PROJECT 740-001-001

Fate and Transport/Remedial Action Objectives Evaluation

A&B Jacobson Terminal Facility
5355 28th Avenue NW
Seattle, Washington

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TABLE OF CONTENTS

Section Page

TABLE OF CONTENTS
(continued)

Section Page

LIST OF APPENDICES

Appendix

LIST OF FIGURES

Figure

1.0 INTRODUCTION

TriHydro Corporation (TriHydro) conducted a fate and transport/remedial action objectives (FT/RAO) evaluation for the A&B Jacobson Terminal facility located at 5355 28th Avenue NW, Seattle, Washington (the "Site", Figure 1). The A&B Jacobson Terminal property has been used as a marine support facility since 1975 and is currently owned by Mr. Al Jacobson. A site plan depicting the property and sampling and well locations is presented as Figure 2.

1.1 Objectives

The objectives of the FT/RAO evaluation are as follows:

- To evaluate and better characterize Site hydrogeologic conditions;
- To model potential transfer of impacts from soil to groundwater;
- To estimate source area cleanup objectives for soil and groundwater that would likely result in compliance with MTCA Method B standards for surface water at the point of compliance (remedial action objectives [RAO's]);
- To determine whether natural attenuation is occurring at a rate that exceeds plume migration (i.e., to determine if the plume is stable or shrinking); and
- To assess the changes in plume mass downgradient of the source area.

1.2 Scope of Work

The scope of services performed by TriHydro to fulfill the above-mentioned objectives included the following tasks:

- Review of available project files (supplied by XL Environmental, Hart Crowser, Aspect Consulting) by a TriHydro geochemist to evaluate the potential approach to FT/RAO modeling;
- Review and evaluation of Modified Method B calculations prepared by Hart Crowser;
- Preparation of soil to groundwater migration calculations using MTCA and RBCA equations;

- Performance of a screening level evaluation of migration of constituents of concern in groundwater and estimation of allowable source area concentrations to meet RAOs at the sentinel points;

- Evaluation of biodegradation processes and rates at the site; and

- Preparation of a report documenting the results of FT/RAO modeling for the site.

1.3 Significant Assumptions

In evaluating the property, TriHydro has relied upon representations and information furnished by individuals and companies noted in the report. TriHydro assumes that the information provided by these third party sources is accurate, and has had no reason to believe otherwise.

2.0 SITE DESCRIPTION

2.1 Facility Description

The Jacobson Terminal facility is located at 5355 28th Avenue NW, Seattle, Washington, and is currently occupied by several light industrial businesses, including a boat repair shop, Master Guard Iron, Korvis, Inc., Reisner, Inc., and Raytheon, Inc. The Site is primarily asphalt paved, with several corrugated metal structures along the western and eastern portions of the property. The northern portion of the Site is used for storage of equipment and materials.

The Site is bordered by the former Burlington Northern Railroad right of way (now owned by the City of Seattle) and the Market Street property to the north, the Hiram Chittendam Locks to the south, the U.S. Army Corps of Engineers property to the west, and Seaborn to the east.

2.2 Site Geology and Hydrogeology

The Site is located on a former estuarine tidal flat that was filled with sand (dredged from the Lake Washington Ship Canal), wood waste, and construction debris in the 1920's. To aid in the interpretation of subsurface lithology, boring logs prepared by Hart Crowser during previous site investigations were reviewed. The boring logs were presumably recorded during the drilling of these borings and therefore provide a description of the representative lithology underlying the Site.

The uppermost lithologic zone beneath the Site is a medium brown, moist, medium dense silty sand (fill) that extends from the surface to approximately 10 feet below ground surface (bgs). Up to 8 feet of wood debris and sawdust are present in several areas within this zone of fill material. Brown to gray, medium dense wet sands underlie the fill material and extend to a depth of approximately 15 to 18 feet bgs. The sand layer is underlain by a 2 to 4 foot thick zone of moist, gray, silty clay. Beneath the clay zone, boring logs indicate the presence of dense fine sands and sandy silts to the maximum depth investigated of 24 feet bgs. Glacial till, comprised of very dense, gravelly, sandy silt, has been identified at the Market Street property at depths below 20 to 25 feet bgs. During drilling, groundwater was identified in soils at the Site at depths ranging from 7 to 12 feet bgs.

Static groundwater levels were measured in selected groundwater monitoring wells at the Jacobson Terminals site on March 14, 2003. The depth to groundwater beneath the Jacobson Terminals site ranged from 6.17 feet bgs in well JT-9 to 17.67 feet bgs in well MW-18S. Groundwater elevations calculated from the March 14, 2003 depth to groundwater measurements indicated a direction of site-wide subsurface flow to the southeast with an approximate hydraulic gradient of 0.02 meter per meter (m/m). This value is consistent with previous site-wide hydraulic gradients and was used in the model calculations.

Measurable liquid phase hydrocarbons (LPHs) and dense non-aqueous phase liquids (DNAPLs) were not observed in any of the wells during the March 14, 2003 groundwater sampling activities.

3.0 INVESTIGATION APPROACH

3.1 Fate and Transport Evaluation – Migration to Groundwater Pathway

In the *Draft Focused Feasibility Study*, Hart Crowser states that the primary remedial goal with respect to soil is protection from direct contact, with a point of compliance extending from ground surface to 15 feet bgs. The *Draft Focused Feasibility Study* goes on to state that this goal results in a preliminary RAO of 10 milligram per kilogram (mg/kg) (Washington Department of Ecology Model Toxics Control Act [WDOE MTCA] Method A, industrial soil) for PCBs, which if not attainable, may be adjusted to a higher concentration in conjunction with institutional controls. Based on this summary, it appears that there are no constituents other than PCBs that exceed a direct contact MTCA standard. In addition, direct contact with soil will be eliminated as a pathway through institutional or other controls, if necessary.

In addition to direct contact pathways, soil RAOs may be established under MTCA using a scenario in which soil impacts migrate to groundwater and groundwater discharging at the downgradient boundary of the site must meet MTCA surface water standards. These RAOs were not previously developed for the Site by Hart Crowser. Developing these RAOs is a two step process. One step consists of evaluating migration of soil impacts to groundwater. The other step (described in Section 3.3) is evaluating the fate of constituents during migration in groundwater. The groundwater protection issue for soil is raised in the *Draft Focused Feasibility Study* with respect to the potential for migration of 1,2,4-trichlorobenzene (1,2,4-TCB) impacts in soil to groundwater, followed by degradation to 1,4-dichlorobenzene (1,4-DCB). As stated above, 1,4-DCB concentrations in the down-gradient wells exceed the current RAO. Chlorobenzene may also be a reductive dechlorination product of 1,2,4-TCB.

Therefore the migration to groundwater pathway was evaluated for constituents at the site. Guidance and calculation worksheets for modeling the migration of impacts from soil to groundwater are provided by WDOE (MTCA Method B). A geotechnical engineer from Hart Crowser estimated bulk density from empirical relationships based on SPT blow counts from previously completed borings. Hart Crowser estimated porosity/moisture content from dry bulk density and conducted sensitivity analysis for use in TriHydro's transport evaluations to identify effects of uncertainty in moisture content and porosity estimates.

An additional parameter that is used as input into the MTCA B equations for evaluating the soil to groundwater migration is the dilution factor (DF). MTCA guidance provides default values of DF = 20 for unsaturated soil and DF = 1 for impacts within the saturated zone. TriHydro determined that these values were appropriate (see Section 4.1.1).

3.2 Fate and Transport - Natural Attenuation and Degradation in Groundwater

Based on the site model presented in the *Draft Focused Feasibility Study*, the main uncertainty in evaluating the potential for impacts reaching the compliance point relates to the processes of attenuation that occur during migration in the groundwater between the source and the compliance wells. The attenuation processes include dispersion, dilution, and chemical transformation (i.e. degradation). Incorporation of these processes into the RAO development is provided for in WAC173-340-720(6)(E) and 173-340-720(4c5).

TriHydro used a simple one-dimensional model to conduct a preliminary evaluation of reductive dechlorination processes and constituent migration in groundwater. The model is a numerical finite difference model that simulates sequential transformation reactions that appear to be occurring at the Site. TriHydro evaluated whether historic and current site data provided sufficient evidence to document biodegradation and biodegradation rates.

3.3 Remedial Action Objectives - Groundwater

According to the submittals reviewed by TriHydro, the current site groundwater objectives are based on the WDOE MTCA Standard Method B values for surface water. In the *Draft Focused Feasibility Study*, Hart Crowser states that the primary remedial goal with respect to groundwater is prevention of the discharge of contaminants in groundwater above cleanup levels to sensitive surface water receptors. Based on this goal, it is stated that the "point of compliance is groundwater quality at the Terminals property boundary directly up-gradient of the ship canal." Existing groundwater wells JT-6 (upper saturated zone) and JT-5 (lower saturated zone) appear to be suitable compliance wells for the shallow/intermediate and deep groundwater zones, respectively. JT-3 may also be a suitable down-gradient compliance well. Based on this site model and the most recent available data, the RAO for 1,4-DCB is currently exceeded at JT-3 and JT-6. The RAOs for vinyl chloride and benzene have been met at these wells during the most recent sampling. Recent (2003) monitoring results for polychlorinated biphenyls (PCBs) were not provided to TriHydro. Based on the *Draft Focused Feasibility Study*, PCBs (Arochlor 1260) have been detected at low concentrations, one time each in samples from JT-3 and JT-6.

Therefore, the effort to develop alternate RAOs focused on 1,4-DCB. TriHydro qualitatively evaluated the evidence for production of vinyl chloride through degradation of chloroethenes. The results of this evaluation are that the pattern of detection of vinyl chloride and parent compounds (PCE, TCE, and DCE) is not uniform enough to allow for a quantitative evaluation of degradation rates. In addition, based on discussions with Hart Crowser and Aspect personnel, TriHydro did not evaluate the potential for (risk-based) modification of standards at the points of compliance.

4.0 PRELIMINARY APPROACHES TO RAO DEVELOPMENT

Initial approaches to developing RAOs consisted of evaluating a site specific dilution factor (DF) to the MTCA calculations for the soil to groundwater migration pathway, and application of the ASTM RBCA equation for evaluating constituent attenuation in groundwater. These preliminary calculations are described below.

4.1 MTCA Soil Cleanup Level Calculations

Soil cleanup levels were calculated by first determining dilution factors for the saturated and unsaturated zones. These dilution factors were entered into MTCA spreadsheets, which calculate soil cleanup levels based on soil direct contact and groundwater protection. The relevant Washington State Regulations are WAC 173-340-720, 740, 745, 747, and 750.

4.1.1 Dilution Factor Determination

The dilution factor (DF) was evaluated for the Jacobson Terminal site. The default values provided in the Washington State Regulations indicate a DF of 1 for saturated zone soils and 20 for unsaturated zone soils. The DF quantifies the decrease in contaminant concentration as soil leachate mixes with water below the groundwater table.

Because soil in the saturated zone is in immediate contact with the groundwater, the default DF of 1 is appropriate. This conclusion was verified for the Jacobson Terminals site by examining the "observed" dilution factors (DF_{obs}) at locations where constituent concentration was measured in both the soil and the groundwater. DF_{obs} is defined as:

$$DF_{obs} = \frac{C_t}{C_w\left(K_{oc}f_{oc} + \frac{\theta_w}{\rho_b}\right)}$$

where:

C_t = measured soil concentration (mg/kg)

C_w = measured groundwater concentration (mg/L)

K_{oc} = organic carbon partition coefficient (L/kg)

f_{oc} = fraction of organic carbon in soil (mg/kg)

θ_w = water-filled soil porosity (Lwater/Lsoil)

ρ_b = dry soil bulk density (kg/L)

The value for K_{oc} is chemical specific, while θ_w, ρ_b, and f_{oc} are site-specific. The DF_{obs} at nine sampling locations were calculated for 1,4-DCB and 1,2,4-TCB for the saturated zone. A DF_{obs}

near 1 (mean: 1,4-DCB DF_{obs} = 0.80; mean: 1,2,4-TCB DF_{obs} = 1.55) was calculated with measured θ_{w}, and ρ_b at the site, and f_{oc} = 0.035. This f_{oc} value is consistent with the measured value in the upper section of the shallow saturated zone. The DF_{obs} calculations are shown in Table A-1.

Leachate that originates in the unsaturated zone is diluted by mixing with groundwater. Thus, a DF greater than 1 is appropriate; the default DF = 20 was used for the unsaturated zone. This value may be conservative, as the surface overlying the contamination at this site is paved.

Conservative assumptions are inherent in the use of the DF's described above. The EPA Soil Screening Guidance: Technical Background Document indicates that a dilution factor does not take into account processes that attenuate contaminants in the subsurface (i.e., adsorption and degradation processes), therefore the calculation addresses only the dilution-attenuation process. It also assumes that there is an infinite source resulting in all sorption sites eventually being filled and no longer available to attenuate contaminants, and that the soil contamination extends to the water table.

4.1.2 MTCA calculations

The DFs for the saturated and unsaturated zones were applied to the MTCA worksheet to determine soil cleanup levels. Different cleanup levels were obtained for the saturated and unsaturated zones to correspond to each zone's DF. A site-specific value for fraction of organic carbon (f_{oc}: 0.035) was used in the calculations. The MTCA B surface water standards were used as the target groundwater cleanup levels for each constituent. The MTCA worksheets are included in Appendix A. The soil cleanup levels obtained using this approach are:

	Unsaturated zone	Saturated zone
1,2,4-TCB:	264.5 mg/kg	13.3 mg/kg
1,4-DCB:	2.1 mg/kg	0.1 mg/kg

Soil cleanup levels obtained using the MTCA B groundwater cleanup levels may be conservative, because they do not take degradation/transformation and dispersion of constituents in groundwater via natural attenuation into consideration. This conservative assumption may be unrealistic at the Jacobson Terminals, as natural attenuation appears to be an important process (see Section 5.2). Modeling efforts described in Section 5.3 determine soil cleanup levels that account for not only dilution, but also degradation and dispersion.

