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DRAFT HUMAN HEALTH RISK ASSESSMENT – FORMER BERKELEY FARMS PROPERTY

Located at
4575 San Pablo Avenue
Emeryville, California

February 10, 1999

Prepared for: **Harman Management Corporation**

Prepared by: **Waterstone Environmental, Inc.**
2712 Rawson Street
Oakland, CA 94619
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Proprietary Notice

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Human Health Risk Assessment

The purpose of this human health risk assessment is to evaluate the potential health hazards with current concentrations of chemicals in soil and groundwater below the Former Berkeley Farms Property. ("Property"). This evaluation assesses the potential for exposure of commercial workers and construction workers to groundwater containing gasoline, diesel, benzene, toluene, ethylbenzene, and xylene and soil containing gasoline, benzene, toluene, ethylbenzene, xylene, methyl tertiary butyl ether (MTBE), and lead. The potential populations at risk could include commercial workers and construction workers. Exposure to the chemicals is due to inhalation of vapors that may migrate upwards from chemicals in soil and groundwater into a building (for commercial workers) or into the outdoor air (for construction workers) and direct contact with soil (for construction workers).

This risk assessment demonstrates that the potential carcinogenic risk to construction workers is lees than the USEPA's typically accepted range of 1 in 1,000,000 (1×10^{-6}) and 1 in 100,000 (1×10^{-4}). The total calculated risk to to a construction worker is 2.5×10^{-8}. The hazard index (non-carcinogenic exposure) to the commercial worker is 0.03 while the hazard index for the construction worker is 0.04. However, the potential carcinogenic risk to commercial workers was calculated at 1.32×10^{-4}, slightly outside the USEPA's acceptable range.

To remdiate this potential risk and avoid potential exposure to commercial workers, Waterstone Environmental, Inc. recommended and the property owner installed a vapor barrier during construction, along with a backup vapor exhaust system designed to move any vapors collecting beneath the building directly to the roof. These remdial activities should eliminate the vapor transport route of exposure, significantly reducing the concentration of chemicals in the indoor air, and thereby reducing the cancer risk to an acceptable level.

1.0 Introduction

The purpose of this Health Risk Assessment (HRA) is to evaluate the potential human health risks posed by chemicals in the groundwater below the Former Berkeley Farms Property (the

Property).

The approaches used in this analysis are those recommended by the American Society of Testing Material (ASTM) in their document designated E 1739-95 entitled *"Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites"* (RBCA) (ASTM, 1995). The guidance presented in the RBCA document is consistent with both California State and federal risk assessment guidance documents, including:

- The California Environmental Protection Agency ("Cal/EPA") Department of Toxic Substances Control *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities* (DTSC, 1992).
- The *Preliminary Endangerment Assessment Guidance Manual (*"PEA") (DTSC, 1994a).
- The U.S. Environmental Protection Agency ("USEPA*") Risk Assessment Guidance for Superfund. Human Health Evaluation Manual* (USEPA, 1989a).

Although this HRA is consistent with all of the guidance documents listed above, exposure point concentrations ("EPCs") and attendant potential risks are estimated primarily through the use of transport models and risk equations provided in RBCA. The calculated concentrations and resulting potential health risks associated with benzene did not pass the initial Tier 1 RBCA Screening (Table 1) using the maximum detected concentrations. Therefore a Tier II RBCA utilizing available site-specific information was conducted. Representative soil and groundwater concentrations were first calculated and are shown on Tables @a & 2B. The models used to calculate air concentrations from chemicals in groundwater and groundwater are presented in Tables 3A through 3D.

The overall strategy used to evaluate risk at the Property is as follows. The Property is currently being developed into a Kentucky Fried Chicken restaurant. We therefore assumed that the potential populations at the highest risk (i.e., those with the longest daily exposure and/or largest exposure concentration) include future commercial workers and construction workers.

Commercial workers will work inside the restaurant on the Property. It is possible that vapors from chemicals in soil and groundwater may migrate upwards and into the restaurant on the Property. Construction workers will work outdoors. It is possible that vapors from chemicals in soil and groundwater may migrate upwards and into the outdoor air. Construction workers may also come into contact with mildly impacted soils, based on findings by Davenport & Associates (1997), Geo-Logic (1998), and Waterstone Environmental, Inc. (1999). Inhalation of chemical vapors and contact with chemicals in soil and groundwater may result in a potential cancer risk or noncancer hazard. Using environmental fate and transport models, we can estimate concentrations of chemicals in the air inside the restaurant and outdoors due to vapors from chemicals in soil and groundwater. We can then estimate a dose or intake of these chemicals using conservative exposure parameters. We compare the dose with a "safe" level established by USEPA or California EPA.

In developing this HRA, the following steps were taken.

- **Step 1:** The Property was characterized to determine the chemicals of concern. Since a significant database of concentrations over time was not available for groundwater, the maximum concentration of each chemical in the groundwater was used in the HRA. Since an adequate database of concentrations was available for soil, the 95% upper confidence limit of the arithmetic mean concentration for each chemical in soil was used in the HRA. This method is consistent with the California EPA (DTSC, 1992 and Cal/EPA, 1994a) and USEPA (1989a). While elevated levels of gasoline and diesel are present in site groundwater, these compounds are actually comprised of numerous chemical species, and as such, unsuitable for evaluation in the HRA. Accordingly, the chemicals of concern are benzene, toluene, ethylbenzene and xylene (BTEX). Benzene, being a suspected carcinogen, is the main chemical of concern. Chemicals detected in soil include BTEX, MTBE, and lead.
- **Step 2:** The plausible exposure pathways and human receptors were identified.
- **Step 3:** Using groundwater and soil data obtained from fieldwork performed at the Property and environmental fate and transport models presented in RBCA, we calculated

indoor and outdoor air concentrations for each chemical of concern.

- **Step 4:** The chemical concentrations were combined with human physiologic parameters (e.g., body weight and inhalation rate) and population-specific exposure assumptions (e.g., exposure frequency and duration) to derive reasonable estimates of chemical intake for the commercial workers.
- **Step 5:** Safe cancer and non-cancer doses (referred to as toxicity values) were identified from State and Federal risk assessment guidance for each of the chemicals.
- **Step 6:** The potential intakes calculated in Step 4 were compared with chemical-specific safe doses to calculate the individual lifetime excess cancer risks and noncancer hazard indices for the commercial workers and construction workers. These values determine whether the populations of concern are potentially at risk from the subsurface chemicals.

2.0 Selection of Population and Exposure Pathways

The potential populations and exposure pathways by which individuals might contact site-related chemicals were identified. The potentially exposed populations are workers at the Kentucky Fried Chicken restaurant as well as construction workers during grading operations at the Property. Restaurant patrons may also be exposed to chemicals, however, since the patrons spend significantly less time at the restaurant, the greatest risk is to the workers. All workers are considered to be adults. The groundwater is not potable at the Property and is at least 7 feet below grade (and is most likely between 12 and 15 feet below grade), therefore, there is no potential for restaurant workers to have direct contact with groundwater. There is the potential for chemicals in both soil and groundwater to migrate upwards into buildings and into the outdoor air as vapors. For construction workers, some small dermal contact and ingestion exposure may exist due to the levels of chemicals known to still reside in site soils.

In summary, the only pathway of exposure for commercial workers is inhalation of vapors from soil and groundwater. The pathways of exposure for construction workers are inhalation of vapors from soil and groundwater and direct dermal contact and ingestion of soil.

3.0 Chemical Selection

The purpose of the chemical selection is to identify the site-related chemicals of potential concern. Based on site history available to Waterstone, groundwater samples were analyzed for gasoline, diesel/motor oil, CAM 17 metals, methyl tertiary butyl ether, benzene, toluene, ethylbenzene, and xylene (GeoLogic, 1998). Soil sample results revealed the presence of BTEX, MTBE, and lead. Groundwater sample results revealed the presence of benzene, toluene, ethylbenzene, and xylene. These chemicals are components of gasoline and diesel/motor oil, which were detected at the Property. However, because gasoline and diesel/motor oil are mixtures of chemicals, gasoline and diesel/motor oil, as such, are not evaluated in the HRA. Benzene concentrations detected in groundwater and soil samples were above the Tier 1 levels cited in RBCA (ASTM, 1995). Maximum soil and groundwater concentrations along with Tier 1 levels are presented in Table 1. Although concentrations of toluene, ethylbenzene and xylene did not exceed Tier 1 levels for commercial workers, they are included in the HRA because they are detected at least one time at the Property.

4.0 Exposure Concentrations

Monitoring wells and soil sampling locations in the vicinity of the future restaurant are shown on Figure 1, along with areas of impacted soils removed in 1998 (Geo-logic, 1998 and Waterstone, 1999). Maximum concentrations of chemicals in groundwater are used as representative concentrations (see Table 2B) to calculate concentrations of vapors in indoor and outdoor air. Due to the limited sampling conducted to date at the Property, statistical concentrations (i.e., averages) are not appropriate for groundwater.

The 95th percent upper confidence limit of the arithmetic mean concentrations of chemicals in soil are used as representative concentrations (see Table 2A) to calculate concentrations of vapors in indoor and outdoor air as well as to calculated risk via direct (dermal and ingestion) exposure. Although the PEA guidance manual (DTSC, 1994) recommends using the maximum detected value of each chemical as a representative exposure point concentration, the California

EPA guidance (Cal/EPA, 1994a and DTSC, 1992) suggests using a more sophisticated approach than the maximum concentrations of chemicals if sufficient samples exist. Sufficient sampling results are available for the petroleum mixtures (i.e., total petroleum hydrocarbons or TPH) and for the individual chemicals in soil. We have therefore estimated a representative chemical concentration of chemicals in soil by calculating the 95% upper confidence level (UCL) of the arithmetic mean. If a chemical was detected at least one time and reported as "not detected" in a particular sample, we assumed that the chemical is present in that sample at a concentration of one-half the detection limit. This method of establishing representative concentrations follows California EPA guidance (DTSC, 1992) and is consistent with estimating exposure for the reasonable maximum exposure (RME) (USEPA, 1989a).

To calculate the 95% UCL, the following four steps are performed on the data for each chemical:

- The arithmetic mean of the data is calculated;
- The standard deviation of the data is calculated;
- The one-tailed t-statistic is determined; and
- The UCL is calculated using the following equation:

$$UCL = x + t(s/\sqrt{n})$$

Where:

UCL	=	upper confidence limit
x	=	mean of the data
s	=	standard deviation of the data
t	=	Student-t statistic, 1.771
n	=	number of samples

The 95% UCL of each chemical is calculated in Table 2B and representative concentrations of chemicals used in the risk assessment are presented in Table 2A.

