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RESEARCH LABORATORY**

**TPH CRITERIA WORKING GROUP
DEMONSTRATION FIELD SAMPLING
REPORT: ROBINS AIR FORCE BASE,
WARNER-ROBINS, GA**

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FOR THE DIRECTOR



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13. ABSTRACT (Maximum 200 words) Underground storage tank Site 70, Robins Air Force Base, Georgia, is part of a large aircraft refueling/defueling hydrant system. Site 70 was impacted by JP-4 and JP-8 jet fuels through spill, overflows and leaks dating back many years. This total petroleum hydrocarbon (TPH) contamination has been identified and interim corrective action applied to remove free product from above the shallow groundwater table. Using limited site data and the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG or Working Group) approach for evaluation of weathered fuel spills, a Tier 1 Risk-Based Corrective Action (RBCA) analysis demonstration was performed. Soils from the site were analyzed using the Direct Method recommended by the Working Group to characterize the fuel residuals present in terms of 13 total petroleum hydrocarbon (TPH) fractions. The TPH contamination present was composed predominantly of aliphatic equivalent carbon (EC) fractions > EC8 to EC16 with some > EC10 to EC16 aromatics. The lowest average risk-based screening level (RBSL) calculated for the current commercial use scenario was approximately 9000 mg/kg for the direct soil to skin contact pathway. For a futuristic residential scenario, the lowest average RBSL was about 3000 mg/kg for the contaminant leaching to groundwater pathway. This demonstration, however, does not represent a complete site assessment as only soil contamination pathways were evaluated.				
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PREFACE

This effort was performed by Operational Technologies Corporation (OpTech) under Contract Number DAHA 90-06-D-0014, Delivery Order TG01. OpTech activities were conducted under the Project Management of Dr. Peter Lurker, 1370 North Fairfield Road, Suite A, Beavercreek, Ohio 45432. Lt Col Steve Channel of the Air Force Research Laboratory, Human Effectiveness Directorate, Operational Toxicology Branch (AFRL/HEST) at Wright-Patterson Air Force Base (AFB), Ohio, served as contract monitor.

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LIST OF ABBREVIATIONS AND ACRONYMS

78 AMDS/SGPB	78 th Aerospace Medicine Squadron, Bioenvironmental Engineering Flight
AFB	Air Force Base
AFRL/HEST	Air Force Research Laboratory, Operational Toxicology Branch
ASTM	American Society for Testing and Materials
atm	atmosphere
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene and xylene
cm ³	cubic centimeter
C _{sat}	saturation concentration (mg/kg)
DRO	diesel range organics
EC	effective carbon number of chemical molecule
EPA	U.S. Environmental Protection Agency
FID	flame ionization detector
ft	feet
g	gram
GDNR	Georgia Department of Natural Resources
GC	gas chromatograph
GRO	gasoline range organics
HAZWRAP	Hazardous Waste Remedial Actions Program
H _c	Henry's Law Constant (cm ³ /cm ³)
HI	hazard index
HQ	hazard quotient
kg	kilogram
K _{oc}	organic carbon sorption coefficient (cm ³ /cm ³)
k _s	soil-water sorption coefficient (cm ³ /g)
L	liter
LOQ	limit of quantitation
m ³	cubic meter
mg	milligram
mm	millimeter
MS	mass spectrometry
NAPL	non-aqueous phase liquid
ND	nondetect
OpTech	Operational Technologies Corporation
PAH	polycyclic aromatic hydrocarbon
PF	partition factors for soil to water and soil to vapor concentrations at equilibrium
RBCA	Risk Based Corrective Action
RBSL	risk based screening level (mg/kg)
RES	residual saturation (mg/kg)
RfD	reference dose (mg/kg/day)
SCAPS	Site Characterization and Analysis Penetrometer System
TPH	total petroleum hydrocarbons
TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group
UST	underground storage tank

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**TPH CRITERIA WORKING GROUP
DEMONSTRATION FIELD SAMPLING REPORT:
ROBINS AIR FORCE BASE, WARNER-ROBINS, GA**

1.0 INTRODUCTION

Site 70, a large aircraft refueling/defueling hydrant system, at Robins Air Force Base near Warner-Robins, Georgia, was impacted by JP-4 and JP-8 jet fuels through fuel transfer spills and underground leaks. A Tier 1 Risk-Based Corrective Action (RBCA) analysis was conducted, using limited site data and the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG or Working Group) approach for evaluation of weathered fuel spills. Soils from the site were analyzed using the Direct Method recommended by the Working Group to characterize the fuel residuals present in terms of 13 total petroleum hydrocarbon (TPH) fractions. The analysis results were then used in the simple fate and transport models recommended by the RBCA guidance document (ASTM, 1995) for soil exposure pathways.

1.1 Objectives

This analysis is part of a series of field demonstrations of the effectiveness of the Working Group approach. The goals of this demonstration are to:

- Calculate human health protective risk-based screening levels (RBSLs) using the Direct Method fractionation analysis results and a Tier 1 RBCA approach
- Evaluate human health risk at Site 70 using the RBSLs
- Determine the variability in the RBSLs
- Compare RBSLs with State of Georgia cleanup criteria

1.2 Working Group Approach

The Working Group approach is incorporated into the American Society for Testing and Materials (ASTM) RBCA framework. The RBCA framework integrates site assessment techniques with risk assessment practices recommended by the U.S. Environmental Protection Agency (EPA) (ASTM, 1995). Risk assessment elements, including source contaminant characterization, exposure pathway identification, existing and potential receptor identification and exposure calculation, are incorporated into a tiered approach using increasingly site-specific parameters and data analysis. In Tier 1, conservative default assumptions and simple models are used. In later tiers (i.e., Tiers 2 and 3), site specific parameters and selected models replace conservative assumptions and models. This increased specificity in later tiers is more costly but the more site-specific RBSLs generated from higher tiers may result in lower costs for cleanup without compromising human health. The RBCA user must decide if the cost of the higher tier analysis is warranted by the potential reduction in cleanup costs. A tiered approach is generally considered more cost-effective than traditional approaches, which require uniform standards and analysis procedures.

The Working Group approach assesses human health non-cancer risks from petroleum hydrocarbons. Since TPH is composed of multiple types of hydrocarbons, the Working Group approach relies on the analytical separation of petroleum into 13 fractions (see Table 1-1). The fractions are based on their aliphatic or aromatic nature and their equivalent carbon (EC) number, a function of boiling point. Fractions are analyzed by retention time on a gas chromatograph (GC) relative to n-alkanes with specified carbon numbers. The fractions have been assigned toxicological and transport parameters which resulted from extensive reviews of data from individual compounds in the fraction or from petroleum mixtures represented within the fraction. Volumes 3 and 4 of the Working Group publications explain this rationale for transport and toxicity, respectively (TPHCWG, 1998a and 1998b).

TABLE 1-1 WORKING GROUP AROMATIC AND ALIPHATIC FRACTIONS

Aromatic Fraction	Aliphatic Fraction
EC5-EC7 (Benzene)*	EC5-EC6
>EC7-EC8 (Toluene)	>EC6-EC8
>EC8-EC10	>EC8-EC10
>EC10-EC12	>EC10-EC12
>EC12-EC16	>EC12-EC16
>EC16-EC21	>EC16-EC21
>EC21-EC35	

Notes: * Evaluated only as a carcinogen.

EC - equivalent carbon fractions are determined by the retention time on a GC column, relative to alkane compounds of known carbon number (TPHCWG, 1998a)

The Working Group fractionation data results, fraction toxicity information and transport parameters can be used to perform a risk-based analysis for each fraction present at the site being evaluated. The hypothetical risk and the resulting soil screening level (i.e., the RBSL) for the "whole TPH" mixture are calculated by combining the non-cancer risks from individual fractions weighted by their percent composition within the TPH mixture.

1.3 Demonstration Site Description

Robins Air Force Base (AFB) lies in central Georgia south of Macon and immediately east of the city of Warner-Robins. The base is home to the Warner-Robins Air Logistics Center, Air Force Material Command and several tenant air groups (HAZWRAP, 1996).

Underground storage tank (UST) Site 70 is located in the northeastern portion of Robins AFB. It serves as a large aircraft refueling/defueling hydrant system providing ground support to the 19th Air Refueling Group and the 93rd Air Control Wing. The aircraft refueling/defueling hydrant system at Site 70 consists of a small storage building (Building 28) and a pumphouse/control room (Building 2070). Six 50,000 gallon steel USTs contain jet fuel, a 2,000

gallon steel UST contains waste fuel and a 400 gallon UST contains water. Approximately 5200 feet of 4- to 6-inch diameter steel lines supply six hydrants located on the adjacent parking apron (HAZWRAP, 1996).

Site 70 was contaminated from a combination of various JP-4 and JP-8 spills, overfills and leaks that date back many years. The USTs and associated lines were originally installed in 1958. The tanks were used for storage of JP-4 jet fuel until June 1994 and JP-8 since. A leak was documented in 1995 at lateral control pit #3. Soil contamination and free product were found relatively near this lateral control pit, suggesting that it may represent a significant source of contamination. Free product has also been found up to 150 feet away from the tankfield, including several areas near the valve junction boxes just off the east end of the concrete tarmac. These junction boxes may also have been significant sources over time. Environmental staff report that various fuel spills and overfills have occurred on the tarmac. These spills were washed over the edge of the concrete tarmac and may have contributed significantly to the contamination (HAZWRAP, 1996).

1.3.1 Soils

Much of Robins AFB lies within the Ocmulgee River Valley, characterized by gently sloping terraces and swampy floodplains. The floodplain and terrace system extends one to three miles in width. Total relief within one mile of Site 70 is less than 20 ft. UST Site 70 is situated on fill material and alluvial sediments which are recent floodplain deposits of the Ocmulgee River and include sand, clay and peat (HAZWRAP, 1996).

1.3.2 Hydrology

Site 70 overlies the Cretaceous-age upper Providence sediment layer. The groundwater table at Site 70 ranges from 6 to 9 feet deep and discharges to the floodplain east of the site. The floodplain that lies about 800 feet to the east is a critical wetland environment (hardwood swampland) which may be impacted by contaminated discharge. The Ocmulgee River is approximately 1300 feet downgradient (i.e., southeast). Site 70 lies within one of Georgia's most significant groundwater recharge zones (HAZWRAP, 1996).

Under the sediment layer lies the Cusetta clay aquitard. The Blufftown Aquifer below is used as a regional drinking water source. Base well WS-8, the closest supply well, lies about 1600 feet northwest (i.e., up-gradient) from Site 70. There are no other public or private wells within three miles down-gradient (HAZWRAP, 1996).

1.3.3 Previous Investigations

Vapor monitoring wells were installed in the tankfield of UST Site 70 during a base-wide UST environmental upgrade program in 1992 and 1993. The wells are approximately 12 feet deep and extend into the shallow groundwater at the site. Free product was detected in most of the vapor monitoring wells in September 1993. Initial remedial actions at the vapor monitoring wells included manual bailing of free product and cleanup with petroleum-adsorbent pads, removing approximately 16 gallons of free product. In October 1993, electrical contractors encountered free product on groundwater while excavating a pit for new underground lines. The excavation

was approximately 35 to 40 feet south-southwest of the tankfield at UST Site 70. Remedial actions included removal of approximately 20 gallons of liquid hydrocarbons using a vacuum waste pumping truck (HAZWRAP, 1996).

In response to the detection of free product, an Initial Site Characterization in the area of Site 70 was undertaken in late 1993. Following completion of the initial site characterization, the Air Force conducted a UST contamination assessment. Monitoring wells were installed near UST Site 70 during January 1994. Free product was removed from the monitoring wells using manual and skimmer techniques. In March 1994, a DPI Petro-belt hydrocarbon-only belt skimmer was installed on monitoring well EA-2 to recover free product. Nearly 2,000 gallons of liquid hydrocarbons were collected through July 1995 (HAZWRAP, 1996).

Assessment activities were continued with additional monitoring wells installed in August 1994. Analytical results indicated a large residual petroleum hydrocarbon pool surrounding the tankfield at Site 70 and a large dissolved phase petroleum hydrocarbon plume extending downgradient east and southeast of the site (HAZWRAP, 1996).

These findings were supported in February 1995 with the demonstration of the Site Characterization and Analysis Penetrometer System (SCAPS) at Site 70 by the U.S. Army Corps of Engineers. The SCAPS system uses a laser induced fluorescence tool to indicate free product and/or residual contamination thickness and depth. The demonstration was limited to an area around the EA-2 monitoring well. The results showed a 2.5 ft interval from 6 to 8.5 ft below ground surface (bgs) of elevated hydrocarbon fluorescence, which correlated well with the maximum free product thickness measured in the nearby monitoring well (HAZWRAP, 1996).

In July 1995, Batelle performed a short-term field pilot test of the Bioslurper system at Site 70. In 1996, the Batelle Bioslurper began running full time at monitoring well EA-2. Approximately 3,400 gallons of free product were recovered. The Bioslurper was removed in October 1997 when the free product layer had been removed in the vicinity of monitoring well EA-2 (HAZWRAP, 1997).

In October 1996, the Department of Energy's Hazardous Waste Remedial Action Program (HAZWRAP) investigated soils and groundwater upgradient and to the east of the known source using the Geoprobe direct push system or hand augers. The investigation included contaminant transport in groundwater and natural attenuation modeling for the site (HAZWRAP, 1997).

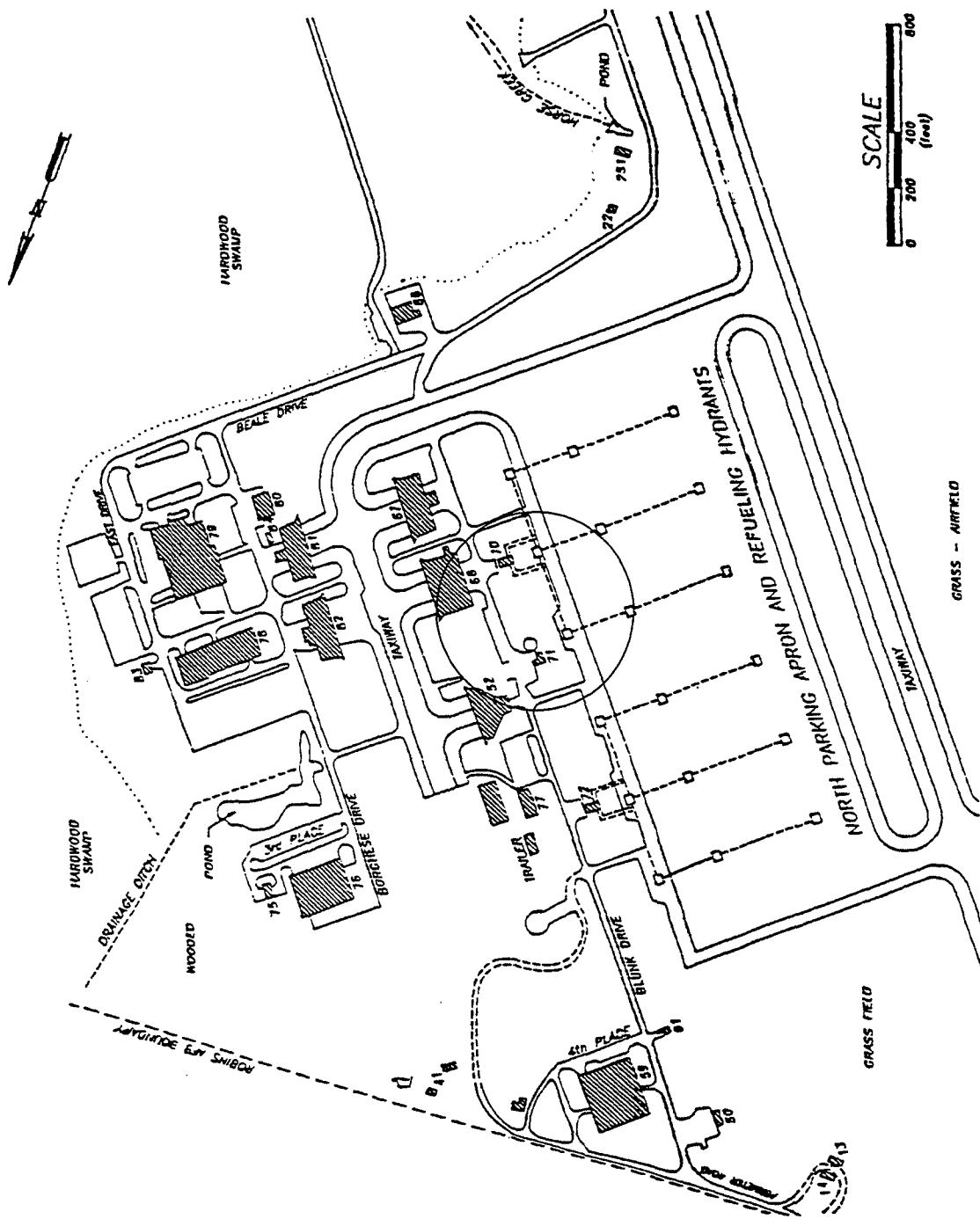


Figure 1-1 Site 70, Robins AFB, Georgia*
 *Adapted from HAZWRAP, 1996

2.0 SAMPLING AND ANALYSIS

2.1 Soil Sample Collection

Samples collected for moisture content, fractionation and BTEX (benzene, toluene, ethylbenzene and xylene) analyses were packed into glass jars with minimal head space. Samples were stored on ice and shipped the same day to Lancaster Laboratory, Lancaster, Pennsylvania, via an overnight express service.

2.1.1 Hollow Core Auger Samples

Hollow core auger soil samples were taken on two occasions, 19 January and 4 February 1999. These samples were collected by Geophex Corporation and split with OpTech for the purpose of this demonstration. The soil was packaged and shipped to the laboratory by Lt Marcia Kankelfritz of the 78th Aerospace Medicine Squadron, Bioenvironmental Engineering Flight (78 AMDS/SGPB) located at Robins AFB.

Samples were taken from two separate borings at depths ranging from 2 to 13 feet bgs. Soil from each sampling interval was composited; a sample taken from the composite was submitted to the laboratory for moisture content and fractionation analyses only. BTEX analyses were not run.

Soil sampling locations were chosen based on the Geophex sampling plan. The main intent governing sampling location was to determine and characterize the extent of contamination and the edge of the plume (Peters, 1998, personal communication). The sampling performed on 4 February was located immediately adjacent to monitoring well EA-2. Sample GX-4 is located over 100 feet west of EA-2. Sampling locations are presented in Figure 2-1.

2.1.2 Hand Auger Samples

Hand auger samples were taken on 12 February 1999. Samples were taken from two separate borings at depths ranging from three to six feet bgs. Sampling sites were chosen to characterize soil contamination 8 feet east and 12 feet southeast (down-gradient) from a known hot spot, monitoring well EA-2. Soil from each foot-long sampling interval was composited in a new plastic bag. A photo-ionization detector, appearance (i.e., staining) and smell were used to help determine the presence of petroleum in the composited sample. Only positive samples were submitted for analysis. Three samples were submitted per positive composite; moisture content, fractionation and BTEX analyses were all performed.