4.2 RBCA Estimates of Attenuation in Groundwater

The ASTM RBCA equation (ASTM 1995) was used to estimate steady state attenuation along the centerline of flow, between the source and the point of compliance at well JT-6 (Figure 2).

$$\frac{c(x)}{c_o} = \exp\left(\frac{x}{2\alpha_x}\right)\left(1-\sqrt{1+\frac{4\lambda\alpha_x}{U}}\right) erf\left(\frac{S_w}{4\sqrt{\alpha_y x}}\right) erf\left(\frac{S_d}{2\sqrt{\alpha_z x}}\right)$$

where:

$c(x)$ = centerline constituent concentration at any distance (x) from the source micrograms per liter (μg/L)
c_o = centerline constituent concentration at the source (μg/L)
λ = constituent first-order degradation rate (d^{-1})
U = specific discharge (cm/d)
α_x = longitudinal dispersivity (cm)
α_y = transverse dispersivity (cm)
α_z = vertical dispersivity (cm)
S_w = source width perpendicular to groundwater flow direction in horizontal plane (cm)
S_d = source width perpendicular to groundwater flow direction in vertical plane (cm)

The ASTM RBCA equation results in a conservative estimation of attenuation downgradient from a source. Empirically based default values for first order degradation constant and longitudinal, transverse, and vertical dispersivity were used. These values were obtained from the Illinois Tiered Approach to Cleanup objectives Regulations (35 IAC 742). Site-specific values for flow direction (southeast), hydraulic gradient (0.02 m/m), hydraulic conductivity (K: 90 cm/d), source width perpendicular to flow direction in the vertical plane (S_d: 300 cm), source width perpendicular to flow direction in the horizontal plane (S_w: 1,218 cm), distance along the centerline from source to point of compliance (X: 2,436 cm) and total soil porosity (Θ_T: 0.42) were provided by or based on site information provided by Hart Crowser and Aspect Consulting.

The spreadsheets containing inputs and results of the RBCA evaluations are included in Appendix A. In general, when using the default values for longitudinal dispersion and first order degradation constants, the equation predicts an attenuation factor of 0.2. The result is independent of the constituent since the default values for first order degradation constant are the same for 1,2,4-TCB, 1,4-DCB, and CB. This corresponds to a reduction in concentration by a factor of 5 along the flowpath between source well JT-8 and compliance well JT-6.

There are three important caveats to these results:

- The equation incorporates the conservative assumption that a source of contaminants from soil to groundwater in the source area continues to exist at a steady state (no remediation);

- The default values for the first order degradation constants are much lower than those estimated based on site specific results. Application of the site-specific decay constant into the RBCA equation indicates that 1,4-DCB attenuates along the flow path by an approximate factor of 60; and

- The equation does not account for transformations (e.g., increases in constituent concentrations) along the flow path. This limits the utility of this equation as the sole basis for determining conservative remediation objectives.

It is very likely that 1,4-DCB, the chlorobenzene constituent with the lowest MTCA Method B surface water standard (4.6 ug/l) is produced through degradation of 1,2,4-TCB along the flow path. Along portions of the flowpath where degradation of 1,2,4-TCB occurs, the otherwise conservative and potentially acceptable RBCA model overestimates the attenuation of 1,4-DCB.

5.0 NATURAL ATTENUATION

5.1 General

The following section of this report presents the results of the qualitative and quantitative evaluation of the evidence of natural attenuation of COCs at the Site. The purpose of the evaluation is to assess the loss of COC mass along the flow path and to determine site-specific degradation rates to the extent possible given data limitations.

The following sections present the assessment approach, describe the qualitative evaluation, and present quantitative evaluation. In general, the data show that geochemical conditions in the water-bearing units are reducing and support the reductive biodegradation of chlorinated organic compounds.

5.2 Qualitative Evidence Supporting the Occurrence of Natural Attenuation

In order to verify that conditions downgradient of the source area support the conclusion that natural attenuation is occurring, sampling and analysis of natural attenuation indicator parameters was conducted by Hart Crowser on March 3, 2003. A weight-of-evidence approach was used to demonstrate the effectiveness of natural attenuation at the Site, allowing converging lines of evidence to be used to document the occurrence of natural attenuation. Evidence of natural attenuation includes the following indicators:

- Decreasing constituent concentrations along the primary flow path;
- Presence of degradation products and/or metabolic by-products;
- Redox and geochemical indicators of biodegradation; and
- Availability of primary substrate (i.e. organic carbon).

Each of the above indicators represents a distinct line of evidence, which collectively support the occurrence of natural attenuation.

5.2.1 Redox and Geochemical Indicators of Biodegradation in Groundwater

To identify and distinguish possible redox zones present in the subsurface, various chemical species were analyzed from the groundwater samples collected by Hart Crowser. The concentrations of dissolved oxygen (DO), dissolved manganese, dissolved iron, chloride, sulfate, sulfide, carbon monoxide, hydrogen sulfide, and methane were measured, as were the oxidation-reduction potential (ORP), and pH. The results of these analyses are included as Table B-1 in Appendix B.

Transformation of highly chlorinated benzenes (such as TCB) most likely occurs via reductive dechlorination (Suflita and Townsend 1995), which is optimized in methanogenic conditions (Dragun 1988). In this process, the chlorinated benzene acts as an electron acceptor, and so another organic carbon source is required. Methane is produced as a byproduct of the process.

The order in which electron acceptors are consumed in microbial mediated reactions in groundwater is based on the energy that is released during their reaction. Dissolved oxygen is first consumed, as it releases the most energy, followed by nitrate, manganese and iron coatings in soil, dissolved sulfate, and carbon dioxide. The sequential use of these electron acceptors occurs as groundwater Redox potential becomes increasingly reducing during the biodegradation of organic compounds. In an idealized setting, where the aquifer is under naturally oxidizing conditions, the sequence of Redox zones (USEPA 1998) in order of nearest to furthest away from the source area, will be as follows:

- Methanogenic zone – methane is formed at the expense of other organic carbon species or at the expense of hydrogen and carbon dioxide;
- Sulfate reduction zone;
- Iron (III) reduction zone;
- Manganese (IV) reduction zone;
- Denitrification zone – nitrate is reduced to molecular nitrogen; and
- Aerobic zone – dissolved oxygen is relatively abundant.

It is not necessary to encounter each of these zones in every site; however, both the electron acceptor and an appropriate carbon source must be available. Total organic carbon concentrations in soil (Table B-2) within the uppermost saturated zone (0.13% to 5.1%) at the Jacobson Terminals site are consistent with presence of a sufficient carbon source.

5.2.1.1 ORP

The ORP data gathered by Hart Crowser for groundwater monitoring wells BR-1, IP-4, IP-10, JT-6, JT-8, and JT-9 during the March 13, 2003 sampling event is summarized in Table B-1 of Appendix B. It is noted that meaningful measurements of ORP can only be obtained if there is an electroactive Redox couple of sufficient concentration present in the groundwater. This means that there must be a Redox couple in solution at equilibrium that can transfer electrons between the two members of the couple quickly enough for the ORP electrode to measure a current. In many cases, Fe^{+2}/Fe^{+3} serves as the electroactive couple. However, if the concentration of each iron species is not large enough (0.6 ppm), then the measurement taken with the ORP probe is unstable and less meaningful. Average concentrations of dissolved iron were significantly higher than 0.6 ppm in five of the six samples analyzed, indicating that a Redox couple is present in solution and that ORP data is likely valid and able to determine the Redox character of the water.

Low ORP values measured in groundwater monitoring wells IP-4, IP-10, JT-6, JT-8, and JT-9 indicate the presence of consistent reducing conditions within the plume area. The values ranged from -55 millivolts (mV) to -97 mV. These readings correspond to the recommended value of ORP being less than 50 mV (USEPA 1998) to support iron reducing, sulfate reducing, and methanogenic conditions, and are therefore broadly consistent with occurrence of reductive dechlorination.

5.2.1.2 Sulfate/Sulfide

The results of laboratory analyses for sulfate/sulfide indicated the presence of sulfate at concentrations ranging 9.7 to 38 mg/L and sulfide concentrations ranging from below laboratory method detection limits (0.05 mg/L) to 0.07 mg/L. USEPA indicates sulfate concentrations greater than 20 mg/L may compete with reductive processes (USEPA 1998). It should be noted that differences in sulfate concentrations along the flow path decrease from 38 mg/L (IP-4) to 12 mg/L (JT-8), indicating sulfate reduction may be occurring in the plume area. Sulfide concentrations above 1 mg/L are indicative of reductive processes (USEPA 1998). The reported sulfide concentrations were generally below the laboratory reporting limit (0.05 mg/L). However, the reported concentration from JT-8 (0.07 mg/L), located in the plume area, indicated the presence of sulfide, demonstrating sulfate reduction in this area may be occurring, which correlates with the reduced sulfate concentrations along the flow path.

5.2.1.3 Dissolved Oxygen

Hart Crowser field personnel measured dissolved oxygen (DO) concentrations in groundwater during sampling activities on March 13, 2003. Groundwater in the vicinity of the plume area exhibited concentrations of dissolved oxygen ranging from 0.8 to 1.9 milligrams per liter (mg/L). The recommended range for dissolved oxygen is less than 0.5 mg/L to promote anaerobic biodegradation processes (USEPA 1998), therefore the DO concentrations recorded during the March 2003 event are slightly above the recommended concentration. However, DO readings tend to be heavily influenced by collection techniques and are often recorded higher than the actual concentration due to sampling error and equipment sensitivity.

5.2.1.4 Dissolved Manganese

Specific manganese concentrations recommended for anaerobic degradation are not available. Manganese is utilized as an electron acceptor during anaerobic biodegradation of constituents. In general, the reduced form (Mn^{+2}) is the soluble form. Concentrations ranging from 1.01 to 3.05 mg/L were detected in the analyzed groundwater samples. Detection of manganese is consistent with the presence of reduced manganese, and overall reducing conditions.

5.2.1.5 Dissolved Iron

Average concentrations for dissolved iron in the analyzed groundwater samples ranged from 0.53 mg/L (BR-1) to 49.2 mg/L (IP-4). Iron concentrations greater than 1 mg/L tend to be indicative of iron reductive processes (USEPA 1998). The lowest reading was collected from BR-1, located outside of the plume area. The remaining readings were well the above the 1 mg/L benchmark.

5.2.1.6 Methane

Methane production in an aquifer is an indication of strongly reducing conditions. Concentrations of methane in the well headspace, as measured using a Multirae gas detector, were less than 1% LEL in wells IP-4 and JT-6. At JT-8, 48% LEL was observed, and at JT-9 and BR-1 100% LEL was present. The fact that methane was detected in the headspace of the source area wells presents strong secondary evidence for chlorinated benzene degradation, as the reductive chlorination process is likely optimized under methanogenic conditions.

5.2.1.7 Chloride

The results of laboratory analyses of groundwater samples indicated the presence of chloride at concentrations ranging from 14 to 25 mg/L. Differences in chloride concentrations along the flow path could be indicative of dehalogenation processes. Chloride increases from 14 mg/L (IP-4) to 21 mg/L (JT-8) to 25 mg/L (JT-6) may result from addition of chloride to the groundwater as TCB and DCB are degraded.

5.2.1.8 Summary of Redox and Geochemical Indicators

A wide variety of parameters and dissolved chemical species were analyzed to verify that reducing conditions exist at the Site. While some of the data from the March 13, 2003, sampling program is inconclusive, the preponderance of evidence indicates that reducing conditions are present at the Site. Most importantly, the methanogenic processes that reportedly optimize chlorinated benzene degradation appear to be present. These conditions are sufficient to promote the reductive degradation of the chlorinated benzenes in groundwater.

5.2.2 Availability of a Primary Substrate

Anaerobic reductive dechlorination of chlorinated benzenes requires the presence of a primary substrate for microbial metabolism. This primary substrate can be in the form of natural organic matter in the soil and groundwater or as an anthropogenic source. Total organic carbon data gathered during the installation of well borings IP-4, IP-6, IP-9, IP-12, and JT-9 indicated the presence of total organic carbon in the uppermost saturated zone at concentrations ranging from 0.13% to 5.1% (Table B-2). The organic carbon likely partitions to the groundwater phase, making the primary substrate available to assist in the degradation process.

5.2.3 Evidence for Biodegradation of Chlorobenzenes

Basic primary evidence for biodegradation via the pathway 1,2,4-TCB → 1,4-DCB → Chlorobenzene (CB) is shown on Table B-1, graphically in Figure C-1, and in more detail in Table 4 of the Hart Crowser report dated July 18, 2002 (included in Appendix B). Monitoring well IP-4, located upgradient from the source area, exhibits background concentrations of the three compounds. Well JT-8, located at the leading edge of the source area contains elevated concentrations of TCB and DCB. At the downgradient well JT-6, TCB is generally not detected, 1,4-DCB is detected at relatively low concentrations, and CB is detected at slightly higher concentrations.

The biodegradation described above likely requires reducing, and possibly methanogenic, conditions. Table B-1 includes data for parameters (e.g., that illustrate Redox conditions) at the three wells. Background conditions (IP-4) are more oxidizing than those near the source (JT-8), where it appears that methanogenic conditions are present. Downgradient of the source (JT-6), the Redox conditions appear to have shifted toward more oxidizing conditions. This pattern is consistent with microbially mediated reductive dechlorination reactions occurring in the source area.

5.3 Quantitative Evaluation of Natural Attenuation

In order to complement the qualitative evaluation presented above, quantitative evaluations were undertaken in accordance with the proposed scope of work. The quantitative evaluation consisted of:

- The determination of mass reduction along the groundwater flow path; and
- The determination of site-specific degradation rates.

The following section of the report describes the evaluation methodology and results. The model input parameters of hydraulic gradient (0.02 m/m), hydraulic conductivity (1×10^{-3} cm/s), fraction of organic carbon (f_{oc}: 0.035), and soil porosity (0.42) were taken directly from site data provided by Hart Crowser and Aspect Consulting.

5.3.1 Estimation of Degradation Rates

Sequential biodegradation of 1,2,4-TCB to 1,4-DCB to CB was modeled for the flowpath between wells JT-8 and JT-6 at the Jacobson Terminal Site. A one-dimensional screening level model, Remediation Toolkit (EISE, Waterloo, Ontario 2002) was used in conjunction with the RBCA steady state attenuation model. Remediation Toolkit contains modules that calculate site-specific and chemical specific biodegradation rates and estimate downgradient migration in conjunction with biodegradation for hypothetical site conditions. The results of the modeling efforts and relevant spreadsheets are included in Appendix C.

