to ACHCSA in the Draft Risk Assessment Report. The SCM was approved without comment by ACHCSA.

3.2.1 *Potentially Complete and Significant Exposure Pathways*

The SCM indicates the following exposure pathways are potentially complete and significant for the onsite worker. Other potential receptors are discussed in the SECOR report (June 26, 1996).

3.2.1.1 Identified Exposure Pathways for the Onsite Commercial Worker

The SCM indicates the onsite commercial worker may be exposed to benzene via the following exposure pathways:

- Inhalation of volatile organic compounds (VOCs) that emanate from subsurface soil to indoor air. This pathway was identified in the SCM as a potentially complete pathway. Exposure via this pathway is quantitatively evaluated in this risk assessment.
- Inhalation of VOCs that emanate from groundwater to indoor air. Benzene is present in groundwater and it may volatilize and the vapor could potentially migrate upward through the foundation of the onsite building. Exposure via this pathway is quantitatively evaluated in this risk assessment.

3.2.1.2 Incomplete Exposure Pathways

The SCM indicates the following exposure pathways are incomplete. These incomplete pathways are not addressed in the Risk Assessment Addendum.

- Ingestion and dermal contact with soil for the onsite worker. It is assumed that the onsite commercial worker is engaged in indoor activities. Exposure via this pathway is not expected.

- Ingestion and dermal contact with groundwater for the onsite worker. It is assumed that the onsite commercial worker is engaged in indoor activities and has access to public water supply; therefore, exposure via this pathway is not expected.

Downgradient exposure pathways were not evaluated for this Addendum. Evaluations for these and other potential receptors are discussed in the Draft Risk Assessment Report prepared by SECOR, dated June 26, 1996.

3.3 Quantification of Exposure

This section presents the mechanism to quantify exposure by estimating constituent concentrations at the exposure point and the magnitude of exposure or intake for each receptor.

3.3.1 Estimation of Exposure Point Concentrations

The exposure point concentration (EPC) is the estimated concentration of each constituent in each medium at the location of potential contact with a receptor. Development of EPCs includes an underlying assumption about the representativeness of the monitoring data. No physical, chemical, or biological processes that could result in the reduction of constituent concentrations over time were included in the estimation of EPCs. The EPC generally used in an intake calculation is the arithmetic average concentration for a constituent in the medium being evaluated. Because this average is derived from a limited data set, it is uncertain how accurately it represents the true average concentration at the subject property. USEPA guidance recommends using the 95 percent upper confidence limit (UCL) as the exposure point concentration for intake calculations. At the 95 percent UCL, all data are assumed to be normally distributed. Tables 3-1 and 3-2 calculate the 95 percent UCL for soil and groundwater concentrations, respectively.

If the calculated 95 percent UCL of a chemical in a medium specific data set exceeds the maximum concentrations detected in that data set, the USEPA recommends that the maximum detected concentration be selected as the EPC (USEPA, 1989a). Exceedence of the maximum concentration typically occurs when dilution effects have resulted in reporting of very high sample quantitation limits (nondetect values), or if there is a limited number of samples (less than 10).

EPCs for COPCs in groundwater are used in vapor phase migration models to estimate the concentration of site specific COPCs in enclosed space air. Tables 3-3 through 3-6 contain diffusion coefficient calculations and Tables 3-7 and 3-8 contain volatilization factor calculations based on ASTM 1995. Appendix 3 includes ASTM parameter definitions and values.

3.3.1.1 Enclosed Space Air Exposure Point Concentrations -Soil

To estimate the concentration of benzene in enclosed space air, the vapor phase migration model presented in ASTM E1739-95 is used. The model uses closed form analytical solutions for connective and diffusive transport of vapor phase chemicals in subsurface soil. The calculation of enclosed space air concentrations is performed in two steps: 1) deriving a site-specific and chemical specific volatilization factor, and 2) estimating enclosed space air concentrations from the calculated volatilization factor and subsurface soil concentrations.

Volatilization Factor Derivation

$$VF_{sesp}\left[\frac{mg/m^3-air}{mg/kg-soil}\right]=\frac{\dfrac{H\rho_s}{\left[\theta_{ws}+k_s\rho_s+H\theta_{as}\right]}\left[\dfrac{D_s^{eff}/L_s}{ERL_B}\right]}{1+\left[\dfrac{D_s^{eff}/L_s}{ERL_B}\right]+\left[\dfrac{D_s^{eff}/L_s}{\left(D_{crack}^{eff}/L_{crack}\right)\eta}\right]}\times 10^3\frac{cm^3-kg}{m^3-g}$$

Where:

VF_{sesp}	=	volatilization factor for groundwater to enclosed space vapors [(mg/m^3-air)/(mg/kg-soil)]
H	=	Henry's law constant (unitless)
ρ_s	=	soil bulk density (g-soil/cm^3 -soil)
θ_{ws}	=	volumetric water content in vadose zone soils (cm^3-H_20/cm^3-soil)
k_s	=	soil-water sorption coefficient (cm^3-H_20/g -soil)
θ_{as}	=	volumetric air content in vadose zone soils (cm^3-air/cm^3-soil)
D_s^{eff}	=	effective diffusion coefficient in soil based on vapor-phase concentration (cm^2/soil)
L_s	=	depth to subsurface soil surfaces (cm)
ER	=	enclosed space air exchange rate (1/s)
L_B	=	enclosed space volume/infiltration area ratio (cm)
D_{cracks}^{eff}	=	effective diffusion coefficient through foundation cracks
L_{crack}	=	enclosed space foundation or wall thickness (cm)
η	=	areal fraction of cracks in foundation/wall (cm^2-cracks/cm^2 -total area)

This model is based on the following assumptions:

- a constant dissolved chemical concentration in groundwater;
- equilibrium partitioning between dissolved chemicals in groundwater and chemical vapors at the groundwater table;
- steady-state vapor and liquid phase diffusion through the capillary fringe, vadose zone, and foundation cracks;
- no loss of chemical as it diffused toward ground surface (i.e., no biodegradation); and
- steady, well-mixed atmospheric dispersion of the emanating vapors within the enclosed space.

Soil-water sorption coefficient:

$$K_s = f_{oc} \times k_{oc}$$

K_s = soil-water sorption coefficient (cm^3-H_20/g -soil)
f_{oc} = fraction of organic carbon in soil (g-C/g-soil)
k_{oc} = carbon/water sorption coefficient (cm^3-H_20/g -C)

Enclosed Space Air Concentrations

Using the calculated volatilization factors for benzene, enclosed space air concentrations are estimated with the following algorithm:

$$C_{enclosed\ space\ air} = C_{soil} \times VF_{sesp}$$

Where:

$C_{enclosed\ space\ air}$ = chemical concentration in enclosed space air (mg/m^3)
C_{soil} = chemical concentration in groundwater (mg/L)
VF_{sesp} = chemical specific soil to enclosed space air volatilization factor [(mg/m^3-air)/mg/L-H_2O)]

Calculated enclosed space air concentrations of benzene from soil for the interior of Building G are presented in Table 3-9.

3 3.1 2 Enclosed Space Air Exposure Point Concentrations - Groundwater

To estimate the concentration of benzene in enclosed space air, the vapor-phase migration model presented in ASTM E1739-95 is used. The model uses closed form analytical solutions for connective and diffusive transport of vapor phase chemicals in groundwater. The calculation of enclosed space air concentrations is performed in two steps 1) deriving a site-specific and

chemical specific volatilization factor, and 2) estimating enclosed space air concentrations from the calculated volatilization factor and groundwater concentrations.