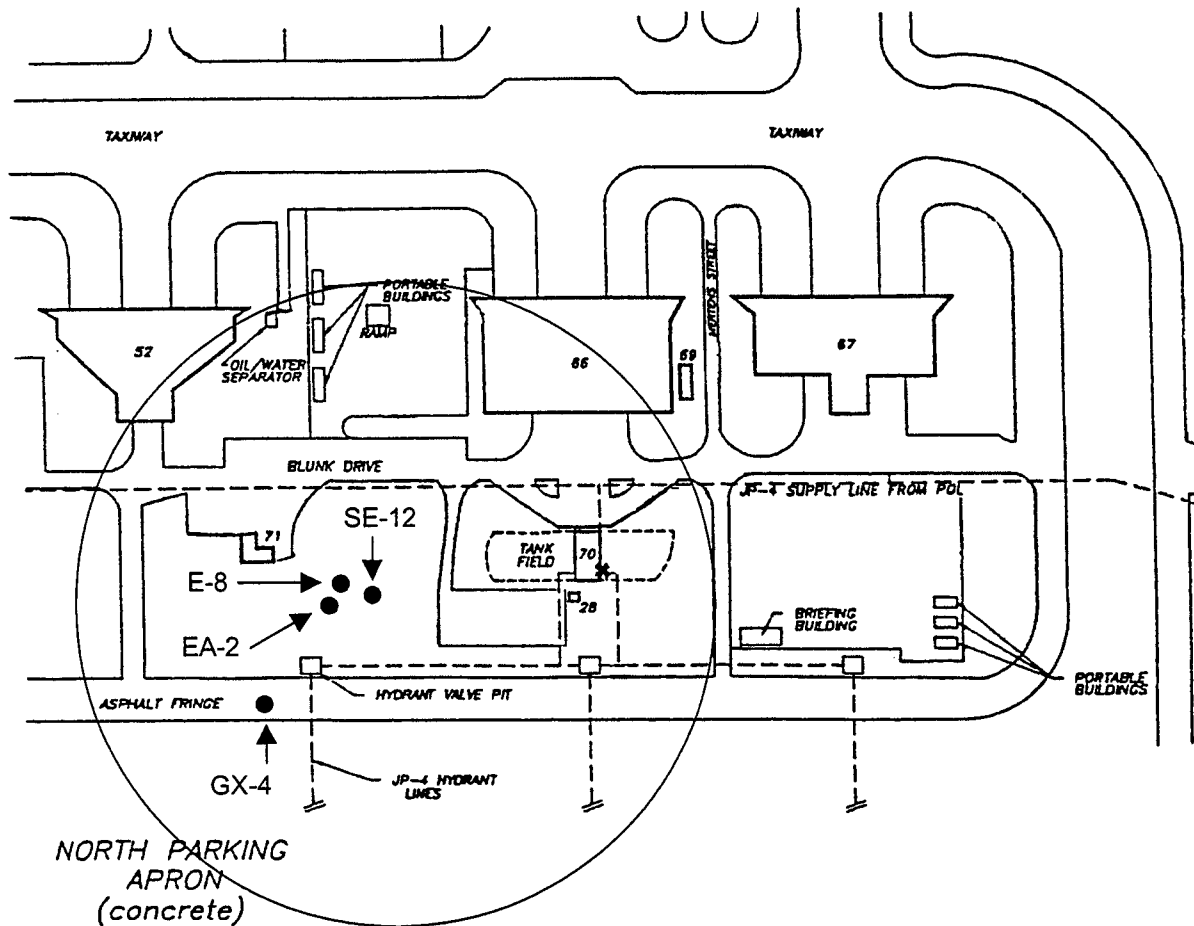


Figure 2-1 Working Group Demonstration Sampling Locations, Site 70*
 *Adapted from HAZWRAP, 1996

2.2 Analytical Approach

TPH in environmental matrices may be measured by several analytical techniques. TPH analytical methods currently in use for quantification of hydrocarbons in soils and water are discussed in Volume 1 of the Working Group's publications (TPHCWG, 1998c). Methods identified by product type, like diesel range organics (DRO) and gasoline-range organics (GRO) analyses, indicate the approximate carbon range for the method. For example, GRO uses a gasoline standard and quantifies over an effective hydrocarbon range of EC6 through EC10 or 12. However, presence of GRO hydrocarbons in a sample does not indicate that gasoline is actually present. The GRO method can be used to quantify the lighter hydrocarbons present in environmental samples contaminated with other products such as mixed naphthas, Stoddard solvent or light mineral spirits. JP-4 and JP-8 fuels are comprised of hydrocarbons both in the GRO and DRO effective carbon ranges (EC6 to EC12 and EC12 to EC24, respectively). Using GRO and DRO to characterize a jet fuel spill may result in overestimation of hydrocarbon concentrations.

Analytical techniques vary in how much TPH is measured. Methods using more rigorous extraction techniques and more efficient solvents will remove more TPH from soils. Infrared techniques (e.g., EPA Method 418.1) can measure naturally occurring organics in topsoil or other carbon-rich soils (TPHCWG, 1998a). Such interference can result in TPH concentrations higher than what is attributable to the petroleum contamination.

Conventional TPH analyses do not correlate well with site human health risk. Two sites with the same TPH value may have completely different risks. At one site, the TPH may be composed almost entirely of carcinogens while the other site may have very low concentrations of carcinogens. Cleanup criteria based on TPH values, therefore, do not relate directly to health risk. Many conventional TPH-method based criteria were set based on aesthetics, analytical detection or reporting limits, or other non-risk-based values. Frequently these criteria are coupled with analyses of carcinogenic indicator compounds (e.g., benzene). The use of non-risk-based criteria can result in higher cleanup costs without human health benefit. At some sites, however, human health risk is not the driving factor. Ecological risk, aesthetics or other factors may drive the cleanup values at these sites.

Quantification of TPH in soils from Site 70 was performed using both a conventional TPH method and the Direct Method for comparison. The Direct Method was developed by the Working Group for use within a risk-based framework for determining cleanup levels. It quantifies TPH in terms of the 13 aliphatic and aromatic fractions, as seen in Table 1-1.

2.2.1 Direct Method

The Direct Method first employs a single analysis for the entire EC6 to EC28 range. n-Pentane is used to extract the sample. It is then analyzed with a GC/FID (flame ionization detector) to directly obtain the "whole" TPH measurement. This preliminary analysis can be used to "fingerprint" the contaminant (s) (i.e., determine the nature of the hydrocarbons present).

Aliphatics and aromatics must be separated prior to the fractionation analysis of the n-pentane extract. Either alumina (modified EPA Method 3611B) or silica gel (modified EPA Method 3630B or C) may be used for the separation into saturates, polars and aromatics. Although similar to these EPA Methods, the Direct Method uses a smaller column to minimize dilution; n-pentane is used not only for extraction but also for elution of the aliphatics. Use of n-pentane instead of n-hexane allows the detection of TPH starting at EC6 and includes quantification of n-hexane. Aromatics are eluted from silica gel by methylene chloride and from alumina by methylene chloride with acetone. Total aromatics and aliphatics can then be reported separately.

Aliphatic and aromatic extracts may be fractionated by GC/FID. If light-end constituents smaller than EC9 are measured in the direct sample, GC/MS (mass spectrometry) is also used. The Direct Method is a tiered analytical approach in that the entire process does not have to be followed and that useful analytical data result from each step in the process.

Direct Method analysis is not necessary for all soil samples collected at a site. The Direct Method should be used to characterize the contamination present. If the "fingerprint" is consistent across the site, less expensive conventional analytical methods may be used during additional sampling to determine the extent of contamination. Depending on state specific

requirements, additional EPA analytical methods may be necessary to characterize indicator compounds (e.g., polycyclic aromatic hydrocarbons) or carcinogenic risk.

2.2.2 Quality Control Analysis

Trip blanks, method blanks, lab controls and matrix spikes were analyzed for each round (occasion) of sampling. All samples were analyzed at Lancaster Laboratories located in Lancaster, Pennsylvania.

3.0 WORKING GROUP APPROACH FOR TIER 1 ASSESSMENTS

The Working Group approach RBSLs protect for human health non-cancer risks. If carcinogens are detected, carcinogenic risk must be evaluated separately, using EPA risk values and methodology (TPHCWG, 1998a). At Site 70, BTEX analyses were run only on the hand auger samples. Benzene concentrations were found at one of the two hand auger borings. Specific tests for carcinogenic polycyclic aromatic hydrocarbons (PAHs, e.g., benzo(a)pyrene) were not performed at this time and were not reported in previous investigations (i.e., HAZWRAP, 1996 and 1997). Since benzene was detected, carcinogenic assessment should be evaluated. The present project is being conducted as a demonstration of the Working Group approach to non-carcinogenic risks from TPH contaminated soils. It should be noted, however, that the remedial actions at Site 70 would likely be driven by the state of Georgia's benzene cleanup level of 0.008 mg/kg (GDNR, 1996).

RBSLs are calculated for each exposure pathway using the TPH fractionation results and the Working Group approach. Beyond the scope of the RBCA guidance (ASTM, 1995), the Working Group approach incorporates the chemical saturation concentration (C_{sat}), the residual saturation (RES) and the additivity of risks across the fractions. Treating TPH as an additive mixture instead of a single compound allows toxicological and fate and transport interactions between the fractions to be considered.

Noncarcinogenic risk for each fraction is the hazard quotient (HQ). The HQ is the ratio of the estimated daily intake of a contaminant in a given medium (e.g., soil) to the reference dose (RfD) (see Equation 1). All equations in Section 3.0 were adapted from Volume 5 of the Working Group's publications (TPHCWG, 1999).

$$HQ = \frac{IntakeRate(\frac{mg}{kg-day})}{RfD(\frac{mg}{kg-day})} \quad (Equation 1)$$

The intake rate depends upon the frequency and duration of exposure, the source concentration and the transport rates between the source and the receptor for cross-media pathways. Additivity is incorporated into the calculation of "whole TPH" hazard index (HI) and RBSL. Total risk is apportioned over the different fractions present. Rather than each fraction assuming risk equal to a HI, each fraction is allotted a portion of the risk, with the sum of the HQs from each fraction equal to the HI for the mixture as depicted in Equation 2. If the HI is less than or equal to 1, then the "whole TPH" does not represent an excess health hazard.

$$HI = \sum_{i=1}^{i=n} HQ_i = \sum \frac{f_i C_{TPH}}{RBSL_i} \quad (\text{Equation 2})$$

where:

HI	=	Hazard Index [unitless]
n	=	Number of fractions (13 total)
HQ _i	=	Hazard Quotient for i th specific fraction [unitless]
f _i	=	Percent Weight of i th TPH fraction in "whole TPH" mixture [unitless]
C _{TPH}	=	TPH concentration in soil [mg/kg]
RBSL _i	=	Tier 1 risk-based screening level for a TPH fraction [mg/kg]

The assumption of additivity for calculating a "whole TPH" RBSL is conservative. The toxicological information for the fractions indicates that these fractions impact different organs (TPHCWG, 1998b). Typically, additivity of individual HQs is only applied to constituents or constituent classes that impact the same organ.

Transport and exposure for cross-media pathways are maximized at the saturation concentration. For cross media pathways where specific fractions are at saturation concentration, the following equations are solved:

$$HI = \sum_{i=1}^{i=n} HQ_i = \sum \text{Min} \left(\frac{f_i C_{TPH}}{RBSL_i}, \frac{C_{sat,i}}{RBSL_i} \right) \leq 1 \quad \text{given,} \quad (\text{Equation 3})$$

$$\sum_{i=1}^{i=13} f_i = \sum \frac{C_i}{C_{TPH}} = 1 \quad (\text{Equation 4})$$

where:

C _{TPH}	=	TPH Concentration [mg/kg]
C _{sat,i}	=	Saturation concentration for i th TPH fraction [mg/kg]
C _i	=	Concentration of the i th TPH fraction (mg/kg)

C_{sat} is the upper exposure limit for cross media pathways. It represents the chemical concentration in soil at which the sorption limit of the soil particles, the solubility limit of the soil pore water and the saturation limit of the soil pore air have been reached. A concentration above the C_{sat} does not automatically indicate the presence of mobile, free-phase chemicals. Actual mobility of a non-aqueous phase liquid (NAPL) depends on the contaminant and soil properties, including various capillary, gravitational, hydrodynamic and surface tension forces. However, at soil concentrations greater than C_{sat}, the likelihood of free phase NAPL should be considered. Once free product transfers, the assumptions of the Working Group approach are no longer valid and multi-phase transport should be considered. C_{sat} is defined by Equation 5.

$$C_{sat,i} [mg / kg] = \frac{S_i}{\rho_s} [H_{c,i} \theta_{as} + \theta_{ws} + k_{s,i} \rho_s] \quad (\text{Equation 5})$$

where:

S_i	=	Water Solubility for i^{th} TPH fraction [mg/L]
ρ_s	=	Soil Bulk Density [g/cm^3]
$H_{c,i}$	=	Henry's Law Constant for i^{th} TPH fraction [cm^3/cm^3]
θ_{as}	=	Volumetric air content of the soil [cm^3/cm^3]
θ_{ws}	=	Volumetric water content of the soil [cm^3/cm^3]
$k_{s,i}$	=	Soil-water sorption coefficient for i^{th} TPH fraction ($k_s = K_{oc} * f_{oc}$) [cm^3/g]

The C_{sat} limit does not apply to direct exposure pathways, such as the surface soil contact pathway. The direct exposure is to the original impacted media (e.g., contaminated soil) rather than to the cross media, to which the contamination has been transferred.

Residual saturation should not be confused with C_{sat} . A value of RES may be reached when calculating a "whole TPH" RBSL. RES means that the selected risk level (e.g., HI = 1) could not be reached or exceeded for the pathway and scenario given the constituents present, regardless of the contaminant concentration. RES can only be obtained at the TPH concentration where the C_{sat} of the TPH mixture is reached (i.e., each fraction has reached C_{sat}). This means that even if the concentration of each fraction is set equal to C_{sat} for that pathway, the combined risk of each fraction still does not equal a HI of "1".

3.1 TPH Fractions Physical Properties

The 13 Working Group fractions were selected based on order of magnitude differences in partitioning properties (TPHCWG, 1998a). These properties are used in the simple fate and transport models for RBCA analysis (ASTM, 1995). These models evaluate the partitioning and migration of the TPH fractions for the different applicable pathways. Using fraction properties allows a more accurate estimation of exposure to the complex mixture than can be modeled from single TPH measurements.

Chemical properties govern how a chemical interacts with its environment. These properties include solubility, vapor pressure, sorption coefficient and Henry's Law Constant. In general, for chemicals of the same equivalent carbon number, the solubility of aromatic hydrocarbons is greater than that of aliphatic hydrocarbons. This is especially noticeable at high EC values. The variability in solubility at any given EC is about an order of magnitude. Aromatic hydrocarbons are more likely to be present as dissolved constituents in groundwater than are the corresponding aliphatic hydrocarbons. There is very little difference in vapor pressure between aliphatic and aromatic constituents of an equivalent EC. In effect, the EC and vapor pressure are closely related (TPHCWG, 1998a).

The soil-water sorption coefficient (k_s) represents the tendency of a chemical to be adsorbed onto a soil particle. Aliphatic fractions are more likely to remain bound to a soil particle than the aromatic fractions of an equivalent EC. As stated above, aliphatics exhibit lower solubility (TPHCWG, 1998a).

Henry's Law Constant (H_c) is the ratio of a compound's concentration in air to its concentration in water, when at equilibrium (TPHCWG, 1998a). Although aliphatic hydrocarbons tend to be less soluble and more volatile than aromatic hydrocarbons, benzene is a very volatile aromatic and is more toxic than the corresponding aliphatic fraction. Therefore, when present, benzene is likely to drive risk calculations for pathways involving volatilization from soil or groundwater.

The physical properties used to determine partitioning factors for the 13 TPH fractions are listed in Table 3-1. The equations used to develop these fate and transport properties are found in Volume 3 of the Working Group Publications (TPHCWG, 1998a).

TABLE 3-1 FATE AND TRANSPORT PROPERTIES OF TPH FRACTIONS¹

	Solubility (mg/L)	Henry's Constant	Molecular Weight (g/mole)	Vapor Pressure (atm)	log K_{oc} ² (cm^3/cm^3)	PF ³ (soil/ water)	PF ³ (soil/ vapor)
Aliphatics							
EC5-EC6	3.6E+01	3.4E+01	8.1E+02	3.5E-01	2.9E+00	1E+01	3E-01
>EC6-EC8	5.4E+00	5.1E+01	1.0E+02	6.3E-02	3.6E+00	4E+01	9E-01
>EC8-EC10	4.3E-01	8.2E+01	1.3E+02	6.3E-03	4.5E+00	3E+02	6E+00
>EC10-EC12	3.4E-02	1.3E+02	1.6E+02	6.3E-04	5.4E+00	3E+03	5E+01
>EC12-EC16	7.6E-04	5.4E+02	2.0E+02	4.8E-05	6.7E+00	7E+04	1E+03
>EC16-EC35	1.3E-06	6.4E+03	2.7E+02	7.6E-06	9.0E+00	1E+07	1E+05
Aromatics							
EC6-EC6	1.8E+03	2.3E-01	7.8E+01	1.3E-01	1.9E+00	9E-01	4E+00
>EC6-EC8	5.2E+02	2.7E-01	9.2E+01	3.8E-02	2.4E+00	2E+00	9E+00
>EC8-EC10	6.5E+01	4.9E-01	1.2E+02	6.3E-03	3.2E+00	2E+01	5E+01
>EC10-EC12	2.5E+01	1.4E-01	1.3E+02	6.3E-04	3.4E+00	2E+01	2E+02
>EC12-EC16	5.8E+00	5.4E-02	1.5E+02	4.8E-05	3.7E+00	5E+01	2E+03
>EC16-EC21	5.1E-01	1.3E-02	1.9E+02	7.6E-06	4.2E+00	1E+02	4E+04
>EC21-EC35	6.6E-03	6.8E-04	2.4E+02	4.4E-09	5.1E+00	1E+03	3E+07

Notes: Table extracted in part from Volume 3 of Working Group Publications (TPHCWG, 1998a).

¹ Properties based on an equivalent carbon number. Values are for pure compounds. Behavior may differ in complex mixtures.

² K_{oc} - organic carbon sorption coefficient

³ PF - partition factors for soil to water and soil to vapor concentrations at equilibrium

3.2 Fate and Transport Fractions Toxicity Criteria

The Working Group approach focuses mainly on non-carcinogenic impacts to human health. Carcinogenic impacts are evaluated separately if carcinogenic indicators are found during sampling. Some of the indicator compounds used to assess carcinogenic risk include benzene and the carcinogenic PAHs such as benzo(a)pyrene. Carcinogenic risks often drive cleanup even in relatively low concentrations. The majority of constituents in TPH are noncarcinogenic (TPHCWG, 1998b).

Reference doses are developed for non-carcinogenic compounds. RfDs are estimates of daily exposure to the human population, including sensitive subgroups, which are likely to be without appreciable risk of deleterious effects during a lifetime. In the Working Group approach, the same toxicity criterion is assigned to more than one fate and transport fraction due to the similarity of toxicity findings across these fractions or limitations in the available toxicity data (see Table 3-2). Fractions are still assessed separately, allowing the exposure potential of each fraction to be estimated appropriately.

TABLE 3-2 WORKING GROUP FRACTION-SPECIFIC RfDs

Effective Carbon Range	Aromatic RfD (mg/kg/day)	Critical Effect	Aliphatic RfD (mg/kg/day)	Critical Effect
Aromatic >EC6-EC8 Aliphatic EC5-EC6 >EC6-EC8	0.20 - Oral 0.10 - Inhalation	Hepatotoxicity, Nephrotoxicity	5.0 - Oral 5.0 - Inhalation	Neurotoxicity
>EC8-EC10 >EC10-EC12 >EC12-EC16	0.04 - Oral 0.05 - Inhalation	Decreased body weight	0.1 - Oral 0.3 - Inhalation	Hepatic and hematological changes
>EC16-EC21 >EC21-EC35	0.03 - Oral	Decreased body weight	2.00 - Oral	Hepatic granuloma (foreign body reaction)

Adapted from TPHCWG, 1998b.

Aromatic fractions generally have lower RfDs than aliphatic fractions and are approximately an order of magnitude more toxic than the corresponding aliphatic fraction. RfDs are based on chronic effects, including hepatotoxicity (liver toxicity), nephrotoxicity (kidney toxicity) and decreased body weight.

The Working Group approach is most appropriate for use at sites where carcinogenic indicator compounds are not present or are present below regulatory action levels. Information on the development of TPH fraction RfDs is provided in Volume 4 of the Working Group Publications (TPHCWG, 1998b).

4.0 ANALYTICAL RESULTS

4.1 Direct Method Results

The aliphatic and aromatic fraction distributions from UST Site 70 soils are displayed in Tables 4-1 and 4-2. Total TPH concentrations ranged from nondetect (ND) to 16300 mg/kg. Of the ten samples analyzed, only five (EA-2-4, EA-2-7, E-8-4, SE-12-5 and SE-12-6) resulted in detectable hydrocarbon levels across the fractions. Two additional samples, GX-4-13 and E-8-

3, showed hits in one or two fractions; these hits are not indicative of a fuel fingerprint and may represent organic carbon content.