5.3.1.1 Selection of Relevant "Steady-State" Groundwater Quality Data

The next step to estimate biodegradation rates at the Jacobson Terminal site was to establish an appropriate chemical concentration data set. A substantial amount of soil and groundwater quality data has been collected at the site. Based on these data, it was determined that well JT-8 is located near the source. Contaminant concentration data from groundwater samples collected at JT-8 were utilized to represent concentrations at the leading edge of the source. Well JT-6 is located adjacent to the ship canal, approximately 80 feet downgradient from the identified source area. Under the current site model, monitoring well JT-6 is considered the point of compliance.

The Interim Action performed in 2001 complicates the choice of representative 1,2,4-TCB and 1,4-DCB data for wells JT-6 and JT-8. The Interim Action consisted of injection of hydrogen peroxide into wells within the chlorinated benzene source area. TriHydro's examination of sampling data revealed that, after this injection, concentrations of chlorobenzenes (in particular, 1,2,4-TCB) increased at several locations. In order to estimate the steady state conditions for the site, it was important to consider sampling data that represented conditions before the hydrogen peroxide injection affected the chemical concentrations in the wells. Upon consideration of distances from injection points to the monitoring wells, and average groundwater velocities (approximately 50 ft/yr), the sampling data for JT-8 on April 10, 2001, and JT-6 on March 13, 2003, were selected as representative of steady state groundwater conditions prior to hydrogen peroxide injection. Based on the information in the July 18, 2002 report, the first large scale hydrogen peroxide event was conducted in August-September 2001 Based on a simple Darcy calculation, transport of contaminants from the injection points to JT-6 via advection would require more than 18 months. The sampling data used in the modeling effort are shown in Table C-1.

5.3.1.2 Intermediate Well Scenarios

The constituent 1,2,4-TCB typically has not been detected in groundwater samples collected from JT-6. Does degradation of TCB and/or DCB occur along the entire flowpath and/or is TCB attenuated/degraded below the detection limit at some intermediate point between JT-8 and JT-6? This question was evaluated by installing an additional groundwater monitoring well approximately 35 feet southeast of well JT-8 (on a line with JT-6), and by varying distances of TCB/DCB degradation and evaluating the effect on calculated degradation rates and resulting overall attenuation. It follows that different calculated values for degradation rates may mean different calculated values for the maximum allowable concentrations of the constituents at the source. For this reason, several degradation scenarios were explored.

5.3.1.2.1 TCB Degradation Scenarios A summary of the degradation/dispersion scenarios investigated is presented in Table C-2. Three possible TCB degradation scenarios were modeled. The "No Intermediate Well" scenario assumes that TCB degradation and dispersion both occur along the entire flowpath, from JT-8 to JT-6. The second TCB degradation scenario assumes that both degradation and dispersion of TCB occur along the first 40 feet of the flowpath, at which point the TCB concentration reaches non-detect values. Beyond this point, the TCB concentration remains at non-detect. The final TCB degradation scenario assumes that TCB degradation and dispersion occur along the first 20 feet of the flowpath, with TCB concentrations remaining below detection limits along the final 60 feet of the flowpath.

5.3.1.2.2 DCB Degradation Scenarios The secondary evidence for natural attenuation shows that Redox conditions may be more reducing near the source than at sentinel well JT-6. Thus, it is possible that DCB degradation also occurs in stages in a similar fashion to that modeled for TCB. Three possible DCB degradation scenarios were examined (Table C-2). The "No Intermediate Well" scenario assumes that both DCB degradation and dispersion occur along the entire flowpath. The second DCB degradation scenario assumes that degradation and dispersion of DCB occur along the first 40 feet of the flowpath. After this, DCB only undergoes attenuation via dispersion. The final DCB degradation scenario assumes that DCB degradation and dispersion occur along the first 20 feet of the flowpath, with DCB undergoing only dispersion for the final 60 feet of the flowpath.

5.3.1.2.3 Concurrent vs. Disparate Degradation TCB and DCB degradation may both undergo "staged" attenuation, in which degradation and dispersion occur early along the flowpath, and only dispersion occurs afterwards. The possibility that TCB undergoes staged degradation, while DCB degrades along the entire flowpath, was also evaluated. This situation was termed "disparate" degradation. Scenarios in which both TCB and DCB degrade along the same length of the flowpath were termed "concurrent."

5.3.1.2.4 Dispersion Scenarios Finally, two different values of dispersion were modeled. The first was the flowpath length multiplied by 0.2, and the second was the flowpath length multiplied by 0.1. The value of 0.1 is consistent with IEPA recommendations. A summary of the different scenarios is shown in Table C-2.

5.3.2 Calculation of Degradation Rates

TCB biodegradation rates for each of the scenarios described above were computed using the Buscheck and Alcantar method (ASTM 1998). Use of this method for DCB degradation results in the calculation of an apparent degradation rate, as some DCB is added via the breakdown of TCB. This apparent degradation rate of DCB is not useful if the initial TCB and/or DCB concentrations at the source change. Actual DCB degradation rates were calculated using a finite difference model that considered concentrations of both TCB and DCB at the upgradient and downgradient wells. The method used is described in Appendix C.

Assumptions for the inputs and calculations for degradation rates are:

1) Steady state conditions;

2) Groundwater velocity, dispersivity, and soil conditions are constant/homogeneous;

3) The source concentration is constant; and

4) Biodegradation is a first-order process.

Note: In calculating degradation rates, retardation was not included. This approach is consistent with the recommendations of Carey et al. (2002).

The degradation rates for each scenario are shown in Table C-2. Calculated degradation rates demonstrate considerable sensitivity for varying length of the degradation segment with larger calculated rates corresponding to shorter degradation segments. Because the assumptions of these scenarios restrict contaminant concentrations to low values early in the flowpath, greater degradation rates are necessary in order to accomplish the degradation over a short distance. In addition, the greater the dispersion of contaminants, the greater the degradation rates. This results from the primary effect of dispersion being due to increased spreading of the contaminant in the longitudinal direction.

5.3.3 Estimation of Maximum Allowable Concentrations at the Source

Based on the available data provided by Hart Crowser and Aspect Consulting, concentrations of 1,4-DCB at compliance well JT-6 are currently above the CUO. Thus, natural attenuation and dispersion are not capable of decreasing the current source concentrations to below CUO's before their arrival at JT-6. However, because evidence for biodegradation does exist, the rates calculated for degradation can be used to obtain Maximum Allowable Concentrations at the Source (MACS). If future contaminant concentrations at the source are reduced to below the MACS, then the model predicts that concentrations of constituents of concern in JT-6 will be below the CUO's. Because 1,2,4-TCB degrades to 1,4-DCB, MACS must be estimated for both constituents. MACS were estimated for each of the modeled scenarios in Table C-2.

Each scenario included the evaluation of a combination of biodegradation and dispersion in order to ascertain the estimated MACS for that scenario. Each set of scenario conditions (i.e. length of degradation path and length of dispersion path) was simulated in order to calculate degradation rates applied to these "predictive" simulations. For example, the conditions of degradation rate modeling in Scenario A included: TCB/DCB degradation and dispersion occur along the first 40 feet of the flowpath; and only dispersion of TCB/DCB occurs along the final 40 feet. The simulation used to calculate MACS for Scenario A assumed that these same conditions will exist in the future.

For sections of the flowpath in which both degradation and dispersion occurred, the BioTracker® utility in Remediation Toolkit® was used to evaluate migration and concentrations. Assumptions included in this model are:

1) Steady state conditions exist;
2) No chlorobenzene degradation is occurring;
3) The source concentrations of TCB and DCB remain constant;
4) Groundwater velocity, dispersivity, and soil conditions are constant/homogeneous; and
5) Biodegradation is a first-order, sequential process.

For sections of the flowpath in which only dispersion occurred, the ASTM RBCA equation was used. Assumptions used for this segment of the modeling included:

1) Steady state conditions exist;
2) No biodegradation is occurring;
3) "Source" concentrations of TCB and DCB are constant. In this case, the "source" is the location along the flowpath at which degradation halts;
4) Transverse dispersivity is 1/3 longitudinal dispersivity. Vertical dispersivity is 1/20 longitudinal dispersivity. Source width and depth are 40 feet and 9.8 feet, respectively; and
5) Groundwater velocity, dispersivity, and soil conditions are constant/homogeneous.

5.3.4 Modeling Results

The results for maximum allowable source concentrations of 1,2,4-TCB and 1,4-DCB are shown on Figure C-2. Because transformation from TCB to DCB was included in the evaluation, a linear relationship exists for the MACS for each constituent. Increasing the MACS for 1,2,4-TCB requires that 1,4-DCB at the source be reduced, and vice versa. In general, the values shown are controlled by the low CUO for 1,4-DCB at JT-6. Based on the results of this evaluation, even large sources of 1,2,4-TCB degrade sufficiently to below the 1,2,4-TCB CUO at JT-6, but these large sources of 1,2,4-TCB result in concentrations of 1,4-DCB that are in excess of the CUO at JT-6. Figure C-2 shows the relationships of each of the scenarios. While the overall relationship is the same, the y-intercept and slope for each linear relationship vary slightly between the different scenarios.

Other ramifications of these results are as follows. First, a generalization can be made concerning concurrent degradation. For a given dispersivity, decreasing the length of degradation results in a "steepening" of the DCB vs. TCB line. The consequence is greater MACS for DCB, and lower MACS for TCB if degradation occurs within a distance shorter than the entire flowpath. The effect of increasing dispersivity for concurrent degradation is also an increasing in the steepness of this line. For the case of disparate degradation, a decrease in the length of degradation means a "flattening" of the DCB vs. TCB line. That is, the MACS for DCB decreases, and the MACS for TCB increases.

Predicted natural attenuation along the flowpath from JT-8 to JT-6 for each of the scenarios is shown in Figure C-3. The initial concentrations are MACS at which the mass ratio of 1,4-DCB to 1,2,4-TCB is 0.12. This ratio is consistent with that observed at source for recent sampling events. Each concentration trend graph illustrates that 1,2,4-TCB concentrations decrease along the entire flowpath, regardless of the form of attenuation. Concentrations of 1,4-DCB in groundwater initially increase due to transformation of 1,2,4-TCB to 1,4-DCB. Once the rate of 1,4-DCB addition is smaller than the rate of 1,4-DCB degradation, then 1,4-DCB is seen to decrease. Each simulation shows that the final amount of 1,2,4-TCB and 1,4-DCB at JT-6 (80 feet) is less than the CUO for that constituent of concern.

5.3.5 Comparison of Observed and Modeled Data

An additional well (JT-11) was drilled at the approximate midpoint along the flowpath between monitoring wells JT-8 and JT-6. Concentrations of chlorobenzenes in groundwater were measured in well JT-11 on June 5, 2003. The results from this sampling event did not indicate the presence of TCB above laboratory method detection limits. DCB was detected in well JT-11 at a concentration of 50 ug/L. These sample results correspond with modeled values at this location for Scenario A (where dispersivity = 0.2X, and degradation of both TCB and DCB occurs only within the first 40 feet of the flowpath). This relationship is shown in Figure C-4. These sample results provide evidence that Scenario A may be utilized to describe degradation/dispersion processes occurring along the flowpath. The model predicts that MACS determined for this scenario will result in contaminant concentrations below the CUOs at the POC (JT-6). Further measurements from this new well will aid in confirming this conclusion.

5.3.6 Possible Site-Specific MACs for 1,2,4-TCB and 1,4-DCB

The goal of the modeling exercise was to estimate source area MACs for 1,2,4-TCB and 1,4-DCB that would likely result in meeting the CUO at JT-6. Because migration of 1,4-DCB from the source area, and degradation of 1,2,4-TCB followed by migration of 1,4-DCB may both result in the occurrence of 1,4-DCB at JT-6, there is a "trade-off" between allowable 1,2,4TCB and 1,4-DCB in the source area. This relationship is shown on Figure C-2. To find specific values for the MACs for 1,2,4-TCB and 1,4-DCB requires that the ratio of the concentrations of these two constituents in the source area be specified. Based on existing data, the concentration of 1,4-DCB has typically been approximately 0.05x to 0.2x that of 1,2,4-TCB. If this ratio is considered, then possible groundwater MACS are as follows:

1,2,4-TCB: 65.2 ug/L

1,4-DCB: 8.1 ug/L

The value for 1,2,4-TCB is less than the MTCA B surface water standard of 227 ug/L. The value for 1,4-DCB is slightly greater than the MTCA B surface water standard of 4.86 ug/L.

Corresponding source area CUOs for soil can be calculated by entering these MACS into the MTCA worksheet. The resulting soil cleanup levels are:

	Unsaturated zone	Saturated zone
1,2,4-TCB:	76.0 mg/kg	3.8 mg/kg
1,4-DCB:	3.5 mg/kg	0.2 mg/kg

The corresponding spreadsheets are included in Appendix D.

6.0 CONCLUSIONS

Based on the findings of this FT/RAO assessment and a review of previous investigations, TriHydro presents the following conclusions. The conclusions are based on the aforementioned field observations, laboratory results and available Site information.

- Groundwater elevations calculated from the March 3, 2003 depth to groundwater measurements indicated a direction of subsurface flow to the southeast with an approximate hydraulic gradient of 0.02 foot per foot. The March 3, 2003 subsurface groundwater flow direction is in general concurrence with the flow directions observed in previous groundwater gauging events.

- Measurable LPHs and DNAPLs were not observed during March 3, 2003 groundwater sampling activities.

- Initial calculations of soil cleanup levels performed using MTCA Method B surface water standards, and RBCA default biodegradation rates, were likely inadequate in characterizing fate and transport at the site because they did not quantify site-specific biodegradation/dispersion processes.

- Following hydrogen peroxide injection at the source area, TCB concentrations in groundwater increased from 250 ug/L on April 10, 2001, to 9,100 ug/L on March 13, 2003. This result may indicate that hydrogen peroxide results in mobilization of target constituents.

- Physical conditions in the water-bearing zone beneath the Site are favorable for reductive biodegradation to occur. ORP measurements from selected groundwater monitoring wells showed consistent reducing conditions in the plume area. This conclusion was supported by the aerial distribution of dissolved methane and iron, and by the ORP measurements in the groundwater monitoring wells, which showed strongly reducing conditions near the source of the plume. The low dissolved sulfate concentrations in the source area wells also support the presence of reducing conditions in the source area.

- Redox conditions at the plume source area are more reducing than locations upgradient and downgradient of the source. Further, methanogenic conditions may be present at the source area.

- There is an anthropogenic carbon source available for use as an electron donor for the reductive degradation of the chlorinated benzene compounds identified in groundwater at the site.