Volatilization Factor Derivation

$$VF_{wesp}\left[\frac{(mg/m^3 - air)}{mg/L - H_2O}\right] = \frac{H \times \left[\frac{D_{ws}^{eff} / L_{GW}}{ER \times L_B}\right]}{1 + \left[\frac{D_{ws}^{eff} / L_{GW}}{ER \times L_B}\right] + \left[\frac{D_{ws}^{eff} / L_{GW}}{D_{cracks}^{eff} / L_{crack} + n}\right]} \times 10^3 \frac{L}{m^3}$$

Where:

VF_{wesp}	=	volatilization factor for groundwater to enclosed space vapors [(mg/m^3-air)/(mg/L-H_2O)]
H	=	Henry's law constant (unitless)
D_{ws}^{eff}	=	effective diffusion coefficient between groundwater and soil surface
L_{GW}	=	depth to groundwater (cm)
ER	=	enclosed space air exchange rate (1/s)
LB	=	enclosed space volume/infiltration area ratio (cm)
D_{cracks}^{eff}	=	effective diffusion coefficient through foundation cracks
L_{crack}	=	enclosed space foundation or wall thickness (cm)
n	=	areal fraction of cracks in foundation/wall (cm^2-cracks/cm^2 -total area)

This model is based on the following assumptions:

- a constant dissolved chemical concentration in groundwater;
- equilibrium partitioning between dissolved chemicals in groundwater and chemical vapors at the groundwater table;
- steady-state vapor and liquid phase diffusion through the capillary fringe, vadose zone, and foundation cracks;
- no loss of chemical as it diffused toward ground surface (i.e., no biodegradation); and
- steady, well-mixed atmospheric dispersion of the emanating vapors within the enclosed space.

Enclosed Space Air Concentrations

Using the calculated volatilization factors for benzene, enclosed space air concentrations are estimated with the following algorithm.

$$C_{enclosed\ space\ air} = C_{groundwater} \times VF_{wesp}$$

Where:

$C_{enclosed\ space\ air}$ = chemical concentration in enclosed space air (mg/m^3)
$C_{groundwater}$ = chemical concentration in groundwater (mg/L)
VF_{wesp} = chemical specific groundwater to enclosed space air volatilization factor [$(mg/m^3\text{-air})/mg/L\text{-}H_2O$)]

Calculated enclosed space air concentrations of benzene from groundwater for the interior of Building G are presented in Table 3-10.

3.3.2 *Estimation of Chemical Intakes*

To assess the potential adverse health effects associated with benzene exposure at the subject property, the potential level of human exposure to benzene must be determined. The USEPA has published exposure algorithms for the calculation of chemical intake (USEPA, 1989a). In these algorithms, chemical intake is a function of the exposure point concentration of the target chemical, the receptor specific contact rate, exposure frequency, exposure duration, body weight, and averaging time. Chemical intakes are conservatively estimated using upper bound default exposure assumptions recommended by the USEPA. Upper bound exposure assumptions are chosen for these parameters so that the combination of all exposure variables results in a reasonable maximum exposure (RME) for the exposure pathway evaluated. The goal of the RME is to quantify the maximum exposure which is reasonably expected to occur at the subject property, not necessarily the worst possible exposure (USEPA, 1989a).

3.3.2.1 Inhalation of Benzene (Enclosed Space Air) Emanating from Soil

Inhalation of benzene in enclosed space air is a function of the enclosed space air concentration, the inhalation rate, and the time, frequency, and duration of exposure. Intake of benzene via this exposure pathway is evaluated for the onsite commercial worker as estimated with the following algorithm.

$$Intake(mg/kg-day) = \frac{C_A \times IR \times ET \times EF \times ED}{BW \times AT}$$

where

CA = Chemical concentration in indoor air (mg/m^3)
IR = Inhalation rate (m^3/hour)
ET = Exposure time (hour/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)

BW = Body weight (kg)
AT = Averaging time (days)

Enclosed-space air concentrations for benzene from soil are derived in Section 3.3.1.1. For the onsite commercial worker, the inhalation rate is assumed to be 0.83 m^3/hour (ASTM, 1995). It is conservatively assumed that exposure to the onsite commercial worker occurs 8 hours per day, 250 days per year, for 25 years. The averaging time for exposure to carcinogens is equivalent to the average lifetime (i.e., 70 years) expressed in days (25,550 days) regardless of the age of the receptor evaluated.

These exposure assumptions and the calculated chemical intake for the onsite commercial worker via inhalation of benzene in enclosed space air are presented in Table 3-11.

3.3.2.2 Inhalation of Benzene (Enclosed Space Air) Emanating from Groundwater

Chemical intake of benzene via inhalation of enclosed space air is a function of the enclosed space air concentration, the inhalation rate, the time, frequency and duration of exposure. Intake of benzene via this exposure pathway is evaluated for the onsite commercial worker and is estimated with the following algorithm.

$$Intake(mg/kg-day) = \frac{C_A \times IR \times ET \times EF \times ED}{BW \times AT}$$

where:

C_A = Chemical concentration in indoor air (mg/m^3)
IR = Inhalation rate (m^3/hour)
ET = Exposure time (hour/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

Enclosed space air concentrations for benzene are derived in Section 3.3.1.2. For the onsite, indoor commercial worker, the inhalation rate is assumed to be 0.83 m^3/hr (USEPA and ASTM). It is conservatively assumed that exposure to the onsite commercial worker occurs 8 hours per day, 250 days per year, for 25 years. The averaging time for exposure to carcinogens is equivalent to the average lifetime (i.e., 70 years) expressed in days (25,550 days) regardless of the age of the receptor evaluated

These exposure assumptions and the calculated chemical intake for the onsite commercial worker via inhalation of benzene in enclosed space air are presented in Table 3-12.

4.0 TOXICOLOGICAL ASSESSMENT

An assessment of the potential for COPCs at the site to cause adverse effects in exposed individuals is presented below. The means of quantifying toxicity is discussed below. Several numerical values can be used to describe the toxicity of a specific compound. As a broad first step, the effects of exposure to a specific compound are divided into two categories, carcinogenic and noncarcinogenic. Only carcinogenic constituents identified at the subject property are evaluated in this risk assessment.

4.1 Toxicity Information for Carcinogenic Effects

Carcinogens are constituents that cause or induce cancer. The USEPA Human Health Assessment Group uses a weight-of-evidence classification system to identity compounds as carcinogens. Information used in developing the classification includes: 1) evaluating the quality of data from human studies of the association between cancer incidence and exposure; 2) evaluating long-term animal studies; 3) combining the two types of studies to obtain an overall human carcinogenic weight-of-evidence; and 4) assessing all other types of information such as short-term tests for genotoxicity, metabolic and pharmacokinetic properties, and structure activity relationships to determine whether a modification of the weight-of-evidence is necessary. Five categories of carcinogens are used:

- Group A, Human Carcinogen. Sufficient information exists from human epidemiological studies to support a causal association between exposure and cancer.

- Group B, Probable Human Carcinogen. This includes compounds for which limited evidence of carcinogenicity in humans exists based on epidemiological studies and those compounds for which sufficient evidence of carcinogenicity in animals exists, but adequate evidence of carcinogenicity in humans is not available.

- Group C, Possible Human Carcinogen. This includes those compounds for which there is limited evidence of carcinogenicity in animals.