TABLE 4-1 DIRECT METHOD RESULTS - HOLLOW CORE AUGER SAMPLES¹

LOCATION	GX-4	GX-4	GX-4	EA-2	EA-2	EA-2
DEPTH (ft)	3	7.5	13	2	4	7
Laboratory ID:	3074868	3074869	3074870	3086915	3086916	3086917
Aliphatics						
EC5-EC6	<0.25 ²	<0.24	<0.23	<0.24	<45	433.2
>EC6-EC8	<0.25	<0.24	<0.23	<0.24	160	825.8
>EC8-EC10	<10	<10	<9	<9	1078.4	4269.3
>EC10-EC12	<10	<10	<9	<9	1495.8	4236.7
>EC12-EC16	<25	<24	<23	<24	1128	2883
>EC16-EC21	<25	<24	<23	<24	27	<452
>EC21-EC35	<64	<60	142³	<59	<57	<1130
Aromatics						
EC5-EC6 (benzene only)	<0.006	<0.006	<0.006	<0.006	<1.1	11.4
>EC6-EC8 (toluene only)	<0.006	<0.006	<0.006	<0.006	2.0	<5.6
>EC8-EC10	<10	<10	<9	<9	137.2	455.5
>EC10-EC12	<10	<10	<9	<9	352.5	992.9
>EC12-EC16	<25	<24	<23	<24	340	864
>EC16-EC21	<25	<24	<23	<24	<23	24
>EC21-EC35	<64	<60	165	<59	<57	<56
Total Aliphatics⁴	<127	<120	154	<118	3915	12781
Total Aromatics	<127	<120	173	<118	846	2350
Total "TPH"	ND	ND	327	ND	4761	15131

Notes: ¹ Units: mg/kg dry weight

² < - Value is less than limit of quantitation (LOQ) value presented.

³ Bolded values indicate detected quantities.

⁴ Totals do not reflect the arithmetic sum of the detected fraction values because NDs are not necessarily zeros and contribute to the total area under the chromatogram curve.

TABLE 4-2 DIRECT METHOD RESULTS - HAND AUGER SAMPLES¹

LOCATION	E-8	E-8	SE-12	SE-12
DEPTH (ft)	3	4	5	6
Laboratory ID:	3092072	3092069	3092070	3092071
Aliphatics				
EC5-EC6	<0.24 ²	<0.24	<45	84
>EC6-EC8	0.60³	52	127	313
>EC8-EC10	<10	146.7	1697	3870
>EC10-EC12	<10	245.2	1923	4501
>EC12-EC16	<24	194	1260	3290
>EC16-EC21	<24	<24	<227	<449
>EC21-EC35	<60	<59	<568	<1124
Aromatics				
EC5-EC6 (benzene only)	<0.006	<0.6	1.92	2.54
>EC6-EC8 (toluene only)	<0.006	<0.6	1.71	1.55
>EC8-EC10	<10	16.2	127.9	773
>EC10-EC12	<10	61.9	293.7	1657
>EC12-EC16	<24	73	287	1586
>EC16-EC21	<24	<24	<23	<225
>EC21-EC35	<60	<59	<57	<562
Total Aliphatics⁴	<120	660	5110	12207
Total Aromatics	<120	161	726	4093
Total "TPH"	ND	821	5836	16300

Notes: ¹ Units: mg/kg dry weight

² < - Value is less than LOQ value presented.

³ Bolded values indicate detected quantities.

⁴ Totals do not reflect the arithmetic sum of the detected fraction values because NDs are not necessarily zeros and contribute to the total area under the chromatogram curve.

The Direct Method quantitation limits are variable for the samples in this demonstration. Reporting limits tend to be lower for this method if most of the petroleum hydrocarbons represented in a given fraction are from fewer GC peaks (i.e. fewer constituents) (Tuomi *et al.*, 1999). This method is still under development and refinements of limits of quantitation (LOQs) are expected.

The fraction profiles of samples resulting in detectable hydrocarbon levels across the fractions are depicted in Figure 4-1. The similarity of the profiles between samples indicates that the same fuel exists across the sampled portion of this site and that the same types and extent of weathering of the fuel has occurred. The TPH present is comprised mostly of >EC8 to EC16 aliphatics and >EC10 to EC16 aromatics. More specifically, >EC8 to EC10 aliphatic hydrocarbons make up 19 to 30% of all hydrocarbons, the >EC10 to EC12 aliphatic range makes up 28 to 34% and the >EC12 to EC16 aliphatic range contributes 19 to 25%. Aromatics contribute smaller overall percentages; the >EC10 to EC12 and the >EC12 to EC16 aromatic ranges make up only 5 to 10% each. The highest aliphatic percentage (34% >EC10 to EC12) and subsequently lowest aromatic percentages (about 5% each >EC10 to EC12 and >EC12 to EC16) were found in the SE-12, 5 ft bgs sample; this pattern, although similar to the other samples, may be more typical of a fresher jet fuel profile.

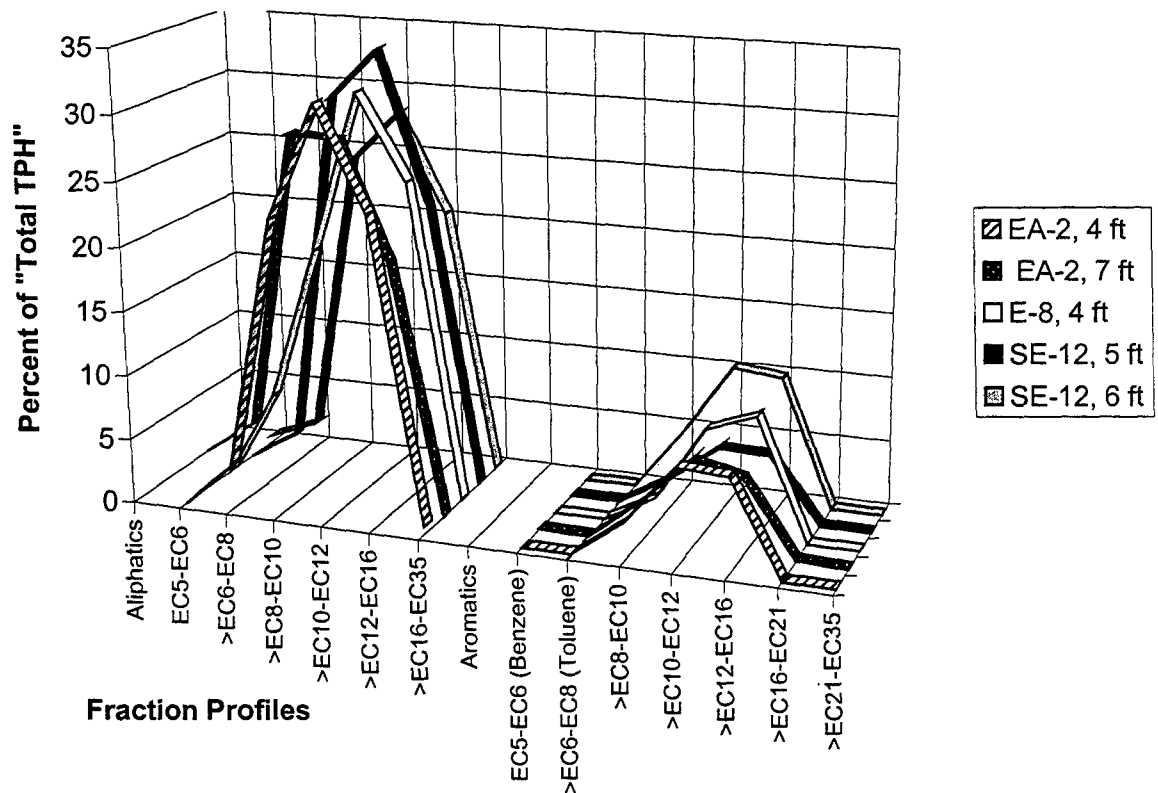


Figure 4-1 Fraction Profiles

4.2 BTEX Results

Results of the BTEX analysis performed on the hand auger samples are found in Table 4-3. These results are compared with Georgia Cleanup Standards for Hydrocarbon Contaminated Soil. Site 70 lies within an area defined by the Georgia Department of Natural Resources (GDNR) as a "zone of higher contamination susceptibility" and also within "one of Georgia's most significant groundwater recharge zones" (HAZWRAP, 1996). The standards reported below pertain to an area within 2.0 or 0.5 miles of public or non-public water supplies, respectively, with no water supply withdrawal point located within 500 ft of the contaminated site (GDNR, 1996). At Site 70, the closest well is 1600 ft upgradient, the Ocmulgee River is 1300 ft downgradient and the Ocmulgee floodplain/recharge zone is 800 ft downgradient (HAZWRAP, 1996).

TABLE 4-3 BTEX RESULTS AND COMPARISON WITH GDNR CLEANUP STANDARDS¹

Location, Depth ²	Laboratory ID	Benzene	Toluene	Ethylbenzene	Total Xylenes
E-8, 3 ft	3092072	<0.006 ³	<0.006	0.042	<0.24
E-8, 4 ft	3092069	<0.59	<0.59	3.7	39
SE-12, 5 ft	3092070	1.8	1.6	7.7	110
SE-12, 6 ft	3092071	2.5	1.5	15	<170
GDNR Cleanup Standards⁴		0.008	6.0	10	700

Note: ¹ Units = mg/kg dry weight (EPA Method SW-846 8021A)

² BTEX results not available for hollow core auger samples; Direct Method was performed on these samples alone.

³ < - Value is less than LOQ value presented.

⁴ GDNR Cleanup Standards for Hydrocarbon Contaminated Soil

Benzene and toluene were detected in both samples from the location SE-12; benzene levels exceeded GDNR cleanup standards. Xylenes were found in the 4 ft sample from E-8 and the 5 ft sample from SE-12; none of these values exceeded GDNR standards. Ethylbenzene was detected in all four soil samples; only the 6 ft sample from SE-12 exceeded ethylbenzene cleanup values. The reported LOQ value for benzene in the E-8, 4 ft sample exceeded GDNR cleanup standards. Lancaster Laboratories frequently documented interference from the sample matrix, resulting in an increased LOQ, and poor surrogate recovery due to dilution necessary to perform analyses.

4.3 Quality Control Results

Trip blanks, method blanks, lab controls and matrix spikes were analyzed for each round of sampling. Values were not outside of quality control limits. Matrix spike analysis results are provided in Appendix A.

4.4 Analytical Summary

Total TPH contamination, as measured by the Direct Method, increased with depth at each sampling location. The highest concentrations were found directly downgradient (SE-12) of the former hotspot, monitoring well EA-2. Additionally, samples at SE-12 exhibited marginally higher percentages of aliphatics, a profile likely more similar to fresh jet fuels. The lowest concentrations were from sampling point GX-4, which was located over 100 feet west (across- and upgradient) from EA-2. The lack of hydrocarbons in the shallow samples indicates that contamination at these points was from the free product plume that had been distributed on top of the groundwater. During periods of increased rainfall, the hydrocarbons would have been forced up into the shallower soil by higher groundwater tables. Subsequently, some hydrocarbons would have remained in the soil well above the water table after the groundwater had receded to normal levels.

5.0 RISK-BASED SCREENING LEVELS

The RBCA analysis using the Working Group approach was based on a site conceptual model of soil contamination with hydrocarbons leaching from the soil to the groundwater and with contaminants volatilizing to indoor and outdoor air. Exposure pathways evaluated include direct soil contact, contaminants leaching from the soil to the groundwater and ingestion of the groundwater, volatilization of contaminants from subsurface soils to outdoor air and volatilization of contaminants from subsurface soils to indoor air (see Figure 5-1).

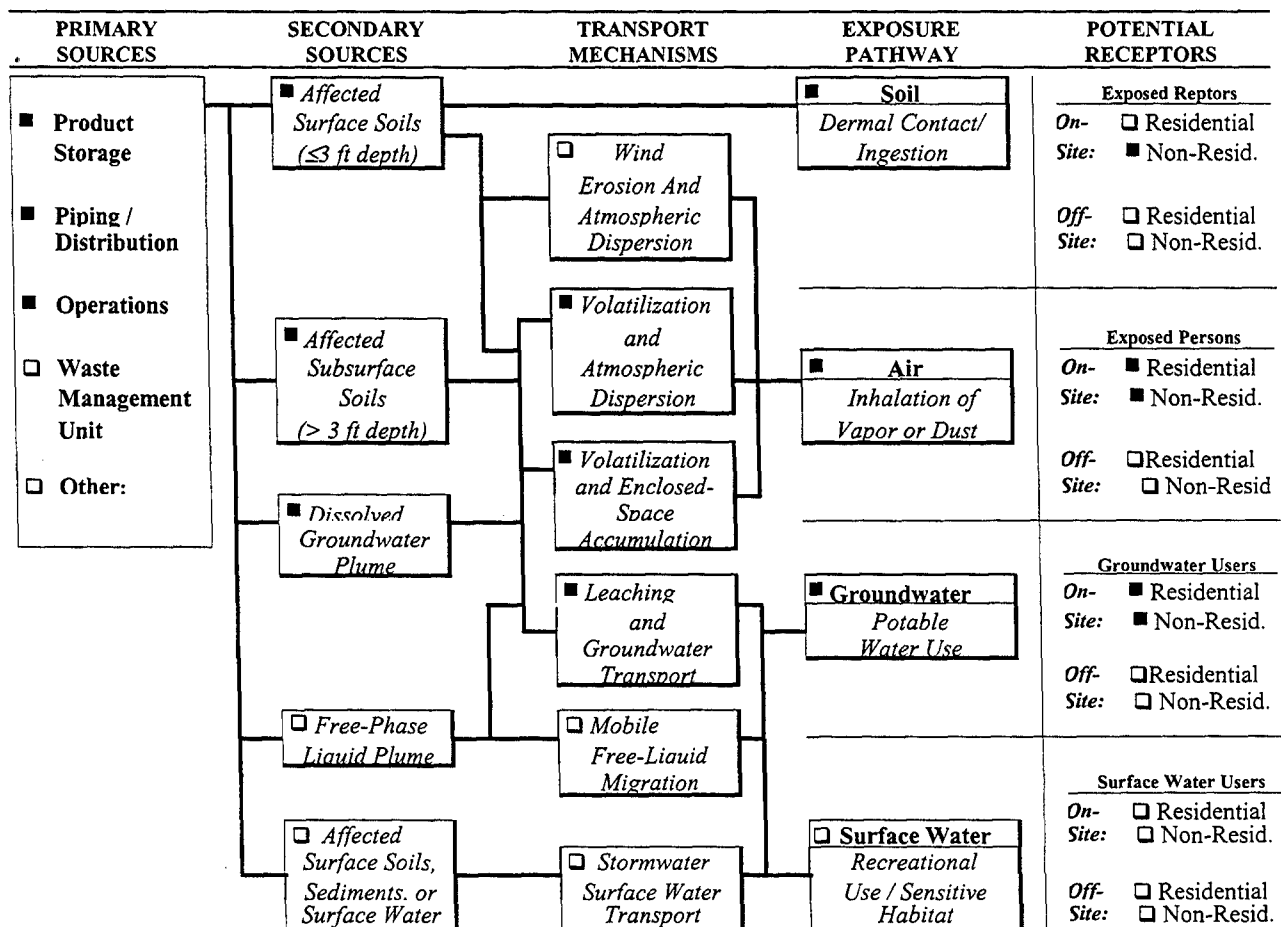


Figure 5-1 Exposure Pathway Analysis

Currently Site 70 has a commercial-type land use, being located adjacent to the runway and containing the refueling/defueling hydrant system. Direct soil contact is likely at the site when workers maintain the hydrant system. Leaching to groundwater is a common concern at TPH sites. At Site 70, the closest well is 1600 feet upgradient; however, Site 70 lies within 800 feet of a significant groundwater recharge zone, the Ocmulgee River floodplain. Furthermore, groundwater levels at the site are very shallow (HAZWRAP, 1996). Volatilization to outdoor air is a concern for workers during normal activities at Site 70 as well as during maintenance of the hydrant system. Volatilization to indoor is a very minor pathway at Site 70. The only buildings on the site are a small storage building and the pump house (HAZWRAP, 1996). Neither is a full-time place of work; however, because workers must occupy those buildings for some time period, contaminant volatilization to indoor air has been included.

Site 70 will likely remain in commercial land use as long as Robins AFB operates the runway. Future land use, should the base not remain operational, does not preclude an industrial or residential scenario. Therefore, residential RBSLs for each exposure pathway have been included.

The Tier 1 RBCA assessment results are presented in the following sections as a pathway-specific RBSL and HI for each soil sample evaluated. The RBSLs represent soil concentrations that do not result in unacceptable risk. The hazard index is a comparison of the TPH concentration and the RBSL (see Equation 6).

$$\text{Hazard Index (HI)} = \frac{\text{TPH concentration (mg / kg)}}{\text{RBSL}_{\text{pathway}} \text{ (mg / kg)}} \quad (\text{Equation 6})$$

RBSLs were calculated using zero for nondetects. Weathered TPH, in general, and jet fuels, even when fresh, contain very low concentrations of the light end and the heavy end aromatics. The lack of light end aromatics is reflected in the low BTEX results shown in Table 4-2, even though free product was present at the site fairly recently. Use of one-half the nondetect level, a typical risk assessment assumption, for fractions which are not present at a site causes the nondetect fractions to drive risk (Merrill, 1998), thereby defeating the benefits of speciation using the Direct Method and the Working Group approach. This highlights the need for obtaining the lowest detection level feasible for samples that will be used to calculate risk.

Appendix B contains a detailed discussion of RBSL development. Appendix C provides the RBCA model runs complete with risk results.

5.1 Commercial Scenario RBSLs

Current use commercial scenario Tier 1 RBSLs are presented in Table 5-1. RBSLs for the direct soil to skin contact pathway averaged approximately 9000 mg/kg and the HI for the pathway was just under 1.0. The average RBSL for the contaminant leaching to groundwater pathway was a little higher, approximately 10,000 mg/kg, and the average HI was just over 1.0. The RBSLs for the volatilization to outdoor air pathway reflect the low risk of that exposure route; the average RBSL exceeded purity (i.e., more than 1 kg weathered product/1 kg soil) and the average HI for the pathway was only 0.01. Since the leaching to groundwater pathway exceeded a HI of 1.0 and the direct contact pathway was very near 1.0, further sampling combined with a Tier 2 analysis is recommended. The average HI exceeded 1.0 by only a very narrow margin for the leaching pathway; the HIs ranged from 0.06 to 2.7. Typically, the shallower samples had lower HIs which offset the higher HIs of deeper samples. The same trend is displayed in the HIs for the direct contact pathway. Because the contamination representing the highest risk is deep (i.e., about six to seven feet bgs), direct contact with the soil is likely only in cases of hydrant system maintenance involving considerable excavation. Leaching to the groundwater is already occurring due to the shallow water table at the site; remediation of the soil would not address the water contamination (i.e., the media of greatest concern). Therefore further delineation of the contamination and a Tier 2 assessment of the soil risk would be appropriate.

TABLE 5-1 TIER 1 COMMERCIAL SOIL RBSLs AND HIs

Location, Depth	Total TPH (mg/kg)	Direct Contact		Leaching to Groundwater		Volatilization to Outdoor Air		Volatilization to Indoor Air ¹	
		RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI
EA-2, 4 ft	4761	9199	0.52	9981	0.48	2617725 ²	0.00	254	18.75
EA-2, 7 ft	15131	9786	1.55	9208	1.64	498007	0.03	208	72.64
E-8, 4 ft	821	9207	0.09	14397	0.06	80321	0.01	293	2.80
SE-12, 5 ft	5836	9733	0.60	12355	0.47	1050572 ²	0.01	215	27.19
SE-12, 6 ft	16300	8291	1.97	6094	2.67	1886325 ²	0.01	238	68.55
Average	8570	9243	0.94	10407	1.06	1226590²	0.01	241	37.99

Note: ¹ This pathway included for demonstration purposes only.

² Exceeds purity ($\geq 100\%$ TPH)

The volatilization to indoor air pathway was included in the commercial scenario because of the pump house and the storage building located on Site 70. This pathway is useful for demonstration purposes only. The calculated RBSLs and HIs for this pathway are unrealistically conservative. The RBCA indoor air model makes several conservative assumptions: the concentration of the contaminant is constant and does not attenuate over time, the partitioning between vapor, dissolved and sorbed phases of the contaminant is linear and in equilibrium, and the diffusion through the vadose zone and the foundation (with 1.0% foundation cracks) is steady state. Most conservatively, the model assumes that the concentration of the contaminant is constant with respect to distance, thereby not allowing for any degradation, sorption or other attenuation to occur between the contaminated zone and the foundation. Because of these overly conservative assumptions, model developers and the EPA itself recognize that this model does not provide worthwhile output (Tuomi *et al.*, 1999). This pathway could be re-examined in a Tier 2 assessment, using validated models and more appropriate occupancy times (i.e., part-time work schedules instead of 40 hours/week for 50 weeks/year) for these two buildings.

5.2 Residential Scenario RBSLs

Tier 1 RBSLs for the futuristic residential scenario pathways are provided in Table 5-2. The soil to skin direct contact pathway is considered incomplete, as residents do not typically come into contact with soil at depths greater than three feet bgs. Construction activities at a residential site fall under the commercial scenario. Therefore, RBSLs and HIs for this pathway are provided merely as points of interest, but have no bearing on decision making in this scenario.