Exposure to chemicals of concern inside the restaurant is estimated for volatilization of chemicals from soil and groundwater into the breathing zone. Exposure to chemicals of concern outdoors is estimated for volatilization of chemicals from groundwater into the breathing zone. Volatilized chemicals have the potential to move upward through interconnected air-filled soil pores in the unsaturated zone, collecting inside the building, and impact the breathing zone of individuals either outdoors or within buildings constructed on top of such soils.

Emission fluxes of chemicals volatilizing from soil and groundwater were estimated from transport models in RBCA calculations. The RBCA models are presented in Tables 3A through 3D. Parameter assumptions used in the model are presented in Table 4. Physical and chemical properties for the chemicals (values used in the model) are presented in Table 5. Results of the model (i.e., indoor air concentrations and outdoor air concentrations) are calculated in Tables 3A through 3D and presented in Table 6.

BTEX data was available for all samples except the SB series. For these sample locations, we assumed that the amount of BTEX in the gasoline in the soil was the same as the amount of BTEX in gasoline in the groundwater. For example, there was 48,000 mg/L gasoline in groundwater and 2,200 mg/L benzene in groundwater. Therefore, the benzene represented 4.6 % of the groundwater. We assumed that benzene represented 4.6% of the TPH as gasoline in the soil. The estimated concentrations of BTEX in soil are presented in Table 2B. Where data was not available for MTBE, we assumed that MTBE was 15% of TPH as gasoline (Chem Eng News, 1993). Where data was not available for lead, we assumed that lead was 0.1% of TPH as gasoline (Kerr McGee MSDS for Leaded Gasoline). These latter two assumptions are overly conservative, as the concentrations in gasoline are likely to be greater than those in soil, due to degradation processes over time.

5.0 Estimation of Potential Human Exposure

Population-specific exposure assumptions and calculations are used to estimate potential human intake of benzene, toluene, ethylbenzene, xylene, and MTBE. Chemical intake presented in this risk assessment was calculated using equations recommended by the DTSC (1992), USEPA (1989a), and RBCA (ASTM, 1995). The intake equations include variables that characterize the exposure concentration of the chemicals in indoor air, exposure frequency, exposure duration, body weight, and exposure averaging time. Exposure parameter values used were those recommended by the California EPA (DTSC, 1992 and Cal/EPA, 1994a). The chemical intake calculation estimates the mass of the chemical taken and is expressed by the amount of chemical per unit body weight per unit time (e.g., mg/kg/day). The expression of mg/kg/day is referred to as "intake" or "dose". Exposure parameters used in this assessment are presented in Tables 9 and 10. The commercial worker is assumed to be onsite for 250 days per year for 25 years. The construction worker is assumed to be onsite for 90 days per year for 1 year.

6.0 Dose-Response Assessment

The purpose of a dose-response assessment is to establish a method to calculate the potential for the chemicals of concern to cause adverse effects in exposed individuals. The dose-response assessment also estimates the relationship between the extent of exposure to a chemical and the increased likelihood and/or severity of adverse effects (USEPA, 1989a).

In a dose-response assessment, the toxicity values that have been used to estimate potential human health risk are presented. The toxicity values used in this HRA are derived by Cal/EPA and the USEPA. A cancer slope factor ("CSF") quantifies the potency of a carcinogen. A reference dose ("RfD") or reference concentration ("RfC") is used to quantify the potency of a noncarcinogen. Toxicity values for all chemicals of concern are presented in Table 7.

The traditional reference dose approach to the evaluation of chemicals is not applied to lead because most human health effects data are based on blood lead concentrations, rather than external dose (DTSC, 1992). Blood lead concentration is an integrated measure of internal dose that reflects total exposure from Property-related and background sources. A clear no observed effects level (NOEL) has not been established for such lead-related endpoints as birth weight, gestation period, heme synthesis and neurobehavioral development in children and fetuses, and blood pressure in middle-aged men. Dose-response curves for these endpoints appear to extend down to 10 micrograms/deciliter (μg/dl) or less (ATSDR, 1990). The DTSC has developed a methodology for evaluating exposure and the potential for adverse health effects resulting from exposure to lead in the environment (DTSC, 1992). The methodology results in a blood lead concentration of concern for the protection of human health, and presents an algorithm for estimating blood lead concentrations in children and adults based on a multi-pathway analysis.

DTSC has provided a spreadsheet based on its guidance for evaluating lead toxicity (DTSC 1992). On this spreadsheet, the user enters the current concentrations for soil and drinking water. If no site-specific concentrations are available for lead in drinking water (as is the case for this Property), a default value of 15 μg/l can be used. Airborne dust level and the presence or absence of site-grown produce is also entered. If no site-specific concentrations are available for lead in air (as is the case for this Property), a default value of 0.18 $\mu g/m^3$ can be used. With regard to the absence or presence of site-grown produce, the model was conservatively run with this pathway. The spreadsheet then calculates the blood-lead level associated with various percentiles of the child and adult population. If the blood-lead level for children is below 10 μg/dl, then the current site conditions are not considered to present a risk from the lead present at the Subject Property.

Using the 95% UCL concentration of lead in the soil (3.99 mg/kg, Table 2A), the 99th percentile for blood lead levels in children, assuming that plants uptake lead and children ingest the plants (an extremely conservative assumption), is 7.5 μg/dl. It is important to note that plant ingestion at this Property is highly unlikely. From these calculations it is apparent that the presence of lead at the Property will not be associated with a health risk, even for a hypothetical child resident. Calculations for blood lead concentration can be found in Tables 8.

7.0 Risk Characterization

A risk characterization combines the exposure and toxicity assessments to produce an estimate of risk and to characterize uncertainties in the estimated risk (NRC, 1983). For this assessment, risks are evaluated for a Reasonable Maximum Exposure ("RME").

Benzene is the only chemical of concern at this Property that is considered as a potential carcinogen. The potential cancer risk associated with exposure to benzene *(i.e.,* the incremental probability that an individual will develop cancer over a lifetime of exposure to benzene) is estimated by multiplying the dose by the benzene concentration (estimated in indoor air for the commercial worker, or, outdoor air and soil for the construction worker). This result is then multiplied by the inhalation-specific or oral-specific CSF for benzene. Calculations for cancer risk are presented in Table 9. A summary of cancer risks is presented in Table 11. The estimated cancer risk for commercial workers is 1.32×10^{-4} and that for the construction worker is 4.93×10^{-8}.

To assess the noncarcinogenic effects of toluene, ethylbenzene, xylene, and MTBE the estimated dose is compared with the RfD for each chemical. The resulting ratio, referred to as the Hazard Quotient ("HQ"), is an estimate of the likelihood that noncarcinogenic effects will occur. To assess the total noncarcinogenic hazard to a population, the HQs for each chemical are summed to provide a value called the Hazard Index ("HI") for each exposure pathway. Calculations for hazard indices via the inhalation route of exposure are presented in Table 10. A summary of hazard indices is presented in Table 11. The HI for commercial workers is 0.03 and that for the construction workers is 0.04.

To help establish remedial objectives, the estimated cancer and noncancer risks are compared with acceptable risk goals that the USEPA has recommended in the National Contingency Plan (40 CER 300.430(e)(2)). For carcinogenic chemicals, the USEPA states that acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} using information on the relationship between dose and response. This target risk range has been used in this HRA. Proposition 65, known as the Safe Drinking Water and Toxic Enforcement Act of 1986, generally considers cancer risks less than 1×10^{-5} as not requiring a warning. For noncarcinogenic chemicals, the USEPA states that exposures shall be limited to levels that are without adverse effect during a lifetime or part of a lifetime. A HI of 1 or less is interpreted as corresponding to no adverse effect.

The estimated lifetime incremental RME cancer risks and noncancer hazards associated with all potentially complete exposure pathways for commercial workers and construction workers are summarized in Table 11. The hazard indices for both populations are much less than 1 and are therefore of no concern. The potential cancer risk for commercial workers is estimated at 1.32×10^{-4}. This risk level is slightly outside USEPA's acceptable range and the Proposition 65 acceptance level of 1×10^{-5}. While the actual risk is likely to be significantly lower (see uncertainty analysis section below), Waterstone recommended as a prudent step that a vapor barrier and backup vapor exhaust system be installed during grading operations to further manage the perception of risk at this Property. A vapor barrier will act to decrease the concentration of chemical vapors in the restaurant and thereby reduce the potential risk from chemical exposure. The risk for the construction workers is 4.93×10^{-8}. This value is well below the significant risk range and therefore of no concern.

8.0 Proposition 65 Evaluation

Proposition 65, known as the Safe Drinking Water and Toxic Enforcement Act of 1986, requires the Governor to publish a list of chemicals that are known to the State of California to cause cancer, birth defects or other reproductive harm. Under Proposition 65, businesses are: 1) prohibited from knowingly discharging listed chemicals into sources of drinking water; and 2) required to provide a "clear and reasonable" warning before knowingly and intentionally exposing anyone to a listed chemical. For this risk assessment, benzene and toluene are listed under Proposition 65. Benzene is listed as carcinogens and toluene is listed as a reproductive toxicant. Proposition 65 generally considers cancer risks less than 1×10^{-5} as not requiring a warning. In the case of benzene and toluene, Proposition 65 considers a dose less than or equal to 7 micrograms per day (µg/day) and 7,000 µg/day, respectively, as not requiring a warning.

The Proposition 65 evaluation is the comparison of a calculated daily dose of a chemical with the Proposition 65 no significant risk level (NSRL) (for carcinogens) or acceptable intake level

(AIL) for reproductive toxicants. The Proposition 65 dose level is calculated by multiplying the air concentration by the Proposition 65-recommended inhalation rate of 10 cubic meters per day. This value is converted to micrograms per day by multiplying by 1,000. The calculated daily doses of the two chemicals for each receptor are presented on the following table:

Chemical	**Proposition 65 Dose – Outdoor Air**	**Proposition 65 Dose – Indoor air**	**Proposition 65 NSRL or AIL**
Benzene	73.7 ug/day	120.7 ug/day	7 ug/day
Toluene	67 ug/day	69.3 ug/day	7,000 ug/day

The Proposition 65 dose for benzene indoors and outdoors exceeds the No Significant Risk Level. Therefore, without further abatement of vapors, a warning for construction workers and restaurant workers would be required. Installation of the vapor barrier (see Vapor Barrier below) and other mitigation measures (e.g., increasing the air exchange rate) has been instituted, which should significantly reduce vapor transport into the building, reducing the potential risk to less than 1 x 10^{-5}.