- Group D, Not Classifiable as to Human Carcinogenicity. This includes those compounds for which there is inadequate animal evidence of carcinogenicity.

- Group E, Evidence of Noncarcinogenicity in Humans. This includes compounds for which there is no evidence for carcinogenicity in at least two adequate animal tests in different species or in both adequate epidemiological and animal studies (USEPA, 1986a).

The toxicity value used to describe the dose/response relationship for carcinogenic effects is called the cancer slope factor (CSF). The slope factor is a plausible upper-bound estimate of the

probability of a carcinogenic response per unit intake of a chemical during a lifetime. Slope factors are expressed as the inverse of milligrams of chemical per kilogram of body weight per day $(mg/kg\text{-}day)^{-1}$ (see Table 4-1). As discussed, evidence of chemical carcinogenicity originates primarily from two sources: lifetime studies with animals and human (epidemiological) studies. Assumptions arise from the necessity of extrapolating experimental results across species (i.e., from laboratory animals to humans); from high-dose regions (i.e., levels to which laboratory animals are exposed) to low-dose regions (i.e., levels to which humans are likely to be exposed); and across routes of administration (e.g., inhalation versus ingestion).

For chemical carcinogens, the USEPA assumes a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and tumor induction. This mechanism for carcinogenesis is referred to as stochastic, which means that there is theoretically no level of exposure to a given chemical that does not pose a small, but finite probability of generating a carcinogenic response. Since risk at low exposure levels cannot be measured directly either in laboratory animals or human epidemiology studies, various mathematical models have been proposed to extrapolate from high to low dose (i.e., to estimate the dose/response relationship at low doses).

Regulatory decisions are based on the output of the linearized multistage model (USEPA, 1989a). The basis of the model is that multiple events may be needed to yield tumor induction (Crump, et al., 1977). The linearized model reflects the biological variability in tumor frequencies observed in animal or human studies. The dose/response relationship predicted by this model at low doses is usually linear. It should be noted that the slope factors calculated for chemical carcinogens using the multistage model represent the 95th percentile UCL on the probability of a carcinogenic response. Consequently, risk estimates based on these slope factors are conservative estimates representing upper bound estimates of risk where there is only a 5 percent probability that the actual risk is greater than the estimated risk.

4.2 Toxicity of Benzene

Benzene is highly toxic and exposure to acute levels can irritate mucous membranes, cause restlessness, convulsions, excitement, depression and even death from respiratory failure. Chronic levels of benzene can cause bone marrow depression or leukemia.

The lighter fractions of gasoline (BTEX constituents) are more mobile than other fractions. Benzene can therefore migrate or dissipate away from the main hydrocarbon plume; however, little migration away from the UST excavation has been noted at the subject site

5.0 RISK CHARACTERIZATION

Risk characterization combines the toxicity and exposure assessments to allow for an estimate of the risk at a specific site. Two methods are used to characterize risk. The first method evaluates chemicals with carcinogenic effects by estimating excess lifetime cancer risk. The second method evaluates chemicals with noncarcinogenic effects (USEPA 1989a). In accordance with the approved SCM for the subject property, noncarcinogenic effects are not evaluated in this risk assessment.

5.1 Estimated Lifetime Excess Cancer Risk

Risks are estimated as probabilities for constituents which elicit a carcinogenic response. The excess lifetime cancer risk is the incremental increase in the probability of getting cancer compared with the background probability or that with no exposure to site constituents. A risk of 1×10^{-6}, for example, represents the probability that one person in one million persons exposed to a carcinogen over a lifetime (70 years) will develop cancer. Estimates of risk using the slope factors developed by the USEPA are generally upper bound estimates; actual risks at a specific site would not be greater than the risks estimated in this assessment and are likely to be much lower, even zero.

Risk from chemicals with potential carcinogenic effects are estimated using the following equation:

$$R = 1\text{-}\exp^{(SF \times LDCI)}$$

Where:

R	=	Excess lifetime cancer risk (probability)
exp	=	Base of natural logarithm (2.71828)
SF	=	Slope factor $(mg/kg/day)^{-1}$ from linearized model
LDCI	=	Lifetime daily chemical intake (mg/kg/day)

For low intakes where the estimated cancer risk is lower than 10^{-2}, it can be assumed that the dose/response relationship will be linear, and the equation becomes:

$$R = SF \times LDCI$$

CSFs are used to determine the potential risk associated with exposure to individual COPCs. The CSF is multiplied by the chronic daily intake averaged over 70 years to estimate the risk excess lifetime cancer incidence

Based on regulatory guidelines, it is appropriate to combine risk estimated across exposure pathways if the exposure to a particular pathway is not exclusive of other pathways. Excess lifetime cancer risks are summed by exposure pathway. In addition, the total excess lifetime cancer risk is estimated by summing all the risks from all exposure pathways (USEPA, 1989a).

5.2 Summary of Potential Cancer Risk

This section summarizes the cancer risk estimates for the onsite commercial worker.

5.2.1 *Onsite Commercial Worker*

Tables 5-1 and 5-2 present the excess cancer risks estimated for the onsite commercial worker from benzene concentrations in subsurface soil and groundwater, respectively, in Building G at the subject site. The total excess cancer risk for the onsite commercial worker is 3.6E-06 (Table 5-3). This risk level is below the excess cancer risk of 1E-05 as is typically acceptable for commercial/industrial sites.

6.0 UNCERTAINTIES

Quantitative risk estimates derived in this assessment are conditional estimates that include a number of assumption about land use, exposures and toxicity. None of the risk estimates can be separated from these assumptions or the uncertainties inherent in the numerical values of the parameters used to calculate them. The calculated cancer risks are contingent on the assumptions and parameter assignments made in deriving them and should not be interpreted as "true" risks. Uncertainties associated with each step in the risk assessment process and their potential effect on the numerical risk estimates are discussed below.

6.1 Uncertainties Associated with Data Evaluation and COPC Selection

Uncertainties are associated with the collection, analysis and evaluation of environmental data. Environmental sampling may not have accurately characterized chemical concentrations. Sampling at discrete locations and at discrete times may not be fully representative of potential exposures. Sample locations were selected because the area was likely to be impacted. This would result in overestimates of risk from using these data as representative of the entire site. For environmental media with time varying chemical concentrations (i.e., organic concentrations in soil), long term exposure conditions may not be accurately characterized by a single point-in-time measurement. Estimated exposure point concentrations are subject to temporal variability and uncertainty. Risk calculated from these data could be overestimated or underestimated.

The procedures used to analyze chemicals in environmental media may have introduced errors. A series of samples (laboratory blanks, system blanks, etc.) are designed to detect errors introduced in this manner. These data were not reviewed for this assessment. This assessment assumes all data are of acceptable quality. This assumption can introduce uncertainty into the resulting risk estimates.

6.2 Uncertainties Associated with Exposure Assessment

A number of uncertainties are associated with the exposure assessment, such as exposure point concentrations and the assumptions used to estimate chemical intake in the exposure assessment.

6.2.1 *Vapor Transport Model*

The vapor transport model assumes that the groundwater concentration of benzene beneath the building is uniform. The model further assumes that vapors enter a structure primarily through cracks and openings in the foundation floor. The model assumes that the indoor air exchange mechanism is the only means of dilution of chemicals in air. Chemical biodegradation is not considered in this model. Default values presented in ASTM were used to determine vapor

transport model inputs for building floor area and ventilation rates. This default may not be representative of actual building characteristics at the subject property.