- The presence of degradation products of TCB in groundwater is strong evidence that degradation is occurring to some extent at the Site. The primary evidence for sequential degradation is the presence of favored TCB degradation isomers 1,4-DCB and CB downgradient of the plume source.

- Initial data from the newly installed well (JT-11), located at an intermediate point between source area well JT-8 and POC well JT-6 indicates that 1,2,4-TCB concentrations are below the detection limit at this location. This likely reflects the low mobility and degradation of TCB. Additional sampling results from JT-11 will be required to verify this result.

- Sampling data at well JT-11 matches modeled parameters presented in Scenario A. This scenario assumes that degradation of both TCB and DCB occur only within the first 40 feet of the flowpath from the source, and that dispersivity is 0.2 times the flowpath length. Additional sampling results from JT-11 will be required to verify this result.

- The results of TriHydro's DF analysis indicated that a DF of 1 in the saturated zone, and 20 in the unsaturated zone may be applicable for the Site. Soil cleanup objectives (CUOs) for constituents of concern can therefore be derived using the MTCA worksheet, the groundwater MACS, and these DFs. Example calculations for 1,2,4-TCB and 1,4-DCB are included in Appendix D.

- Concentrations of both 1,2,4-TCB and 1,4-DCB in soil are currently above CUOs calculated by the abovementioned method. Based on the most recent soil sampling in June 2002, this potential 1,2,4-TCB CUO is exceeded at twelve (12) of the sixteen (16) locations sampled. Based on the June 2002 soil data, this potential 1,4,DCB CUO is exceeded at fifteen (15) of the sixteen (16) locations sampled.

- If no action is taken to decrease concentrations of TCB and DCB at the source, TriHydro's models predict that DCB concentrations will exceed the CUO upon reaching the POC. This will occur because of the larger TCB and DCB concentrations at the source, and the addition of more DCB via TCB degradation. If constituent concentrations at the source are decreased to (for example) 65.2 ug/L and 8.1 ug/L respectively then natural attenuation and dispersion may be sufficient to decrease DCB concentrations to below the CUO at the POC. Note that, because both TCB and 1,4-DCB from the source area may result in 1,4-DCB at the POC, there is an inverse linear relationship between allowable source area concentrations.

7.0 REFERENCES

ASTM 1995. *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.* ASTM Designation E 1739, 51p.

Carey, G.R. Van Geel, P.J., and Wiedemeier, T.H. 2002. Clarification of Methods for Calculating First Order Transformation Rates and Modeling Biodegradation.

ASTM 1998. Standard Guide for Remediation of Ground Water by Natural Attenuation at Petroleum Release Sites ASTM Designation E 1943, 43p.

USEPA 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water, Office of Research and Development, EPA/600/R-98/128. September 1998.

USEPA 1996. Soil Screening Guidance: Technical Background Document, Publication 9355.4-17A. May 1996.

8.0 SIGNATURES OF ENVIRONMENTAL PROFESSIONALS

Any questions regarding the work within this report, the presentation of the information, or the interpretation of the data are welcome and should be referred to the undersigned.

Sincerely,
TRIHYDRO CORPORATION

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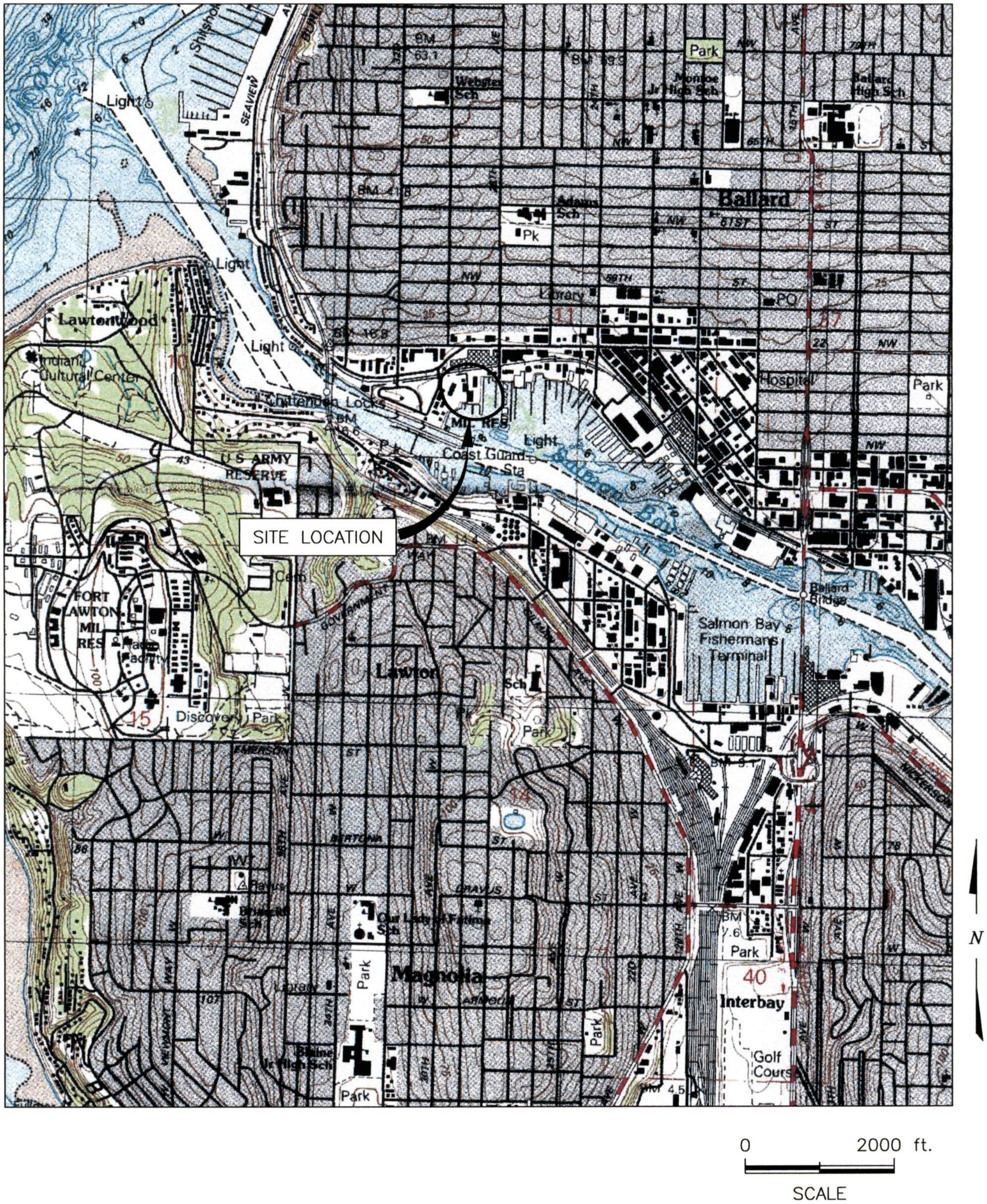
FIGURES



TriHydro Corporation
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Laramie, Wyoming 82070

FIGURE 1

SITE LOCATION, JACOBSON TERMINALS FACILITY, SEATTLE, WASHINGTON

Drawn By: BW	Checked By: BM	Scale: 1" = 2000'	Date: 07/23/03	Ref: 740USGSSITE

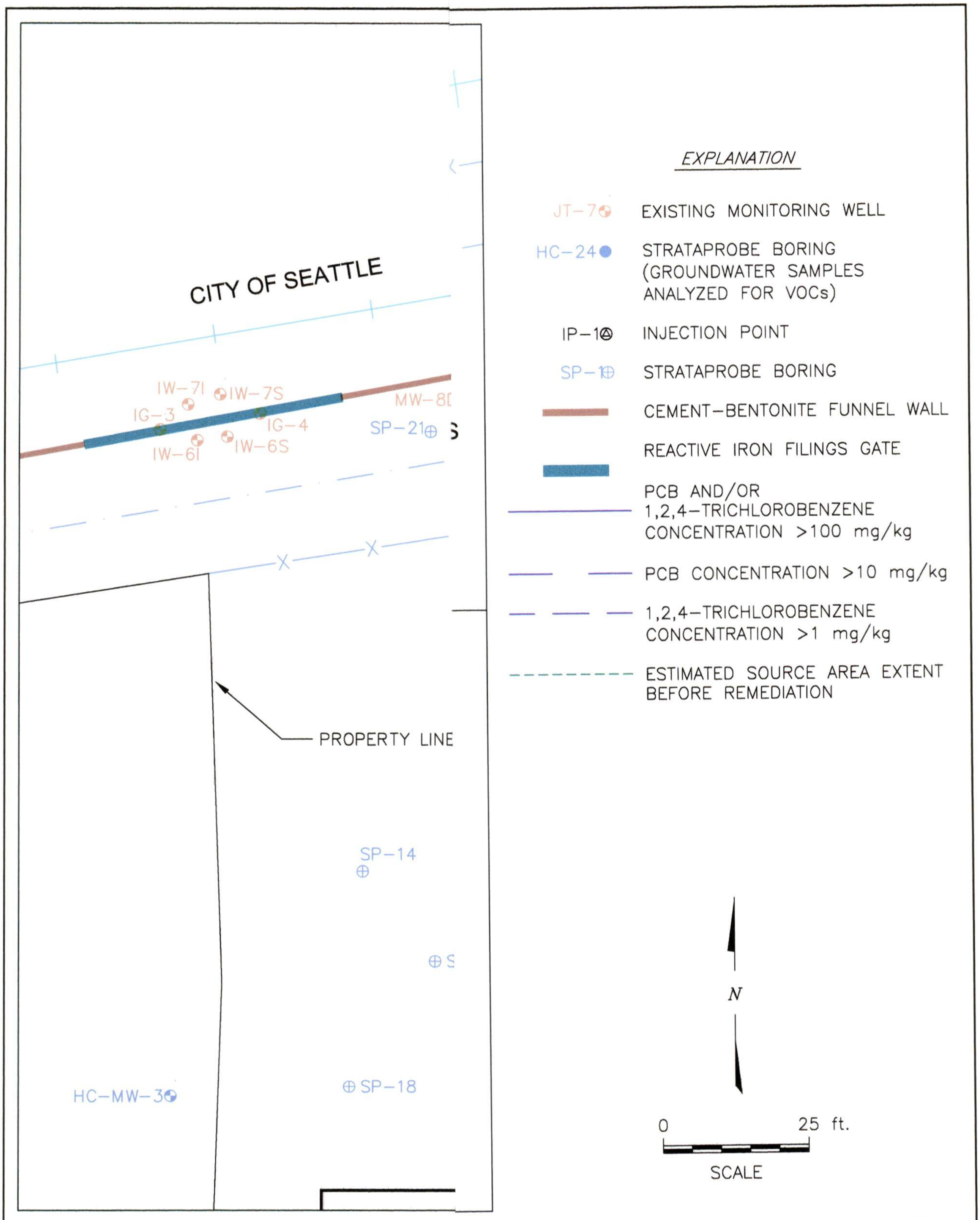

FIGURE 2

SITE MAP SHOWING 1,2,4, TCB SOURCE AREA, FATE AND TRANSPORT EVALUATION FOR CHLOROBENZNES, JACOBSON TERMINALS FACILITY, SEATTLE, WASHINGTON

ADAPTED FROM: Figure 6, Estimated Extent of PCB and Trichl

Scale: 1" = 25'

Date: 6/23/03

Ref: 740CB

APPENDIX A

WORKSHEETS FOR MTCA, SSL, AND RBCA CALCULATIONS

Worksheet for Calculating Soil Cleanup Levels for Unrestricted & Industrial Land Use

Date: 7/22/2003
Site Name: Jacobson Terminal
Evaluator: TriHydro

Refer to WAC 173-340-720, 740, 745, 747 and 750 for details.

A. INPUT PARAMETERS FOR SOIL CLEANUP LEVEL CALCULATIONS

Note: If no data is available for any of the following inputs, then leave the input box blank

Item	Symbol	Value	Units
1. General information			
Name of Chemical:		1,2,4-TCB (Unsat'd zone)	
Measured Soil Concentration, if any:	C_s	560	mg/kg
Natural Background Concentration for Soil:	NB_s	0	mg/kg
Practical Quantitation Limit for Soil:	PQL_s	0.05	mg/kg
To evaluate the ingestion and dermal pathways concurrently, check here and input values for AF, ABS_d, GI:	☑		
2. Toxicological Properties of the Chemical: Chemical-Specific			
Oral Reference Dose:	RfD_o	0.01	mg/kg-day
Oral Carcinogenic Potency Factor:	CPF_o		kg-day/mg
Inhalation Reference Dose:	RfD_i	0.0571	mg/kg-day
Inhalation Carcinogenic Potency Factor:	CPF_i		kg-day/mg
3. Exposure Parameters			
Inhalation Correction Factor (default = "2" for volatiles; "1" for all others): for target ground water cleanup level	INH	2	unitless
Inhalation Absorption Fraction (default = "1"): for target air cleanup level	ABS_i	1	unitless
Gastrointestinal Absorption Fraction (default = "1"): for ingestion & dermal exposure pathways	$AB1$	1	unitless
Adherence Factor (default = "0.2"): for dermal exposure pathway	AF	0.2	mg/cm^2-day
Dermal Absorption Fraction (chemical-specific or defaults): for dermal exposure pathway	ABS_d	1	unitless
Gastrointestinal Absorption Conversion Factor (chemical-specific or defaults): for dermal exposure pathway	GI	1	unitless
4. Physical and Chemical Properties of the Chemical: Chemical-Specific			
Soil Organic Carbon-Water Partitioning Coefficient: for metals, enter K_d value here and enter "1" for f_{oc} value	K_{oc}	1.659E+03	l/kg
Henry's Law Constant: for the evaluation of ground water and vapor exposure pathway	H_{cc}	5.820E-02	unitless
**If the value for Henry's Law Constant is given in the unit of "atm.m^3/mol", enter value here:*	H		atm.m^3/mol
**Converted unitless form of H_{cc} @13° C: (Enter this converted value into "H_{cc} input Box" above for a calculation)*	H_{cc}	*0.000E+00*	unitless

Solubility of the Chemical in Water: for the calculation of soil saturation limit	S	3.000E+02	mg/l

5. Target Ground Water Cleanup Level

Target Ground Water Cleanup Level applicable for a soil cleanup level calculation: **Results from the Ground Water Cleanup Level Worksheet are not automatically transferred into this worksheet.*	C_w	**2.27E+02**	ug/l

6. Site-Specific Hydrogeological Characteristics

Total Soil Porosity (default = "0.43"):	n	0.43	unitless
Volumetric Water Content (default = "0.30"):	Θ_w	0.3	unitless
Volumetric Air Content (default = "0.13"):	Θ_α	0.13	unitless
Dry Soil Bulk Density (default = "1.50"):	ρ_b	1.5	kg/l
Fraction Soil Organic Carbon (default = "0.001"): for metals, enter "1" for f_{oc} value here	f_{oc}	0.035	unitless
Dilution Factor (default = "20" for unsaturated zone soil; "1" for saturated zone soil; or site-specific)	DF	20	unitless

7. Vapor Attenuation Factor due to Advection (building structure) & Diffusion (soil layer) Mechanisms

** Vapor Attenuation Factor is the ratio of vapor-phase contaminant concentration within the soil at the source to the air concentration at the exposure point (e.g., within the building)*

Enter Vapor Attenuation Factor: for the evaluation of vapor exposure pathway	VAF		unitless

---

B. SUMMARY OF SOIL CLEANUP LEVEL CALCULATIONS

Chemical of Concern: 1,2,4-TCB (Unsat'd zone)

1. Summary of Results

To calculate a soil cleanup level based on Industrial Land Use (Method C) for Direct Soil Contact, check here: ☑

To calculate a soil concentration based on Method C vapor pathway, check here: ☑

Basis for Soil Concentration	Conc	Units
Most stringent soil concentration based on Soil Direct Contact & Ground Water Protection:	2.645E+02	mg/kg
Natural Background concentration for Soil:	0	mg/kg
Practical Quantitation Limit for Soil:	0.05	mg/kg
Soil Cleanup Level (not considering vapor pathway):	2.645E+02	mg/kg
Warning! Soil Cleanup Level above may not be protective of vapor exposure pathway - evaluate vapor pathway further.		
Soil concentration based on Vapor Pathway (informational purposes only):	0.000E+00	mg/kg

C_{sat} corresponds to the total soil chemical concentration saturated in soil.