TABLE 5-2 TIER 1 RESIDENTIAL SOIL RBSLs AND HIs

Location, Depth	Total TPH (mg/kg)	Direct Contact ¹		Leaching to Groundwater		Volatilization to Outdoor Air		Volatilization to Indoor Air ²	
		RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI
EA-2, 4 ft	4761	6227	0.76	2798	1.70	1234858 ³	0.00	97	49.06
EA-2, 7 ft	15131	6624	2.28	2976	5.08	156080	0.10	80	188.10
E-8, 4 ft	821	6233	0.13	2799	0.29	51248	0.02	110	7.46
SE-12, 5 ft	5836	6587	0.89	3857	1.51	495588	0.01	83	70.66
SE-12, 6 ft	16300	5615	2.90	1921	8.48	591515	0.03	91	178.28
Average	8570	6257	1.39	2870	3.42	505858	0.03	92	98.71

- Note:**
- ¹ This pathway is incomplete.
 - ² This pathway included for demonstration purposes only.
 - ³ Exceeds purity ($\geq 100\%$ TPH)

The average RBSL for the contaminant leaching to groundwater pathway was approximately 2900 mg/kg. The accompanying HI was calculated at 3.4. Again, the RBSLs and HIs for the volatilization to outdoor air pathway reflect low risk. The average RBSL of 500,000 mg/kg is equivalent to 50% contaminant and 50% soil. The HI of 0.03 is marginally higher than the same pathway in the commercial scenario. Since the HI for the leaching pathway exceeds 1.0 by a factor of 3, soil remediation or addition sampling for a Tier 2 assessment would again be indicated. As with the commercial scenario, the leaching pathway HIs are lower in shallower samples and higher in deeper samples; they ranged from 0.29 to 8.48. As stated in Section 5.1, due to shallow water tables, contamination of the media of greatest concern, the groundwater, has already occurred. Further delineation of the soil contamination followed by a Tier 2 assessment is again the most appropriate option. Separate evaluation of the groundwater is indicated.

The volatilization to indoor air pathway was included because future residential use of Site 70 has not been excluded. As stated in Section 5.1, this pathway is for demonstration purposes only due to overly conservative assumptions in this RBCA model. Evaluation in a Tier 2 assessment using validated models would be appropriate in the event that residential use of the site is foreseeable.

5.3 Risk Discussion

Five of the ten soil samples evaluated using the Direct Method had detectable levels of TPH useful for RBSL development. The RBSLs for the leaching pathway were lowest for both the commercial and future residential scenarios; the average RBSLs were 10,000 and 2900 mg/kg, respectively. The commercial RBSL was exceeded by two deep samples, EA-2 at 7 feet and SE-12 at 6 feet, causing the average HI to be greater than 1.0 even though the average TPH contamination across the site was less than the RBSL. The future use residential RBSL was exceeded by all but one shallow sample. Further sampling and a Tier 2 assessment for soil contamination risk is recommended under both scenarios.

The Working Group's approach was developed solely to provide risk-based soil cleanup criteria. Therefore only soil pathways were evaluated in this demonstration. Risk from impacted groundwater was not assessed.

5.4 Comparison with Georgia Guidance

The State of Georgia expressed interest in this demonstration project as they are currently working to address TPH contaminated sites that do not contain chemicals of concern (Heathman and Lurker, 1998). Georgia's current regulations focus on BTEX and PAHs. The State currently has no rules regulating TPH itself at contaminated sites (Muhanna, 1999, personal communication). The Working Group approach advocates sampling for carcinogenic compounds prior to evaluating non-carcinogenic risk from TPH (TPHCWG, 1998b). In this way, the Working Group approach correlates well with current Georgia regulations. Additionally, the Working Group approach offers to the State a method for dealing with TPH sites containing noncarcinogenic components without carcinogenic chemicals of concern.

Four of the ten Site 70 soil samples were tested for BTEX. At two sampling locations, the BTEX levels exceeded Georgia's cleanup standards. The confirmed presence of benzene, a known human carcinogen, indicates the need for further action. PAHs were not assessed in this demonstration; this additional sampling is necessary prior to use of the RBSLs generated in this Tier 1 assessment.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The TPH Criteria Working Group approach was demonstrated at Site 70, Robins AFB, Georgia. Five of ten soil samples resulted in detectable levels of TPH as measured by the Direct Method. Total TPH concentrations were highest approximately 12 feet downgradient of the former hot spot, monitoring well EA-2 (i.e., sampling location SE-12). Total TPH levels increased with depth at the sampling locations. The TPH fractions present were similar between samples and consisted primarily of >EC8 to EC16 aliphatics, along with >EC10 to EC16 aromatics. Tier 1 RBSLs and HIs were calculated using these Direct Method fractionated concentrations and ASTM RBCA models. In the current commercial scenario, average HIs were greater than 1.0 for the leaching to groundwater pathway only; the direct soil to skin contact pathway was very near, but did not exceed, 1.0. The Tier 1 RBSL was calculated at 10,000 mg/kg based on the leaching pathway. In the futuristic residential scenario, the average HI was 3.4 for the leaching to groundwater pathway, resulting in a RBSL of 2900 mg/kg. Further sampling to characterize the extent of contamination and a Tier 2 evaluation are recommended. Additional characterization was ongoing by Robins AFB at the time of this demonstration.

During the course of future contamination characterization and Tier 2 evaluation, soil samples should be divided and analyzed not only by the Direct Method but also by conventional analyses (i.e., GRO and DRO). The total TPH values from both types of analyses should be correlated against each other. If they correlate well, the cheaper conventional analyses should be used to delineate contamination. Using the correlation coefficient, the TPHCWG approach can be used to determine RBSLs based on a larger number of samples at a lower analytical cost. The Direct Method, however, should be further refined to obtain consistently low quantitation limits. The LOQs reported for several samples in this demonstration were high and exhibited considerable variability.

Only soil risk and the risk of contamination from the soil transferring into other media are addressed by the Working Group approach. At Site 70, the groundwater is not only already

impacted but the groundwater is currently acting as the source for TPH contamination, instead of the TPH residing predominantly in the soil. This is evident from the site history (i.e., the pool of free product on top of the shallow groundwater table that was removed from well EA-2). The pattern of TPH concentration in the soil (i.e., concentrations increase with depth bgs, the highest being just above the water table, downgradient from EA-2) is indicative of smearing that occurs with the temporal rise and fall of groundwater levels. Further assessment of soil contamination is recommended after the groundwater contamination is resolved.

The Working Group approach effectively provided noncarcinogenic risk-based cleanup criteria for TPH impacted soil at Site 70. Carcinogenic risk must still be addressed. BTEX was analyzed in four of the ten soil samples. Benzene, a known human carcinogen, was found to be present. Analyses for carcinogenic PAHs were not conducted. Both the Working Group approach and the Georgia Department of Natural Resources require the assessment of carcinogens present at the TPH site. The Working Group approach for noncarcinogenic risk is best utilized at a site without these carcinogenic contaminants of concern. As stated above, the shallow groundwater appears to be acting as the source for the soil TPH contamination. After the groundwater contamination is resolved, the soil benzene levels may drop below the GDNR cleanup criteria (i.e., 0.008 mg/kg for this type of site) and the Working Group approach for noncarcinogenic risk may be more applicable to Site 70 soils at that time.

7.0 REFERENCES

GDNR. 6/25/1996. Rules of Georgia Department of Natural Resources Environmental Protection Division. Chapter 391-3-15: Underground Storage Tank Management. 30 pages.

HAZWRAP. November 1996. Draft Corrective Action Plan - Part A for Underground Storage Tank Sites 70 and 72 at Robins AFB. Hazardous Waste Remedial Actions Program, Department of Energy, Oak Ridge, TN.

HAZWRAP. February 1997. Draft Corrective Action Plan - Part B for Underground Storage Tank Sites 70 and 72 at Robins AFB. Hazardous Waste Remedial Actions Program, Department of Energy, Oak Ridge, TN.

Heathman, TW. and Lurker, PA. 1998. TPH Criteria Working Group field demonstration site report:: Robins Air Force Base, Warner-Robins, GA. Air Force Research Laboratory, Operational Toxicology Branch, Wright-Patterson AFB, OH. AFRL-HE-WP-TR-1999-0001.

Merrill, E. 1998. TPH Criteria Working Group field demonstration: Scott AFB, Belleville, IL. Air Force Research Laboratory, Operational Toxicology Branch, Wright-Patterson AFB, OH. AFRL-HE-WP-TR-1999-0025.

Muhanna, Shaheer. 7 July 1999. Personal communication regarding current Georgia TPH regulations. Office of Underground Storage Tanks, Department of Natural Resources, GA.

Peters, Doug. 22 Dec 1998. Personal communication regarding Geophex sampling plan. Geophex Corporation, Warner Robins, GA.

TPHCWG. 1998a. A Risk-based Approach for the Management of Total Petroleum Hydrocarbons in Soil, Volume 3. Selection of TPH Fractions Based on Fate and Transport Considerations.

TPHCWG. 1998b. A Risk-based Approach for the Management of Total Petroleum Hydrocarbons in Soil, Volume 4: Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH).

TPHCWG. 1998c. A Risk-based Approach for the Management of Total Petroleum Hydrocarbons in Soil, Volume 1: Petroleum Hydrocarbon Analysis of Soil and Water in the Environment.

TPHCWG. 1999. A Risk-based Approach for the Management of Total Petroleum Hydrocarbons in Soil, Volume 5. Human Health Risk-based Evaluation of Petroleum Release Sites: Implementing the Working Group Approach.

Tuomi E, Stroo H, Weisman W. Field Demonstration Report - Defense Fuel Support Point, Mukilteo, Washington. Air Force Research Laboratory, Operational Toxicology Branch. AFRL-HE-WP-TR-1999-0030.

APPENDIX A ANALYTICAL DATA

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 99025-0002A

Laboratory ID: 3074868
 Sample ID: GX-4, 3 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ		Aliphatic (mg/kg)	LOQ		Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
		TPH Pentane Extract	LOQ		Aliphatic	LOQ		
VRH 1 *	NA	NA	0.20	ND	0.20	ND	ND	NA
VRH 2 **	NA	NA	0.20	ND	0.20	ND	ND	NA
>C8 - <=C10	ND	8	8	ND	8	ND	ND	NA
>C10 - <=C12	ND	8	8	ND	8	ND	ND	NA
>C12 - <=C16	ND	20	20	ND	20	ND	ND	NA
>C16 - <=C21	ND	20	20	ND	20	ND	ND	NA
>C21 - <=C35	ND	50	50	ND	50	ND	ND	NA
Total >C8 - <=C35	ND	100	100	ND	100	ND	ND	NA
Total >C5 - <=C35	NA	NA	100	ND	100	ND	ND	NA

% moisture = 21.4

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 3074868
 Sample ID: GX-4, 3 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ		Aliphatic (mg/kg)	LOQ		Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
		TPH Pentane Extract	LOQ		Aliphatic	LOQ		
VRH 1 *	NA	NA	0.25	ND	0.25	ND	ND	NA
VRH 2 **	NA	NA	0.25	ND	0.25	ND	ND	NA
>C8 - <=C10	ND	10	10	ND	10	ND	ND	NA
>C10 - <=C12	ND	10	10	ND	10	ND	ND	NA
>C12 - <=C16	ND	25	25	ND	25	ND	ND	NA
>C16 - <=C21	ND	25	25	ND	25	ND	ND	NA
>C21 - <=C35	ND	64	64	ND	64	ND	ND	NA
Total >C8 - <=C35	ND	127	127	ND	127	ND	ND	NA
Total >C5 - <=C35	NA	NA	127	ND	127	ND	ND	NA

* Volatile Range Hydrocarbons (Range 1): Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2): Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Laboratory ID: 3074869
 Sample ID: GX-4, 7.5 ft
 Extractable Batch ID: 99025-0002A

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	LOQ	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	0.20	ND	0.005	ND	0.005	NA
VRH 2 **	NA	NA	ND	0.20	ND	0.005	ND	0.005	NA
>C8 - <=C10	ND	8	ND	8	ND	8	ND	8	NA
>C10 - <=C12	ND	8	ND	8	ND	8	ND	8	NA
>C12 - <=C16	ND	20	ND	20	ND	20	ND	20	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	20	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	50	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	100	NA
Total >C5 - <=C35	NA	NA	ND	100	ND	100	ND	100	NA

% moisture = 16.9

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 3074869
 Sample ID: GX-4, 7.5 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	LOQ	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	0.24	ND	0.006	ND	0.006	NA
VRH 2 **	NA	NA	ND	0.24	ND	0.006	ND	0.006	NA
>C8 - <=C10	ND	10	ND	10	ND	10	ND	10	NA
>C10 - <=C12	ND	10	ND	10	ND	10	ND	10	NA
>C12 - <=C16	ND	24	ND	24	ND	24	ND	24	NA
>C16 - <=C21	ND	24	ND	24	ND	24	ND	24	NA
>C21 - <=C35	ND	60	ND	60	ND	60	ND	60	NA
Total >C8 - <=C35	ND	120	ND	120	ND	120	ND	120	NA
Total >C5 - <=C35	NA	NA	ND	120	ND	120	ND	120	NA

* Volatile Range Hydrocarbons (Range 1): Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2): Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 99025-0002A

Laboratory ID: 3074870

Sample ID: GX-4, 13 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	Aliphatic (mg/kg)		Aromatic Hydrocarbons (mg/kg)		Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
		LOQ	LOQ	LOQ	LOQ		
VRH 1 *	NA	NA	0.20	ND	ND	ND	NA
VRH 2 **	NA	NA	0.20	ND	ND	ND	NA
>C8 - <=C10	ND	8	8	ND	ND	ND	NA
>C10 - <=C12	ND	8	8	ND	ND	ND	NA
>C12 - <=C16	ND	20	20	ND	ND	ND	NA
>C16 - <=C21	ND	20	20	ND	ND	ND	NA
>C21 - <=C35	270	50	50	126	145	271	100%
Total >C8 - <=C35	291	100	100	136	153	288	99%
Total >C5 - <=C35	NA	NA	100	136	153	288	NA

% moisture = 11.8

Laboratory ID: 3074870

Sample ID: GX-4, 13 ft

C5 to C35 Hydrocarbons "Dry Weight Data"

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	Aliphatic (mg/kg)		Aromatic Hydrocarbons (mg/kg)		Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
		LOQ	LOQ	LOQ	LOQ		
VRH 1 *	NA	NA	0.23	ND	ND	ND	NA
VRH 2 **	NA	NA	0.23	ND	ND	ND	NA
>C8 - <=C10	ND	9	9	ND	ND	ND	NA
>C10 - <=C12	ND	9	9	ND	ND	ND	NA
>C12 - <=C16	ND	23	23	ND	ND	ND	NA
>C16 - <=C21	ND	23	23	ND	ND	ND	NA
>C21 - <=C35	307	57	57	142	165	307	100%
Total >C8 - <=C35	330	113	113	154	173	327	99%
Total >C5 - <=C35	NA	NA	113	154	173	327	NA

* Volatile Range Hydrocarbons (Range 1): Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2): Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 99091-0001A

Laboratory ID: 3086915
 Sample ID: EA-2, 2 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)		Aromatic Hydrocarbons (mg/kg)		LOQ	Aliphatics + Aromatics (mg/kg)		Aliph + Arom Total (%)
			Aliphatic (mg/kg)	LOQ	Hydrocarbons (mg/kg)	LOQ		Aromatics (mg/kg)	Aliphatics + Aromatics (mg/kg)	
VRH 1 *	NA	NA	ND	0.20	ND	0.005	ND	ND	ND	NA
VRH 2 **	NA	NA	ND	0.20	ND	0.005	ND	ND	ND	NA
>C8 - <=C10	ND	8	ND	8	ND	8	ND	ND	ND	NA
>C10 - <=C12	ND	8	ND	8	ND	8	ND	ND	ND	NA
>C12 - <=C16	ND	20	ND	20	ND	20	ND	ND	ND	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	ND	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	ND	ND	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	ND	ND	NA
Total >C5 - <=C35	NA	NA	ND	100	ND	100	ND	ND	ND	NA

Laboratory ID: 3086915
 Sample ID: EA-2, 2 ft

C5 to C35 Hydrocarbons "Dry Weight Data"

% moisture =

15.1

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)		Aromatic Hydrocarbons (mg/kg)		LOQ	Aliphatics + Aromatics (mg/kg)		Aliph + Arom Total (%)
			Aliphatic (mg/kg)	LOQ	Hydrocarbons (mg/kg)	LOQ		Aromatics (mg/kg)	Aliphatics + Aromatics (mg/kg)	
VRH 1 *	NA	NA	ND	0.24	ND	0.006	ND	ND	ND	NA
VRH 2 **	NA	NA	ND	0.24	ND	0.006	ND	ND	ND	NA
>C8 - <=C10	ND	9	ND	9	ND	9	ND	ND	ND	NA
>C10 - <=C12	ND	9	ND	9	ND	9	ND	ND	ND	NA
>C12 - <=C16	ND	24	ND	24	ND	24	ND	ND	ND	NA
>C16 - <=C21	ND	24	ND	24	ND	24	ND	ND	ND	NA
>C21 - <=C35	ND	59	ND	59	ND	59	ND	ND	ND	NA
Total >C8 - <=C35	ND	118	ND	118	ND	118	ND	ND	ND	NA
Total >C5 - <=C35	NA	NA	ND	118	ND	118	ND	ND	ND	NA

* Volatile Range Hydrocarbons (Range 1):

Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2):

Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

**C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"**

Extractable Batch ID: 99091-0001A

Laboratory ID: 3086916
Sample ID: EA-2, 4 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)		Aromatic Hydrocarbons (mg/kg)		LOQ	Aliphatics + Aromatics (mg/kg)		Aliph + Arom Total (%)
			Aliphatic (mg/kg)	LOQ	Hydrocarbons (mg/kg)	LOQ		Aliphatics (mg/kg)	Aromatics (mg/kg)	
VRH 1 *	NA	NA	ND	40	ND	ND	1.0	ND	ND	NA
VRH 2 **	NA	NA	141	40	1.8	1.8	1.0	143	143	NA
>C8 - <=C10	1200.9	40	952.2	8	121.1	121.1	8	1073	1073	89%
>C10 - <=C12	1287.0	40	1320.8	8	311.3	311.3	8	1632	1632	127%
>C12 - <=C16	939	100	996	20	300	300	20	1296	1296	138%
>C16 - <=C21	23	20	24	20	ND	ND	20	33	33	147%
>C21 - <=C35	ND	50	ND	50	ND	ND	50	ND	ND	NA
Total >C8 - <=C35	3457	500	3294	100	745	745	100	4039	4039	117%
Total >C5 - <=C35	NA	NA	3457	180	747	747	100	4204	4204	NA

% moisture = 11.7

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 3086916
Sample ID: EA-2, 4 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)		Aromatic Hydrocarbons (mg/kg)		LOQ	Aliphatics + Aromatics (mg/kg)		Aliph + Arom Total (%)
			Aliphatic (mg/kg)	LOQ	Hydrocarbons (mg/kg)	LOQ		Aliphatics (mg/kg)	Aromatics (mg/kg)	
VRH 1 *	NA	NA	ND	45	ND	ND	1.1	ND	ND	NA
VRH 2 **	NA	NA	160	45	2.0	2.0	1.1	162	162	NA
>C8 - <=C10	1360.0	45	1078.4	9	137.2	137.2	9	1216	1216	89%
>C10 - <=C12	1457.5	45	1495.8	9	352.5	352.5	9	1848	1848	127%
>C12 - <=C16	1063	113	1128	23	340	340	23	1468	1468	138%
>C16 - <=C21	26	23	27	23	ND	ND	23	38	38	147%
>C21 - <=C35	ND	57	ND	57	ND	ND	57	ND	ND	NA
Total >C8 - <=C35	3915	566	3731	113	844	844	113	4574	4574	117%
Total >C5 - <=C35	NA	NA	3915	204	846	846	113	4761	4761	NA

* Volatile Range Hydrocarbons (Range 1): Aliphatics = C5 to C6 aliphatic (total hydrocarbons)

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbon (Range 2): Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

C8 to C35 Hydrocarbons by Purge & Trap GC PID/FID
C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Laboratory ID: 3086917
 Sample ID: EA-2, 7 ft
 Extractable Batch ID: 99091-0001A