6.2.2 *Chemical Intake*

For estimating chemical intake, there are uncertainties associated with standard exposure assumptions such as body weight, period exposed, life expectancy, population characteristics, and lifestyle. Assumptions made for these exposure parameters may not be representative of actual exposure scenarios associated with the subject property. It is assumed that the period of chemical intake is constant and representative of the exposed population. This assumption has the potential for overestimating exposure, as does the assumption that exposure occurs on a daily basis.

The data from the subject property were grouped to evaluate average area wide exposure conditions. Assumptions made for this grouping of data may not be representative of any actual exposure situation associated with the subject property.

6.3 Uncertainties Associated with Toxicity Assessment

Use of reference doses and cancer slope factors are subject to several types of uncertainties. Typically the studies from which these values are derived involve conditions that are not identical to the type of exposures of interest involving chemicals in the environment. Extrapolations from animal experiments are frequently required to derive a toxicity value for use in risk assessments. These extrapolations can include the following uncertainty:

- from high experimental doses to low doses for environmental exposures
- from animals used in experimental studies to humans
- from short term exposure to long term exposure
- from relatively homogenous experimental populations to individuals who can vary substantially in their individual dose/response reactions
- from continuos experimental doses to intermittent human exposures (e.g., through the use of calculated lifetime average exposure)

The methods used to derive slope factors and reference doses are intended to be conservative in recognition of these types of uncertainties. For carcinogens, a slope factor at the estimated 95 percent upper confidence limit is used. Carcinogenic slope factors assume no threshold for effects. If there are in fact thresholds for carcinogenicity, the slope factor could be altered considerably.

The overall quality of the toxicology database contains numerous uncertainties including:

- lack of consistency between different experimental studies
- small numbers of studies

- lack of available information on multiple species and multiple routes of administration
- lack of a demonstration of clear dose/response relationship
- lack of plausible biological mechanism of action
- lack of direct evidence of effects in humans

6.4 Uncertainties Associated with Risk Characterization

Potential risks were based on an assumed site wide average exposure. A number of limitations are associated with the risk characterization approach for carcinogens. For estimating potential excess cancer risk, the slope factor used to convert chemical intake averaged over a lifetime to incremental risk is often an upper 95th percentile confidence limit of the probability of response. In addition, slope factors derived from animal data will be given the same weight as slope factors derived from human data. These factors may contribute to an overestimate of risk.

6.5 Summary of Risk Assessment Uncertainties

An analysis of the uncertainties associated with the risk assessment indicates that cancer health risk estimates are likely to overestimate actual risks posed the subject property COPCs. Although many factors can contribute to the potential for over- or underestimating risk, a mixture of conservative and upper bound input values were selected to estimate potential exposures. Compounding conservative and upper bound input values in the risk calculations result in reasonable, maximum, health-protective risk estimates. Actual risks are likely to be less.

7.0 SUMMARY AND CONCLUSIONS

The Tier 1 structure is the most conservative approach to estimating risk to human health and environment. Only the cleanup levels for inhalation of indoor air exceed the target RBSL; however, the estimated excess cancer risk (3.6E-06) to the onsite commercial worker is less than target risk level (1E-05). All other cleanup level estimates at 2099 Grand Avenue are well below allowable RBSLs for soil and groundwater. ACC believes that the risk to human health and environment is minimal to nonexistent because of the following:

- After evaluation, the only complete exposure pathways for benzene were from soil and groundwater to enclosed space (indoor) air.

- The conservatively calculated excess cancer risk to onsite commercial workers is significantly less than target risk levels.

8.0 REFERENCES

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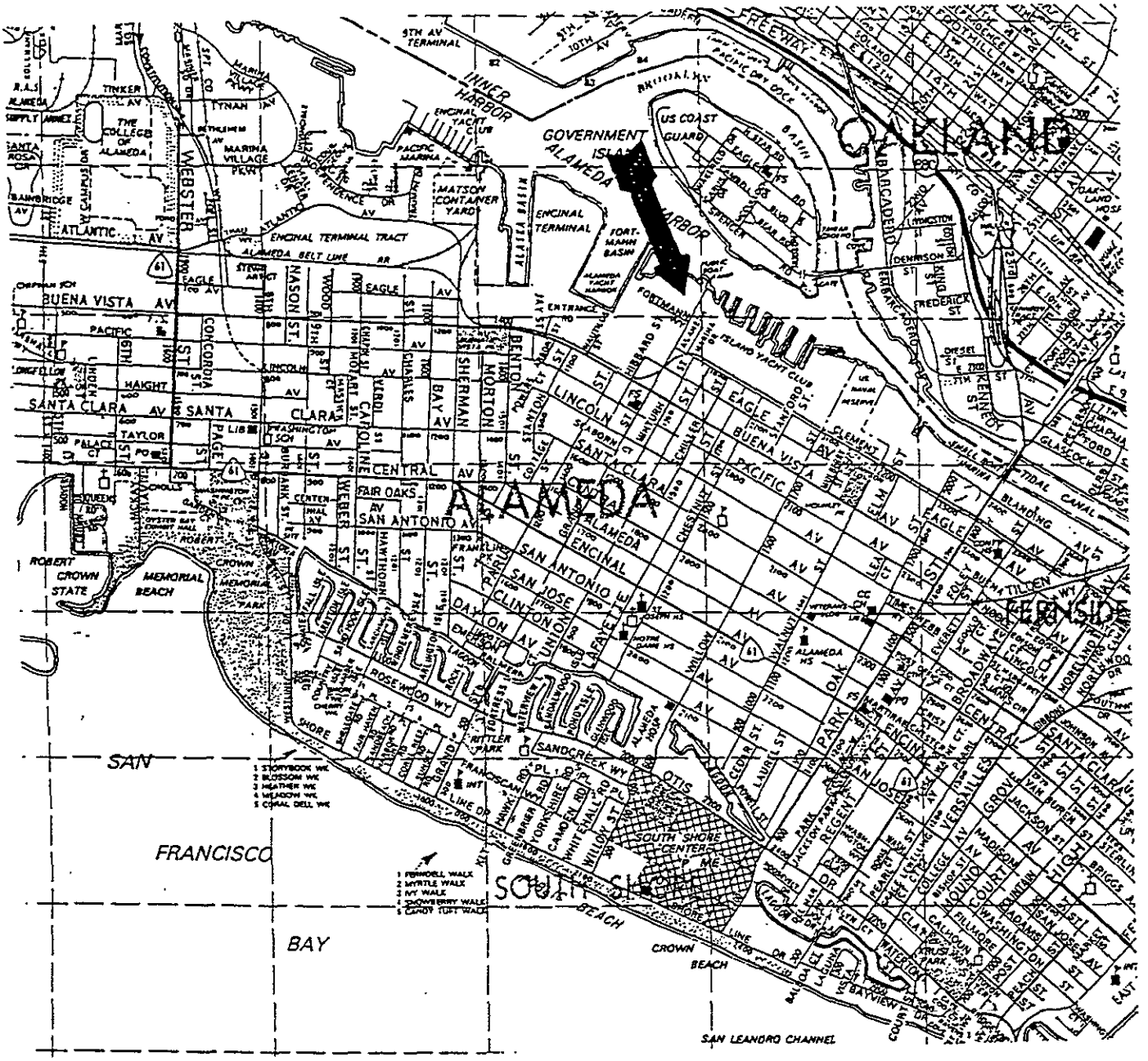

SOURCE: THOMAS BROTHERS GUIDE, 1990 ed.