9.0 Vapor Barrier

Based on the residual concentrations of petroleum hydrocarbons in soils beneath those excavated by the former property owner, the current property owner and Waterstone were concerned about the long-term potential risk to commercial workers from vapors arising from soils beneath the future building. After some discussions and research, the current property owner authorized their general contractor, COE Construction, to lay a vapor liner above residual soils, place slotted PVC piping above the liner, backfill the excavation with imported fill, and connect a special vapor exhaust system to the slotted PVC pipe to capture any fugitive vapors that made it past the vapor barrier.

The vapor barrier was constructed with a total thickness of 40-mil plastic. The bottom of the excavation was first covered with 2-3 inches of compacted engineered fill to protect the liner from below. A 20-mil thick layer of Paraseal GM Waterproofing & Gas membrane was then placed into the excavation. Paraseal consists of a layer of high density polyethylene laminated to a one pound per square foot layer of bentonite, which "together produce a self-sealing product which in the presence of water creates a gas and waterproof barrier". Overlap areas, 6-8 inches on all sides, were sealed using Para JT joint sealing compound. COE Construction then laid two layers of 10-mil visqueen over the Paraseal with 6-inch overlap and seams oriented perpendicular to the first layer. A 3-inch perforated flexible pipe was placed in the backfill above the vapor barrier along the inside of the foundation walls and through the interior. The piping system was brought up the inside of the wall and directed outside at the roof top. An exhaust fan can be added in the future if necessary to capture fugitive emissions that make it through the vapor barrier.

10.0 Uncertainty Analysis

The values presented in this analysis result from conservative assumptions. Although these assumptions are based upon available guidance and our professional judgement, they introduce uncertainties in the estimated values. The assumptions used in this study and their impacts on the results are described below.

10.1 Uncertainties in Determining Potential Exposure Pathways and Populations

In Section 5, we identified the human populations potentially exposed to chemicals and the complete exposure pathways. The usefulness of the risk assessment is dependent upon the accuracy of this information.

10.2 Uncertainties in the Estimation of Representative Air Concentrations

The uncertainties in this analysis may be attributed to those uncertainties associated with the estimation of emissions from the groundwater and those uncertainties associated with the dispersion modeling to estimate air concentrations.

Uncertainties in Emission Calculations

Surface Emissions

The uncertainties in the calculated emission flux of organic contaminants from soil and groundwater are associated primarily with the limitations of the flux model and the uncertainty in soil properties. First, there are inherent limitations in the soil and groundwater flux models. In particular, the model assumes vertical homogeneity in soil characteristics within the vadose zone. In reality, there is variation in soil characteristics with depth along the vadose zone. In addition, the model does not account for horizontal transport of chemicals within the vadose zone. If contamination is highly localized such that a contaminated area is surrounded by clean areas, horizontal transport tends to dilute the localized contamination and decreases the emissions of chemicals to the atmosphere.

Uncertainties in Concentration Calculations

Indoor

The uncertainties in the calculated indoor chemical airborne concentrations using the box model are primarily associated with the limitations of the vapor flux model and the variations in the air exchange rate, the leakage rate, and the height of the box estimates. The limitations of the vapor flux model were discussed in the previous section. The variations in the air exchange rate are attributed to the fact that each building design has its own heating, ventilation, and air conditioning (HVAC) system. The design of the HVAC system is dependent, amongst other factors, on the intended use of the building, the size of the building, and the expected occupancy. No design-specific information about the proposed restaurant at the Property was provided to Waterstone Environmental, Inc. Therefore, we used default values of ceiling height and air exchange rate at standard commercial/industrial facilities. Also, as discussed earlier, vapor leakage rate from the subsurface to the building is dependent on the age of the building, the size of the crack on the slab, and the quality of the concrete. No building-specific information is available to quantify vapor leakage. Hence, default parameters as suggested by published data was used for the proposed restaurant.

10.3 Uncertainties in the Estimation of Human Intakes

Numerous assumptions related to human exposure are made in the process of estimating human exposure to chemicals. These assumptions include, but are not limited to, such parameters as daily breathing rates, human activity pattern, and worker mobility (time spent working at a single location). Although it is difficult to identify the magnitude of the uncertainties associated with chemical intake parameters, it is clear that the use of a large number of generic values (typically conservative in nature) contributes substantially to the conservatism associated with the estimate of chemical intake.

It is also highly unlikely that workers will remain at the restaurant for 25 years. The majority of workers at the restaurant will be teenagers and young adults, who may work at the restaurant 5-10 years before moving on to other careers. Managers are also unlikely to spend more than 5-10 years before transfer to other restaurants.

Primarily because the estimates of human exposure to chemical are based on the compounding of multiple conservative assumptions, we believe that the intakes may be overestimated for the exposure scenario presented. *As a result, the actual risk is likely to be lower than that calculated based on these multiple conservative assumptions.*

10.4 Uncertainties in Toxicity Assessment

In this risk assessment, as in a great majority of risk assessments, available scientific information is insufficient to provide a thorough understanding of all the toxic properties of each of the chemicals to which humans may be exposed. It is generally necessary, therefore, to infer these properties by extrapolating them from data obtained under other conditions of exposure, generally in laboratory animals. Although reliance on experimental animal data has been widely used in general risk assessment practices, chemical absorption, metabolism, excretion, and toxic responses may differ between humans and the species for which experimental toxicity data are available. Uncertainties in using animal data to predict potential effects in humans are introduced when routes of exposure in animal studies differ from human exposure routes; when the exposures in animal studies are short-term or subchronic; and when effects seen at relatively high exposure levels in animal studies are used to predict effects at the much lower exposure levels found in the environment. Uncertainties in the toxicological assessments for carcinogens and noncarcinogens are discussed in the following paragraphs.

10.4.1 Uncertainties in the Characterization of the Toxicity of Carcinogens

First, the lack of knowledge regarding the validity and the accuracy of the mathematical models (i.e., linearized multi-stage model) used by the USEPA to derive low-dose CSFs from the high exposure levels used in experiments also contributes to the uncertainties in cancer risk estimates. The linearized multi-stage model provides a conservative estimate of risk at low doses (likely to overestimate the actual CSF). Several of the alternative models often predict lower risk at low doses, sometimes differing from USEPA values by orders of magnitude.

Second, application of these mathematical low-dose extrapolation models for carcinogens is predicated on the conservative assumption generally made by regulatory agencies that no threshold exists for carcinogens (i.e., that there is some risk of cancer at all exposure levels above zero). The no-threshold hypothesis for carcinogens, however, has not been proven and may not be valid for substances that have not been shown to be carcinogenic via other mechanisms (i.e., mechanisms that do not appear to act directly on genetic material [DNA]).

10.4.2 Uncertainties in the Characterization of the Toxicity of Noncarcinogens

In order to adjust for uncertainties that arise from the use of animal data, regulatory agencies often base the RfD for noncarcinogenic effects on the most sensitive animal species (i.e., the species that experiences adverse effects at the lowest dose) and adjust the dose via the use of safety or uncertainty factors. The adjustment compensates for the lack of knowledge regarding interspecies extrapolation and guards against the possibility that humans are more sensitive than the most sensitive experimental animal species tested. The use of uncertainty factors is considered to be conservative and health-protective. Second, when route-specific toxicity data were lacking, we derived data by route-to-route extrapolation (i.e., oral to inhalation) by using standard default exposure assumption. In the absence of specific data, we assumed equal absorption rates for both routes.

Although it is difficult to quantify the uncertainties associated with all the assumptions made in this risk assessment, the use of conservative assumptions is likely to contribute to a substantial overestimate exposure and, hence, of risk.

Language suggested by the USEPA (1989b, p. 22) to explain the effect of using conservative assumptions in regulatory risk assessments is as follows:

> *"These values are upper-bound estimates of excess cancer risk potentially arising from lifetime exposure to the chemical in question. A number of assumptions have been made in the derivation of these values, many of which are likely to overestimate exposure and toxicity. The actual incidence of cancer is likely to be lower than these estimates and may be zero."*

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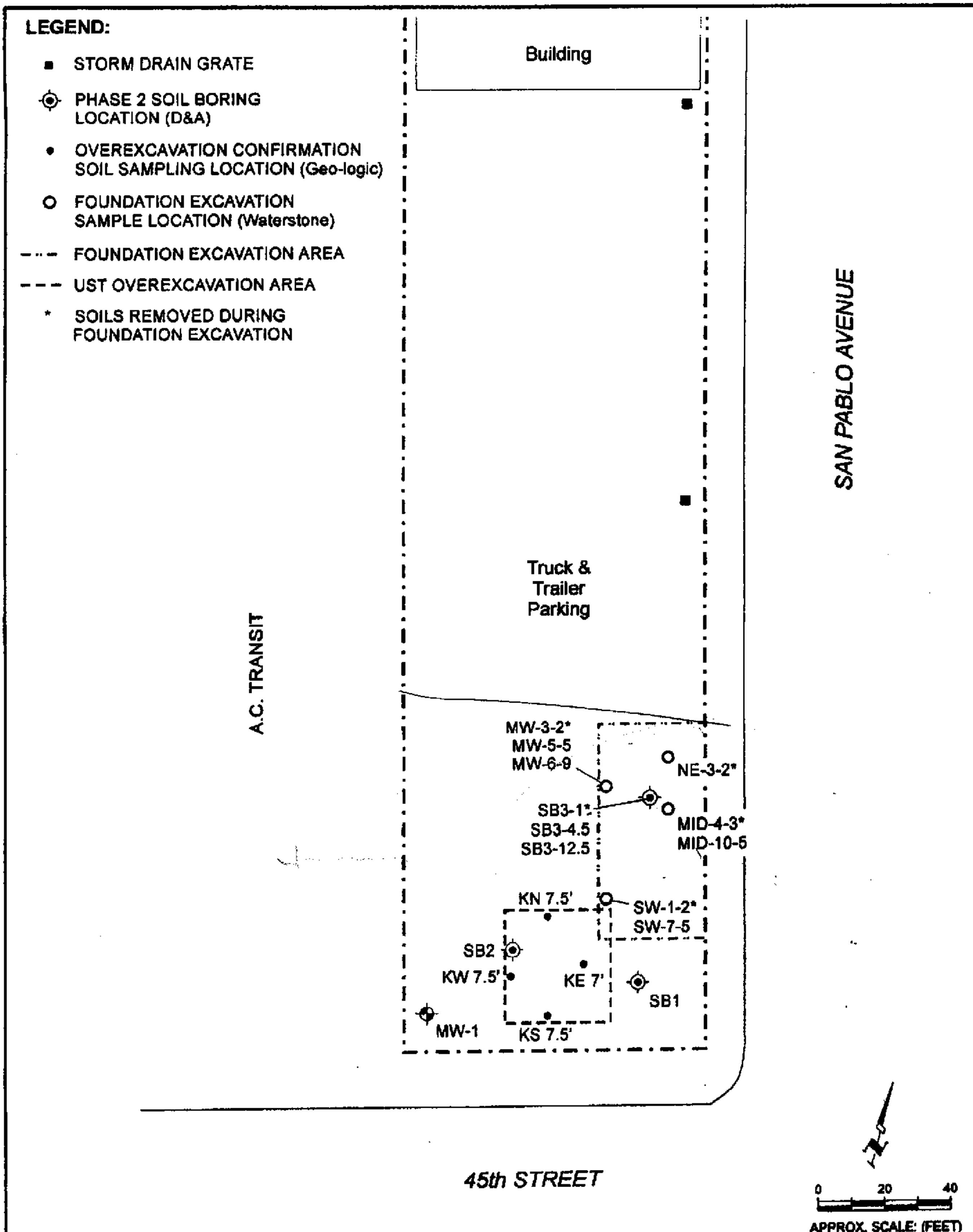