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	383.4	200	10.1	5.0	393	NA
VRH 2 **	NA	NA	730.9	200	ND	5.0	731	NA
>C8 - <=C10	5923.5	40	3778.4	160	403.1	8	4182	71%
>C10 - <=C12	6584.0	40	3749.5	160	878.8	8	4628	70%
>C12 - <=C16	4800	100	2552	400	764	20	3316	69%
>C16 - <=C21	ND	100	ND	400	21	20	59	66%
>C21 - <=C35	ND	250	ND	1000	ND	50	ND	NA
Total >C8 - <=C35	17441	500	10197	2000	2070	100	12267	70%
Total >C5 - <=C35	NA	NA	11311	2500	2080	110	13391	NA

% moisture = 11.5

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 3086917
 Sample ID: EA-2, 7 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	433.2	226	11.4	5.6	445	NA
VRH 2 **	NA	NA	825.8	226	ND	5.6	826	NA
>C8 - <=C10	6693.2	45	4269.3	181	455.5	9	4725	71%
>C10 - <=C12	7439.5	45	4236.7	181	992.9	9	5230	70%
>C12 - <=C16	5424	113	2883	452	864	23	3747	69%
>C16 - <=C21	ND	113	ND	452	24	23	67	66%
>C21 - <=C35	ND	282	ND	1130	ND	56	ND	NA
Total >C8 - <=C35	19707	565	11522	2260	2339	113	13861	70%
Total >C5 - <=C35	NA	NA	12781	2825	2350	124	15131	NA

* Volatile Range Hydrocarbons (Range 1): Aliphatics = C5 to C6 aliphatic (total) hydrocarbons
 Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)
 ** Volatile Range Hydrocarbons (Range 2): Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
 Aromatics = >C7 to C8 aromatics (toluene only)

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 99109-0017A

Laboratory ID: 3092069
 Sample ID: E-8, 4 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	Aliphatic (mg/kg)		Aromatic Hydrocarbons (mg/kg)		LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
		LOQ	LOQ	LOQ	LOQ			
VRH 1 *	NA	NA	ND	20	ND	0.5	7.1	NA
VRH 2 **	NA	NA	44	20	ND	0.5	45	NA
>C8 - <=C10	176.6	8	124.4	8	13.7	8	138.1	78%
>C10 - <=C12	347.2	8	207.9	8	52.5	8	260.4	75%
>C12 - <=C16	298	20	165	20	62	20	227	76%
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	840	100	508	100	136	100	644	77%
Total >C5 - <=C35	NA	NA	559	100	137	100	696	NA

% moisture = 15.2

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 3092069
 Sample ID: E-8, 4 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	Aliphatic (mg/kg)		Aromatic Hydrocarbons (mg/kg)		LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
		LOQ	LOQ	LOQ	LOQ			
VRH 1 *	NA	NA	ND	24	ND	0.6	8.4	NA
VRH 2 **	NA	NA	52	24	ND	0.6	53	NA
>C8 - <=C10	208.3	9	146.7	9	16.2	9	162.9	78%
>C10 - <=C12	409.4	9	245.2	9	61.9	9	307.1	75%
>C12 - <=C16	352	24	194	24	73	24	267	76%
>C16 - <=C21	ND	24	ND	24	ND	24	ND	NA
>C21 - <=C35	ND	59	ND	59	ND	59	ND	NA
Total >C8 - <=C35	990	118	599	118	161	118	760	77%
Total >C5 - <=C35	NA	NA	660	118	161	118	821	NA

* Volatile Range Hydrocarbons (Range 1): Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2): Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Laboratory ID: 3092070
 Sample ID: SE-12, 5 ft
 Extractable Batch ID: 99109-0017A

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	40	1.69	1.0	ND	NA
VRH 2 **	NA	NA	112	40	1.50	1.0	113	NA
>C8 - <=C10	1514.3	80	1494	80	112.6	8	1606	106%
>C10 - <=C12	1881.5	80	1693	80	258.5	8	1951	104%
>C12 - <=C16	1322	200	1108	200	253	20	1361	103%
>C16 - <=C21	ND	200	ND	200	ND	20	56	119%
>C21 - <=C35	ND	500	ND	500	ND	50	ND	NA
Total >C8 - <=C35	4775	1000	4356	1000	636	100	4992	105%
Total >C5 - <=C35	NA	NA	4497	1100	639	100	5136	NA

33 7-9

% moisture = 12.0

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 3092070
 Sample ID: SE-12, 5 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	45	1.92	1.1	ND	NA
VRH 2 **	NA	NA	127	45	1.71	1.1	129	NA
>C8 - <=C10	1720.8	91	1697	91	127.9	9	1825	106%
>C10 - <=C12	2138.1	91	1923	91	293.7	9	2217	104%
>C12 - <=C16	1502	227	1260	227	287	23	1547	103%
>C16 - <=C21	ND	227	ND	227	ND	23	63	119%
>C21 - <=C35	ND	568	ND	568	ND	57	ND	NA
Total >C8 - <=C35	5426	1136	4950	1136	723	114	5673	105%
Total >C5 - <=C35	NA	NA	5110	1250	726	114	5836	NA

* Volatile Range Hydrocarbons (Range 1): Aliphatics = C5 to C6 aliphatic (total) hydrocarbons
 Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)
 ** Volatile Range Hydrocarbons (Range 2): Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
 Aromatics = >C7 to C8 aromatics (toluene only)

**C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"**

Extractable Batch ID: 99109-0017A

Laboratory ID: 3092071

Sample ID: SE-12, 6 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)		Aromatic Hydrocarbons (mg/kg)		LOQ	Aliphatics + Aromatics (mg/kg)		Aliph + Arom Total (%)
			Aliphatic (mg/kg)	LOQ	Hydrocarbons (mg/kg)	LOQ		Aliphatics (mg/kg)	Aromatics (mg/kg)	
VRH 1 *	NA	NA	74	40	2.27	1.0	77	77	NA	
VRH 2 **	NA	NA	278	40	1.38	1.0	280	280	NA	
>C8 - <=C10	4262.4	160	3444	160	688	80	4132	4132	97%	
>C10 - <=C12	5477.1	160	4006	160	1474	80	5480	5480	100%	
>C12 - <=C16	4265	400	2928	400	1411	200	4339	4339	102%	
>C16 - <=C21	ND	400	ND	400	ND	200	ND	ND	NA	
>C21 - <=C35	ND	1000	ND	1000	ND	500	ND	ND	NA	
Total >C8 - <=C35	14181	2000	10512	2000	3639	1000	14151	14151	100%	
Total >C5 - <=C35	NA	NA	10865	2100	3643	1000	14507	14507	NA	

% moisture = 11.0

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 3092071

Sample ID: SE-12, 6 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)		Aromatic Hydrocarbons (mg/kg)		LOQ	Aliphatics + Aromatics (mg/kg)		Aliph + Arom Total (%)
			Aliphatic (mg/kg)	LOQ	Hydrocarbons (mg/kg)	LOQ		Aliphatics (mg/kg)	Aromatics (mg/kg)	
VRH 1 *	NA	NA	84	45	2.54	1.1	86	86	NA	
VRH 2 **	NA	NA	313	45	1.55	1.1	314	314	NA	
>C8 - <=C10	4789.3	180	3870	180	773	90	4643	4643	97%	
>C10 - <=C12	6154.0	180	4501	180	1657	90	6158	6158	100%	
>C12 - <=C16	4793	449	3290	449	1586	225	4876	4876	102%	
>C16 - <=C21	ND	449	ND	449	ND	225	ND	ND	NA	
>C21 - <=C35	ND	1124	ND	1124	ND	562	ND	ND	NA	
Total >C8 - <=C35	15934	2247	11811	2247	4089	1124	15900	15900	100%	
Total >C5 - <=C35	NA	NA	12207	2360	4093	1124	16300	16300	NA	

* Volatile Range Hydrocarbons (Range 1): Aliphatics = C5 to C6 aliphatic (total hydrocarbons)

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2): Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Laboratory ID: 3092072
 Sample ID: E-8, 3 ft

Extractable Batch ID: 99109-0017A

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	0.20	ND	0.005	ND	NA
VRH 2 **	NA	NA	0.50	0.20	ND	0.005	0.50	NA
>C8 - <=C10	ND	8	ND	8	ND	8	ND	NA
>C10 - <=C12	ND	8	ND	8	ND	8	ND	NA
>C12 - <=C16	ND	20	ND	20	ND	20	ND	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	NA
Total >C5 - <=C35	NA	NA	ND	100	ND	100	ND	NA

% moisture = 16.7

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 3092072
 Sample ID: E-8, 3 ft

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	0.24	ND	0.006	ND	NA
VRH 2 **	NA	NA	0.60	0.24	ND	0.006	0.60	NA
>C8 - <=C10	ND	10	ND	10	ND	10	ND	NA
>C10 - <=C12	ND	10	ND	10	ND	10	ND	NA
>C12 - <=C16	ND	24	ND	24	ND	24	ND	NA
>C16 - <=C21	ND	24	ND	24	ND	24	ND	NA
>C21 - <=C35	ND	60	ND	60	ND	60	ND	NA
Total >C8 - <=C35	ND	120	ND	120	ND	120	ND	NA
Total >C5 - <=C35	NA	NA	ND	120	ND	120	ND	NA

* Volatile Range Hydrocarbons (Range 1): Aliphatics = C5 to C6 aliphatic (total hydrocarbons)
 Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)
 ** Volatile Range Hydrocarbons (Range 2): Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
 Aromatics = >C7 to C8 aromatics (toluene only)



LLI Sample No. SW 3092069
 Collected: 2/12/99 at 11:50 by EM

Submitted: 2/16/99 Reported: 5/ 5/99
 Discard: 5/27/99

E-8-4 Composite Soil Sample

TPHCWG Demo. - Robins AFB - GA
 E-8-4 SDG#: OPT07-01

Account No: 09729
 Operational Technologies Corp.
 4100 N.W. Loop 410, Suite 230
 San Antonio TX 78229-4253

P.O. 8309-223-TH08/S002
 Rel.

CAT NO.	ANALYSIS NAME	AS RECEIVED			DRY WEIGHT	
		RESULTS	LIMIT OF QUANTITATION	UNITS	RESULTS	LIMIT OF QUANTITATION
BTEX (Total Xylenes)						
8183	Benzene	< 500.	500.	ug/kg	< 590.	590.
8184	Toluene	< 500.	500.	ug/kg	< 590.	590.
8185	Ethylbenzene	3,100.	500.	ug/kg	3,700.	590.
8186	Total Xylenes	33,000.	1,500.	ug/kg	39,000.	1,800.

Poor surrogate recoveries were observed for this sample due to the dilution needed to perform the analysis.

Due to interferences from the sample matrix, the limits of quantitation for the above determinations were increased.



LLI Sample No. SW 3092070
 Collected: 2/12/99 at 12:20 by EM

Submitted: 2/16/99 Reported: 5/ 5/99
 Discard: 5/27/99

SE-12-5 Composite Soil Sample

TPHCWG Demo. - Robins AFB - GA
 SE125 SDG#: OPT07-02

Account No: 09729
 Operational Technologies Corp.
 4100 N.W. Loop 410, Suite 230
 San Antonio TX 78229-4253

P.O. 8309-223-TH08/S002
 Rel.

CAT NO.	ANALYSIS NAME	AS RECEIVED			DRY WEIGHT	
		RESULTS	LIMIT OF QUANTITATION	UNITS	RESULTS	LIMIT OF QUANTITATION
BTEX (Total Xylenes)						
8183	Benzene	1,600.	1,000.	ug/kg	1,800.	1,100.
8184	Toluene	1,400.	1,000.	ug/kg	1,600.	1,100.
8185	Ethylbenzene	6,800.	1,000.	ug/kg	7,700.	1,100.
8186	Total Xylenes	94,000.	3,000.	ug/kg	110,000.	3,400.

Poor surrogate recoveries were observed for this sample due to the dilution needed to perform the analysis.



LLI Sample No. SW 3092071

Collected: 2/12/99 at 12:40 by EM

Submitted: 2/16/99 Reported: 5/ 5/99
Discard: 5/27/99

SE-12-6 Composite Soil Sample

TPHCWG Demo. - Robins AFB - GA
SE126 SDG#: OPT07-03

Account No: 09729
Operational Technologies Corp.
4100 N.W. Loop 410, Suite 230
San Antonio TX 78229-4253

P.O. 8309-223-TH08/S002
Re1.

CAT NO.	ANALYSIS NAME	AS RECEIVED			DRY WEIGHT	
		RESULTS	LIMIT OF QUANTITATION	UNITS	RESULTS	LIMIT OF QUANTITATION
BTEX (Total Xylenes)						
8183	Benzene	2,200.	1,000.	ug/kg	2,500.	1,100.
8184	Toluene	1,400.	1,000.	ug/kg	1,500.	1,100.
8185	Ethylbenzene	13,000.	1,000.	ug/kg	15,000.	1,100.
8186	Total Xylenes	< 150,000.	150,000.	ug/kg	< 170,000.	170,000.

Due to interferences from the sample matrix, the limit of quantitation for the xylenes determination was increased.

Poor surrogate recoveries were observed for this sample due to the dilution needed to perform the analysis.



LLI Sample No. SW 3092072

Collected: 2/12/99 at 11:40 by EM

Submitted: 2/16/99 Reported: 5/ 5/99
Discard: 5/27/99

E-8-3 Composite Soil Sample

TPHCWG Demo. - Robins AFB - GA
E-8-3 SDG#: OPT07-04

Account No: 09729
Operational Technologies Corp.
4100 N.W. Loop 410, Suite 230
San Antonio TX 78229-4253

P.O. 8309-223-TH08/S002
Re1.

CAT NO.	ANALYSIS NAME	AS RECEIVED			DRY WEIGHT	
		RESULTS	LIMIT OF QUANTITATION	UNITS	RESULTS	LIMIT OF QUANTITATION
BTEX (Total Xylenes)						
8183	Benzene	< 5.0	5.0	ug/kg	< 6.0	6.0
8184	Toluene	N.D.	5.0	ug/kg	N.D.	6.0
8185	Ethylbenzene	35.	5.0	ug/kg	42.	6.0
8186	Total Xylenes	< 200.	200.	ug/kg	< 240.	240.

Due to interferences from the sample matrix, the limit of quantitation for the xylenes determination was increased.

APPENDIX B RBSL CALCULATIONS

The procedure for calculating a TPH RBSL for cross-media pathways based upon summing the risk from each fraction is complex. Please note that the following procedure is only appropriate for calculation of RBSLs for cross-media pathways since it sets as an upper limit for the RBSL the degree of saturation, which does not limit exposure for direct routes such as soil ingestion, dermal exposure, and inhalation of particulates. An additional procedure used to calculate exposure for direct pathways is also provided. These procedures are based on Volume 2 of the

Cross-media Pathways

Partitioning qualities govern how a chemical interacts with its environment. Specific physical properties responsible include solubility, vapor pressure, sorption coefficient and Henry's Law Constant. A brief discussion of the role these parameters play in basic partitioning in the environment is provided in the following paragraphs. The fraction-specific values for each of the described fate and transport parameters is provided in Table 3-1. The equations used to develop these fate and transport properties are available in the TPH Criteria Working Group "Volume III. Selection of Representative TPH Fractions Based on Fate and Transport Considerations" (1998).

The solubility of aromatic hydrocarbons, for any EC number, is generally greater than that of aliphatic hydrocarbons, especially at high EC values. The variability in solubility around any given EC value is about an order of magnitude. The higher solubility of the aromatics means that aromatic hydrocarbons are more likely to be present as dissolved constituents in groundwater than are the corresponding aliphatic hydrocarbons.

The soil-water sorption coefficient (k_s) expresses the tendency of a chemical to be adsorbed onto a soil particle. The magnitude of the sorption coefficient for most soil/water systems is a function of the hydrophobicity of the chemical (as indicated by its solubility) and the organic carbon content of the soil. For non-ionic, hydrophobic chemicals such as petroleum hydrocarbons, the primary property controlling sorption is the organic carbon content (f_{oc}) of the soil.

In general, aliphatic fractions are more likely to remain bound to a soil particle than the aromatic fraction of an equivalent EC. This tendency was previously indicated by the low solubility observed for aliphatic fractions. The majority of $\log k_{oc}$ (carbon-water sorption coefficient) values presented in Table 3-1 were derived from the octanol-water partitioning coefficient.

There is very little difference in vapor pressure between aliphatic and aromatic constituents of an equivalent EC. In effect, the EC and vapor pressure are closely related. This relationship is expected because both EC and vapor pressure are largely functions of a compound's boiling point.

The Henry's law constant (H_c) is definable as an air-water partitioning coefficient and may be measured as the ratio of a compound's concentration in air to its concentration in water at equilibrium. Aliphatics and aromatics behave differently based on Henry's law constant. For aromatic fractions, the Henry's law constant decreases with increasing EC; for aliphatic fractions, the Henry's law constant is virtually unaffected by EC. In general, aliphatic hydrocarbons are less soluble and more volatile than aromatic hydrocarbons. It is important to note, however, that benzene, an aromatic compound, is very volatile and more toxic than the

corresponding aliphatic fractions. Therefore, when present, benzene is likely to drive risk calculations for pathways involving volatilization from soil or groundwater.

The parameters described above are combined into simple fate and transport models to evaluate the partitioning and migration of chemicals for the different applicable pathways. For leaching and volatilization pathways where transport and therefore exposure are maximized at the saturation concentration for specific fractions, the following equations are solved. These three equations were adapted from Volume 5 of the Working Group's publications (TPHCWG, 1999).

$$HI = \sum_{i=1}^{i=n} HQ_i = \sum \text{Min} \left(\frac{f_i C_{TPH}}{RBSL_i}, \frac{C_{sat,i}}{RBSL_i} \right) \leq 1 \quad \text{given,} \quad \text{(Equation B-1)}$$

$$\sum_{i=1}^{i=13} f_i = \sum \frac{C_i}{C_{TPH}} = 1 \quad \text{(Equation B-2)}$$

where:

- HI = Hazard Index (typically ≤ 1) [unitless]
- n = number of fractions (13 total) [unitless]
- HQ_i = Hazard Quotient for ith TPH fraction [unitless]
- f_i = Percent Weight of ith TPH fraction in total TPH mixture [unitless]
- C_{TPH} = Concentration of TPH mixture
- C_{sat,i} = Saturation concentration for ith TPH fraction (mg/kg)
- RBSL_i = Tier 1 risk-based screening level for ith TPH fraction (mg/kg)

The saturation concentration is defined by Equation B-3:

$$C_{sat,i} [mg/kg] = \frac{S_i}{\rho_s} [H_{c,i} \theta_{as} + \theta_{ws} + k_{s,i} \rho_s] \quad \text{(Equation B-3)}$$

where:

- S_i = Fraction effective solubility [mg/L]
- ρ_s = Soil Bulk Density [g/cm³]
- H_{c,i} = Henry's Constant for ith TPH fraction [atm-m³/mol]
- θ_{as} = Volumetric air content of the soil [cm³/cm³]
- θ_{ws} = Volumetric water content of the soil [cm³/cm³]
- k_{s,i} = Soil sorption coefficient for ith TPH fraction (k_{oc}*f_{oc}) [cm³/g]

Note: The effective solubility of a hydrocarbon fraction is equal to the fraction's solubility limit multiplied by the mole fraction of the hydrocarbon fraction in the mixture (i.e., TPH).

The value obtained for C_{sat} will vary considerably if the effective C_{sat} of each fraction present in the sample is considered through the use of Raoult's law. Equations B-1 through B-3 are iteratively solved for each TPH fraction, which is the additive mixture RBSL for the soil sample.

Residual saturation is the point at which any increase in chemical concentration will not change the risk, up until the point at which free product migration becomes an issue. For purposes of comparing RBSLs obtained using different analytical fractionation methods, such as the MADEP TPH Method, Raoult's law was not used to calculate the RBSLs presented in the following sections.