R is the ratio of the ground water flow velocity to the

Soil Saturation Limit, C_{sat}:	1.748E+04	mg/kg
Retardation Factor, ***R***:	203.6	unitless

R is the ratio of the ground water flow velocity to the contaminant migration velocity in saturated zone.

2. Summary of Calculation for each Exposure Pathway

Summary by Exposure Pathway						
Soil Direct Contact			*Method B* *Unrestricted Land Use* @ HQ=1.0; RISK =1.0E-6		*Method C* *Industrial Land Use* @ HQ=1.0; RISK =1.0E-5	
			Ingestion only	Ingestion & Dermal	Ingestion only	Ingestion & Dermal
	Under the Current Condition	HQ? @ Exposure Point	7.000E-01	2.240E+00	1.600E-02	3.080E-01
		RISK? @ Exposure Point	N/A	N/A	N/A	N/A
	Target Soil CUL? mg/kg	@HQ=1.0	8.000E+02	2.500E+02	3.500E+04	1.818E+03
		@RISK =1.0E-6 or 1.0E-5	N/A	N/A	N/A	N/A
Protection of Potable Ground Water			*Method B* @ HQ=1.0; RISK =1.0E-6		*Method C* @ HQ=1.0; RISK =1.0E-5	
	Under the Current Condition	Predicted Ground Water Conc? ug/l	4.805E+02			
		HQ? @ Exposure Point	6.007E+00		2.746E+00	
		RISK? @ Exposure Point	N/A		N/A	
	Target Ground Water CUL? ug/l		2.270E+02			
	Target Soil CUL? mg/kg		2.645E+02			
Protection of Air Quality *(for informational purpose only)*			*Method B* @ HQ=1.0; RISK =1.0E-6		*Method C* @ HQ=1.0; RISK =1.0E-5	
	Under the Current Condition	Predicted Air Conc? ug/m^3 @Exposure Point	#DIV/0!			
		HQ? @ Exposure Point	#DIV/0!		#DIV/0!	
		RISK? @ Exposure Point	N/A		N/A	
	Target Air CUL? ug/m^3	@ HQ=1.0	9.136E+01		1.999E+02	
		@ RISK=1.0E-6 or 1.0E-5	N/A		N/A	
	Target Soil CUL? mg/kg	@ HQ=1.0	0.000E+00		0.000E+00	
		@ RISK=1.0E-6 or 1.0E-5	N/A		N/A	

NOTES: "CUL" = Cleanup Level; "Conc" = concentration; "HQ" = hazard quotient; "RISK" = carcinogenic risk.

CAUTION: The requirements and procedures for establishing soil cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-740, 173-340-745, 173-340-747 and 173-340-7490 through 173-340-7494). The use of this Workbook is not sufficient to establish soil cleanup levels under the regulation. Specifically, the soil cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-740(3)(b)(i) and 173-340-745(5)(b)(i));
- Soil residual saturation (see WAC 173-340-747(10));
- Ecological impacts (see WAC 173-340-7490 through 7494); and
- Total site risk (see WAC 173-340-740(5)(a) and 173-340-745(6)(a)).

Other exposure pathways may also need to be evaluated on a site-specific basis to establish soil cleanup levels.

CAUTION: The requirements and procedures for establishing air cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-750). The use of this Workbook may not be sufficient to establish air cleanup levels under the regulation. Specifically, the air cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-750(3)(b)(i) and (4)(b)(i));
- Concentrations based on natural background and the practical quantitation limit (see WAC 173-340-750(5)(c));
- Total site risk (see WAC 173-340-750(5)(a)).

Worksheet for Calculating Soil Cleanup Levels for Unrestricted & Industrial Land Use

Date: 7/22/2003
Site Name: Jacobson Terminal
Evaluator: TriHydro

Refer to WAC 173-340-720, 740, 745, 747 and 750 for details.

A. INPUT PARAMETERS FOR SOIL CLEANUP LEVEL CALCULATIONS

Note: If no data is available for any of the following inputs, then leave the input box blank

Item	Symbol	Value	Units
1. General information			
Name of Chemical:		**1,2,4-TCB (Sat'd zone)**	
Measured Soil Concentration, if any:	C_s	560	mg/kg
Natural Background Concentration for Soil:	NB_s	0	mg/kg
Practical Quantitation Limit for Soil:	PQL_s	0.05	mg/kg
To evaluate the ingestion and dermal pathways concurrently, check here and input values for AF, ABS_d, GI:	☑		
2. Toxicological Properties of the Chemical: Chemical-Specific			
Oral Reference Dose:	RfD_o	0.01	mg/kg-day
Oral Carcinogenic Potency Factor:	CPF_o		kg-day/mg
Inhalation Reference Dose:	RfD_i	0.0571	mg/kg-day
Inhalation Carcinogenic Potency Factor:	CPF_i		kg-day/mg
3. Exposure Parameters			
Inhalation Correction Factor (default = "2" for volatiles; "1" for all others): for target ground water cleanup level	INH	2	unitless
Inhalation Absorption Fraction (default = "1"): for target air cleanup level	ABS_i	1	unitless
Gastrointestinal Absorption Fraction (default = "1"): for ingestion & dermal exposure pathways	$AB1$	1	unitless
Adherence Factor (default = "0.2"): for dermal exposure pathway	AF	0.2	mg/cm^2-day
Dermal Absorption Fraction (chemical-specific or defaults): for dermal exposure pathway	ABS_d	1	unitless
Gastrointestinal Absorption Conversion Factor (chemical-specific or defaults): for dermal exposure pathway	GI	1	unitless
4. Physical and Chemical Properties of the Chemical: Chemical-Specific			
Soil Organic Carbon-Water Partitioning Coefficient: for metals, enter K_d value here and enter "1" for f_{oc} value	K_{oc}	1.659E+03	l/kg
Henry's Law Constant: for the evaluation of ground water and vapor exposure pathway	H_{cc}	5.820E-02	unitless
**If the value for Henry's Law Constant is given in the unit of "$atm.m^3/mol$", enter value here:*	H		$atm.m^3/mol$
**Converted unitless form of H_{cc} @13° C: (Enter this converted value into "H_{cc} input Box" above for a calculation)*	H_{cc}	*0.000E+00*	unitless

Solubility of the Chemical in Water: for the calculation of soil saturation limit	S	3.000E+02	mg/l

5. Target Ground Water Cleanup Level

Target Ground Water Cleanup Level applicable for a soil cleanup level calculation: **Results from the Ground Water Cleanup Level Worksheet are not automatically transferred into this worksheet.*	C_w	**2.27E+02**	ug/l

6. Site-Specific Hydrogeological Characteristics

Total Soil Porosity (default = "0.43"):	n	0.43	unitless
Volumetric Water Content (default = "0.30"):	Θ_w	0.43	unitless
Volumetric Air Content (default = "0.13"):	Θ_α	0.00	unitless
Dry Soil Bulk Density (default = "1.50"):	ρ_b	1.5	kg/l
Fraction Soil Organic Carbon (default = "0.001"): for metals, enter "1" for f_{oc} value here	f_{oc}	0.035	unitless
Dilution Factor (default = "20" for unsaturated zone soil; "1" for saturated zone soil; or site-specific)	DF	1	unitless

7. Vapor Attenuation Factor due to Advection (building structure) & Diffusion (soil layer) Mechanisms

** Vapor Attenuation Factor is the ratio of vapor-phase contaminant concentration within the soil at the source to the air concentration at the exposure point (e.g., within the building)*

Enter Vapor Attenuation Factor: for the evaluation of vapor exposure pathway	VAF		unitless

B. SUMMARY OF SOIL CLEANUP LEVEL CALCULATIONS

Chemical of Concern: 1,2,4-TCB (Sat'd zone)

1. Summary of Results

To calculate a soil cleanup level based on Industrial Land Use (Method C) for Direct Soil Contact, check here: ☑

To calculate a soil concentration based on Method C vapor pathway, check here: ☑

Basis for Soil Concentration	Conc	Units
Most stringent soil concentration based on Soil Direct Contact & Ground Water Protection:	1.325E+01	mg/kg
Natural Background concentration for Soil:	0	mg/kg
Practical Quantitation Limit for Soil:	0.05	mg/kg
Soil Cleanup Level (not considering vapor pathway):	1.325E+01	mg/kg
Warning! Soil Cleanup Level above may not be protective of vapor exposure pathway - evaluate vapor pathway further.		
Soil concentration based on Vapor Pathway (informational purposes only):	0.000E+00	mg/kg

C_{sat} corresponds to the total soil chemical concentration saturated in soil.

R is the ratio of the ground water flow velocity to the

Soil Saturation Limit, C_{sat}:	1.751E+04	mg/kg
Retardation Factor, ***R*** :	203.6	unitless

R is the ratio of the ground water flow velocity to the contaminant migration velocity in saturated zone.

2. Summary of Calculation for each Exposure Pathway

Summary by Exposure Pathway

			Method B *Unrestricted Land Use* @ HQ=1.0; RISK =1.0E-6		*Method C* *Industrial Land Use* @ HQ=1.0; RISK =1.0E-5	
Soil Direct Contact			Ingestion only	Ingestion & Dermal	Ingestion only	Ingestion & Dermal
	Under the Current Condition	HQ? @ Exposure Point	7.000E-01	2.240E+00	1.600E-02	3.080E-01
		RISK? @ Exposure Point	N/A	N/A	N/A	N/A
	Target Soil CUL? mg/kg	@HQ=1.0	8.000E+02	2.500E+02	3.500E+04	1.818E+03
		@RISK =1.0E-6 or 1.0E-5	N/A	N/A	N/A	N/A

			Method B @ HQ=1.0; RISK =1.0E-6	*Method C* @ HQ=1.0; RISK =1.0E-5
Protection of Potable Ground Water	Under the Current Condition	Predicted Ground Water Conc? ug/l	9.597E+03	
		HQ? @ Exposure Point	1.200E+02	5.484E+01
		RISK? @ Exposure Point	N/A	N/A
	Target Ground Water CUL? ug/l		2.270E+02	
	Target Soil CUL? mg/kg		1.325E+01	

			Method B @ HQ=1.0; RISK =1.0E-6	*Method C* @ HQ=1.0; RISK =1.0E-5
Protection of Air Quality ***(for informational purpose only)***	Under the Current Condition	Predicted Air Conc? ug/m^3 @Exposure Point	#DIV/0!	
		HQ? @ Exposure Point	#DIV/0!	#DIV/0!
		RISK? @ Exposure Point	N/A	N/A
	Target Air CUL? ug/m^3	@ HQ=1.0	9.136E+01	1.999E+02
		@ RISK=1.0E-6 or 1.0E-5	N/A	N/A
	Target Soil CUL? mg/kg	@ HQ=1.0	0.000E+00	0.000E+00
		@ RISK=1.0E-6 or 1.0E-5	N/A	N/A

NOTES: "CUL" = Cleanup Level; "Conc" = concentration; "HQ" = hazard quotient; "RISK" = carcinogenic risk.

CAUTION: The requirements and procedures for establishing soil cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-740, 173-340-745, 173-340-747 and 173-340-7490 through 173-340-7494). The use of this Workbook is not sufficient to establish soil cleanup levels under the regulation. Specifically, the soil cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-740(3)(b)(i) and 173-340-745(5)(b)(i));
- Soil residual saturation (see WAC 173-340-747(10));
- Ecological impacts (see WAC 173-340-7490 through 7494); and
- Total site risk (see WAC 173-340-740(5)(a) and 173-340-745(6)(a)).

Other exposure pathways may also need to be evaluated on a site-specific basis to establish soil cleanup levels.

CAUTION: The requirements and procedures for establishing air cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-750). The use of this Workbook may not be sufficient to establish air cleanup levels under the regulation. Specifically, the air cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-750(3)(b)(i) and (4)(b)(i));
- Concentrations based on natural background and the practical quantitation limit (see WAC 173-340-750(5)(c));
- Total site risk (see WAC 173-340-750(5)(a)).

Worksheet for Calculating Soil Cleanup Levels for Unrestricted & Industrial Land Use

Date: 7/22/2003
Site Name: Jacobson Terminal
Evaluator: TriHydro

Refer to WAC 173-340-720, 740, 745, 747 and 750 for details.