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FIGURE 1
LOCATIONS OF SAMPLING AND SOIL EXCAVATION AREAS
FORMER BERKELEY FARMS TRUCK PARKING AND REPAIR FACILITY
EMERYVILLE, CALIFORNIA

Table 1
Tier 1 Risk-Based Screening Levels Versus Maximum Soil and Groundwater Concentrations

Chemical	Groundwater - Maximum Concentration (mg/l)	Tier 1 RBCL (mg/l) (residential)	Tier 1 RBCL (mg/l) (commercial)	Soil - Maximum Concentration (mg/kg)	Tier 1 RBCL (mg/kg) (residential)	Tier 1 RBCL (mg/kg) (commercial)
Benzene	2.20	0.0238	0.0739	9.6	5.70E-03	1.90E-02
Toluene	2.40	32.8	85	27	20.6	54.5
Ethylbenzene	2.40	77.5	>S	16	427	1100
Xylenes	3.50	>S	>S	77	RES	RES

Notes:
mg/l - milligrams chemical per liter groundwater
mg/kg - milligrams chemical per kilogram soil
RBCL - Risk-Based Screening Level, ASTM E 1793-95
Values are for vapor intrusion into buildings
Benzene values are based on a 1e-6 risk.
>S means selected risk level is not exceeded for all possible dissolved levels
RES means selected risk level is not exceeded for pure compound present at any concentration

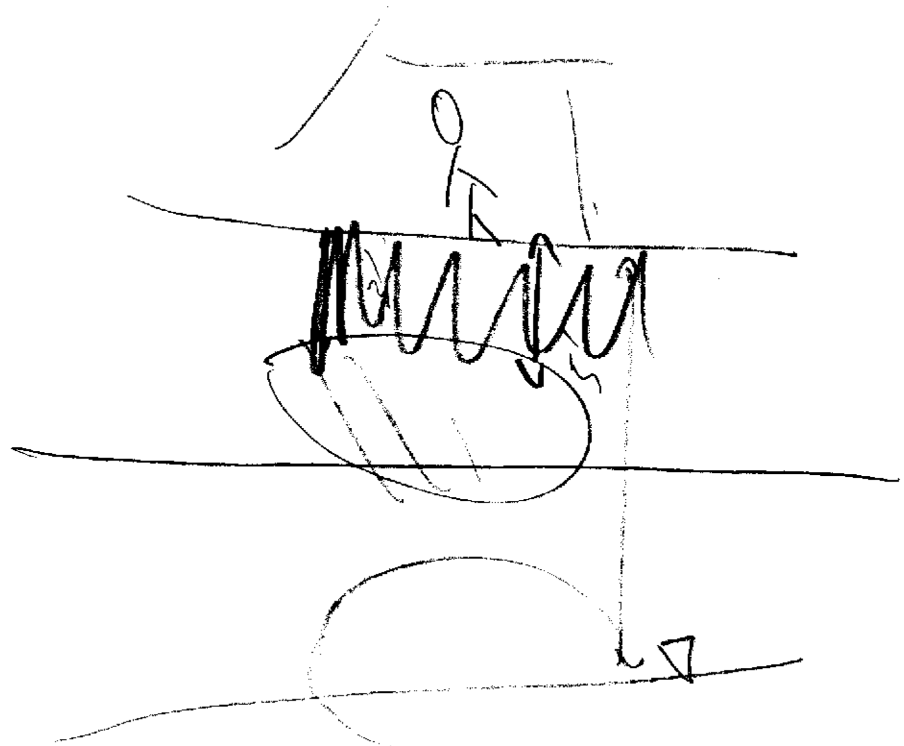

Table 2A

Representative Concentrations of Chemicals in Soil and Groundwater [1]

Chemical	Representative Groundwater Concentration(mg/l)	Representative Soil Concentration (mg/kg)
Benzene	2.20	5.2
Ethylbenzene	2.40	6.69
Toluene	1.60	9.16
Total Xylenes	3.50	23.6
MTBE	not detected	9.2
Lead	not detected	3.99

Notes:
TPHg - Total Petroleum Hydrocarbons as gasoline
TPHd - Total Petroleum Hydrocarbons as diesel
ug/l - micrograms per liter
mg/kg - milligrams per kilogram

(1) - All concentrations from Geo-Logic, 1998 unless otherwise noted

Table 2B
Concentrations of Chemicals in Soil - 95% UCL Calculations

Sample ID NO	Concentration in Soil (mg/kg)						
	Benzene (1)	Toluene (1)	Ethylbenzene (1)	Xylenes (1)	MTBE(2)	Lead (3)	TPHg
SW-7-5	3.8	3.2	4.6	12	1.5	9.5	490
MW-5-5	13	30	16	66	21	8.6	800
MW-6-9	6.3	16	11	47	3.5	7.1	540
Mid-10-5	13	27	18	77	5	13	980
KN-7.5	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.05
KS-7.5	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.05
KW-7.5	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.05
KE2-7.0	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.05
SB1(2.5)	0.27938	0.20313	0.305	0.44469	0.915	0.0061	6.1
SB1(7.5)	6.412	4.662	7	10.206	21	0.14	140
SB1(13.5)	0.00916	0.00666	0.01	0.01458	0.03	0.0002	0.2
SB2(13.0)	1.145	0.8325	1.25	1.8225	3.75	0.025	25
SB3(4.5)	0.7786	0.5661	0.85	1.2393	2.55	0.017	17
SB3(12.5)	9.618	6.993	10.5	15.309	31.5	0.21	210

AVERAGE	3.88	6.39	4.97	16.50	6.48	2.76	229.18
SD DEV	4.94	10.36	6.44	26.56	10.18	4.62	335.29
# SAMPLES	14	14	14	14	14	14	
t STATISTIC	1.771	1.771	1.771	1.771	1.771	1.771	
95% UCL	5.20	9.16	6.69	23.60	9.20	3.99	

(1) - Where data was not available for soil concentrations, the concentrations are estimated based on the ratio of the concentration of these chemicals in groundwater to the concentration of TPH in groundwater

(2) - Where data was not available for MTBE, the concentration was assumed to be 15% of TPH as gasoline in soil. MTBE is typically 15% of gasoline (Chem Eng. News, 9/20/93)

(3) - Where data was not available for lead, the concentration was assumed to be 0.1% of TPH as gasoline (Kerr McGee MSDS for Leaded Gasoline)

Note: The K-series samples were assigned values of 1/2 the detection limit for calculation purposes

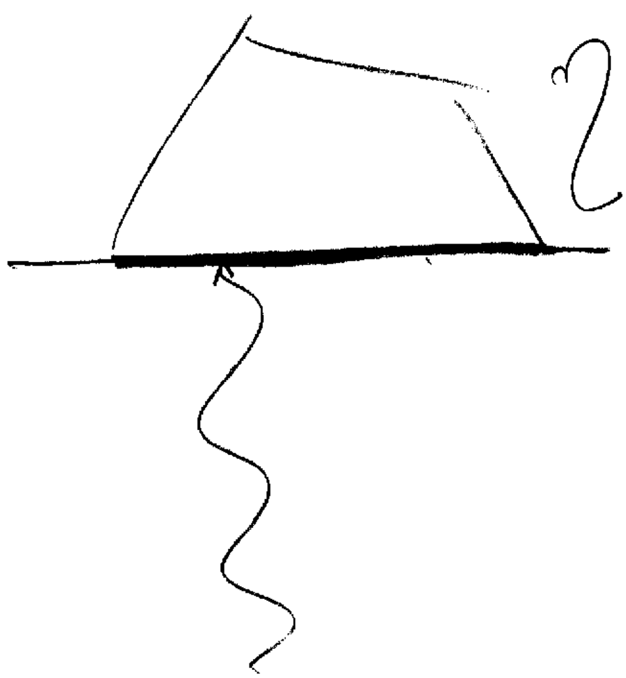

Table 3A

Former Berkeley Farms Property
Environmental Fate and Transport Model - Indoor Concentrations from Soil Vapors

		Dair	Dwet	W	Ps	Uair	gammair	Thetaas	Thetaas^3.33	Thetaws	Thetaws^3.33	Thetat	Thetat^2
Chemical	Concentration in soil (mg/kg)	Diffusivity in Air Dair (cm2/s)	Diffusivity in Water Dwater (cm2/s)	Width of source area (cm)	Soil Bulk Density (gsoil/cm3soil)	Wind speed (cm/sec)	Ambient air mixing zone height (cm)	vol air content - vadose zone soils (cm3air/cm3soil	vol air content - vadose zone soils (cm3air/cm3soil	volumetric water content - vadone zone soils	volumetric water content in vadose zone soils (cm3water/cm3soil)	total soil porosity (cm3/cm3-soil	total soil porosity 2 (cm3/cm3-soil
Benzene	5.2	9.30E-02	1.10E-05	1.22E+03	1.7	340	200	0.15	1.80E-03	1.70E-01	2.74E-03	3.20E-01	1.02E-01
Ethylbenzene	6.69	7.60E-02	8.50E-06	1.22E+03	1.7	340	200	0.15	1.80E-03	1.70E-01	2.74E-03	3.20E-01	1.02E-01
Toluene	9.16	8.50E-02	9.40E-06	1.22E+03	1.7	340	200	0.15	1.80E-03	1.70E-01	2.74E-03	3.20E-01	1.02E-01
Total Xylenes	23.6	7.20E-02	8.50E-06	1.22E+03	1.7	340	200	0.15	1.80E-03	1.70E-01	2.74E-03	3.20E-01	1.02E-01
MTBE	9.2	1.00E-01	1.00E-05	1.22E+03	1.7	340	200	0.15	1.80E-03	1.70E-01	2.74E-03	3.20E-01	1.02E-01