Title:	**Location Map** 2099 Grand Street Alameda, California		
Figure Number	1.0	Scale	1" = 1/4 mi
Drawn By	MCR	Date	4/06/96
Project Number	6167-1.0		

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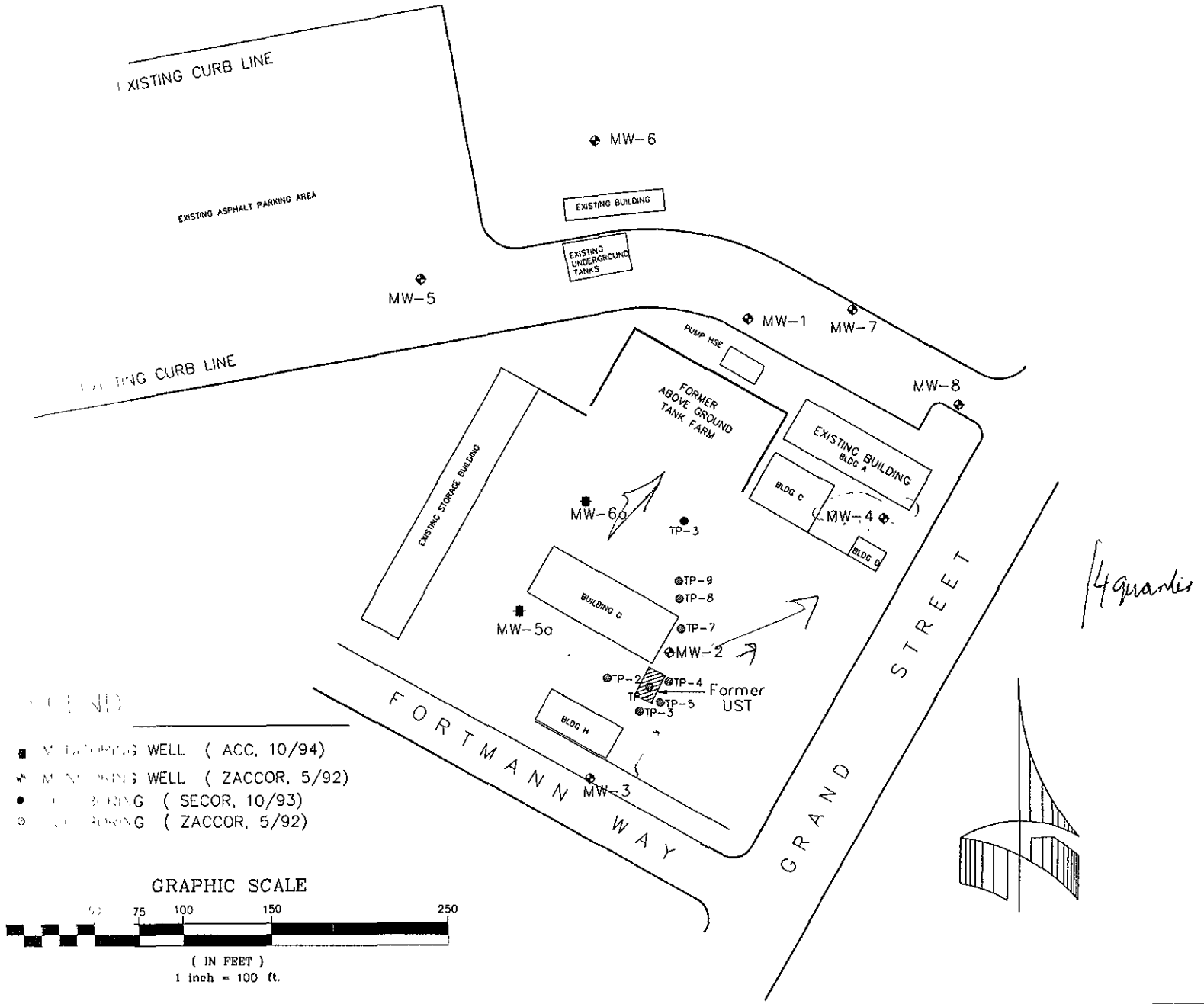

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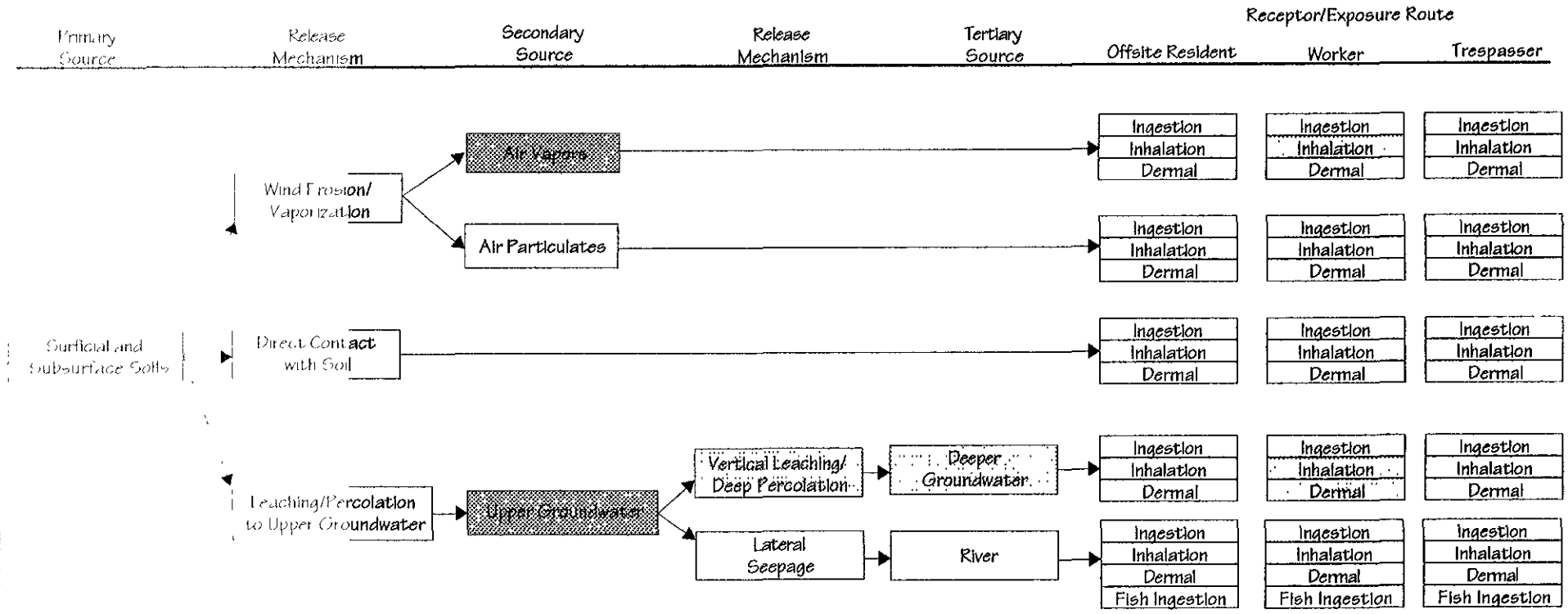
SITE PLAN

GRAND MARINA – 2099 GRAND STREET
ALAMEDA, CALIFORNIA

DATE
30 DEC. 96
DRAWN BY:
T. H.