A. INPUT PARAMETERS FOR SOIL CLEANUP LEVEL CALCULATIONS

Note: If no data is available for any of the following inputs, then leave the input box blank

Item	Symbol	Value	Units
1. General information			
Name of Chemical:		**1,4-DCB Unsat'd zone**	
Measured Soil Concentration, if any:	C_s	15	mg/kg
Natural Background Concentration for Soil:	NB_s	0	mg/kg
Practical Quantitation Limit for Soil:	PQL_s	0.05	mg/kg
To evaluate the ingestion and dermal pathways concurrently, check here and input values for ***AF, ABS*** $_d$**, *GI***:	☑		
2. Toxicological Properties of the Chemical: Chemical-Specific			
Oral Reference Dose:	RfD_o		mg/kg-day
Oral Carcinogenic Potency Factor:	CPF_o	0.024	kg-day/mg
Inhalation Reference Dose:	RfD_i	0.228571	mg/kg-day
Inhalation Carcinogenic Potency Factor:	CPF_i		kg-day/mg
3. Exposure Parameters			
Inhalation Correction Factor (default = "2" for volatiles; "1" for all others): for target ground water cleanup level	INH	2	unitless
Inhalation Absorption Fraction (default = "1"): for target air cleanup level	ABS_i	1	unitless
Gastrointestinal Absorption Fraction (default = "1"): for ingestion & dermal exposure pathways	$AB1$	1	unitless
Adherence Factor (default = "0.2"): for dermal exposure pathway	AF	0.2	mg/cm^2-day
Dermal Absorption Fraction (chemical-specific or defaults): for dermal exposure pathway	ABS_d	1	unitless
Gastrointestinal Absorption Conversion Factor (chemical-specific or defaults): for dermal exposure pathway	GI	1	unitless
4. Physical and Chemical Properties of the Chemical: Chemical-Specific			
Soil Organic Carbon-Water Partitioning Coefficient: for metals, enter K_d value here and enter "1" for f_{oc} value	K_{oc}	6.160E+02	l/kg
Henry's Law Constant: for the evaluation of ground water and vapor exposure pathway	H_{cc}	9.960E-02	unitless
**If the value for Henry's Law Constant is given in the unit of "atm.m^3/mol", enter value here:*	H		atm.m^3/mol
**Converted unitless form of H_{cc} @13° C: (Enter this converted value into "H_{cc} input Box" above for a calculation)*	H_{cc}	*0.000E+00*	unitless

Solubility of the Chemical in Water: for the calculation of soil saturation limit	S	7.380E+01	mg/l

5. Target Ground Water Cleanup Level

Target Ground Water Cleanup Level applicable for a soil cleanup level calculation: **Results from the Ground Water Cleanup Level Worksheet are not automatically transferred into this worksheet.*	C_w	**4.86E+00**	ug/l

6. Site-Specific Hydrogeological Characteristics

Total Soil Porosity (default = "0.43"):	n	0.43	unitless
Volumetric Water Content (default = "0.30"):	Θ_w	0.3	unitless
Volumetric Air Content (default = "0.13"):	Θ_a	0.13	unitless
Dry Soil Bulk Density (default = "1.50"):	ρ_b	1.5	kg/l
Fraction Soil Organic Carbon (default = "0.001"): for metals, enter "1" for f_{oc} value here	f_{oc}	0.035	unitless
Dilution Factor (default = "20" for unsaturated zone soil; "1" for saturated zone soil; or site-specific)	DF	20	unitless

7. Vapor Attenuation Factor due to Advection (building structure) & Diffusion (soil layer) Mechanisms

** Vapor Attenuation Factor is the ratio of vapor-phase contaminant concentration within the soil at the source to the air concentration at the exposure point (e.g., within the building)*

Enter Vapor Attenuation Factor: for the evaluation of vapor exposure pathway	VAF		unitless

B. SUMMARY OF SOIL CLEANUP LEVEL CALCULATIONS

Chemical of Concern: 1,4-DCB Unsat'd zone

1. Summary of Results

To calculate a soil cleanup level based on Industrial Land Use (Method C) for Direct Soil Contact, check here: ☑

To calculate a soil concentration based on Method C vapor pathway, check here: ☑

Basis for Soil Concentration	Conc	Units
Most stringent soil concentration based on Soil Direct Contact & Ground Water Protection:	2.116E+00	mg/kg
Natural Background concentration for Soil:	0	mg/kg
Practical Quantitation Limit for Soil:	0.05	mg/kg
Soil Cleanup Level (not considering vapor pathway):	2.116E+00	mg/kg
Warning! Soil Cleanup Level above may not be protective of vapor exposure pathway - evaluate vapor pathway further.		
Soil concentration based on Vapor Pathway (informational purposes only):	0.000E+00	mg/kg

C_{sat} corresponds to the total soil chemical concentration saturated in soil.

R is the ratio of the ground water flow velocity to the

Soil Saturation Limit, C_{sat}:	1.607E+03	mg/kg
Retardation Factor, ***R***:	76.2	unitless

R is the ratio of the ground water flow velocity to the contaminant migration velocity in saturated zone.

2. Summary of Calculation for each Exposure Pathway

Summary by Exposure Pathway

			Method B *Unrestricted Land Use* @ HQ=1.0; RISK =1.0E-6		*Method C* *Industrial Land Use* @ HQ=1.0; RISK =1.0E-5	
Soil Direct Contact			Ingestion only	Ingestion & Dermal	Ingestion only	Ingestion & Dermal
	Under the Current Condition	HQ? @ Exposure Point	N/A	N/A	N/A	N/A
		RISK? @ Exposure Point	3.600E-07	1.152E-06	2.743E-08	5.280E-07
	Target Soil CUL? mg/kg	@HQ=1.0	N/A	N/A	N/A	N/A
		@RISK =1.0E-6 or 1.0E-5	4.167E+01	1.302E+01	5.469E+03	2.841E+02
Protection of Potable Ground Water			*Method B* @ HQ=1.0; RISK =1.0E-6		*Method C* @ HQ=1.0; RISK =1.0E-5	
	Under the Current Condition	Predicted Ground Water Conc? ug/l	3.445E+01			
		HQ? @ Exposure Point	N/A		N/A	
		RISK? @ Exposure Point	1.890E-05		1.890E-05	
	Target Ground Water CUL? ug/l		4.860E+00			
	Target Soil CUL? mg/kg		2.116E+00			
Protection of Air Quality *(for informational purpose only)*			*Method B* @ HQ=1.0; RISK =1.0E-6		*Method C* @ HQ=1.0; RISK =1.0E-5	
	Under the Current Condition	Predicted Air Conc? ug/m^3 @Exposure Point	#DIV/0!			
		HQ? @ Exposure Point	#DIV/0!		#DIV/0!	
		RISK? @ Exposure Point	N/A		N/A	
	Target Air CUL? ug/m^3	@ HQ=1.0	3.657E+02		8.000E+02	
		@ RISK=1.0E-6 or 1.0E-5	N/A		N/A	
	Target Soil CUL? mg/kg	@ HQ=1.0	0.000E+00		0.000E+00	
		@ RISK=1.0E-6 or 1.0E-5	N/A		N/A	

NOTES: "CUL" = Cleanup Level; "Conc" = concentration; "HQ" = hazard quotient; "RISK" = carcinogenic risk.

CAUTION: The requirements and procedures for establishing soil cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-740, 173-340-745, 173-340-747 and 173-340-7490 through 173-340-7494). The use of this Workbook is not sufficient to establish soil cleanup levels under the regulation. Specifically, the soil cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-740(3)(b)(i) and 173-340-745(5)(b)(i));
- Soil residual saturation (see WAC 173-340-747(10));
- Ecological impacts (see WAC 173-340-7490 through 7494); and
- Total site risk (see WAC 173-340-740(5)(a) and 173-340-745(6)(a)).

Other exposure pathways may also need to be evaluated on a site-specific basis to establish soil cleanup levels.

CAUTION: The requirements and procedures for establishing air cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-750). The use of this Workbook may not be sufficient to establish air cleanup levels under the regulation. Specifically, the air cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-750(3)(b)(i) and (4)(b)(i));
- Concentrations based on natural background and the practical quantitation limit (see WAC 173-340-750(5)(c));
- Total site risk (see WAC 173-340-750(5)(a)).

Worksheet for Calculating Soil Cleanup Levels for Unrestricted & Industrial Land Use

Date: 7/22/2003
Site Name: Jacobson Terminal
Evaluator: TriHydro

Refer to WAC 173-340-720, 740, 745, 747 and 750 for details.

A. INPUT PARAMETERS FOR SOIL CLEANUP LEVEL CALCULATIONS

Note: If no data is available for any of the following inputs, then leave the input box blank

Item	Symbol	Value	Units
1. General information			
Name of Chemical:		**1,4-DCB Sat'd zone**	
Measured Soil Concentration, if any:	C_s	15	mg/kg
Natural Background Concentration for Soil:	NB_s	0	mg/kg
Practical Quantitation Limit for Soil:	PQL_s	0.05	mg/kg
To evaluate the ingestion and dermal pathways concurrently, check here and input values for AF, ABS_d, GI:	☑		
2. Toxicological Properties of the Chemical: Chemical-Specific			
Oral Reference Dose:	RfD_o		mg/kg-day
Oral Carcinogenic Potency Factor:	CPF_o	0.024	kg-day/mg
Inhalation Reference Dose:	RfD_i	0.228571	mg/kg-day
Inhalation Carcinogenic Potency Factor:	CPF_i		kg-day/mg
3. Exposure Parameters			
Inhalation Correction Factor (default = "2" for volatiles; "1" for all others): for target ground water cleanup level	INH	2	unitless
Inhalation Absorption Fraction (default = "1"): for target air cleanup level	ABS_i	1	unitless
Gastrointestinal Absorption Fraction (default = "1"): for ingestion & dermal exposure pathways	$AB1$	1	unitless
Adherence Factor (default = "0.2"): for dermal exposure pathway	AF	0.2	mg/cm^2-day
Dermal Absorption Fraction (chemical-specific or defaults): for dermal exposure pathway	ABS_d	1	unitless
Gastrointestinal Absorption Conversion Factor (chemical-specific or defaults): for dermal exposure pathway	GI	1	unitless
4. Physical and Chemical Properties of the Chemical: Chemical-Specific			
Soil Organic Carbon-Water Partitioning Coefficient: for metals, enter K_d value here and enter "1" for f_{oc} value	K_{oc}	6.160E+02	l/kg
Henry's Law Constant: for the evaluation of ground water and vapor exposure pathway	H_{cc}	9.960E-02	unitless
**If the value for Henry's Law Constant is given in the unit of "$atm.m^3/mol$", enter value here:*	H		$atm.m^3/mol$
**Converted unitless form of H_{cc} @13 °C: (Enter this converted value into "H_{cc} input Box" above for a calculation)*	H_{cc}	*0.000E+00*	unitless

Solubility of the Chemical in Water: for the calculation of soil saturation limit	***S***	7.380E+01	mg/l

5. Target Ground Water Cleanup Level

Target Ground Water Cleanup Level applicable for a soil cleanup level calculation: **Results from the Ground Water Cleanup Level Worksheet are not automatically transferred into this worksheet.*	C_w	**4.86E+00**	ug/l

6. Site-Specific Hydrogeological Characteristics

Total Soil Porosity (default = "0.43"):	n	0.43	unitless
Volumetric Water Content (default = "0.30"):	Θ_w	0.43	unitless
Volumetric Air Content (default = "0.13"):	Θ_a	0.00	unitless
Dry Soil Bulk Density (default = "1.50"):	ρ_b	1.5	kg/l
Fraction Soil Organic Carbon (default = "0.001"): for metals, enter "1" for f_{oc} value here	f_{oc}	0.035	unitless
Dilution Factor (default = "20" for unsaturated zone soil; "1" for saturated zone soil; or site-specific)	***DF***	1	unitless

7. Vapor Attenuation Factor due to Advection (building structure) & Diffusion (soil layer) Mechanisms

* *Vapor Attenuation Factor is the ratio of vapor-phase contaminant concentration within the soil at the source to the air concentration at the exposure point (e.g., within the building)*

Enter Vapor Attenuation Factor: for the evaluation of vapor exposure pathway	***VAF***		unitless

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B. SUMMARY OF SOIL CLEANUP LEVEL CALCULATIONS

Chemical of Concern: 1,4-DCB Sat'd zone

1. Summary of Results

To calculate a soil cleanup level based on Industrial Land Use (Method C) for Direct Soil Contact, check here: ☑

To calculate a soil concentration based on Method C vapor pathway, check here: ☑

Basis for Soil Concentration	Conc	Units
Most stringent soil concentration based on Soil Direct Contact & Ground Water Protection:	1.062E-01	mg/kg
Natural Background concentration for Soil:	0	mg/kg
Practical Quantitation Limit for Soil:	0.05	mg/kg
Soil Cleanup Level (not considering vapor pathway):	1.062E-01	mg/kg
Warning! Soil Cleanup Level above may not be protective of vapor exposure pathway - evaluate vapor pathway further.		
Soil concentration based on Vapor Pathway (informational purposes only):	0.000E+00	mg/kg

C_{sat} corresponds to the total soil chemical concentration saturated in soil.

R is the ratio of the ground water flow velocity to the

Soil Saturation Limit, C_{sat}:	1.612E+03	mg/kg
Retardation Factor, ***R***:	76.2	unitless

R is the ratio of the ground water flow velocity to the contaminant migration velocity in saturated zone.

2. Summary of Calculation for each Exposure Pathway

Summary by Exposure Pathway

			Method B *Unrestricted Land Use* @ HQ=1.0; RISK =1.0E-6		*Method C* *Industrial Land Use* @ HQ=1.0; RISK =1.0E-5	
Soil Direct Contact			Ingestion only	Ingestion & Dermal	Ingestion only	Ingestion & Dermal
	Under the Current Condition	HQ? @ Exposure Point	N/A	N/A	N/A	N/A
		RISK? @ Exposure Point	3.600E-07	1.152E-06	2.743E-08	5.280E-07
	Target Soil CUL? mg/kg	@HQ=1.0	N/A	N/A	N/A	N/A
		@RISK =1.0E-6 or 1.0E-5	4.167E+01	1.302E+01	5.469E+03	2.841E+02
Protection of Potable Ground Water			*Method B* @ HQ=1.0; RISK =1.0E-6		*Method C* @ HQ=1.0; RISK =1.0E-5	
	Under the Current Condition	Predicted Ground Water Conc? ug/l	6.866E+02			
		HQ? @ Exposure Point	N/A		N/A	
		RISK? @ Exposure Point	3.767E-04		3.767E-04	
	Target Ground Water CUL? ug/l		4.860E+00			
	Target Soil CUL? mg/kg		1.062E-01			
Protection of Air Quality ***(for informational purpose only)***			*Method B* @ HQ=1.0; RISK =1.0E-6		*Method C* @ HQ=1.0; RISK =1.0E-5	
	Under the Current Condition	Predicted Air Conc? ug/m^3 @Exposure Point	#DIV/0!			
		HQ? @ Exposure Point	#DIV/0!		#DIV/0!	
		RISK? @ Exposure Point	N/A		N/A	
	Target Air CUL? ug/m^3	@ HQ=1.0	3.657E+02		8.000E+02	
		@ RISK=1.0E-6 or 1.0E-5	N/A		N/A	
	Target Soil CUL? mg/kg	@ HQ=1.0	0.000E+00		0.000E+00	
		@ RISK=1.0E-6 or 1.0E-5	N/A		N/A	

NOTES: "CUL" = Cleanup Level; "Conc" = concentration; "HQ" = hazard quotient; "RISK" = carcinogenic risk.