Table 3A

Deffs	H	PIE	Ks	foc	koc	T	d	tacrck^3.33	twerck^3.33	Ls	Deffcrack				ER	LB	Lcrack	n
effective diffusion coeff in soil based on vapor-phase conc(cm2/sec)	Henry's Law Constant Hc (L-H20/L-air)	PIE	Soil-water sorption coefficient (cm3water/g-C)	Fraction of organic carbon in soil (g-C/g-soil)	Organic Carbon Partition Coeff Koc (ml/g)	Averaging time for vapor flux (s)	Lower depth of surficial soil zone (cm)	Volumetric air content in foundation cracks(cm3air/cm3tot vol	Volumetric H2O content in foundation cracks(cm3H2)/cm3soil	Depth to subsurface soil source	Effective Diffusion Coeff thru Found Cracks	Vfsesp	Air Concentration in (mg/m3)	Air Concentration in (ug/m3)	L/s	cm	cm	(cm2-crack/cm2-total area)
1.64E-03	2.20E-01	3.14	6.27E-01	9.65E-03	6.50E+01	7.88E+08	91.44	1.13E-02	8.58E-04	122	1.02E-02	2.77E-03	1.44E-02	1.44E+01	2.30E-04	3.00E+02	1.50E+01	1.00E-03
1.34E-03	3.20E-01	3.14	2.12E+00	9.65E-03	2.20E+02	7.88E+08	91.44	1.13E-02	8.58E-04	122	8.36E-03	1.09E-03	7.31E-03	7.31E+00	2.30E-04	3.00E+02	1.50E+01	1.00E-03
1.50E-03	2.60E-01	3.14	2.48E+00	9.65E-03	2.57E+02	7.88E+08	91.44	1.13E-02	8.58E-04	122	9.35E-03	8.59E-04	7.87E-03	7.87E+00	2.30E-04	3.00E+02	1.50E+01	1.00E-03
1.27E-03	2.90E-01	3.14	2.32E+00	9.65E-03	2.40E+02	7.88E+08	91.44	1.13E-02	8.58E-04	122	7.92E-03	8.65E-04	2.04E-02	2.04E+01	2.30E-04	3.00E+02	1.50E+01	1.00E-03
1.77E-03	2.40E-02	3.14	1.06E-01	9.65E-03	1.10E+01	7.88E+08	91.44	1.13E-02	8.58E-04	122	1.10E-02	1.17E-03	1.07E-02	1.07E+01	2.30E-04	3.00E+02	1.50E+01	1.00E-03

.001

Table 3B

Former Berkeley Farms Property
Environmental Fate and Transport Model - Outdoor Concentrations from Soil Vapors

		Dair	Dwet	W	Ps	Uair	gammair	Thetaas	Thetaas^3.33	Thetaws	Thetaws^3.33	Thetat	Thetat^2
Chemical	Concentration in soil (mg/kg)	Diffusivity in Air Dair (cm2/s)	Diffusivity in Water Dwater (cm2/s)	Width of source area (cm)	Soil Bulk Density (gsoil/cm3soil)	Wind speed (cm/sec)	Ambient air mixing zone height (cm)	vol air content - vadose zone soils (cm3air/cm3soil)	vol air content - vadose zone soils (cm3air/cm3soil) 3	volumetric water content - vadone zone soils	volumetric water content - vadone zone soils 3.33	total soil porosity (cm3/cm3-soil	total soil porosity (cm3/cm3-soil) 2
Benzene	5.2	9.30E-02	1.10E-05	1.22E+03	1.7	340	200	0.26	1.13E-02	0.12	8.58E-04	0.32	1.02E-01
Ethylbenzene	6.69	7.60E-02	8.50E-06	1.22E+03	1.7	340	200	0.26	1.13E-02	0.12	8.58E-04	0.32	1.02E-01
Toluene	9.16	8.50E-02	9.40E-06	1.22E+03	1.7	340	200	0.26	1.13E-02	0.12	8.58E-04	0.32	1.02E-01
Total Xylenes	23.6	7.20E-02	8.50E-06	1.22E+03	1.7	340	200	0.26	1.13E-02	0.12	8.58E-04	0.32	1.02E-01
MTBE	9.2	1.00E-01	1.00E-05	1.22E+03	1.7	340	200	0.26	1.13E-02	0.12	8.58E-04	0.32	1.02E-01

Table 3B

Deffs	H	PIE	Thetaws	Thetaws^3.33	Ks	foc	Koc	T	d	tacrck^3.33	twcrck^3.33		deffcrack		
effective diffusion coeff in soil based on vapor-phase conc(cm2/sec)	Henry's Law Constant Hc (L-H20/L-air)	PIE	volumetric water content - vadone zone soils	volumetric water content in vadose zone soils (cm3water/cm3soil)	Soil-water sorption coefficient (cm3water/g-C)	Fraction of organic carbon in soil (g-C/g-soil)	Organic Carbon Partition Coeff Koc (ml/g)	Averaging time for vapor flux (s)	Lower depth of surficial soil zone (cm)	Volumetric air content in foundation cracks(cm3air/cm3tot vol	Volumetric H2O content in foundation cracks(cm3H2)/cm3 soil	Ls	Effective Diffusion Coeff thru Found Cracks	Vfsamb	Outdoor Air (mg/m3air)
1.02E-02	2.20E-01	3.14	0.12	8.58E-04	6.27E-01	9.65E-03	6.50E+01	7.88E+08	91.44	1.13E-02	8.58E-04	122	1.02E-02	4.53E-04	2.35E-03
8.36E-03	3.20E-01	3.14	0.12	8.58E-04	2.12E+00	9.65E-03	2.20E+02	7.88E+08	91.44	1.13E-02	8.58E-04	122	8.36E-03	1.75E-04	1.17E-03
9.35E-03	2.60E-01	3.14	0.12	8.58E-04	2.48E+00	9.65E-03	2.57E+02	7.88E+08	91.44	1.13E-02	8.58E-04	122	9.35E-03	1.38E-04	1.26E-03
7.92E-03	2.90E-01	3.14	0.12	8.58E-04	2.32E+00	9.65E-03	2.40E+02	7.88E+08	91.44	1.13E-02	8.58E-04	122	7.92E-03	1.39E-04	3.28E-03
1.10E-02	2.40E-02	3.14	0.12	8.58E-04	1.06E-01	9.65E-03	1.10E+01	7.88E+08	91.44	1.13E-02	8.58E-04	122	1.10E-02	2.15E-04	1.98E-03

Former Berkeley Farms Property
Environmental Fate and Transport Model - Indoor Concentrations from Groundwater Vapors

Chemical	Dair Diffusivity in Air Dair (cm2/s)	Tas^3.33 vol air content - vadose zone soils (cm3air/cm3 soil)	Tt^2 total soil porosity (cm3/cm3-soil)	Dwet Diffusivity in Water Dwater (cm2/s)	H Henry's Law Constant Hc (L-H20/L-air)	Tws^3.33 volumetric water content - vadone zone soils	Deffs effective diffusion coeff in soil based on vapor-phase conc	Tacap^3.33 volumetric air content in cap fringe soils (cm3air/cm3soil)	Twcap^3.33 volumetric water content in cap fringe soils (cm3water/cm3soil)	Deffcap effective diffusion coeff in capillary fringe (cm2/sec)	Deffws effective diffusion coeff between groundwater and soil surface(cm2/sec)	Vfwesp (mg/m3air/mg/lH2O) - numerator	Vfwesp (mg/m3air/mg/lH2O) - denominator
Benzene	8.30E-02	1.13E-02	1.02E-01	1.10E-05	2.20E-01	8.58E-04	1.02E-02	1.87E-05	2.81E-02	3.06E-05	1.97E-03	3.54E-02	1.73E+01
Ethylbenzene	7.60E-02	1.13E-02	1.02E-01	8.50E-06	3.20E-01	8.58E-04	8.36E-03	1.87E-05	2.81E-02	2.11E-05	1.40E-03	3.65E-02	1.51E+01
Toluene	8.50E-02	1.13E-02	1.02E-01	9.40E-06	2.60E-01	8.58E-04	9.35E-03	1.87E-05	2.81E-02	2.54E-05	1.66E-03	3.52E-02	1.60E+01
Total Xylenes	7.20E-02	1.13E-02	1.02E-01	8.50E-06	2.90E-01	8.58E-04	7.92E-03	1.87E-05	2.81E-02	2.11E-05	1.39E-03	3.28E-02	1.58E+01
MTBE	1.00E-01	1.13E-02	1.02E-01	1.00E-05	2.40E-02	8.58E-04	1.10E-02	1.87E-05	2.81E-02	1.32E-04	5.40E-03	1.06E-02	4.25E+01
	default	def/calc	sitespeccalc	default	default	site-spec	calculated	default	default/cal	calc	ss/calc	ss/calc	

The equation to calculate enclosed space vapors from groundwater is:
Vfwesp[(mg/m3air)/(mg/LH2O)] = H[(deffws/Lgw)/ER*Lb)] / {1 + [(Deffws/Lgw)/ER*Lb] + [Deffws/Lgw)/(Deffcrack/Lcrack)*n]} *1000 L/m3

The equation to calculate ambient (outdoor) vapors from groundwater is:
Vfwamb[(mg/m3air)/(mg/LH2O)] = H / {[1 + (Uair*Gair*Lgw)/(Wdeffws)]} *1000 L/m3

The equation to calculate effective diffusion coefficient between groundwater and soil surface is:
Deffws(cm2/sec) = (hcap + hv) * [(hcap/deffcap)+(Hv/Deffs)]-1

The equation to calculation effective diffusion coefficient through foundation cracks is:
Deffcrack (cm2/s) = Diar(Tacrack^3.33)/Tt^2) + Dwet(1/H)(Twcrack^3.33)/Tt^2

The equation to calculation effective diffusion in soil based on vapor-phase concentration
Deffs (cm2/s) = Diar(Tas^3.33)/Tt^2) + Dwet(1/H)(Tws^3.33)/Tt^2