Soil Leaching to Groundwater Pathway

Leaching of contaminants from impacted soil into groundwater through infiltrating water is one exposure pathway evaluated in the RBCA analysis. Soil RBSLs are calculated to be protective of groundwater quality. This involves: 1) calculating a groundwater RBSL ($RBSL_{gw}$) to determine an acceptable water concentration, 2) calculating a leachate concentration protective of groundwater (based on the groundwater RBSL), and 3) calculating a soil concentration which would result in this leachate concentration. Equation B-4 (adapted from ASTM, 1995) calculates the ingestion $RBSL_{gw}$ for each TPH fraction. The $RBSL_{gw}$ is based on a target hazard quotient of 1.0. Exposure parameters are provided in Table B-1. RfDs for the fractions are listed in Table 3-2.

$$RBSL_{gw,i} \left[\frac{mg}{L-water} \right] = \frac{THQ \times RfD_{o,i} \times BW \times AT_n \times 365 \frac{days}{yr}}{IR_{water} \times EF \times ED} \quad \text{(Equation B-4)}$$

where:

- THQ = Target hazard quotient [unitless] = 1
- RfD_{o,i} = Oral chronic reference dose for ith TPH fraction [mg/kg-day]
- BW = Body weight [kg]
- AT_n = Averaging time for noncarcinogens [yrs]
- IR_{water} = Daily ingestion rate [L/day]
- EF = Exposure frequency [days/yr]
- ED = Exposure Duration [yrs]

TABLE B-1 TIER 1 DEFAULT EXPOSURE FACTORS

Name	Parameter	Units	Residential Scenario	Commercial Scenario
Averaging Time: carcinogens	AT _c	y	70	70
Averaging Time: non-carcinogens	AT _n	y	30	25
Body Weight	BW	kg	70	70
Exposure Duration	ED	y	30	25
Exposure Frequency	EF	days/y	350	250
Ingestion rate: soil	IR _{soil}	mg/day	100	50
Inhalation Rate: air-indoor	IR _{air-in}	m ³ /day	20	20
Inhalation Rate: air-outdoor	IR _{air-out}	m ³ /day	20	20
Ingestion rate: water	IR _{water}	L/day	2	1
Soil Adherence Factor	M	mg/cm ²	0.5	0.5
Dermal Absorption Factor	RAF _{d,i}	-	c.s.	c.s.
Oral Absorption Factor	RAF _o	-	1	1
Skin surface area	SA	cm ² /day	3160	3160
Target Hazard Quotient for Individual Constituents.	THQ	-	1	1
Target Excess Ind. Lifetime Cancer Risk	TR	-	1E-06	1E-06

Note: c.s. = chemical specific

The analytical model used to estimate soil leaching to groundwater determines the partitioning of a constituent into water, vapor and sorbed phases based on the physical and chemical properties of the constituent. In this model, infiltrating water migrates through contaminated soils in the vadose zone. At this point, some of the contaminant partitions from the soil or vapor transfer into the water phase. This leachate is then assumed to migrate completely and instantaneously into groundwater. Some dilution of the leachate is included using an attenuation factor based on infiltration rate, groundwater velocity, source width and height of the mixing zone in the water column. Equation B-5 describes this attenuation factor (AF).

$$AF = \left[1 + \frac{U_{gw} \delta_{gw}}{IW} \right] \quad \text{(Equation B-5)}$$

where:

- U_{gw} = Groundwater velocity [ft/day]
- δ_{gw} = Height of groundwater mixing zone [ft]
- I = Precipitation infiltration rate [ft/day]
- W = Width of the source area parallel to the mixing zone [ft]

Partitioning into the three phases, soil, water and air, is governed by the partitioning factor. As Henry's law constant is applicable only to dilute solutions, the use of this model is not appropriate when free phase liquid is present. The partitioning factor (PF) for each TPH fraction is shown in Equation B-6.

$$PF_i = \frac{[\theta_{ws} + k_{s,i}\rho_s + H_{c,i}\theta_{as}]}{\rho_s} \quad \text{(Equation B-6)}$$

where,

- θ_{ws} = Soil volumetric water content [cm^3/cm^3]
- $k_{s,i}$ = Soil sorption coefficient ($k_{oc} * f_{oc}$) for i^{th} TPH fraction [cm^3/g]
- ρ_s = Soil density [g/cm^3]
- $H_{c,i}$ = Henry's Constant for i^{th} TPH fraction [$\text{atm}\cdot\text{m}^3/\text{mol}$]
- θ_{as} = Soil volumetric air content [cm^3/cm^3]

The inverse of the product of PF multiplied by AF, which accounts for dilution of leached water into underlying groundwater, is termed the soil to water leaching factor (LF_{sw}). The ultra-conservative leaching model assumes that no attenuation of leachate occurs from the vadose to the saturated zone. In fact, biological degradation of the constituent or repartitioning onto soil or into the vapor phase are all likely to occur as the leachate migrates to groundwater. Other assumptions of the model include: 1) a constant chemical concentration in the subsurface soils, 2) linear equilibrium partitioning within the soil matrix between sorbed, dissolved and vapor phases, 3) steady-state leaching from the vadose zone to groundwater, and 4) steady state, well-mixed dispersion of the leachate within the groundwater mixing zone. Therefore the LF_{sw} , which governs the movement of contaminants from soil to infiltrating water, incorporates both the PF and the AF, in Equation B-7:

$$LF_{sw,i} = \frac{\rho_s}{[\theta_{ws} + k_{s,i} + H_{c,i}\theta_{as}] \left(1 + \frac{U_{gw}\delta_{gw}}{IW}\right)} \quad \text{(Equation B-7)}$$

where:

- $LF_{sw,i}$ = leaching factor for i^{th} TPH fraction [$\text{mg}/\text{L}\cdot\text{H}_2\text{O} / \text{mg}/\text{kg}\cdot\text{soil}$]

Parameters for cross-media pathways are provided in Table B-2. Equations B-5 through B-8 were adapted from ASTM's risk-based corrective action (RBCA) standard guide (1995). Once the LF has been established, fraction-specific soil RBSLs may be calculated as follows:

$$RBSL_{s,i} \left[\frac{\text{mg}}{\text{kg}\cdot\text{soil}} \right] = \frac{RBSL_{gw,i} \left[\frac{\text{mg}}{\text{L}\cdot\text{air}} \right]}{LF_{sw,i}} \quad \text{(Equation B-8)}$$

TABLE B-2 PARAMETERS FOR CROSS-MEDIA RBSL CALCULATIONS

Description	Parameter	Units	Tier 1 Default Values
Ambient air mixing zone height	δ_{air}	cm	200
Areal fraction of cracks in foundations/walls	η	cm ² /cm ²	0.01
Averaging time for vapor flux	τ	s	7.88E+8
Carbon-water sorption coefficient	k_{oc}	cm ³ /g	c.s.
Depth to groundwater (h _{cap} +h _v)	L_{GW}	cm	300
Depth to subsurface soil sources	L_s	cm	61
Diffusion coefficient in air	D^{air}	cm ² /s	c.s.
Diffusion coefficient in water	D^{wat}	cm ² /s	c.s.
Enclosed space air exchange rate	ER	1/s	0.00023
Enclosed space foundation or wall thickness	L_{crack}	cm	15
Enclosed space volume/infiltration area ratio	L_B	cm	300.
Fraction organic carbon in soil	f_{oc}	g/g	0.01
Groundwater Darcy velocity	μ_{gw}	cm/yr	2500
Groundwater mixing zone thickness	δ_{gw}	cm	200
Henry's Law Constant	H	(cm ³ /cm ³)	c.s.
Infiltration rate of water through soil	I	cm/yr	30
Lower depth of surficial soil zone	d	cm	100
Particulate emission rate	PE	g/cm ² -s	2.2E-10
Particulate Emission Rate	VF_p	(mg/m ³)/ (mg/kg)	6.90E-14
Pure component solubility in water	S	mg/L	c.s.
Soil bulk density	ρ	g/cm ³	1.7
Soil-water sorption coefficient	k_s	cm ³ /g	F _{oc} *k _{oc}
Thickness of capillary fringe	h_{cap}	cm	5
Thickness of vadose zone	h_v	cm	295
Total soil porosity	θ_T	cm ³ /cm ³	0.38
Volatilization Factor	VF_i	(mg/m ³)/ (mg/m ³)	c.s. & m.s.
Volumetric air content in vadose zone soils	θ_{as}	cm ³ /cm ³	0.03
Volumetric air content in capillary fringe soils	θ_{acap}	cm ³ /cm ³	0.038
Volumetric air content in foundation cracks	θ_{acrack}	cm ³ /cm ³	0.26
Volumetric water content vadose zone soils	θ_{ws}	cm ³ /cm ³	0.12
Volumetric water content: capillary fringe	θ_{wcap}	cm ³ /cm ³	0.342
Volumetric water content: foundation cracks	θ_{wcrack}	cm ³ /cm ³	0.12
Width of source area parallel to flow direction	W	cm	1500

Notes: c.s. = chemical specific
m.s. = media specific

Volatilization to Indoor Air Pathway

The mathematical model used to estimate volatilization from soil to indoor air is based upon the partitioning of a constituent into water, vapor and sorbed phases as determined by the physical properties of the chemical. The model accounts for the contaminant partitioning into soil pore gas and migrating through the vadose zone to the base of a building foundation. From there the gas diffuses through cracks in the foundation and into the building air space, where exposure through inhalation may occur.

The first step in calculating a soil RBSL for the indoor air pathway requires the calculation of an air concentration or RBSL, which is protective of indoor air quality (based on a target HQ of 1.0). Indoor air RBSLs are calculated for each TPH fraction and then a whole TPH RBSL is calculated based on the percent composition of each fraction. Equation B-9 is used to calculate the air RBSLs for TPH fractions. Parameter values are presented in Table B-2.

$$RBSL_{air,i} \left[\frac{\mu g}{m^3 \text{ air}} \right] = \frac{THQ \times RfD_{i,i} \times BW \times AT_n \times 365 \frac{\text{days}}{\text{yr}} \times 10^3 \frac{\mu g}{\text{mg}}}{IR_{air} \times EF \times ED}$$

(Equation B-9)

where:

THQ	=	Target hazard quotient [unitless] = 1
RfD _{i,i}	=	Inhalation chronic reference dose for i th TPH fraction [mg/kg-day]
BW	=	Body weight [kg]
AT _n	=	Averaging time for noncarcinogens [yrs]
IR _{air}	=	Daily inhalation rate [m ³ /day]
EF	=	Exposure frequency [days/yr]
ED	=	Exposure Duration [years]

The second step in calculating a soil concentration (RBSL_{soil}) which will result in an acceptable indoor air concentration (RBSL_{air}) is to model the transport of contaminants from the vadose soil to indoor air. This model is extremely conservative, assuming: 1) a constant chemical concentration in subsurface soils; 2) linear equilibrium partitioning in the soil between sorbed, dissolved and vapor phases; and 3) steady-state vapor- and liquid-phase diffusion through the vadose zone and foundation cracks. In addition, the model assumes that vapors migrate completely and instantaneously into the building, i.e., no attenuation occurs. It does not account for any biodegradation and soil sorption which could occur as the vapor migrates through the vadose zone.

Dilution of vapor is expected to occur between the source and the building. Therefore the following diffusion coefficient in soil (D^{eff}_s) for each TPH fraction is used (see Equation B-10).

$$D_{s,i}^{eff} \left[\frac{cm^2}{s} \right] = D_i^{air} \frac{\theta_{as}^{3.33}}{\theta_T^2} + D_i^{wat} \frac{1}{H_{c,i}} \times \frac{\theta_{ws}^{3.33}}{\theta_T^2} \quad (\text{Equation B-10})$$

where:

- D_i^{air} = Diffusion coefficient in air for i^{th} TPH fraction [cm^2/sec]
- θ_{as} = Soil volumetric air content [cm^3 -air/ cm^3 -soil]
- θ_T = Total soil porosity [cm^3/cm^3]
- D_i^{wat} = Diffusion coefficient in water for i^{th} TPH fraction [cm^2/sec]
- $H_{c,i}$ = Henry's constant for i^{th} TPH fraction [cm^3 -air/ cm^3 -soil]
- θ_{ws} = Soil volumetric water content [cm^3 -water/ cm^3 -soil]

The diffusion of the pore gas through cracks in the foundation is governed by Equation B-11. Equations B-9 through B-11 were adapted from ASTM RBCA (1995).

$$D_{crack,i}^{eff} \left[\frac{cm^2}{s} \right] = D_i^{air} \frac{\theta_{acrack}^{3.33}}{\theta_T^2} + D_i^{wat} \frac{1}{H_{c,i}} \times \frac{\theta_{wcrack}^{3.33}}{\theta_T^2} \quad (\text{Equation B-11})$$

where:

- D_i^{air} = Diffusion coefficient in air for i^{th} TPH fraction [cm^2/sec]
- θ_{acrack} = Volumetric air content in foundation [cm^3 -air/ cm^3]
- θ_T = Total soil porosity [cm^3/cm^3]
- D_i^{wat} = Diffusion coefficient in water for i^{th} TPH fraction [cm^2/sec]
- $H_{c,i}$ = Henry's constant for i^{th} TPH fraction [cm^3 -air/ cm^3 -soil]
- θ_{wcrack} = Volumetric water content in foundation [cm^3 -water/ cm^3]

Chemical Partitioning

Equation B-12 accounts for the movement of chemicals from the soil into the vapor phase of the soil pore space. This is defined as the partitioning factor (soil/vapor phase) and is fraction specific.

$$PF_{s-v,i} = \frac{H_{c,i} \rho_s}{\theta_{ws} + k_{s,i} \rho_s + H_{c,i} \theta_{as}} \quad (\text{Equation B-12})$$

where:

- $PF_{s-v,i}$ = Soil/Vapor phase partitioning factor for i^{th} TPH fraction [unitless]
- $H_{c,i}$ = Henry's Constant for i^{th} TPH fraction [cm^3 -water/ cm^3 -air]
- ρ_s = Soil bulk density [g/cm^3]
- θ_{ws} = Soil volumetric water content [cm^3/cm^3]
- $k_{s,i}$ = Soil sorption coefficient ($k_{oc} * f_{oc}$) for i^{th} TPH fraction [cm^3/g]
- θ_{as} = Soil volumetric air content [cm^3/cm^3]

The diffusion coefficients and partitioning factor are combined to yield a subsurface soil to enclosed space volatilization factor (VF_{sesp}) for each TPH fraction. VF_{sesp} takes into account partitioning, diffusion in the vadose zone, effective diffusion into an enclosed space and adds terms for accumulation of vapors in the enclosed space (see Equation B-13).

$$VF_{sesp,i} = \frac{(PF_{s-v,i}) \frac{D_{s,i}^{eff} / L_s}{ER \times L_B}}{1 + \frac{D_{s,i}^{eff} / L_s}{ER \times L_B} + \frac{D_{s,i}^{eff} + L_s}{(D_{crack,i}^{eff} / L_{crack}) \times \eta}} \times 10^3 \left[\frac{cm^3 - kg}{m^3 - g} \right] \quad (\text{Equation B-13})$$

where:

- $PF_{s-v,i}$ = Soil/Vapor phase partitioning factor for i^{th} TPH fraction [unitless]
- $D_{s,i}^{eff}$ = Effective diffusion coefficient in soil for i^{th} TPH fraction [cm^2/s]
- L_s = Depth to subsurface soil sources [cm]
- ER = Enclosed-space air exchange rate [s^{-1}]
- L_B = Enclosed-space volume/infiltration area ratio [cm]
- $D_{crack,i}^{eff}$ = Effective diffusion coefficient through foundation cracks for i^{th} TPH fraction [cm^2/s]
- L_{crack} = Enclosed-space foundation or wall thickness [cm]
- η = Areal fraction of cracks in foundation/walls [cm^2/cm^2]

Values in these calculations are provided in Table B-2. The term VF_{sesp} , when combined with the allowable concentration of contaminant in the air space ($RBSL_{air}$), determines the maximum allowable concentration in the subsurface soil source area for each TPH fraction. The RBSL for the volatilization to indoor air pathway ($RBSL_{svin}$) is shown in Equation B-14. Equations B-12 through B-14 were adapted from ASTM RBCA (1995).

$$RBSL_{svin,i} \left[\frac{mg}{kg - soil} \right] = \frac{RBSL_{air,i} \left[\frac{mg}{m^3 - air} \right]}{VF_{sesp,i}} \quad (\text{Equation B-14})$$

Volatilization to Outdoor Air Pathway

The volatilization to outdoor air model is similar to the indoor air model. It assumes contaminants partition into soil pore gas that migrates through the vadose zone to the surface and mixes with the ambient air. Dispersion into ambient air is modeled using a "box model", which is typically valid for source widths of less than 100 feet parallel to wind direction. Steady-state well-mixed atmospheric dispersion of the vapors within the breathing zone is assumed. Other assumptions listed for the indoor air model include linear equilibrium partitioning, steady-state vapor diffusion through the vadose zone and no attenuation of the chemical as it migrates through the vadose zone.

The calculation of a soil RBSL protective of outdoor air quality is similar to that used for the indoor air pathway. A volatilization factor for ambient air (VF_{samb}) is derived for each fraction, using the same effective diffusion coefficient in vadose soils and partitioning factor. Equations

B-15 and B-16 were adapted from ASTM RBCA (1995). Default values are provided in Table B-2.

$$VF_{samb,i} \left[\frac{mg/m^3-air}{mg/kg-soil} \right] = \frac{PF_{s-v,i}}{1 + \frac{U_{air} \delta_{air} L_s}{D_{s,i}^{eff} W}} \times 10^3 \left[\frac{cm^3 - kg}{m^3 - g} \right] \quad (\text{Equation B-15})$$

where:

- $PF_{s-v,i}$ = Soil/Vapor phase partitioning factor for i^{th} TPH fraction [unitless]
- U_{air} = Wind speed above ground surface in ambient mixing zone [cm/s]
- δ_{air} = Ambient air mixing zone height [cm]
- L_s = Depth to subsurface soil sources [cm]
- $D_{s,i}^{eff}$ = Effective diffusion coefficient in soil for i^{th} TPH fraction [cm^2/s]
- W = Width of source area parallel to wind direction [cm]

VF_{samb} is then combined with the allowable concentration of contaminant in the air space ($RBSL_{air}$) to determine the maximum allowable concentration of contaminant in the subsurface soil for each fraction. This concentration, $RBSL_{svout}$, is defined by Equation B-16.

$$RBSL_{svout,i} = \frac{RBSL_{air,i} \left[\frac{mg}{m^3-air} \right]}{VF_{samb,i}} \quad (\text{Equation B-16})$$

Direct Contact Pathway

For direct exposure routes to soil such as ingestion, dermal absorption and inhalation of particulates, exposure is not limited by C_{sat} . The assumption is made that intake will continue to increase linearly with soil loading beyond C_{sat} . For the direct contact pathways, the Equations B-17 and B-18 are solved (adapted from TPHCWG, 1999 and ASTM, 1995, respectively).

$$HI = \sum_{i=1}^{i=n} HQ_i = \sum_{i=1}^{i=n} \frac{f_i C_{TPH}}{RBSL_i} \leq 1 \quad (\text{Equation B-17})$$

$$RBSL_{ss,i} \left[\frac{\mu\text{g}}{\text{kg-soil}} \right] = \frac{THQ \times BW \times AT_n \times 365 \text{ days/yr}}{EF \times ED \times \left[\frac{10^{-6} \text{ kg/mg} \times (IR_{soil} \times RAF_{o,i} \times SA \times M \times RAF_{d,i})}{RfD_{o,i}} \right] + \left[\frac{IR_{air} \times (VF_{ss,i} + VF_{p,i})}{RfD_{i,i}} \right]}$$

(Equation B-18)

where:

- THQ = Target hazard quotient for constituent [unitless]
- BW = Body weight [kg]
- AT_n = Averaging time for noncarcinogens [years]
- EF = Exposure frequency (days/year)
- ED = Exposure duration [years]
- IR_{soil} = Soil ingestion rate [mg/day]
- RAF_{o,i} = Relative oral absorption factor for ith TPH fraction [unitless]
- SA = Skin surface area [cm²/day]
- M = Soil to skin adherence factor [mg/cm²]
- RAF_{d,i} = Relative dermal absorption factor for ith TPH fraction [unitless]
- RfD_{o,i} = Oral chronic reference dose for ith TPH fraction [mg/kg-day]
- IR_{air} = Inhalation rate [m³/day]
- VF_{ss,i} = Surficial soils to ambient air partition factor (vapor) for ith TPH fraction [unitless]
- VF_{p,i} = Surficial soils to ambient air partition factor (particulates) for ith TPH fraction [unitless]
- RfD_{i,i} = Inhalation chronic reference dose for ith TPH fraction [mg/kg-day]

Similar to the HI calculation, the RBSL equation is solved iteratively to find C_{TPH} such that HI is under the constraint of a target hazard index of 1.0. Default exposure parameters are provided in Table B-1. The fraction specific RfDs are provided in Table 3-2.

REFERENCES

ASTM. 1995. Standard Guide for Risk-based Corrective Action Applied at Petroleum Release Sites. American Society for Testing and Materials, West Conshohocken, PA. E-1739-95.

TPHCWG. 1999. A Risk-based Approach for the Management of Total Petroleum Hydrocarbons in Soil, Volume 5. Human Health Risk-based Evaluation of Petroleum Release Sites: Implementing the Working Group Approach.