CAUTION: The requirements and procedures for establishing soil cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-740, 173-340-745, 173-340-747 and 173-340-7490 through 173-340-7494). The use of this Workbook is not sufficient to establish soil cleanup levels under the regulation. Specifically, the soil cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-740(3)(b)(i) and 173-340-745(5)(b)(i));
- Soil residual saturation (see WAC 173-340-747(10));
- Ecological impacts (see WAC 173-340-7490 through 7494); and
- Total site risk (see WAC 173-340-740(5)(a) and 173-340-745(6)(a)).

Other exposure pathways may also need to be evaluated on a site-specific basis to establish soil cleanup levels.

CAUTION: The requirements and procedures for establishing air cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-750). The use of this Workbook may not be sufficient to establish air cleanup levels under the regulation. Specifically, the air cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-750(3)(b)(i) and (4)(b)(i));
- Concentrations based on natural background and the practical quantitation limit (see WAC 173-340-750(5)(c));
- Total site risk (see WAC 173-340-750(5)(a)).

Table A-1. Calculation of dilution factor based on site specific soil and groundwater concentrations, Jacobson Terminal

Jun-02

Constituent	Soil Sample/Gwater Sample ID	Cs	Sample ID	Sample Depth	Cw	Sample ID	Sample Depth	UCF	Koc	foc	Kd	θw	θa	H'	pb	DF
1,4 DCB	SP-41/IP-8	15	SP-41	12 - 16	450	IP-8	14 - 17	1.00E-03	6.16E+02	0.035	2.156E+01	0.43	0	9.96E-02	1.5	1.525786
1,4 DCB	SP-42/IP-2	2.5	SP-42	12 - 16	56	IP-2	14 - 17	1.00E-03	6.16E+02	0.035	2.156E+01	0.43	0	9.96E-02	1.5	2.043463
1,4 DCB	SP-43/IP-1	0.85	SP-43	12 - 16	160	IP-1	14 - 17	1.00E-03	6.16E+02	0.035	2.156E+01	0.43	0	9.96E-02	1.5	0.243172
1,4 DCB	SP-44/IP-5	1	SP-44	12 - 16	62	IP-5	11.5-14.5	1.00E-03	6.16E+02	0.035	2.156E+01	0.43	0	9.96E-02	1.5	0.738283
1,4 DCB	SP-45/IP-14	0.55	SP-45	12 - 16	100	IP-14	14 - 17	1.00E-03	6.16E+02	0.035	2.156E+01	0.43	0	9.96E-02	1.5	0.251755
1,4 DCB	SP-46/IP-15	1.2	SP-46	12 - 16	98	IP-15	14 - 17	1.00E-03	6.16E+02	0.035	2.156E+01	0.43	0	9.96E-02	1.5	0.560493
1,4 DCB	SP-47/IP-16	2	SP-41	12 - 16	87	IP-16	14 - 17	1.00E-03	6.16E+02	0.035	2.156E+01	0.43	0	9.96E-02	1.5	1.052266
1,4 DCB	SP-48/JT-8	1.4	SP-48	12 - 16	240	JT-8	14 - 17	1.00E-03	6.16E+02	0.035	2.156E+01	0.43	0	9.96E-02	1.5	0.267013
1,4 DCB	SP-49/IP-17	0.3	SP-49	12 - 16	26	IP-17	14 - 17	1.00E-03	6.16E+02	0.035	2.156E+01	0.43	0	9.96E-02	1.5	0.528157
														1,4-DCB	**mean DF:**	**0.801154**
1,2,4 TCB	SP-41/IP-8	84	SP-41	12 - 16	250	IP-8	14 - 17	1.00E-03	1.66E+03	0.035	5.807E+01	0.43	0	5.82E-02	1.5	5.75819
1,2,4 TCB	SP-42/IP-2	6.3	SP-42	12 - 16	4700	IP-2	14 - 17	1.00E-03	1.66E+03	0.035	5.807E+01	0.43	0	5.82E-02	1.5	0.022972
1,2,4 TCB	SP-43/IP-1	6.6	SP-43	12 - 16	4000	IP-1	14 - 17	1.00E-03	1.66E+03	0.035	5.807E+01	0.43	0	5.82E-02	1.5	0.028277
1,2,4 TCB	SP-44/IP-5	98	SP-44	12 - 16	300	IP-5	11.5-14.5	1.00E-03	1.66E+03	0.035	5.807E+01	0.43	0	5.82E-02	1.5	5.598241
1,2,4 TCB	SP-45/IP-14	3.2	SP-45	12 - 16	2300	IP-14	14 - 17	1.00E-03	1.66E+03	0.035	5.807E+01	0.43	0	5.82E-02	1.5	0.023843
1,2,4 TCB	SP-46/IP-15	4.6	SP-46	12 - 16	950	IP-15	14 - 17	1.00E-03	1.66E+03	0.035	5.807E+01	0.43	0	5.82E-02	1.5	0.082981
1,2,4 TCB	SP-47/IP-16	360	SP-41	12 - 16	4600	IP-16	14 - 17	1.00E-03	1.66E+03	0.035	5.807E+01	0.43	0	5.82E-02	1.5	1.341193
1,2,4 TCB	SP-48/JT-8	33	SP-48	12 - 16	3900	JT-8	14 - 17	1.00E-03	1.66E+03	0.035	5.807E+01	0.43	0	5.82E-02	1.5	0.145009
1,2,4 TCB	SP-49/IP-17	2.5	SP-49	12 - 16	45	IP-17	14 - 17	1.00E-03	1.66E+03	0.035	5.807E+01	0.43	0	5.82E-02	1.5	0.952082
														1,2,4-TCB	**mean DF:**	**1.55031**

Table A-2: Input Parameters for RBCA ASTM Calculation, Jacobson Terminal Porperty, Seattle, WA

Scenario	Constituent	Hydraulic Gradient i (cm/cm)	Aquifer Hydraulic Conductivity K (cm/d)	Source Width Perpindicular to Groundwater Flow Direction in Vertical Plane S_d (cm)	Source Width Perpindicular to Groundwater Flow Direction in Horizontal Plane S_w (cm)	Distance along the Centerline of the Groundwater Plume Emanating from a Source X (cm)	First Order Degradation Constant λ (d^{-1})	Total Soil Porosity Θ_T (cm^3/cm^3_{soil})	Source Constituent Conc Cx (mg/L)
1. Degradation K= 0.0019, No daughters	124 TCB	0.02	90	300	1218	2436	0.0019	0.42	**1.4**
2. Degradation K= 0.0019, No daughters	14DCB	0.02	90	300	1218	2436	0.0019	0.42	**0.025**
3. Degradation K= SITE, No daughters	14DCB	0.02	90	300	1218	2436	0.0083	0.42	**0.3**
4. Degradation K= 0.0019, No daughters	CB	0.02	90	300	1218	2436	0.0019	0.42	**31**

NOTE: Spreadsheets are formatted per Equation R26 in 35 IAC 742 Appendix C. Cx is Output. Corrective Action Objectives calculated by varying Cs and matching Cx with IEPA Class I Groundwater Standard for benzene

Table A-3: Calculation Results (RBCA Steady-State Atenuation Equation), Jacobson Terminals Property, Seattle, WA

Scenario	Constituent	Source Constituent Concentration (Cx)	Steady State Attenuation Along the Centerline of a Dissolved Plume $C_{(x)}/C_{source}$ (R15) (cm^3_{water}/cm^3_{soil})	Longitudinal Dispersivity α_x (R16) (cm)	Transverse Dispersivity α_y (R17) (cm)	Vertical Dispersivity α_z (R18) (cm)	Specific Discharge U (R19) (cm/day)	Distance along the Centerline of the Groundwater Plume Emanating from a Source X (cm)	First Order Degradation Constant λ (d^{-1})
1. Degradation K= 0.0019, No daughters	124 TCB	**1.4**	0.195111131	243.6	81.2	12.18	4.285714286	2436	0.0019
2. Degradation K= 0.0019, No daughters	14DCB	**0.025**	0.195111131	243.6	81.2	12.18	4.285714286	2436	0.0019
3. Degradation K= SITE, No daughters	14DCB	**0.3**	0.015817698	243.6	81.2	12.18	4.285714286	2436	0.0083
4. Degradation K= 0.0019, No daughters	CB	**31**	0.195111131	243.6	81.2	12.18	4.285714286	2436	0.0019

NOTE: Spreadsheets are formatted per Equation R26 in 35 IAC 742 Appendix C. Cx is Output.
Corrective Action Objectives calculated by varying Cs and matching Cx with IEPA Class I Groundwater Standard for benzene

Table A-3: Calculation Results (RBCA Steady-State Atenuatio

Scenario	Constituent	Source Width Perpindicular to Groundwater Flow Direction in Horizontal Plane S_w (cm)	Source Width Perpindicular to Groundwater Flow Direction in Vertical Plane S_d (cm)	Aquifer Hydraulic Conductivity K (cm/d)	Hydraulic Gradient i (cm/cm)	Total Soil Porosity Θ_T (cm^3/cm^3_{soil})	**Predicted Constituent Conc Cx (mg/L)**	Tier 1 Groundwater Remediation Objective Class I (mg/L)
1. Degradation K= 0.0019, No daughters	124 TCB	1218	300	90	0.02	0.42	**0.2732**	0.277
2. Degradation K= 0.0019, No daughters	14DCB	1218	300	90	0.02	0.42	**0.0049**	0.0045
3. Degradation K= SITE, No daughters	14DCB	1218	300	90	0.02	0.42	0.0047	0.0045
4. Degradation K= 0.0019, No daughters	CB	1218	300	90	0.02	0.42	**6.0484**	5.03

APPENDIX B

RELEVANT SITE DATA PROVIDED BY HART CROWSER
AND
ASPECT CONSULTING

Table B-1 - Chemical Results for Groundwater Samples, Jacobson Terminals Facility, Seattle, Washington
(March 2003 results, provided by Hart Crowser)

Well Name	**BR-1**	**IP-4**	**IP-10**	**JT-6**	**JT-8**	**JT-9**
Sample Date	3/13/2003	3/13/2003	3/13/2003	3/13/2003	3/13/2003	3/13/2003
Depth of Screened Interval in Feet	19 to 22	11.5 to 14.5	14 to 17	14 to 19	14 to 17	12.5 to 17.5
Field Parameters						
Dissolved Oxygen in mg/L	1.9	1.2	1.2	0.8	1.4	1.1
ORP in mV	42	-97	-55	-72	-55	-86
Electrical Conductivity in mS	830	830	890	<100	860	150
pH	6.2	6.0	6.0	6.0	6.2	6.6
Temperature in degrees Celsius	13.5	14.0	14.0	13.5	14.5	12.9
Carbon Monoxide Concentration in ppm [H]	9	<1	16	<1	6	7
VOC Concentration in ppm [H]	17	<1	10	<1	<1	<1
Hydrogen Sulfide Concentration in ppm [H]	<1	<1	<1	<1	<1	<1
Methane Concentration in percent LEL [H]	>100	<1	34	<1	48	>100
Volatile Organic Compounds in ug/L (8260) - Detected Compounds Only						
Chlorinated VOCs						
Vinyl Chloride	0.2 U	52	140	0.2 U	0.2 U	7.4
cis-1,2-Dichloroethene	2,200	22	29	1 U	1 U	1 U
Trichloroethene	900	1 U	1 U	1 U	1 U	1 U
Tetrachloroethene	1,500	1 U	1 U	1 U	2.1	1 U
Chlorobenzene	1 U	65	260	1,100	220	1 U
1,3-Dichlorobenzene	1 U	1 U	41	36	82	1 U
1,4-Dichlorobenzene	1 U	2.6	83	25	450	1 U
1,2-Dichlorobenzene	1 U	1 U	7.7	1 U	560	1 U
1,2,4-Trichlorobenzene	1 U	9.2	9.2	1 U	9,100	1 U
1,2,3-Trichlorobenzene	1 U	1 U	1 U	1 U	650	1 U
Non-Chlorinated VOCs						
Benzene	1 U	1 U	1 U	22	1 U	44
Toluene	1 U	1 U	1 U	1.3	1 U	1 U
Ethylbenzene	1 U	1 U	1 U	1.9	1 U	1 U
Xylenes	1 U	1 U	1 U	2.6	1 U	1 U
1,2,4-Trimethylbenzene	1 U	1 U	1 U	2.6	1 U	1 U
Inorganic Compounds in mg/L						
Iron (Dissolved)	0.53	49.2	37.6	30.3	8.62	--
Manganese (Dissolved)	1.01	2.63	3.05	2.86	1.67	--
Chloride	17	14	19	25	21	--
Sulfate	13	38	18	9.7	12	--
Sulfide	0.05 U	0.05 U	0.05 U	0.05 U	0.07	--

Note

[H] Measured in well headspace with a Multirae gas detector. Meter broke down on sampling date: measurements collected on 4/2/03.