Where:
Vfwesp = volatilization factor for groundwater to enclosed space vapors
mg/m3-air = milligrams per cubic meter air
mg/LH2O = milligrams per liter water
H = Henry's law constant (cm3water / cm3air)
Deffws = effective diffusion coefficient between groundwater and soil surface
Lgw = depth to groundwater (cm)
ER = enclosed-space air exchange rate (L/s)
Lb = enclosed-space volume/infiltration area ratio (cm)
Deffcrack = effective diffusion coefficient through foundation cracks
Lcrack = enclosed space foundation or wall thickness (cm)
n = areal fraction of cracks in foundations/walls (cm2-cracks/cm2-total area)
L/m3 = liters per cubic meter
Vfwamb = volatilization factor for groundwater to ambient vapors
Uair = wind speed above ground surface in ambient mixing zone (cm/s)
Gair = ambient air mixing zone height (cm)
W = width of source area parallel to wind, or ground water flow direction (cm)
Dair = diffusion coefficient in air (cm2/sec)
Dwet = diffusion coefficient in water (cm2/sec)
Tacrack = volumetric water content in foundation/wall cracks (cm3air/cm3total volume)
Tt = total soil porosity (cm3/cm3soil)
Twcrack = volumetric water content in foundation/wall cracks (cm3water/cm3total volume)
Tacrack = volumetric air content in foundation/wall cracks (cm3air/cm3total volume)
hcap = thickness of capillary fringe (cm)
hv = thickness of vadose zone (cm)
Deffcap = effective diffusion coefficient through capillary fringe (cm2/sec)
Deffs = effective diffusion coefficient in soil based on vapor-phase concentrations (cm2/sec)
Tas = volumetric air content in vadose zone soils (cm3air/cm3soil)
Tws = volumetric water content in vadose zone soils (cm3water/cm3soil)

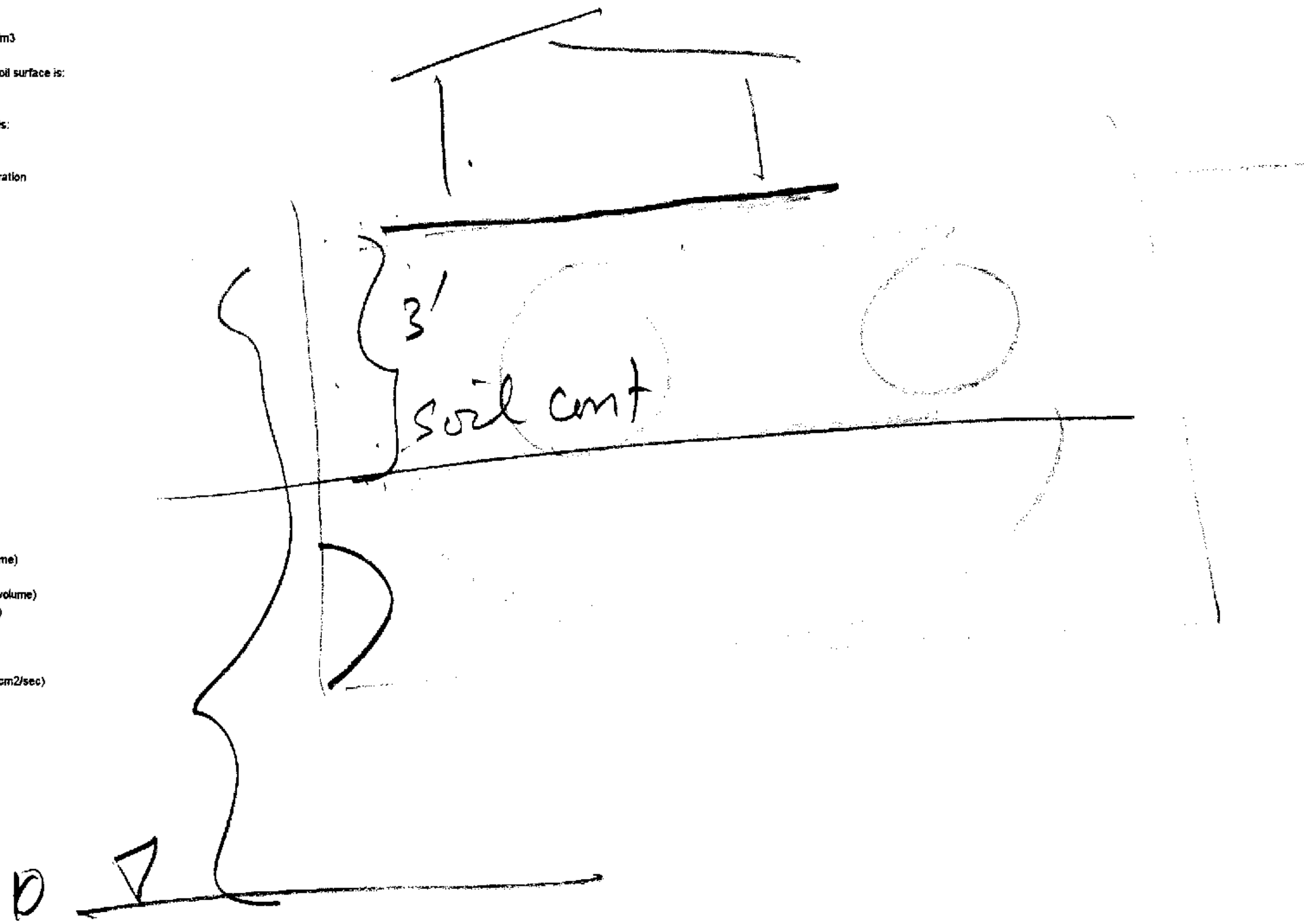

Table 3C

Tacrack	Twcrack	Deffcrack			
volumetric air content in foundation/wall cracks(cm3air/cm3total volume)	volumetric water content in foundation/wall cracks(cm3water/cm3soil)	effective diffusion coeff between foundation cracks(cm2/sec)	Vfwesp (mg/m3air/mg/l H2O) - RESULT	Groundwater Concentration (mg/l)	Indoor air conc: GW Conc x VF = mg/m3
1.13E-02	8.58E-04	1.02E-02	2.05E-03	2.20	4.51E-03
1.13E-02	8.58E-04	8.36E-03	2.41E-03	2.40	5.80E-03
1.13E-02	8.58E-04	9.35E-03	2.20E-03	1.60	3.52E-03
1.13E-02	8.58E-04	7.92E-03	2.08E-03	3.50	7.28E-03
1.13E-02	8.58E-04	1.10E-02	2.49E-04	0	0.00E+00

Table 3D

Former Berkeley Farms Property
Environmental Fate and Transport Model - Outdoor Concentrations from Groundwater Vapors

Chemical	Dair	Uair	Gair	Lgw	W	Tas^3.33	Tt^2	Dwat	H	Tws^3.33	Deffs	Tacap^3.33	Twcap^3.33
	Diffusivity in Air Dair (cm2/s)	Wind speed above ground surface in ambient mixing zone (cm/s)	Ambient air mixing zone height (cm)	Depth to groundwater (cm)	Width of source area parallel to wind or GW flow direction (cm)	vol air content - vadose zone soils (cm3air/cm3soil	total soil porosity (cm3/cm3-soil	Diffusivity in Water Dwater (cm2/s)	Henry's Law Constant Hc (L-H20/L-air)	volumetric water content - vadone zone soils	effective diffusion coeff in soil based on vapor-phase conc	volumetric air content in cap fringe soils (cm3air/cm3soil)	volumetric water content in cap fringe soils (cm3water/cm3soil)
Benzene	9.30E-02	340	2.00E+02	1.77E+02	1.22E+03	1.13E-02	1.02E-01	1.10E-05	2.20E-01	8.58E-04	1.02E-02	1.87E-05	2.81E-02
Ethylbenzene	7.60E-02	340	2.00E+02	1.77E+02	1.22E+03	1.13E-02	1.02E-01	8.50E-06	3.20E-01	8.68E-04	8.36E-03	1.87E-05	2.81E-02
Toluene	8.50E-02	340	2.00E+02	1.77E+02	1.22E+03	1.13E-02	1.02E-01	9.40E-06	2.60E-01	8.58E-04	9.35E-03	1.87E-05	2.81E-02
Total Xylenes	7.20E-02	340	2.00E+02	1.77E+02	1.22E+03	1.13E-02	1.02E-01	8.50E-06	2.90E-01	8.58E-04	7.92E-03	1.87E-05	2.81E-02
	1.00E-01	340			1.22E+03			1.00E-05	2.40E-02				

The equation to calculate enclosed space vapors from groundwater is:
Vfwesp[(mg/m3air)/(mg/LH2O)] = H[(deffws/Lgw)/ER*Lb)] / {1 + [(Deffws/Lgw)/ER*Lb) + [Deffws/Lgw)/(Deffcrack/Lcrack)*n]} *1000 L/m3

The equation to calculate ambient (outdoor) vapors from groundwater is:
Vfwamb[(mg/m3air)/(mg/LH2O)] = H / {[1 + (Uair*Gair*Lgw)/(Wdeffws)]} *1000 L/m3

The equation to calculate effective diffusion coefficient between groundwater and soil surface is:
Deffws(cm2/sec) = (hcap + hv) * [(hcap/deffcap)+(Hv/Deffs)]-1

The equation to calculation effective diffusion coefficient through foundation cracks is:
Deffcrack (cm2/s) = Diar(Tacrack^3.33)/Tt^2) + Dwat(1/H)(Twcrack^3.33)/Tt^2

The equation to calculation effective diffusion in soil based on vapor-phase concentration
Deffs (cm2/s) = Diar(Tas^3.33)/Tt^2) + Dwat(1/H)(Tws^3.33)/Tt^2

Where:
Vfwesp = volatilization factor for groundwater to enclosed space vapors
mg/m3-air = milligrams per cubic meter air
mg/LH2O = milligrams per liter water
H = Henry's law constant (cm3water / cm3air)
Deffws = effective diffusion coefficient between groundwater and soil surface
Lgw = depth to groundwater (cm)
ER = enclosed-space air exchange rate (L/s)
Lb = enclosed-space volume/infiltration area ratio (cm)
Deffcrack = effective diffusion coefficient through foundation cracks
Lcrack = enclosed space foundation or wall thickness (cm)
n = areal fraction of cracks in foundations/walls (cm2-cracks/cm2-total area)
L/m3 = liters per cubic meter
Vfwamb = volatilization factor for groundwater to ambient vapors
Uair = wind speed above ground surface in ambient mixing zone (cm/s)
Gair = ambient air mixing zone height (cm)
W = width of source area parallel to wind, or ground water flow direction (cm)
Dair = diffusion coefficient in air (cm2/sec)
Dwat = diffusion coefficient in water (cm2/sec)
Tacrack = volumetric water content in foundation/wall cracks (cm3air/cm3total volume)
Tt = total soil porosity (cm3/cm3soil)
Twcrack = volumetric water content in foundation/wall cracks (cm3water/cm3total volume)
Tacrack = volumetric air content in foundation/wall cracks (cm3air/cm3total volume)
hcap = thickness of capillary fringe (cm)
hv = thickness of vadose zone (cm)
Deffcap = effective diffusion coefficient through capillary fringe (cm2/sec)
Deffs = effective diffusion coefficient in soil based on vapor-phase concentrations (cm2/sec)
Tas = volumetric air content in vadose zone soils (cm3air/cm3soil)
Tws = volumetric water content in vadose zone soils (cm3water/cm3soil)