SITE CONCEPTUAL MODEL FOR CURRENT CONDITIONS



Air Vapors — denotes exposure media

Inhalation — denotes potentially complete pathways

Inhalation — denotes incomplete pathways

Title: Site Conceptual Model 2099 Grand Avenue Alameda, California	
Figure 3	Project Number: 6176-1.2
Prepared By: MCR	Date: 12/31/96

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Table 2-1
Benzene Concentrations in Soil Versus Tier 1 RBSLs
Grand Marina
2099 Grand Avenue, Alameda, California

	Subsurface Soil (mg/kg)		
Route of Exposure	95% UCL Benzene Concentration in Soil	ASTM RBCA Tier 1 RBSL	Average Concentration Exceeds RBSL?
Indoor Inhalation of Vapor	0.25 mg/kg 2.5E-01	1.09E-01	YES
Outdoor Inhalation of Vapor	0.25 mg/kg 2.5E-01	4.57E+00	no
Ingestion of Soil	0.25 mg/kg 2.5E-01	5.78E-01	no

Table 2-2
Benzene Concentrations in Groundwater Versus Tier 1 RBSLs
Grand Marina
2099 Grand Avenue, Alameda, California

	Groundwater (mg/L)		
Route of Exposure	95% UCL Benzene Concentration in Groundwater	ASTM RBCA Tier 1 RBSL	Average Concentration Exceeds RBSL?
Indoor Inhalation of Vapor	74.70 µg/L 7.47-02 mg/L	7.39E-01	no
Outdoor Inhalation of Vapor	74.70 µg/L 7.47-02 mg/L	1.84E+2	no
Ingestion of Groundwater	74.70 µg/L 7.47-02 mg/L	9.87E-02	no

TABLE 3-1
BENZENE UCL FOR SOIL SAMPLES FROM AREA NEAR BUILDING G
Grand Marina
2099 Grand Avenue
Alameda, California

Sample Number-Depth in Feet	Date Sampled	Sample Result in mg/kg (x)	Deviation ($x-u=x_i$)	Deviation^2 or $(x_i)^2$
MW-2 4.0-4.5	1-92	0.24	0.234	0.05475600
MW-3 6.0-6.5	1-92	0.0025	-0.0035	0.00001225
TP1 4.0-4.5	5-92	0.0025	-0.0035	0.00001225
TP2 4.0-4.5	5-92	0.0025	-0.0035	0.00001225
TP3 4.0-4.5	5-92	0.15	0.144	0.02073600
TP5 4.0-4.5	5-92	0.0025	-0.0035	0.00001225
TP6 4.0-4.5	5-92	0.0025	-0.0035	0.00001225
TP7 4.0-4.5	5-92	0.0025	-0.0035	0.00001225
TP8 4.0-4.5	5-92	0.0025	-0.0035	0.00001225
TP9 4.0-4.5	5-92	0.0025	-0.0035	0.00001225
Tank Pit #1	5-92	0.0025	-0.0035	0.00001225
Tank Pit #2	5-92	0.0025	-0.0035	0.00001225
TP3-4	10-93	0.0025	-0.0035	0.00001225
MW-5A-3.5	10-94	0.0025	-0.0035	0.00001225
MW-5A-4.5	10-94	0.0025	-0.0035	0.00001225
MW-6A-3	10-94	0.0025	-0.0035	0.00001225
TP3A-2	10-94	2.5	2.5	6.22
		Sample Result (x)	Deviation ($x-u=x_i$)	Deviation^2 or $(x_i)^2$
SUM		2.9	2.82	6.30
MEAN (u)				0.006
STANDARD DEVIATION				0.61
90% UCL				0.20
95% UCL				0.25

Total number of samples. 17

For calculations, one-half the reporting limit value was used for those samples that contained no detectable concentrations of benzene

TABLE 3-2
BENZENE UCL FOR GROUNDWATER SAMPLES FROM AREA NEAR BUILDING G
Grand Marina
2099 Grand Avenue
Alameda, California

Sample Number	Date Sampled	Sample Result in µg/L (x)	Deviation ($x-u=x_i$)	Deviation^2 or $(x_i)^2$
MW-2	2-6-95	360	358.2	128,307.24
MW-2	5-9-95	550	548.2	300,523.24
MW-2	8-22-95	290	288.2	83,059.24
MW-2	12-7-95	190	188.2	35,419.24
MW-2	3-7-96	300	298.2	88,923.24
MW-3	11-3-94	0.25	-1.6	2.4025
MW-4	2-6-95	0.25	-1.6	2.4025
MW-4	5-9-95	0.25	-1.6	2.4025
MW-4	8-22-95	0.25	-1.6	2.4025
MW-4	12-7-95	0.25	-1.6	2.4025
MW-4	3-7-96	0.25	-1.6	2.4025
MW-5A	11-3-94	0.25	-1.6	2.4025
MW-5A	2-6-95	0.25	-1.6	2.4025
MW-6A	2-6-95	0.25	-1.6	2.4025
MW-6A	5-9-95	0.25	-1.6	2.4025
MW-6A	8-22-95	0.25	-1.6	2.4025
MW-6A	12-7-95	0.25	-1.6	2.4025
MW-6A	3-7-96	0.25	-1.6	2.4025
		Sample Result (x)	**Deviation ($x-u=x_i$)**	**Deviation^2 or $(x_i)^2$**
SUM		1,693.3	1,661	636,263.43
MEAN (u)				1 8
STANDARD DEVIATION				188.01
90% UCL				58 61
95% UCL				74 70

Total number of samples: 18

For calculations, one-half the reporting limit value was used for those samples that contained no detectable concentrations of benzene

Table 3-3
Effective Diffusion Coefficient in Soil Based on Vapor-Phase Concentration
Grand Marina
2099 Grand Avenue, Alameda, California

$$D_s^{eff}\left(cm^2/s\right)=\left[D_{air}\times\left(\frac{\theta_{as}^{3.33}}{\theta_T^2}\right)\right]+\left[\frac{D_{wat}}{H}\times\left(\frac{\theta_{ws}^{3.33}}{\theta_T^2}\right)\right]$$

Parameter	Value
D_{air}	0.093 cm^2/s
θ_{as}	0.26 cm^3-air/cm^3-soil
θ_T	0.38 cm^3/cm^3-soil
D_{wat}	1.1E-05 cm^2/s
H	0.22 cm^3 H_2O/cm^3-air
θ_{ws}	0.12 cm^3 H_2O/cm^3-soil

Therefore, D_s^{eff} = 7.26E-03 cm^2/s

Table 3-4
Effective Diffusion Coefficient Through Foundation
Grand Marina
2099 Grand Avenue, Alameda, California

$$D_{crack}^{eff}\left(cm^2/s\right)=\left[D_{air}\times\left(\frac{\theta_{acrack}^{3.33}}{\theta_T^2}\right)\right]+\left[\frac{D_{wat}}{H}\times\left(\frac{\theta_{wcrack}^{3.33}}{\theta_T^2}\right)\right]$$

Parameter	Value
D_{air}	0.093 cm^2/s
θ_{acrack}	0.26 cm^3-air/cm^3-soil
θ_T	0.38 cm^3/cm^3-soil
D_{wat}	1.1E-05 cm^2/s
H	0.22 cm^3 H_2O/cm^3-air
θ_{wcrack}	0.12 cm^3 H_2O/cm^3-soil