APPENDIX C RBCA MODEL RUNS

Sample - EA-2, 4 ft
Outdoor

RESIDENTIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) HQ=1	s v out (mg/kg) HQ=1	ss (mg/kg) HQ=1
>5-6 Aliphatics	4.76E+02	2.92E+04	2.73E+03	3.53E+05
>5-7 Aromatics	1.63E+03	8.11E+01	6.50E+02	1.24E+04
>6-8 Aliphatics	2.57E+02	1.05E+05	6.56E+03	3.53E+05
>7-8 Aromatics	1.26E+03	2.17E+02	1.46E+03	1.24E+04
>8-10 Aliphatics	1.41E+02	1.45E+04	1.69E+03	7.78E+03
>8-10 Aromatics	1.04E+03	2.83E+02	2.29E+03	2.91E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	8.20E+03	7.78E+03
>10-12 Aromatics	6.30E+02	4.46E+02	1.26E+04	2.91E+03
>12-16 Aliphatics	3.82E+01	2.22E+06	3.91E+04	7.78E+03
>12-16 Aromatics	2.91E+02	8.88E+02	6.52E+04	3.01E+03
>16-35 Aliphatics	1.30E+01	8.84E+09	4.39E+06	1.51E+05
>16-21 Aromatics	8.09E+01	2.10E+03	5.56E+05	2.39E+03
>21-35 Aromatics	8.31E+00	1.67E+04	7.71E+07	2.45E+03

COMMERCIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) Non-Carc	s v out (mg/kg) Non-Carc	ss (mg/kg) Non-Carc
>5-6 Aliphatics	4.76E+02	8.18E+04	3.82E+03	5.19E+05
>5-7 Aromatics	1.63E+03	2.27E+02	9.10E+02	1.81E+04
>6-8 Aliphatics	2.57E+02	2.95E+05	9.18E+03	5.19E+05
>7-8 Aromatics	1.26E+03	6.07E+02	2.05E+03	1.81E+04
>8-10 Aliphatics	1.41E+02	4.07E+04	2.36E+03	1.15E+04
>8-10 Aromatics	1.04E+03	7.92E+02	3.21E+03	4.28E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	1.77E+04	4.28E+03
>12-16 Aliphatics	3.82E+01	6.21E+06	5.48E+04	1.15E+04
>12-16 Aromatics	2.91E+02	2.49E+03	9.13E+04	4.44E+03
>16-35 Aliphatics	1.30E+01	2.48E+10	6.14E+06	2.23E+05
>16-21 Aromatics	8.09E+01	5.89E+03	7.78E+05	3.54E+03
>21-35 Aromatics	8.31E+00	4.67E+04	1.08E+08	3.64E+03

Fraction (mg/kg/mg/kg) HQ(Ci) HQ(Ci) HQ(Ci) HQ(Ci)

>5-6 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>5-7 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>6-8 Aliphatics	3.39E-02	9.00E-04	3.93E-02	5.98E-04
>7-8 Aromatics	4.24E-04	5.47E-03	3.57E-01	2.13E-04
>8-10 Aliphatics	2.28E-01	9.73E-03	8.38E-02	1.83E-01
>8-10 Aromatics	2.91E-02	2.87E-01	4.54E-01	6.23E-02
>10-12 Aliphatics	3.17E-01	7.69E-04	1.05E-02	2.54E-01
>10-12 Aromatics	7.47E-02	4.69E-01	4.99E-02	1.60E-01
>12-16 Aliphatics	2.39E-01	1.72E-05	9.75E-04	1.91E-01
>12-16 Aromatics	7.20E-02	2.27E-01	4.46E-03	1.49E-01
>16-35 Aliphatics	5.72E-03	1.47E-09	2.96E-06	2.36E-04
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00	1.00E+00	1.00E+00	1.00E+00

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
>5-6 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>5-7 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>6-8 Aliphatics	3.39E-02	8.73E-04	2.80E-02	6.00E-04	6.00E-04
>7-8 Aromatics	4.24E-04	6.97E-03	5.41E-01	2.15E-04	2.15E-04
>8-10 Aliphatics	2.28E-01	3.47E-03	5.98E-02	1.83E-01	1.83E-01
>8-10 Aromatics	2.91E-02	3.66E-01	3.24E-01	6.25E-02	6.25E-02
>10-12 Aliphatics	3.17E-01	2.75E-04	7.50E-03	2.53E-01	2.53E-01
>10-12 Aromatics	7.47E-02	5.05E-01	3.56E-02	1.60E-01	1.60E-01
>12-16 Aliphatics	2.39E-01	6.14E-06	6.96E-04	1.91E-01	1.91E-01
>12-16 Aromatics	7.20E-02	1.17E-01	3.19E-03	1.49E-01	1.49E-01
>16-35 Aliphatics	5.72E-03	5.25E-10	2.12E-06	2.36E-04	2.36E-04
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00

	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
HI	1,00E+00	1,00E+00	1,00E+00
RBSL(HI=1) mg/kg	2,798	1,234,858	6,227

	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
HI	1,00E+00	1,00E+00	1,00E+00
RBSL(HI=1) mg/kg	9,981	2,617,725	9,199

Sample - EA-2, 4 ft
Indoor

RESIDENTIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) HQ=1	s v in (mg/kg) HQ=1	ss (mg/kg) HQ=1
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03

COMMERCIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) Non-Carc	s v in (mg/kg) Non-Carc	ss (mg/kg) Non-Carc
5-6 Aliphatics	4.76E+02	8.18E+04	1.40E+02	5.19E+05
5-7 Aromatics	1.63E+03	2.27E+02	3.35E+01	1.81E+04
>6-8 Aliphatics	2.57E+02	2.95E+05	3.38E+02	5.19E+05
>7-8 Aromatics	1.26E+03	6.07E+02	7.55E+01	1.81E+04
>8-10 Aliphatics	1.41E+02	4.07E+04	8.70E+01	1.15E+04
>8-10 Aromatics	1.04E+03	7.92E+02	1.18E+02	4.28E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	4.22E+02	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	6.51E+02	4.28E+03
>12-16 Aliphatics	3.82E+01	6.21E+06	2.02E+03	1.15E+04
>12-16 Aromatics	2.91E+02	2.49E+03	3.36E+03	4.44E+03
>16-21 Aliphatics	1.30E+01	2.48E+10	2.26E+05	2.23E+05
>16-21 Aromatics	8.09E+01	5.89E+03	2.86E+04	3.54E+03
>21-35 Aromatics	8.31E+00	4.67E+04	3.97E+06	3.64E+03

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5-7 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>6-8 Aliphatics	3.39E-02	9.00E-04	2.52E-02	5.98E-04
>7-8 Aromatics	4.20E-04	5.42E-03	1.40E-03	2.11E-04
>8-10 Aliphatics	2.28E-01	9.73E-03	6.59E-01	1.83E-01
>8-10 Aromatics	2.91E-02	2.87E-01	6.18E-02	6.23E-02
>10-12 Aliphatics	3.17E-01	7.69E-04	1.88E-01	2.54E-01
>10-12 Aromatics	7.47E-02	4.69E-01	2.88E-02	1.60E-01
>12-16 Aliphatics	2.39E-01	1.72E-05	2.98E-02	1.91E-01
>12-16 Aromatics	7.20E-02	2.27E-01	5.38E-03	1.49E-01
>16-21 Aliphatics	5.72E-03	1.47E-09	6.36E-06	2.36E-04
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

SV in Calculation based on 1.0 percent foundation cracks

	s lch (mg/kg)	s v in (mg/kg)	ss (mg/kg)
HI	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg	2,798	97	6,227

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5-7 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>6-8 Aliphatics	3.39E-02	8.73E-04	2.55E-02	6.00E-04
>7-8 Aromatics	4.20E-04	6.91E-03	1.41E-03	2.13E-04
>8-10 Aliphatics	2.28E-01	3.47E-03	6.67E-01	1.83E-01
>8-10 Aromatics	2.91E-02	3.66E-01	6.25E-02	6.25E-02
>10-12 Aliphatics	3.17E-01	2.75E-04	1.90E-01	2.53E-01
>10-12 Aromatics	7.47E-02	5.05E-01	2.91E-02	1.60E-01
>12-16 Aliphatics	2.39E-01	6.14E-06	1.89E-02	1.91E-01
>12-16 Aromatics	7.20E-02	1.17E-01	5.44E-03	1.49E-01
>16-21 Aliphatics	5.72E-03	5.25E-10	6.43E-06	2.36E-04
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

SV in Calculation based on 1.0 percent foundation cracks

	s lch (mg/kg)	s v in (mg/kg)	ss (mg/kg)
HI	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg	9,984	254	9,199

Sample - EA-2, 7 ft
Outdoor

RESIDENTIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) HQ=1	s v out (mg/kg) HQ=1	ss (mg/kg) HQ=1
>5-6 Aliphatics	4.76E+02	2.92E+04	2.73E+03	3.53E+05
>5-7 Aromatics	1.63E+03	8.11E+01	6.50E+02	1.24E+04
>6-8 Aliphatics	2.57E+02	1.05E+05	6.56E+03	3.53E+05
>7-8 Aromatics	1.26E+03	2.17E+02	1.46E+03	1.24E+04
>8-10 Aliphatics	1.41E+02	1.45E+04	1.69E+03	7.78E+03
>8-10 Aromatics	1.04E+03	2.83E+02	2.29E+03	2.91E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	8.20E+03	7.78E+03
>10-12 Aromatics	6.30E+02	4.46E+02	1.26E+04	2.91E+03
>12-16 Aliphatics	3.82E+01	2.22E+06	3.91E+04	7.78E+03
>12-16 Aromatics	2.91E+02	8.88E+02	6.52E+04	3.01E+03
>16-35 Aliphatics	1.30E+01	8.84E+09	4.39E+06	1.51E+05
>16-21 Aromatics	8.09E+01	2.10E+03	5.56E+05	2.39E+03
>21-35 Aromatics	8.31E+00	1.67E+04	7.71E+07	2.45E+03

COMMERCIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) Non-Carc	s v out (mg/kg) Non-Carc	ss (mg/kg) Non-Carc
>5-6 Aliphatics	4.76E+02	8.18E+04	3.82E+03	5.19E+05
>5-7 Aromatics	1.63E+03	2.27E+02	9.10E+02	1.81E+04
>6-8 Aliphatics	2.57E+02	2.95E+05	9.18E+03	5.19E+05
>7-8 Aromatics	1.26E+03	6.07E+02	2.05E+03	1.81E+04
>8-10 Aliphatics	1.41E+02	4.07E+04	2.36E+03	1.15E+04
>8-10 Aromatics	1.04E+03	7.92E+02	3.21E+03	4.28E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	1.77E+04	4.28E+03
>12-16 Aliphatics	3.82E+01	6.21E+06	5.48E+04	1.15E+04
>12-16 Aromatics	2.91E+02	2.49E+03	9.13E+04	4.44E+03
>16-35 Aliphatics	1.30E+01	2.48E+10	6.14E+06	2.23E+05
>16-21 Aromatics	8.09E+01	5.89E+03	7.78E+05	3.54E+03
>21-35 Aromatics	8.31E+00	4.67E+04	1.08E+08	3.64E+03

Fraction
(mg/kg/mg/kg)

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
>5-6 Aliphatics	2.89E-02	2.94E-03	1.74E-01	5.42E-04
>5-7 Aromatics	7.60E-04	2.79E-02	1.83E-01	4.06E-04
>6-8 Aliphatics	5.51E-02	1.56E-03	3.93E-02	1.03E-03
>7-8 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>8-10 Aliphatics	2.85E-01	9.73E-03	8.38E-02	2.42E-01
>8-10 Aromatics	3.04E-02	3.20E-01	4.54E-01	6.93E-02
>10-12 Aliphatics	2.83E-01	7.69E-04	1.05E-02	2.40E-01
>10-12 Aromatics	6.62E-02	4.42E-01	4.99E-02	1.51E-01
>12-16 Aliphatics	1.92E-01	1.72E-05	9.75E-04	1.64E-01
>12-16 Aromatics	5.76E-02	1.93E-01	4.46E-03	1.27E-01
>16-35 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	1.60E-03	2.27E-03	1.45E-04	4.44E-03
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
>5-6 Aliphatics	2.89E-02	3.25E-03	1.25E-01	5.44E-04
>5-7 Aromatics	7.60E-04	3.08E-02	4.16E-01	4.10E-04
>6-8 Aliphatics	5.51E-02	8.73E-04	2.80E-02	1.04E-03
>7-8 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>8-10 Aliphatics	2.85E-01	3.47E-03	5.98E-02	2.42E-01
>8-10 Aromatics	3.04E-02	3.53E-01	3.24E-01	6.94E-02
>10-12 Aliphatics	2.83E-01	2.75E-04	7.50E-03	2.40E-01
>10-12 Aromatics	6.62E-02	4.88E-01	3.56E-02	1.51E-01
>12-16 Aliphatics	1.92E-01	6.14E-06	6.96E-04	1.63E-01
>12-16 Aromatics	5.76E-02	1.17E-01	3.19E-03	1.27E-01
>16-35 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	1.60E-03	2.50E-03	1.04E-04	4.43E-03
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
HI	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg	2,976	156,080	6,624

	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
HI	1.00E+00	1.00E+00	1.00E+00
RBSL(HI=1) mg/kg	9,208	498,007	9,786

Sample - EA-2, 7 ft
Indoor

RESIDENTIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) HQ=1	s v in (mg/kg) HQ=1	ss (mg/kg) HQ=1
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03

COMMERCIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) Non-Carc	s v in (mg/kg) Non-Carc	ss (mg/kg) Non-Carc
5-6 Aliphatics	4.76E+02	8.18E+04	1.40E+02	5.19E+05
5-7 Aromatics	1.63E+03	2.27E+02	3.35E+01	1.81E+04
>6-8 Aliphatics	2.57E+02	2.95E+05	3.38E+02	5.19E+05
>7-8 Aromatics	1.26E+03	6.07E+02	7.55E+01	1.81E+04
>8-10 Aliphatics	1.41E+02	4.07E+04	8.70E+01	1.15E+04
>8-10 Aromatics	1.04E+03	7.92E+02	1.18E+02	4.28E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	4.22E+02	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	6.51E+02	4.28E+03
>12-16 Aliphatics	3.82E+01	6.21E+06	2.02E+03	1.15E+04
>12-16 Aromatics	2.91E+02	2.49E+03	3.36E+03	4.44E+03
>16-21 Aliphatics	1.30E+01	2.48E+10	2.26E+05	2.23E+05
>16-21 Aromatics	8.09E+01	5.89E+03	2.86E+04	3.54E+03
>21-35 Aromatics	8.31E+00	4.67E+04	3.97E+06	3.64E+03

**Fraction
(mg/kg/mg/kg)**

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	2.89E-02	3.25E-03	4.28E-02	5.44E-04
5-7 Aromatics	7.60E-04	3.08E-02	4.73E-03	4.10E-04
>6-8 Aliphatics	5.51E-02	8.73E-04	3.39E-02	1.04E-03
>7-8 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>8-10 Aliphatics	2.85E-01	3.47E-03	6.82E-01	2.42E-01
>8-10 Aromatics	3.04E-02	3.53E-01	5.36E-02	6.94E-02
>10-12 Aliphatics	2.83E-01	2.75E-04	1.39E-01	2.40E-01
>10-12 Aromatics	6.62E-02	4.88E-01	2.12E-02	1.51E-01
>12-16 Aliphatics	1.92E-01	6.14E-06	1.89E-02	1.63E-01
>12-16 Aromatics	5.76E-02	1.17E-01	3.57E-03	1.27E-01
>16-21 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	1.60E-03	2.50E-03	1.16E-05	4.43E-03
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

SV in Calculation based on 1.0 percent foundation cracks

	s lch (mg/kg)	s v in (mg/kg)	ss (mg/kg)
HI	1,00E+00	1,00E+00	1,00E+00
RBSL(HI=1) mg/kg	2,976	208	9,786

SV in Calculation based on 1.0 percent foundation cracks

	s lch (mg/kg)	s v in (mg/kg)	ss (mg/kg)
HI	1,00E+00	1,00E+00	1,00E+00
RBSL(HI=1) mg/kg	2,976	80	6,624

Sample - E-8, 4 ft
Outdoor

RESIDENTIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) HQ=1	s v out (mg/kg) HQ=1	ss (mg/kg) HQ=1
5-6 Aliphatics	4.76E+02	2.92E+04	2.73E+03	3.53E+05
5-7 Aromatics	1.63E+03	8.11E+01	6.50E+02	1.24E+04
>6-8 Aliphatics	2.57E+02	1.05E+05	6.56E+03	3.53E+05
>7-8 Aromatics	1.26E+03	2.17E+02	1.46E+03	1.24E+04
>8-10 Aliphatics	1.41E+02	1.45E+04	1.69E+03	7.78E+03
>8-10 Aromatics	1.04E+03	2.83E+02	2.29E+03	2.91E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	8.20E+03	7.78E+03
>10-12 Aromatics	6.30E+02	4.46E+02	1.26E+04	2.91E+03
>12-16 Aliphatics	3.82E+01	2.22E+06	3.91E+04	7.78E+03
>12-16 Aromatics	2.91E+02	8.88E+02	6.52E+04	3.01E+03
>16-35 Aliphatics	1.30E+01	8.84E+09	4.39E+06	1.51E+05
>16-21 Aromatics	8.09E+01	2.10E+03	5.56E+05	2.39E+03
>21-35 Aromatics	8.31E+00	1.67E+04	7.71E+07	2.45E+03

COMMERCIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) Non-Carc	s v out (mg/kg) Non-Carc	ss (mg/kg) Non-Carc
5-6 Aliphatics	4.76E+02	8.18E+04	3.82E+03	5.19E+05
5-7 Aromatics	1.63E+03	2.27E+02	9.10E+02	1.81E+04
>6-8 Aliphatics	2.57E+02	2.95E+05	9.18E+03	5.19E+05
>7-8 Aromatics	1.26E+03	6.07E+02	2.05E+03	1.81E+04
>8-10 Aliphatics	1.41E+02	4.07E+04	2.36E+03	1.15E+04
>8-10 Aromatics	1.04E+03	7.92E+02	3.21E+03	4.28E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	1.77E+04	4.28E+03
>12-16 Aliphatics	3.82E+01	6.21E+06	5.48E+04	1.15E+04
>12-16 Aromatics	2.91E+02	2.49E+03	9.13E+04	4.44E+03
>16-35 Aliphatics	1.30E+01	2.48E+10	6.14E+06	2.23E+05
>16-21 Aromatics	8.09E+01	5.89E+03	7.78E+05	3.54E+03
>21-35 Aromatics	8.31E+00	4.67E+04	1.08E+08	3.64E+03

Fraction
(mg/kg/mg/kg)

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5-7 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>6-8 Aliphatics	6.59E-02	1.75E-03	3.93E-02	1.16E-03
>7-8 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>8-10 Aliphatics	1.86E-01	9.73E-03	8.38E-02	1.49E-01
>8-10 Aromatics	2.05E-02	2.03E-01	4.54E-01	4.41E-02
>10-12 Aliphatics	3.11E-01	7.69E-04	1.05E-02	2.49E-01
>10-12 Aromatics	7.85E-02	4.93E-01	4.99E-02	1.68E-01
>12-16 Aliphatics	2.46E-01	1.72E-05	9.75E-04	1.97E-01
>12-16 Aromatics	9.25E-02	2.92E-01	4.46E-03	1.92E-01
>16-35 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5-7 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>6-8 Aliphatics	6.59E-02	8.73E-04	2.80E-02	1.17E-03
>7-8 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>8-10 Aliphatics	1.86E-01	3.47E-03	5.98E-02	1.49E-01
>8-10 Aromatics	2.05E-02	3.73E-01	3.24E-01	4.42E-02
>10-12 Aliphatics	3.11E-01	2.75E-04	7.50E-03	2.49E-01
>10-12 Aromatics	7.85E-02	5.05E-01	3.56E-02	1.69E-01
>12-16 Aliphatics	2.46E-01	6.14E-06	6.96E-04	1.97E-01
>12-16 Aromatics	9.25E-02	1.17E-01	3.19E-03	1.92E-01
>16-35 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
HI	1.00E+00	6.43E-01	1.00E+00
RBSL(HI=1) mg/kg	2,799	51,248	6,233

	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
HI	1.00E+00	4.59E-01	1.00E+00
RBSL(HI=1) mg/kg	14,397	80,321	9,207