Table 3D

Deffcap	Deffws			Tacrack^3.33	Twcrack^3.33	Deffcrack							
effective diffusion coeff in capillary fringe (cm2/sec)	effective diffusion coeff between groundwater and soil surface(cm2/sec)	Vfwesp (mg/m3air/mg/lH2O) - numerator	Vfwesp (mg/m3air/mg/lH2O) - denominator	volumetric air content in foundation/wall cracks(cm3air/cm3total volume)	volumetric water content in foundation/wall cracks(cm3water/cm3 soil)	effective diffusion coeff between foundation cracks(cm2/sec)	Vfwesp (mg/m3air/mg/lH2O) RESULT	Groundwater Concentration (mg/l)	GW Conc x VF = mg/m3	Organic Carbon Partition Coeff Koc (ml/g)	Solubility in Water S (mg/l)	Groundwater to ambient vapors (mg/m3air / mg/LH2O)	Air conc from groundwater chemicals(mg/m3air)
3.06E-05	1.56E-03	1.66E-02	8.63E+00	1.13E-02	8.58E-04	1.02E-02	1.92E-03	2.20	4.23E-03	6.50E+01	1.80E+03	3.47E-05	7.84E-05
2.11E-05	1.10E-03	1.71E-02	7.59E+00	1.13E-02	8.58E-04	8.36E-03	2.25E-03	2.40	5.39E-03	2.20E+02	1.60E+02	3.57E-05	8.56E-05
2.54E-05	1.31E-03	1.65E-02	8.02E+00	1.13E-02	8.58E-04	9.35E-03	2.06E-03	1.60	3.29E-03	2.87E+02	5.30E+02	3.45E-05	5.62E-05
2.11E-05	1.10E-03	1.54E-02	7.92E+00	1.13E-02	8.58E-04	7.92E-03	1.94E-03	3.50	6.79E-03	2.40E+02	2.00E+02	3.21E-05	1.12E-04
										1.10E+01			

Table 4
Assumptions Used in Risk Based Corrective Action Transport Model

Parameter	Definition	Units	Value	Source
ER	enclosed-space air exchange rate	l/s	0.00023	RBCA, 1995
Foc	fraction of organic carbon	g-C/g-soil	0.00965	Site-Specific
Ps	Soil bulk density	gsoil/cm3soil	1.7	Site-Specific
Hcap	thickness of capillary fringe	cm	5	RBCA, 1995
Hv	thickness of vadose zone	cm	Lgw-hcap	RBCA, 1995
Ks	Soil-water sorption coefficient	cm3-water/g-C	foc*koc	RBCA, 1995
Lb	Enclosed-space volume/infiltration area ratio	cm	300	RBCA, 1995
Lcrack	Enclosed-space foundation or wall thickness	cm	15	RBCA, 1995
Lgw	Depth to groundwater	cm	177.39	Site-Specific
Ls	Depth to subsurface soil source	cm	122	Site-Specific
Uair	Wind speed above ground surface in ambient mixing zone	cm/s	340	RBCA, 1995
Gair	ambient air mixing zone height	cm	200	RBCA, 1995
N	Areal fraction of cracks in foundations/walls	cm2-cracks/cm2-total area	0.001	USEPA, 1992
q acap	Volumetric air content in capillary fringe soils	cm3-air/cm3-soil	0.038	RBCA, 1995
Tacrack	Volumetric air content in foundations/wall cracks	cm3-air/cm3-total volume	0.26	RBCA, 1995
Tas	Volumetric air content in vadose zone soils	cm3-air/cm3-soil	0.26	RBCA, 1995
Tt	Total soil porosity	cm3/cm3-soil	0.32	Site-Specific
Twcap	Volumetric water content in capillary fringe soils	cm3-water/cm3-soil	0.342	RBCA, 1995
Twcrack	Volumetric water content in foundation/wall cracks	cm3-water/cm3-soil	0.26	RBCA, 1995
Tws	Volumetric water content in vadose zone soils	cm3-water/cm3-soil	0.12	Site-Specific
T	Averaging time for vapor flux	sec	7.88E+08	RBCA, 1995
W	Width of source area parallel to wind, or groundwater flow direction	cm	1200	RBCA, 1995

RBCA, 1995 - ASTM E1739-95: Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.

USEPA, 1992 - U.S. Environmental Protection Agency, 1992, Air/Superfund Exposure National Technical Guidance Study Series: Assessing Potential Aidoor Air Impacts for Superfund Sites. Office of Air Auality. EPA-45 1/R-92-002

Site-Specific: Data specific to site (Geo-logic, 1998), or collected from the adjacent Standard Brand Paints Property (McLaren/Hart, 1997).

Table 5
Physical / Chemical Properties of Chemicals in Soil and Groundwater

Chemical	Henry's Law Constant Hc (L-$H_2$0/L-air)	Diffusivity in Air Dair (cm2/s)	Diffusivity in Water Dwater (cm2/s)	Organic Carbon Partition Coeff Koc (ml/g)
Benzene	2.20E-01	9.30E-02	1.10E-05	6.50E+01
Ethylbenzene	3.20E-01	7.60E-02	8.50E-06	2.20E+02
Toluene	2.60E-01	8.50E-02	9.40E-06	2.57E+02
Total Xylenes	2.90E-01	7.20E-02	8.50E-06	2.40E+02
MTBE	2.40E-02	1.00E-01	1.00E-05	1.10E+01

Table 6
Concentrations of Chemicals in Air Due to Chemicals in Soil and Groundwater

Chemical	Indoor Air Concentration from Groundwater (mg/m3)	Indoor Air Concentration from Soil (mg/m3)	Total Indoor Air Concentration (mg/m3)	Outdoor Air Concentration from Soil (mg/m3)	Outdoor Air Concentration from Groundwater (mg/m3)	Total Outdoor Air Concentration (mg/m3)
Benzene	4.51E-03	1.44E-02	**1.89E-02**	2.35E-03	7.64E-05	**2.43E-03**
Ethylbenzene	5.80E-03	7.31E-03	**1.31E-02**	1.17E-03	8.56E-05	**1.26E-03**
Toluene	3.52E-03	7.87E-03	**1.14E-02**	1.26E-03	5.52E-05	**1.32E-03**
Total Xylenes	7.28E-03	2.04E-02	**2.77E-02**	3.28E-03	1.12E-04	**3.39E-03**
MTBE	0.00E+00	1.07E-02	**1.07E-02**	1.98E-03	0	**1.98E-03**

mg/m3 = milligrams pr meter cubed

MTBE - methyl tertiary butyl ether

Table 7
Summary of Toxicity Values for Chemicals in Soil and Groundwater

	Inhalation Toxicity Value		Oral Toxicity Value	
Chemical	**RfD**	**CSF**	**RfD**	**CSF**
Benzene	na	0.1	na	0.1
Ethylbenzene	0.29	na	0.1	na
Toluene	0.11	na	0.2	na
Total Xylenes	2	na	2	na
MTBE	0.86	na	na	na

Notes:
RfD - Reference Dose in milligrams per kilogram per day (mg/kg-day)
CSF - Cancer Slope Factor in inverse milligrams per kilogram per day (mg/kg-day)-1
na - not applicable - no toxicity value available from USEPA or Cal/EPA

TABLE 8

LEAD RISK ASSESSMENT SPREADSHEET

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL

INPUT | **OUTPUT**

MEDIUM	LEVEL		percentiles 50th	90th	95th	98th	99th	PRG-99 (ug/g)	PRG-95 (ug/g)
LEAD IN AIR (ug/m^3)	0.18								
LEAD IN SOIL (ug/g)	4.0	BLOOD Pb, ADULT (ug/dl)	2.0	3.1	3.5	4.1	4.5	846.4	1264.0
LEAD IN WATER (ug/l)	15	BLOOD Pb, CHILD (ug/dl)	3.3	5.2	5.9	6.8	7.5	123.7	254.3
PLANT UPTAKE? 1=YES 0=NO	1	BLOOD Pb, PICA CHILD (ug/dl)	3.5	5.5	6.2	7.2	8.0	18.8	38.6
RESPIRABLE DUST (ug/m^3)	50	BLOOD Pb, INDUSTRIAL (ug/dl)	1.9	3.0	3.4	4.0	4.4	4203.1	6247.1

EXPOSURE PARAMETERS

	units	residential adults	residential children	residential children with pica	industrial adults
General					
Days per week	days/wk	7	7	7	5
Dermal Contact					
Skin area	cm^2	3700	2800	2800	5800
Soil adherence	mg/cm^2	0.5	0.5	0.5	0.5
Route-specific constant	(ug/dl)/(ug/day)	0.00011	0.00011	0.00011	0.00011
Soil ingestion					
Soil ingestion	mg/day	25	55	790	25
Route-specific constant	(ug/dl)/(ug/day)	0.0176	0.0704	0.0704	0.0176
Inhalation					
Breathing rate	m^3/day	20	10	10	20
Route-specific constant	(ug/dl)/(ug/day)	0.082	0.192	0.192	0.082
Water ingestion					
Water ingestion	l/day	1.4	0.4	0.4	1.4
Route-specific constant	(ug/dl)/(ug/day)	0.04	0.16	0.16	0.04
Food ingestion					
Food ingestion	kg/day	2.2	1.3	1.3	2.2
Route-specific constant	(ug/dl)/(ug/day)	0.04	0.16	0.16	0.04
Dietary concentration	ug/kg	9.5	9.5	9.5	10.0
Lead in produce	ug/kg	1.8	1.8	1.8	

PATHWAYS, ADULTS

Pathway	Residential Blood Pb ug/dl	Residential percent of total	Industrial Blood Pb ug/dl	Industrial percent of total	Concentration in medium
SOIL CONTACT:	0.00	0%	0.00	0%	4 ug/g
SOIL INGESTION:	0.00	0%	0.00	0%	4 ug/g
INHALATION:	0.30	15%	0.21	11%	0.18 ug/m^3
WATER INGESTION:	0.84	42%	0.84	43%	15 ug/l
FOOD INGESTION:	0.84	42%	0.88	46%	9.5 ug Pb/kg diet