Therefore, D_{cracks}^{eff} = 7.26E-03 cm^2/s

Table 3-5
Effective Diffusion Coefficient Through Capillary Fringe
Grand Marina
2099 Grand Avenue, Alameda, California

$$D_{cap}^{eff}\left(cm^2/s\right)=\left[D_{air}\times\left(\frac{\theta_{acap}^{3.33}}{\theta_T^2}\right)\right]+\left[\frac{D_{wat}}{H}\times\left(\frac{\theta_{wcap}^{3.33}}{\theta_T^2}\right)\right]$$

Parameter	Value
D_{air}	0.093 cm^2/s
θ_{acap}	0.38 cm^3-air/cm^3-soil
θ_T	0.38 cm^3/cm^3-soil
D_{wat}	1.1E-05 cm^2/s
H	0.22 cm^3 H_2O/cm^3-air
θ_{wcap}	0.342 cm^3 H_2O/cm^3-soil

Therefore, D_{cap}^{eff} = 2.17E-05 cm^2/s

Table 3-6
Effective Diffusion Coefficient between Groundwater and Subsurface Soil
Grand Marina
2099 Grand Avenue, Alameda, California

$$D_{ws}^{eff}\left(cm^2/s\right)=\left(h_{cap}+h_v\right)\times\left[\left(\frac{h_{cap}}{D_{cap}^{eff}}\right)+\left(\frac{h_v}{D_s^{eff}}\right)\right]^{-1}$$

Parameter	Value
h_{cap}	5 cm
h_v	100 cm
D_{cap}^{eff}	2.7E-05 cm^2/s
D^{eff}	7.26-03 cm^2/s

Therefore, D_{ws}^{eff} = 4.3E-04 cm^2/s

Table 3-7
Volatilization Factor: Soil to Enclosed Space Air
Grand Marina
2099 Grand Avenue, Alameda, California

$$VF_{sesp}\left[\frac{mg/m^3-air}{mg/kg-soil}\right]=\frac{\dfrac{H\rho_s}{\left[\theta_{ws}+k_s\rho_s+H\theta_{as}\right]}\left[\dfrac{D_s^{eff}/L_s}{ERL_B}\right]}{1+\left[\dfrac{D_s^{eff}/L_s}{ERL_B}\right]+\left[\dfrac{D_s^{eff}/L_s}{\left(D_{crack}^{eff}/L_{crack}\right)\eta}\right]}\times 10^3\,\frac{cm^3-kg}{m^3-g}$$

Parameter	Value
H	0.22 cm^3 H_2O/cm^3-air
ρ_s	1.7 g/cm^3
θ_{ws}	0.12g/cm^3 ✓
k_s	cm^3-H_2O/g -soil
θ_{as}	0.26 cm^3-air/cm^3 ✓
D_s^{eff}	7.26-03 cm^2/s
ER	2.3E-04 s^{-1}
L_s	100 cm
L_B	300 cm
D_{cracks}^{eff}	7.26E-03 cm^2/s
L_{crack}	1.5E+01 cm
n	1.0E-02 cm^2-cracks/cm^2 -total area

34

Therefore, VF_{sesp} = 3.3E-04 (mg/m^3-air)/(mg/kg-soil)

× 10

Table 3-8
Volatilization Factor: Groundwater to Enclosed Space Air
Grand Marina
2099 Grand Avenue, Alameda, California

$$VF_{wesp}\left[\frac{(mg/m^3-air)}{mg/L-H_2O}\right]=\frac{H\times\left[\frac{D_{ws}^{eff}/L_{GW}}{ER\times L_B}\right]}{1+\left[\frac{D_{ws}^{eff}/L_{GW}}{ER\times L_B}\right]+\left[\frac{D_{ws}^{eff}/L_{GW}}{(D_{cracks}^{eff}/L_{crack})n}\right]}\times 10^3\frac{L}{m^3}$$

Parameter	Value
H	0.22 cm^3 H_2O/cm^3-air
D_{ws}^{eff}	4.3E-04 cm^2/s
L_{GW}	105 cm
ER	2.3E-04 s^{-1}
L_B	300 cm
D_{cracks}^{eff}	7.26E-03 cm^2/s
L_{crack}	1.5E+01 cm
n	1.0E-02 cm^2-cracks/cm^2 -tota

Therefore, VF_{wesp} = 7.2E-02 (mg/m^3-air)/(mg/L-H_2O)]

Table 3-9
Exposure Point Concentrations for Soil COPCs
Grand Marina
2099 Grand Avenue, Alameda, California

Chemical	Direct Soil Contact (mg/kg)	VF_{sesp} (mg/m^3-air)/ (mg/kg-soil)	Enclosed Air Concentration (mg/m^3) [1]
Benzene	2.5E-01	3.3E-04	8.25E-05

[1] Enclosed space air concentration calculated by multiplying groundwater concentration by appropriate volatilization factor (VF_{sesp}).

Table 3-10
Exposure Point Concentrations for Groundwater COPCs
Grand Marina
2099 Grand Avenue, Alameda, California

Chemical	Direct Groundwater Contact (mg/L)	VF_{wesp} (mg/m^3-air)/ ($mg/L\text{-}H_2O$)	Enclosed Air Concentration (mg/m^3) [1]
Benzene	7.47E-02	7.02E-02	5.2E-03

[1] Enclosed space air concentration calculated by multiplying groundwater concentration by appropriate volatilization factor (VF_{wesp}).

Table 3-11
Chemical Intake Exposure Assumptions Onsite Commercial Worker - Soil
Inhalation of Indoor Air
Grand Marina
2099 Grand Avenue, Alameda, California

$$Intake(mg/kg-day) = \frac{C_A \times IR \times ET \times EF \times ED}{BW \times AT}$$

Parameter			Onsite Commercial Worker Value
CA	=	Chemical concentration in air (mg/m^3)	8.25E-05 (see Table 3-9)
IR	=	Inhalation rate (m^3/hour)	0.83
ET	=	Exposure time (hour/day)	8
EF	=	Exposure frequency (days/year)	250
ED	=	Exposure duration (years)	25
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	25,550

Therefore, Intake for the onsite commercial worker = 1.9E-06 mg/kg-day

Table 3-12
Chemical Intake Exposure Assumptions Onsite Commercial Worker - Groundwater
Inhalation of Indoor Air
Grand Marina
2099 Grand Avenue, Alameda, California

$$Intake(mg/kg-day) = \frac{C_A \times IR \times ET \times EF \times ED}{BW \times AT}$$

Parameter			Onsite Commercial Worker Value
CA	=	Chemical concentration in air (mg/m^3)	5.2E-03 (see Table 3-10)
IR	=	Inhalation rate (m^3/hour)	0.83
ET	=	Exposure time (hour/day)	8
EF	=	Exposure frequency (days/year)	250
ED	=	Exposure duration (years)	25
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	25,550

Therefore, Intake for the onsite commercial worker = 1.2E-04 mg/kg-day

Table 4-1
Toxicity Values for Benzene
Grand Marina
2099 Grand Avenue, Alameda, California

Chemical	Carcinogenic Weight of Evidence	Inhalation Slope Factor (SF) $(mg/kg\text{-}day)^{-1}$	
		Value	Source
Benzene	A	2.9E-02	ASTM/USEPA

Table 5-1
Excess Cancer Risk Summary for Onsite Commercial Worker - Soil
Grand Marina
2099 Grand Avenue, Alameda, California