COMMERCIAL SCENARIO

Sample - E-8, 4 ft Indoor	RESIDENTIAL SCENARIO			COMMERCIAL SCENARIO				
	Csat (mg/kg)	s lch (mg/kg) HQ=1	s v in (mg/kg) HQ=1	ss (mg/kg) HQ=1	Csat (mg/kg)	s lch (mg/kg) Non-Carc	s v in (mg/kg) Non-Carc	ss (mg/kg) Non-Carc
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05	4.76E+02	8.18E+04	1.40E+02	5.19E+05
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04	1.63E+03	2.27E+02	3.35E+01	1.81E+04
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05	2.57E+02	2.95E+05	3.38E+02	5.19E+05
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04	1.26E+03	6.07E+02	7.55E+01	1.81E+04
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03	1.41E+02	4.07E+04	8.70E+01	1.15E+04
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03	1.04E+03	7.92E+02	1.18E+02	4.28E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03	8.61E+01	3.13E+05	4.22E+02	1.15E+04
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03	6.30E+02	1.25E+03	6.51E+02	4.28E+03
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03	3.82E+01	6.21E+06	2.02E+03	1.15E+04
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03	2.91E+02	2.49E+03	3.36E+03	4.44E+03
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05	1.30E+01	2.48E+10	2.26E+05	2.23E+05
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03	8.09E+01	5.89E+03	2.86E+04	3.54E+03
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03	8.31E+00	4.67E+04	3.97E+06	3.64E+03

Sample - E-8, 4 ft Indoor	RESIDENTIAL SCENARIO			COMMERCIAL SCENARIO				
	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5-7 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>6-8 Aliphatics	6.59E-02	1.75E-03	5.55E-02	1.16E-03	6.59E-02	8.73E-04	5.71E-02	1.17E-03
>7-8 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>8-10 Aliphatics	1.86E-01	9.73E-03	6.09E-01	1.49E-01	1.86E-01	3.47E-03	6.26E-01	1.49E-01
>8-10 Aromatics	2.05E-02	2.03E-01	4.95E-02	4.41E-02	2.05E-02	3.73E-01	5.09E-02	4.42E-02
>10-12 Aliphatics	3.11E-01	7.69E-04	2.09E-01	2.49E-01	3.11E-01	2.75E-04	2.04E-01	2.49E-01
>10-12 Aromatics	7.85E-02	4.93E-01	3.43E-02	1.68E-01	7.85E-02	5.05E-01	3.53E-02	1.69E-01
>12-16 Aliphatics	2.46E-01	1.72E-05	3.47E-02	1.97E-01	2.46E-01	6.14E-06	1.89E-02	1.97E-01
>12-16 Aromatics	9.25E-02	2.92E-01	7.84E-03	1.92E-01	9.25E-02	1.17E-01	8.06E-03	1.92E-01
>16-21 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00	2,799	110	6,233	1.00E+00	14,397	293	9,207

SV in Calculation based on 1.0 percent foundation cracks

SV in Calculation based on 1.0 percent foundation cracks

HI

RBSL(HI=1) mg/kg

Sample - SE-12, 5 ft
Outdoor

RESIDENTIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) HQ=1	s v out (mg/kg) HQ=1	ss (mg/kg) HQ=1
5-6 Aliphatics	4.76E+02	2.92E+04	2.73E+03	3.53E+05
5-7 Aromatics	1.63E+03	8.11E+01	6.50E+02	1.24E+04
>6-8 Aliphatics	2.57E+02	1.05E+05	6.56E+03	3.53E+05
>7-8 Aromatics	1.26E+03	2.17E+02	1.46E+03	1.24E+04
>8-10 Aliphatics	1.41E+02	1.45E+04	1.69E+03	7.78E+03
>8-10 Aromatics	1.04E+03	2.83E+02	2.29E+03	2.91E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	8.20E+03	7.78E+03
>10-12 Aromatics	6.30E+02	4.46E+02	1.26E+04	2.91E+03
>12-16 Aliphatics	3.82E+01	2.22E+06	3.91E+04	7.78E+03
>12-16 Aromatics	2.91E+02	8.88E+02	6.52E+04	3.01E+03
>16-35 Aliphatics	1.30E+01	8.84E+09	4.39E+06	1.51E+03
>16-21 Aromatics	8.09E+01	2.10E+03	5.56E+05	2.39E+03
>21-35 Aromatics	8.31E+00	1.67E+04	7.71E+07	2.45E+03

COMMERCIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg) Non-Carc	s v out (mg/kg) Non-Carc	ss (mg/kg) Non-Carc
5-6 Aliphatics	4.76E+02	8.18E+04	3.82E+03	5.19E+05
5-7 Aromatics	1.63E+03	2.27E+02	9.10E+02	1.81E+04
>6-8 Aliphatics	2.57E+02	2.95E+05	9.18E+03	5.19E+05
>7-8 Aromatics	1.26E+03	6.07E+02	2.05E+03	1.81E+04
>8-10 Aliphatics	1.41E+02	4.07E+04	2.36E+03	1.15E+04
>8-10 Aromatics	1.04E+03	7.92E+02	3.21E+03	4.28E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	1.77E+04	4.28E+03
>12-16 Aliphatics	3.82E+01	6.21E+06	5.48E+04	1.15E+04
>12-16 Aromatics	2.91E+02	2.49E+03	9.13E+04	4.44E+03
>16-35 Aliphatics	1.30E+01	2.48E+10	6.14E+06	2.23E+05
>16-21 Aromatics	8.09E+01	5.89E+03	7.78E+05	3.54E+03
>21-35 Aromatics	8.31E+00	4.67E+04	1.08E+08	3.64E+03

Fraction (mg/kg/mg/kg)

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5-7 Aromatics	3.36E-04	1.60E-02	2.56E-01	1.78E-04
>6-8 Aliphatics	2.22E-02	8.13E-04	3.93E-02	4.14E-04
>7-8 Aromatics	2.99E-04	5.32E-03	1.01E-01	1.59E-04
>8-10 Aliphatics	2.97E-01	9.73E-03	8.38E-02	2.51E-01
>8-10 Aromatics	2.24E-02	3.05E-01	4.54E-01	5.07E-02
>10-12 Aliphatics	3.36E-01	7.69E-04	1.05E-02	2.85E-01
>10-12 Aromatics	5.14E-02	4.44E-01	4.99E-02	1.16E-01
>12-16 Aliphatics	2.20E-01	1.72E-05	9.75E-04	1.86E-01
>12-16 Aromatics	5.02E-02	2.18E-01	4.46E-03	1.10E-01
>16-35 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5-7 Aromatics	3.36E-04	1.83E-02	3.88E-01	1.80E-04
>6-8 Aliphatics	2.22E-02	8.73E-04	2.80E-02	4.16E-04
>7-8 Aromatics	2.99E-04	6.09E-03	1.53E-01	1.61E-04
>8-10 Aliphatics	2.97E-01	3.47E-03	5.98E-02	2.51E-01
>8-10 Aromatics	2.24E-02	3.49E-01	3.24E-01	5.09E-02
>10-12 Aliphatics	3.36E-01	2.75E-04	7.50E-03	2.84E-01
>10-12 Aromatics	5.14E-02	5.05E-01	3.56E-02	1.17E-01
>12-16 Aliphatics	2.20E-01	6.14E-06	6.96E-04	1.86E-01
>12-16 Aromatics	5.02E-02	1.17E-01	3.19E-03	1.10E-01
>16-35 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
HI	1,00E+00	1,00E+00	1,00E+00
RBSL(HI=1) mg/kg	3,857	495,588	6,587

	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
HI	1,00E+00	1,00E+00	1,00E+00
RBSL(HI=1) mg/kg	12,355	1,050,572	9,733

Sample - SE-12, 5 ft

Indoor	RESIDENTIAL SCENARIO				COMMERCIAL SCENARIO			
	Csat (mg/kg)	s lch (mg/kg)	s v in (mg/kg)	ss (mg/kg)	Csat (mg/kg)	s lch (mg/kg)	s v in (mg/kg)	ss (mg/kg)
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05	4.76E+02	8.18E+04	1.40E+02	5.19E+05
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04	1.63E+03	2.27E+02	3.35E+01	1.81E+04
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05	2.57E+02	2.95E+05	3.38E+02	5.19E+05
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04	1.26E+03	6.07E+02	7.55E+01	1.81E+04
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03	1.41E+02	4.07E+04	8.70E+01	1.15E+04
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03	1.04E+03	7.92E+02	1.18E+02	4.28E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03	8.61E+01	3.13E+05	4.22E+02	1.15E+04
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03	6.30E+02	1.25E+03	6.51E+02	4.28E+03
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03	3.82E+01	6.21E+06	2.02E+03	1.15E+04
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03	2.91E+02	2.49E+03	3.36E+03	4.44E+03
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05	1.30E+01	2.48E+10	2.26E+05	2.23E+05
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03	8.09E+01	5.89E+03	2.86E+04	3.54E+03
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03	8.31E+00	4.67E+04	3.97E+06	3.64E+03

SV in Calculation based on 1.0 percent foundation cracks	RESIDENTIAL SCENARIO				COMMERCIAL SCENARIO			
	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5-7 Aromatics	3.36E-04	1.60E-02	2.14E-03	1.78E-04	3.36E-04	1.83E-02	2.15E-03	1.80E-04
>6-8 Aliphatics	2.22E-02	8.13E-04	1.40E-02	4.14E-04	2.22E-02	8.73E-04	1.41E-02	4.16E-04
>7-8 Aromatics	2.99E-04	5.32E-03	8.47E-04	1.59E-04	2.99E-04	6.09E-03	8.51E-04	1.61E-04
>8-10 Aliphatics	2.97E-01	9.73E-03	7.29E-01	2.51E-01	2.97E-01	3.47E-03	7.32E-01	2.51E-01
>8-10 Aromatics	2.24E-02	3.05E-01	4.05E-02	5.07E-02	2.24E-02	3.49E-01	4.07E-02	5.09E-02
>10-12 Aliphatics	3.36E-01	7.69E-04	1.70E-01	2.85E-01	3.36E-01	2.75E-04	1.71E-01	2.84E-01
>10-12 Aromatics	5.14E-02	4.44E-01	1.69E-02	1.16E-01	5.14E-02	5.05E-01	1.69E-02	1.17E-01
>12-16 Aliphatics	2.20E-01	1.72E-05	2.33E-02	1.86E-01	2.20E-01	6.14E-06	1.89E-02	1.86E-01
>12-16 Aromatics	5.02E-02	2.18E-01	3.19E-03	1.10E-01	5.02E-02	1.17E-01	3.21E-03	1.10E-01
>16-21 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00	3.857	83	6.587	1.00E+00	12.355	215	9.733

SV in Calculation based on 1.0 percent foundation cracks

SV in Calculation based on 1.0 percent foundation cracks

HI

HI

RBSL(HI=1) mg/kg

RBSL(HI=1) mg/kg

Sample - SE-12, 6 ft
Outdoor

RESIDENTIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
5-6 Aliphatics	4.76E+02	2.92E+04	2.73E+03	3.53E+05
5-7 Aromatics	1.63E+03	8.11E+01	6.50E+02	1.24E+04
>6-8 Aliphatics	2.57E+02	1.05E+05	6.56E+03	3.53E+05
>7-8 Aromatics	1.26E+03	2.17E+02	1.46E+03	1.24E+04
>8-10 Aliphatics	1.41E+02	1.45E+04	1.69E+03	7.78E+03
>8-10 Aromatics	1.04E+03	2.83E+02	2.29E+03	2.91E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	8.20E+03	7.78E+03
>10-12 Aromatics	6.30E+02	4.46E+02	1.26E+04	2.91E+03
>12-16 Aliphatics	3.82E+01	2.22E+06	3.91E+04	7.78E+03
>12-16 Aromatics	2.91E+02	8.88E+02	6.52E+04	3.01E+03
>16-35 Aliphatics	1.30E+01	8.84E+09	4.39E+06	1.51E+05
>16-21 Aromatics	8.09E+01	2.10E+03	5.56E+05	2.39E+03
>21-35 Aromatics	8.31E+00	1.67E+04	7.71E+07	2.45E+03

COMMERCIAL SCENARIO

	Csat (mg/kg)	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
5-6 Aliphatics	4.76E+02	8.18E+04	3.82E+03	5.19E+05
5-7 Aromatics	1.63E+03	2.27E+02	9.10E+02	1.81E+04
>6-8 Aliphatics	2.57E+02	2.95E+05	9.18E+03	5.19E+05
>7-8 Aromatics	1.26E+03	6.07E+02	2.05E+03	1.81E+04
>8-10 Aliphatics	1.41E+02	4.07E+04	2.36E+03	1.15E+04
>8-10 Aromatics	1.04E+03	7.92E+02	3.21E+03	4.28E+03
>10-12 Aliphatics	8.61E+01	3.13E+05	1.15E+04	1.15E+04
>10-12 Aromatics	6.30E+02	1.25E+03	1.77E+04	4.28E+03
>12-16 Aliphatics	3.82E+01	6.21E+06	5.48E+04	1.15E+04
>12-16 Aromatics	2.91E+02	2.49E+03	9.13E+04	4.44E+03
>16-35 Aliphatics	1.30E+01	2.48E+10	6.14E+06	2.23E+05
>16-21 Aromatics	8.09E+01	5.89E+03	7.78E+05	3.54E+03
>21-35 Aromatics	8.31E+00	4.67E+04	1.08E+08	3.64E+03

	Fraction (mg/kg/mg/kg)	HQ(Ci) (mg/kg)	HQ(Ci) (mg/kg)	HQ(Ci) (mg/kg)
5-6 Aliphatics	5.22E-03	3.44E-04	1.74E-01	8.31E-05
5-7 Aromatics	1.58E-04	3.74E-03	1.44E-01	7.15E-05
>6-8 Aliphatics	1.95E-02	3.55E-04	3.93E-02	3.10E-04
>7-8 Aromatics	9.64E-05	8.54E-04	3.89E-02	4.37E-05
>8-10 Aliphatics	2.41E-01	9.73E-03	8.38E-02	1.74E-01
>8-10 Aromatics	4.81E-02	3.27E-01	4.54E-01	9.29E-02
>10-12 Aliphatics	2.80E-01	7.69E-04	1.05E-02	2.02E-01
>10-12 Aromatics	1.03E-01	4.44E-01	4.99E-02	1.99E-01
>12-16 Aliphatics	2.05E-01	1.72E-05	9.75E-04	1.48E-01
>12-16 Aromatics	9.86E-02	2.13E-01	4.46E-03	1.84E-01
>16-35 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

	Fraction (mg/kg/mg/kg)	HQ(Ci) (mg/kg)	HQ(Ci) (mg/kg)	HQ(Ci) (mg/kg)
5-6 Aliphatics	5.22E-03	3.89E-04	1.25E-01	8.34E-05
5-7 Aromatics	1.58E-04	4.24E-03	3.28E-01	7.23E-05
>6-8 Aliphatics	1.95E-02	4.02E-04	2.80E-02	3.11E-04
>7-8 Aromatics	9.64E-05	9.68E-04	8.87E-02	4.41E-05
>8-10 Aliphatics	2.41E-01	3.47E-03	5.98E-02	1.73E-01
>8-10 Aromatics	4.81E-02	3.70E-01	3.24E-01	9.31E-02
>10-12 Aliphatics	2.80E-01	2.75E-04	7.50E-03	2.02E-01
>10-12 Aromatics	1.03E-01	5.03E-01	3.56E-02	2.00E-01
>12-16 Aliphatics	2.05E-01	6.14E-06	6.96E-04	1.47E-01
>12-16 Aromatics	9.86E-02	1.17E-01	3.19E-03	1.84E-01
>16-35 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00			

HI	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
HI	1,00E+00	1,00E+00	1,00E+00
RBSL(HI=1) mg/kg	1,921	591,515	5,615

HI	s lch (mg/kg)	s v out (mg/kg)	ss (mg/kg)
HI	1,00E+00	1,00E+00	1,00E+00
RBSL(HI=1) mg/kg	6,094	1,886,325	8,291

Sample - SE-12, 6 ft Indoor	RESIDENTIAL SCENARIO				COMMERCIAL SCENARIO			
	Csat (mg/kg)	s lch (mg/kg) HQ=1	s v in (mg/kg) HQ=1	ss (mg/kg) HQ=1	Csat (mg/kg)	s lch (mg/kg) Non-Carc	s v in (mg/kg) Non-Carc	ss (mg/kg) Non-Carc
5-6 Aliphatics	4.76E+02	2.92E+04	5.43E+01	3.53E+05	4.76E+02	8.18E+04	1.40E+02	5.19E+05
5-7 Aromatics	1.63E+03	8.11E+01	1.29E+01	1.24E+04	1.63E+03	2.27E+02	3.35E+01	1.81E+04
>6-8 Aliphatics	2.57E+02	1.05E+05	1.31E+02	3.53E+05	2.57E+02	2.95E+05	3.38E+02	5.19E+05
>7-8 Aromatics	1.26E+03	2.17E+02	2.92E+01	1.24E+04	1.26E+03	6.07E+02	7.55E+01	1.81E+04
>8-10 Aliphatics	1.41E+02	1.45E+04	3.36E+01	7.78E+03	1.41E+02	4.07E+04	8.70E+01	1.15E+04
>8-10 Aromatics	1.04E+03	2.83E+02	4.56E+01	2.91E+03	1.04E+03	7.92E+02	1.18E+02	4.28E+03
>10-12 Aliphatics	8.61E+01	1.12E+05	1.63E+02	7.78E+03	8.61E+01	3.13E+05	4.22E+02	1.15E+04
>10-12 Aromatics	6.30E+02	4.46E+02	2.52E+02	2.91E+03	6.30E+02	1.25E+03	6.51E+02	4.28E+03
>12-16 Aliphatics	3.82E+01	2.22E+06	7.79E+02	7.78E+03	3.82E+01	6.21E+06	2.02E+03	1.15E+04
>12-16 Aromatics	2.91E+02	8.88E+02	1.30E+03	3.01E+03	2.91E+02	2.49E+03	3.36E+03	4.44E+03
>16-21 Aliphatics	1.30E+01	8.84E+09	8.73E+04	1.51E+05	1.30E+01	2.48E+10	2.26E+05	2.23E+05
>16-21 Aromatics	8.09E+01	2.10E+03	1.11E+04	2.39E+03	8.09E+01	5.89E+03	2.86E+04	3.54E+03
>21-35 Aromatics	8.31E+00	1.67E+04	1.53E+06	2.45E+03	8.31E+00	4.67E+04	3.97E+06	3.64E+03

Sample - SE-12, 6 ft Indoor	RESIDENTIAL SCENARIO				COMMERCIAL SCENARIO			
	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	5.22E-03	3.44E-04	8.80E-03	8.31E-05	5.22E-03	3.89E-04	8.84E-03	8.34E-05
5-7 Aromatics	1.58E-04	3.74E-03	1.12E-03	7.15E-05	1.58E-04	4.24E-03	1.12E-03	7.23E-05
>6-8 Aliphatics	1.95E-02	3.55E-04	1.36E-02	3.10E-04	1.95E-02	4.02E-04	1.37E-02	3.11E-04
>7-8 Aromatics	9.64E-05	8.54E-04	3.02E-04	4.37E-05	9.64E-05	9.68E-04	3.04E-04	4.41E-05
>8-10 Aliphatics	2.41E-01	9.73E-03	6.55E-01	1.74E-01	2.41E-01	3.47E-03	6.58E-01	1.73E-01
>8-10 Aromatics	4.81E-02	3.27E-01	9.64E-02	9.29E-02	4.81E-02	3.70E-01	9.69E-02	9.31E-02
>10-12 Aliphatics	2.80E-01	7.69E-04	1.57E-01	2.02E-01	2.80E-01	2.75E-04	1.58E-01	2.02E-01
>10-12 Aromatics	1.03E-01	4.44E-01	3.75E-02	1.99E-01	1.03E-01	5.03E-01	3.76E-02	2.00E-01
>12-16 Aliphatics	2.05E-01	1.72E-05	2.40E-02	1.48E-01	2.05E-01	6.14E-06	1.89E-02	1.47E-01
>12-16 Aromatics	9.86E-02	2.13E-01	6.94E-03	1.84E-01	9.86E-02	1.17E-01	6.98E-03	1.84E-01
>16-21 Aliphatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>16-21 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
>21-35 Aromatics	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.00E+00				1.00E+00			

SV in Calculation based on 1.0 percent foundation cracks

s lch (mg/kg)	1.00E+00	s v in (mg/kg)	1.00E+00	ss (mg/kg)	1.00E+00
HI	1,921	HI	91	HI	238
RBSL(HI=1) mg/kg		RBSL(HI=1) mg/kg		RBSL(HI=1) mg/kg	8,291