PATHWAYS, CHILDREN

Pathway	Typical Blood Pb ug/dl	Typical percent of total	with pica Blood Pb ug/dl	with pica percent of total	concentration in medium
SOIL CONTACT:	0.00	0%	0.00	0%	4 ug/g
SOIL INGESTION:	0.02	0%	0.22	6%	4 ug/g
INHALATION:	0.35	10%	0.35	10%	0.18 ug/m^3
WATER INGESTION:	0.96	29%	0.96	27%	15 ug/l
FOOD INGESTION:	1.99	60%	1.99	57%	9.5 ug Pb/kg diet

Table 9
Cancer Risk Calculations

Exposure Scenario: Commercial Worker / Inhalation / Risk

*(Ca * IR * EF * ED)/(BW * AT)= Intake factor * CSF = Risk*

Chemical	Ca (mg/m3)	IR (m³/day)	EF (days/year)	ED (yrs)	BW (kg)	AT (days)	Intake factor (mg/kg/day)	CSF (mg/kg-day)⁻¹	Risk
Benzene	1.89E-02	20	250	25	70	25550	1.32E-03	0.1	**1.32E-04**
Ethylbenzene	1.31E-02	20	250	25	70	25550	9.16E-04	na	
Toluene	1.14E-02	20	250	25	70	25550	7.96E-04	na	
Total Xylenes	2.77E-02	20	250	25	70	25550	1.94E-03	na	
MTBE	1.07E-02	20	250	25	70	25550	7.50E-04	na	

Exposure Scenario: Construction Worker / Inhalation / Risk

*(Ca * IR * ET * EF * ED)/(BW * AT)= Intake factor * CSF = Risk*

Chemical	Ca mg/m3	IR (m³/hour)	ET (hours/day)	EF (days/year)	ED (yrs)	BW (kg)	AT (days)	Intake factor (mg/kg/day)	CSF (mg/kg-day)⁻¹	Risk
Benzene	2.43E-03	2.5	8	90	1	70	25550	2.45E-06	1.00E-02	**2.45E-08**
Ethylbenzene	1.26E-03	2.5	8	90	1	70	25550	1.27E-06	na	
Toluene	1.32E-03	2.5	8	90	1	70	25550	1.33E-06	na	
Xylene	3.39E-03	2.5	8	90	1	70	25550	3.41E-06	na	
MTBE	1.98E-03	2.5	8	90	1	70	25550	1.99E-06	na	

Exposure Scenario: Construction Worker / Dermal Contact / Soil

*((C * SA * SAF * EF * ED * CF * ABS)/(BW * AT)= Intake factor * CSF = Risk*

Chemical	C (mg/kg)	SA cm2/day	SAF skin	EF days/year	ED year	CF kg/mg	ABS unitless	BW (kg)	AT (days)	Intake factor (mg/kg/day)	CSF (mg/kg-day)⁻¹	Risk
Benzene	5.2	3160	0.0005	90	1	1.00E-03	0.5	70	25550	2.07E-07	1.00E-01	**2.07E-08**
Ethylbenzene	6.69	3160	0.0005	90	1	1.00E-03	0.5	70	25550	2.66E-07	na	na
Toluene	9.16	3160	0.0005	90	1	1.00E-03	0.5	70	25550	3.64E-07	na	na
Xylene	23.60	3160	0.0005	90	1	1.00E-03	0.5	70	25550	9.38E-07	na	na
MTBE	9.2	3160	0.0005	90	1	1.00E-03	0.5	70	25550	3.66E-07	na	na

Exposure Scenario: Construction Worker / Ingestion / Soil

*((C * IR * FD * EF * ED * CF * B)/(BW * AT)= Intake factor / CSF = Risk*

Chemical	C (mg/kg)	IR (mg/day)	FD (fraction of day)	EF (days/yr)	ED (yrs)	CF (kg/mg)	B (unitless)	BW (kg)	AT (days)	Intake factor (mg/m³/kgbw x day)	CSF (mg/kg-day)⁻¹	Risk
Benzene	5.2	480	0.33	90	1	1.00E-06	1	70	25550	4.14E-08	1.00E-01	**4.14E-09**
Ethylbenzene	6.69	480	0.33	90	1	1.00E-06	1	70	25550	5.33E-08	na	na
Toluene	9.16	480	0.33	90	1	1.00E-06	1	70	25550	7.30E-08	na	na
Xylene	23.60	480	0.33	90	1	1.00E-06	1	70	25550	1.88E-07	na	na
MTBE	9.20	480	0.33	90	1	1.00E-06	1	70	25550	7.33E-08	na	na

Total =

Where:
C = concentration
IR = intake rate (either ingestion rate or inhalation rate)
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time
CSF = cancer slope factor
RfD = reference dose
mg/day = milligrams per day
yr = years
kg = kilograms
mg/kg-day = milligrams per kilogram per day

Note: Equations for intake and risk are presented in italics at the top of each exposure scenario.

Table 10
Noncancer Hazard Indices Calculations

Exposure Scenario: Commercial Worker / Inhalation / Hazard

*(Ca * IR * EF * ED)/(BW * AT) = Intake factor / RfD = Hazard Index*

Chemical	*Ca* (mg/m3)	*IR* (m³/day)	*EF* (days/year)	*ED* (yrs)	*BW* (kg)	*AT* (days)	*Intake factor* (mg/kg/day)	*RfD* (mg/kg-day)	*Hazard Index*
Benzene	1.89E-02	20	250	25	70	9125	3.70E-03	na	
Ethylbenzene	1.31E-02	20	250	25	70	9125	2.57E-03	0.29	8.85E-03
Toluene	1.14E-02	20	250	25	70	9125	2.23E-03	0.11	2.03E-02
Total Xylenes	2.77E-02	20	250	25	70	9125	5.42E-03	2	2.71E-03
MTBE	1.07E-02	20	250	25	70	9125	2.10E-03	0.86	2.44E-03
								Total =	**3.43E-02**

Exposure Scenario: Construction Worker / Inhalation / Hazard

*(Ca * IR * ET * EF * ED)/(BW * AT)= Intake factor / RfD = Hazard Index*

Chemical	*Ca* mg/m3	*IR* (m³/hour)	*ET* (hours/day)	*EF* (days/year)	*ED* (yrs)	*BW* (kg)	*AT* (days)	*Intake factor* (mg/kg/day)	*RfD* (mg/kg-day)	*Hazard Index*
Benzene	2.43E-03	2.5	8	90	25	70	365	4.28E-03	na	
Ethylbenzene	1.26E-03	2.5	8	90	25	70	365	2.22E-03	0.29	7.65E-03
Toluene	1.32E-03	2.5	8	90	25	70	365	2.32E-03	0.11	2.11E-02
Total Xylenes	3.39E-03	2.5	8	90	25	70	365	5.97E-03	2	2.99E-03
MTBE	1.98E-03	2.5	8	90	25	70	365	3.49E-03	0.86	4.06E-03
									Total =	**3.58E-02**

Exposure Scenario: Construction Worker / Dermal Contact / Hazard

*((C * SA * SAF * EF * ED * CF * ABS)/(BW * AT)= Intake factor / RfD = Hazard Index*

Chemical	*C* (mg/kg)	*SA* cm2/day	*SAF* gm-soil/cm2-skin	*EF* days/year	*ED* year	*CF* kg/mg	*ABS* unitless	*BW* (kg)	*AT* (days)	*Intake factor* (mg/kg/day)	*RfD* (mg/kg-day)	*Hazard Index*
Benzene	5.2	3160	0.0005	90	1	1.00E-03	0.5				na	
Ethylbenzene	6.69	3160	0.0005	90	1	1.00E-03	0.5	70	365	1.86E-05	1.00E-01	1.86E-04
Toluene	9.16	3160	0.0005	90	1	1.00E-03	0.5	70	365	2.55E-05	2.00E-01	1.27E-04
Xylene	23.60	3160	0.0005	90	1	1.00E-03	0.5	70	365	6.57E-05	2.00E+00	3.28E-05
MTBE	9.20	3160	0.0005	90	1	1.00E-03	0.5	70	365	2.56E-05	na	na
											Total =	**3.46E-04**

Exposure Scenario: Construction Worker / Ingestion / Hazard

*((C * IR * FD * EF * ED * CF * B)/(BW * AT)= Intake factor / RfD = Hazard Index*

Chemical	*C* (mg/kg)	*IR* (mg/day)	*FD* (fraction of day)	*EF* (days/yr)	*ED* (yrs)	*CF* (kg/mg)	*B* (unitless)	*BW* (kg)	*AT* (days)	*Intake factor* (mg/m3/kgbw x day)	*RfD* (mg/kg-day)	*Hazard Index*
Benzene	5.2	480	0.33	90	1	1.00E-06	1	70	365	2.90E-06	1.00E-02	2.90E-04
Ethylbenzene	6.69	480	0.33	90	1	1.00E-06	1	70	365	3.73E-06	1.00E-01	3.73E-05
Toluene	9.16	480	0.33	90	1	1.00E-06	1	70	365	5.11E-06	2.00E-01	2.56E-05
Xylene	23.60	480	0.33	90	1	1.00E-06	1	70	365	1.32E-05	2.00E+00	6.58E-06
MTBE	9.20	480	0.33	90	1	1.00E-06	1	70	365	5.13E-06	na	na
											Total =	**3.60E-04**

Where:
C = concentration
IR = intake rate (either ingestion rate or inhalation rate)
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time
CSF = cancer slope factor
RfD = reference dose
mg/day = milligrams per day
yr = years
kg = kilograms
mg/kg-day = milligrams per kilogram per day

Note: Equations for intake and risk are presented in italics at the top of each exposure scenario.

Table 11
Summary of Cancer Risk and Noncancer Hazard

Future On-site Population	Exposure Pathway	Estimated Non-Carcinogenic Hazard Index	Estimated Incremental Lifetime Carcinogenic Risk
Commercial Building Occupants	Inhalation - soil and groundwater vapors to indoor air	0.03	1.32E-04
	Total Estimated Hazard/Risk	**0.03**	**1.32E-04**
Construction Workers	Inhalation - soil and groundwater vapors to outdoor air	0.0358	2.45E-08
	Dermal contact with chemicals in soil	0.0003	2.07E-08
	Ingestion of chemicals in soil	0.0004	4.14E-09
	Total Estimated Hazard / Risk	**0.0365**	**4.93E-08**