R = SF x LDCI

Parameter			Onsite, Indoor Commercial Worker Value
R	=	Excess lifetime cancer risk (probability)	5.5E-08
SF	=	Slope factor $(mg/kg/day)^{-1}$ for benzene from linearized model	2.9E0-2 (see Table 4-1)
LDCI	=	Lifetime daily chemical intake (mg/kg/day)	1.9E-06 (see Table 3-11)

Therefore, the excess lifetime cancer risk for the onsite, indoor commercial worker = 5.5E-08

Table 5-2
Excess Cancer Risk Summary for Onsite Commercial Worker - Groundwater
Grand Marina
2099 Grand Avenue, Alameda, California

R = SF x LDCI

Parameter			Onsite, Indoor Commercial Worker Value
R	=	Excess lifetime cancer risk (probability)	3.5E -06
SF	=	Slope factor $(mg/kg/day)^{-1}$ for benzene from linearized model	2.9E0-2 (see Table 4-1)
LDCI	=	Lifetime daily chemical intake (mg/kg/day)	1.2E-04 (see Table 3-12)

Therefore, the excess lifetime cancer risk for the onsite, indoor commercial worker = 3.5E-06

Table 5-3
Total Excess Cancer Risk Summary for Onsite Commercial Worker
Grand Marina
2099 Grand Avenue, Alameda, California

Worker/Pathway	Excess Lifetime Cancer Risk
Onsite Commercial Worker/soil	5.5E-08
Onsite Commercial Worker/groundwater	3.5E -06
Total	3.6E-06

SUMMARY OF SOIL SAMPLE ANALYTICAL RESULTS

APPENDIX 1
SOIL SAMPLE ANALYTICAL RESULTS
Grand Marina
2099 Grand Avenue, Alameda, California

Well ID	Date Sampled	Benzene (mg/kg)
MW-2 4.0-4.5	1-92	0.24
MW-3 6.0-6.5	1-92	<0.005
MW-4 10.0-10.5	1-92	<0.005
MW-5A 3.5	10-94	<0.005
MW-5A 4.5	10-94	<0.005
MW-6A 3	10-94	<0.005
TP1 4.0-4.5	5-92	<0.005
TP2 4.0-4.5	5-92	<0.005
TP3 4.0-4.5	5-92	0.15
TP3-4	5-92	<0.005
TP3A-2	10-94	<5.0
TP5 4.0-4.5	5-92	<0.005
TP6 4.0-4.5	5-92	<0.005
TP7 4.0-4.5	5-92	<0.005
TP8 4.0-4.5	5-92	<0.005
TP9 4.0-4.5	5-92	<0.005

Note mg/kg = milligrams per kilogram (approximately equal to parts per million)

SUMMARY OF GROUNDWATER SAMPLE ANALYTICAL RESULTS

APPENDIX 2
GROUNDWATER SAMPLE ANALYTICAL RESULTS
Grand Marina
2099 Grand Avenue, Alameda, California

Well No.	Date Sampled	TPHg (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethyl-benzene (µg/L)	Total Xylenes (µg/L)
MW2	02/06/95	1,900	360	230	20	100
	05/09/95	2,200	550	350	28	120
	08/22/95	2,100	290	120	11	37
	12/07/95	1,000	190	35	6.4	16
	03/07/96	770	300	150	7.6	31
MW3	11/3/94	<50	<0.50	<0.50	<0.50	<0.50
MW4	02/06/95	80	<0.5	<0.5	<0.5	<0.5
	05/09/95	<50	<0.5	<0.5	<0.5	<0.5
	08/22/95	<50	<0.5	<0.5	<0.5	<0.5
	12/07/95	<50	<0.5	<0.5	<0.5	<0.5
	03/07/96	<50	<0.5	<0.5	<0.5	<0.5
MW5a	11/3/94	<50	<0.50	<0.50	<0.50	<0.50
	2/6/95	<50	<0.50	<0.50	<0.50	<0.50
MW6a	02/06/95	<50	<0.5	<0.5	<0.5	2.5
	05/09/95	<50	<0.5	<0.5	<0.5	<0.5
	08/22/95	<50	<0.5	<0.5	<0.5	<0.5
	12/07/95	<50	<0.5	<0.5	<0.5	<0.5
	03/07/96	<50	<0.5	<0.5	<0.5	<0.5

ASTM PARAMETER DEFINITIONS

ASTM Parameter Definitions

Parameter	Definition, Units	Commercial/Industrial Value
d	lower depth of surficial soil zone, cm	100 cm
D^{air}	diffusion coefficient in air for benzene, cm^2/s	0.093 cm^2/s
D^{wat}	diffusion coefficient in water for benzene, cm^2/s	1.1E-05 cm^2/s
ER	enclosed-space air exchange rate, L/s	0.00023 s^{-1}
f_{oc}	fraction of organic carbon in soil, g-C/g-soil	0.01
H	henry's law constant (cm3-H_2O/cm^3-air)	0.22 L-H_2O/L-air
h_{cap}	thickness of capillary fringe	5 cm
h_v	thickness of vadose zone	100 cm (site specific)
I	infiltration rate of water through soil, cm/years	30 cm/year
k_{oc}	carbon-water sorption coefficient, cm^3-H_2O/g-C	38 L/kg
k_s	soil-water sorption coefficient, cm^3-H_2O/g-soil	0.38
L_B	enclosed-space volume/infiltration area ratio, cm	300 cm
L_{crack}	enclosed-space foundation or wall thickness, cm	15 cm
L_{GW}	depth to groundwater = $h_{cap} + h_v$, cm	105 cm (site specific)
L_s	depth to surface soils, cm	100 cm
S	pure component solubility in water, mg/l-H_2O	1750 mg/l-H_2O
SF	slope factor for benzene, kg-day/mg	0.029 kg-day/mg
U_{air}	wind speed above ground surface in ambient mixing zone	225 cm/s
U_{gw}	groundwater Darcy velocity, cm/year	2,500 cm/year
W	width of source area parallel to wind or groundwater flow direction	1,500 cm
δ_{air}	ambient air mixing zone height, cm	200 cm
δ_{gw}	groundwater mixing zone thickness, cm	200 cm
η	areal fraction of cracks in foundation/walls, cm^2-cracks/cm^2-total area	0.01 cm^2-cracks/cm^2-total area
θ_{acap}	volumetric air content in capillary fringe soils, cm^3-air/cm^3-soil	0.038 cm^3-air/cm^3-soil
θ_{acrack}	volumetric air content in foundation/wall cracks, cm^3-air/cm^3 total volume	0.26 cm^3-air/cm^3 total volume
θ_{as}	volumetric air content in vadose zone soils, cm3-air cm^3-soil	0.26 cm^3-air/cm^3-soil
θ_T	total soil porosity, cm^3/cm^3-soil	0.38 cm^3/cm^3-soil
θ_{wcap}	volumetric water content in capillary fringe soils, cm^3-H_2O/cm^3-soil	0.342 cm^3-H_2O/cm^3-soil
θ_{wcrack}	volumetric water content in foundation wall cracks, cm^3-H_2O/cm^3 total volume	0.12 cm^3-H_2O cm^3 total volume
θ_{ws}	volumetric water content in vadose zone soils, cm^3-H_2O cm^3-soil	0.12 cm^3-H_2O cm^3-soil
ρ_s	soil bulk density, g-soil/cm^3-soil	1.7 g-soil cm^3-soil