U Not detected at indicated reporting limit

-- Not analyzed

Table B-2 - Summary of Total Organic Carbon Data

Sample Location	Sample Depth in Feet	Sampling Date	Total Organic Carbon in Percent
IP-4 S1	2.5 to 4	8/22/2001	1.3
IP-4 S2	10 to 11.5	8/22/2001	2.9
IP-6 S1	10 to 11.5	8/22/2001	3.5
IP-9 S1	15 to 16.5	8/21/2001	0.13
IP-12 S1	10 to 11.5	8/22/2001	1.3
JT-9 S2	8 to 9.5	3/5/2002	5.1
JT-9 S3 Comp	15.5 to 18	3/5/2002	0.17

Table B-3 - Groundwater Elevation Data

Sheet 1 of 2

Well	TOC Elevation in Feet	Depth to Water in Feet																							
		1/22/2000	3/7/2000	4/4/2000	5/5/2000	6/7/2000	7/6/2000	8/2/2000	9/7/2000	10/11/2000	11/10/2000	12/7/2000	1/15/2001	6/6/2001	7/9/2001	8/6/2001	9/6/2001	10/11/2001	3/19/2002	4/15/2002	5/16/2002	6/4/2002	6/11/2002	10/1/2002	3/14/2003
Intermediate Water-Bearing Zone																									
IW-1I	20.76	7.78	7.45	8.02	8.46	8.57	8.79	9.01	9.31	9.56	9.14	9.06	--	8.55	8.57	8.87	8.85	9.15	--	7.66	8.28	9.4	8.48	9.48	7.43
IW-2I	20.64	8.09	7.82	8.38	8.84	8.97	9.21	9.4	9.67	9.94	9.6	9.48	9.11	8.92	8.96	9.25	9.25	9.55	--	8.19	8.61	9.81	8.89	9.85	7.82
IW-3I	19.24	9.06	8.85	9.36	9.68	9.7	9.74	9.93	9.96	10.1	9.75	9.8	9.25	9.33	8.88	9.38	9.71	9.44	--	9.07	8.44	9.1	8.97	9.84	8.27
IW-4I	19.64	5.9	5.67	6.16	6.66	6.83	7.25	7.39	7.6	8.11	7.82	7.65	7.21	7.15	7.04	7.36	7.41	7.67	--	6.34	4.72	6.73	6.8	7.55	5.88
IW-6I	19.04	10.09	9.78	9.86	10.18	9.96	10.29	10.36	10.67	10.98	10.6	10.5	10.59	10	10.17	10.55	10.45	10.74	9.74	9.95	9.95	9.93	10.09	11.12	9.75
IW-7I	19.84	8.63	8.36	8.79	9.19	9.29	9.44	9.73	10.11	10.21	9.49	9.33	8.84	8.84	8.91	9.41	9.22	9.61	7.72	8.15	8.48	8.83	8.92	10.08	8.31
IW-9I	19.18	11.37	11.04	11.12	11.14	11.15	11.29	11.43	11.74	11.93	11.8	11.82	11.79	11.1	11.18	11.44	11.15	11.2	10.95	10.55	10.42	10.6	10.61	11.8	11.01
MW-15I	19.92	7.9	7.62	7.84	8.1	8.14	8.32	8.53	8.8	9.11	8.73	8.69	--	--	8.18	8.53	8.5	8.75	--	7.63	7.85	--	8.02	9.19	4.32
MW-16I	20.04	10.97	10.57	10.36	10.65	10.65	10.79	10.95	--	11.46	11.33	11.39	--	n/a	11.27	11.26	11.18	11.08	--	10.74	10.35	--	--	--	--
MW-17I	20.43	5.6	5.35	5.86	6.34	6.47	6.65	6.87	7	7.2	6.72	6.67	--	6.52	6.41	6.69	6.73	n/a	--	5.76	6.1	--	6.32	7.3	--
MW-19I	20.15	6.65	6	6.14	6.5	6.55	7.68	6.79	7.05	6.88	6.56	6.38	--	6.75	6.49	6.58	6.6	6.73	--	5.13	5.43	--	5.88	6.81	6.56
MW-20I	21.89	NM	6.97	8.54	8.03	8.12	8.36	8.59	8.81	9.2	8.88	8.66	--	8.25	8.16	8.55	8.54	n/a	--	abandon	--	--	--	--	--
MW-21I	19.06	9.63	9.17	9.7	9.65	9.7	10.84	10.16	10.62	10.84	10.73	10.89	--	9.38	9.8	10.15	10.19	10.46	--	8.88	9.19	9.3	9.37	--	8.87
RW-8	16.74	NM	5.18	5.5	5.7	NM	6	7.28	Abandon	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Downgradient Shallow/Intermediate Water-Bearing Zone																									
HC-MW-3	16.94	7.7	7.45	7.48	7.3	7.26	7.38	7.57	7.88	8.08	8	8	--	--	--	--	--	--	7.64	6.57	7.23	7.33	7.3	--	--
JT-3	13.42	6.5	5.93	5.63	5.39	5.3	5.95	5.7	6.11	6.3	N/A	6.65	6.62	5.48	5.6	5.82	5.35	5.85	5.64	5.54	4.81	4.92	4.95	6.49	5.81
JT-4	13.35	5.52	4.84	4.33	4	4.02	4.15	4.32	4.83	5.05	5.32	5.58	--	3.94	4.16	4.33	4.52	4.96	4.8	n/a	--	3.99	4	5.32	4.56
JT-6	12.75	5.3	3.15	4.05	3.71	3.74	3.85	4.06	4.48	4.75	4.99	5.3	5.41	3.72	3.9	4.14	4.17	4.74	4.56	3.97	3.56	3.68	3.67	5.2	4.46
JT-7	13.47	6.25	5.46	5.1	4.8	4.81	4.98	5.13	5.5	5.79	5.99	6.21	6.27	4.89	4.95	5.27	5.05	5.59	5.36	4.9	4.47	4.6	4.6	6.08	5.4
JT-8	13.31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.13	--	4.52	4.64	4.68	5.85	5.46
JT-9	13.22																							--	7.05
IG-1	19.68	6.55	5.65	6.23	6.78	6.92	7.12	7.42	7.71	8.08	7.79	7.59	--	7.13	n/a	7.41	7.44	n/a	--	n/a	6.47		6.83	7.98	--
IG-2	19.36	6.31	5.88	5.9	6.27	6.41	6.82	7.12	7.42	7.78	7.52	7.35	7.04	n/a	6.65	6.99	n/a	7.26	--	5.75	5.89	6.3	6.3	7.5	--
IG-3	19.38	8.1	NM	8.31	8.75	8.83	9.03	9.29	9.64	9.86	9.09	8.8	8.42	8.46	8.62	n/a	8.86	9.29	7.5	7.95	8.29	8.51	8.61	9.8	8.14
IG-4	19.19	8.16	7.74	8.16	8.57	8.63	8.8	9.12	9.46	9.65	8.9	8.63	8.3	8.26	8.36	8.86	n/a	n/a	7.23	7.8	8.06	8.3	--	9.59	--
BR-1	18.74	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11.13	10.9	11.03	11.02	11.98	11.85
BR-2	19.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11.58	11.39	11.58	11.49	12.17	12.1
Shallow Water-Bearing Zone																									
IW-2S	20.72	7.69	7.38	7.9	8.49	8.69	9	9.35	9.68	9.94	9.56	9.49	--	8.77	8.77	9.16	9.17	9.52	--	7.72	8.32	8.58	8.68	9.9	7.39
IW-3S	19.32	8.97	8.78	9.37	9.7	9.75	9.85	10.03	10.15	10.3	9.97	9.96	9.72	9.51	9.5	9.75	9.7	9.89	--	8.93	9.43	9.56	9.6	10.27	8.73
IW-4S	19.82	5.87	5.6	6.19	6.79	6.95	7.21	7.6	7.8	8.06	7.9	7.73	7.28	7.21	7.13	7.48	7.5	7.81	--	6.91	6.3	6.82	6.88	8.03	5.85
IW-5S	18.48	7.85	6.72	7.11	7.39	7.54	7.67	7.92	9.12	8.41	9.05	8.43	7.9	7.98	7.79	8.12	8.09	8.17	--	6.8	8.61	7.73	7.73	8.35	7.93
IW-6S	19.08	9.9	9.55	10.08	9.96	10.17	10.18	10.8	10.9	10.88	10.73	10.61	10.31	10.15	10.02	10.4	10.3	10.6	10.25	9.79	9.81	10.06	9.97	10.99	9.83
IW-7S	19.36	7.98	7.68	8.13	8.64	8.71	8.92	9.19	9.5	9.71	8.79	8.49	8.03	8.15	8.23	8.75	8.5	8.96	7.48	6.5	7.55	8.1	8.26	9.44	7.88
MW-1S	22.8	6.11	5.68	6.15	6.73	6.78	6.96	7.19	7.43	7.63	7.3	7.1	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	21.96	7.28	7.08	6.69	7.86	7.89	8.23	8.46	8.78	8.97	8.53	8.6	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-11S	20.31	7.57	7.45	7.43	7.58	7.71	7.81	7.95	8.18	8.44	8.44	8.38	--	7.87	7.74	7.89	7.83	8	--	--	6.4	--	--	7.63	--
MW-15S	20.01	5.84	5.7	5.63	6.14	6.21	6.36	6.58	6.77	5.99	4.52	5.64	--	--	6.06	6.35	6.18	6.27	--	4.88	5.7	--	5.85	6.6	5.83
MW-18S	22.08	4.72	9.4	5.09	5.45	5.53	5.7	5.92	6.1	6.29	5.95	5.78	--	5.43	5.47	n/a	5.7	5.98	--	n/a	5.09	--	5.33	6.15	4.41
TT-1	21.54	6.01	5.69	5.72	6.42	6.44	6.73	6.97	7.12	7.19	7.02	6.88	--	--	--	--	--	--	--	--	--	--	--	--	--
TT-2	21.36	5.71	5.43	5.8	6.23	6.24	6.48	6.45	6.79	6.86	6.64	6.6	--	--	--	--	--	--	--	--	--	--	--	--	--
TT-3	23.16	7.59	7.32	7.67	8.09	8.1	8.45	8.6	8.96	9.8	8.83	8.75	--	--	--	--	--	--	--	--	--	--	--	--	--
TT-MW-7	22.88	5.51	5.24	5.83	6.27	6.31	6.73	7.03	7.42	6.43	7	6.82	--	--	--	--	--	--	--	--	--	--	--	--	--
Injection Points																									
IP-1	13.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.63	--	4.87	5	5.02	5.9	5.76
IP-2	13.37	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.37	--	4.65	4.82	4.82	6.01	5.64
IP-3	13.62	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.6	--	4.8	4.98	4.97	--	--
IP-4	14.86	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.73	--	6.11	6.3	6.3	7.62	6.97
IP-5	12.81	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.2	--	4.5	4.67	4.67	5.8	5.38
IP-6	13.26	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.14	--	4.42	4.7	4.69	5.81	5.35
IP-7	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.03	--	4.27	4.44	4.46	5.79	--
IP-8	13.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.22	--	4.42	4.6	4.59	--	5.45
IP-9	13.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.45	--	4.62	4.78	4.78	6.15	5.62
IP-10	13.12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.45	--	4.81	5.03	5.03	6.28	6.07
IP-11	12.96	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.63	--	5	5.2	5.23	6.23	6.41
IP-12	13.46	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.32	--	--	4.77	4.79	6.16	5.49
IP-13	13.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.33	--	4.66	4.85	4.85	6.17	5.63
IP-14	13.43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.47	--	4.62	4.77	4.83	6.2	5.62
IP-15	13.38	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.46	--	4.68	4.79	4.81	5.98	5.61
IP-16	13.06	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.15	--	4.3	4.5	4.48	5.78	5.28
IP-17	13.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.2	--	4.45	4.12	4.5	5.76	5.3

Elevation in Feet - City of Seattle Datum. Corps of Engineers datum = 12.98 + City of Seattle Datum

Corps Water Elevation varies from 20 to 22 COE = 7.02 to 9.02 CSD

red indicates elevation inconsistent with well history

Well	TOC Elevation in Feet	Elevation in Feet																							
		1/22/2000	3/7/2000	4/4/2000	5/1/2000	6/7/2000	7/6/2000	8/2/2000	9/7/2000	10/11/2000	11/10/2000	12/7/2000	1/15/2001	6/6/2001	7/9/2001	8/6/2001	9/6/2001	10/11/2001	3/19/2002	4/15/2002	5/16/2002	6/4/2002	6/11/2002	10/1/2002	3/14/2003
Intermediate Water-Bearing Zone																									
IW-1I	20.76	12.98	13.31	12.74	12.3	12.19	11.97	11.75	11.45	11.2	11.62	11.7	--	12.21	12.19	11.89	11.91	11.61	--	13.1	12.48	11.36	12.28	11.28	13.33
IW-2I	20.64	12.55	12.82	12.26	11.8	11.67	11.43	11.24	10.97	10.7	11.04	11.16	11.53	11.72	11.68	11.39	11.39	11.09	--	12.45	12.03	10.83	11.75	10.79	12.82
IW-3I	19.24	10.18	10.39	9.88	9.56	9.54	9.5	9.31	9.28	9.14	9.49	9.44	9.99	9.91	10.36	9.86	9.53	9.8	--	10.17	10.8	10.14	10.27	9.4	10.97
IW-4I	19.64	13.74	13.97	13.48	12.98	12.81	12.39	12.25	12.04	11.53	11.82	11.99	12.43	12.49	12.6	12.28	12.23	11.97	--	13.3	14.92	12.91	12.84	12.09	13.76
IW-6I	19.04	8.95	9.26	9.18	8.86	9.08	8.75	8.68	8.37	8.06	8.44	8.54	8.45	9.04	8.87	8.49	8.59	8.3	9.3	9.09	9.09	9.11	8.95	7.92	9.29
IW-7I	19.84	11.21	11.48	11.05	10.65	10.55	10.4	10.11	9.73	9.63	10.35	10.51	11	11	10.93	10.43	10.62	10.23	12.12	11.69	11.36	11.01	10.92	9.76	11.53
IW-9I	19.18	7.81	8.14	8.06	8.04	8.03	7.89	7.75	7.44	7.25	7.38	7.36	7.39	8.08	8	7.74	8.03	7.98	8.23	8.63	8.76	8.58	8.57	7.38	8.17
MW-15I	19.92	12.02	12.3	12.08	11.82	11.78	11.6	11.39	11.12	10.81	11.19	11.23	--	--	11.74	11.39	11.42	11.17	--	12.29	12.07	--	11.9	10.73	15.6
MW-16I	20.04	9.07	9.47	9.68	9.39	9.39	9.25	9.09	--	8.58	8.71	8.65	--	--	8.77	8.78	8.86	8.96	--	9.3	9.69	--	--	--	--
MW-17I	20.43	14.83	15.08	14.57	14.09	13.96	13.78	13.56	13.43	13.23	13.71	13.76	--	13.91	14.02	13.74	13.7	--	--	14.67	14.33	--	14.11	13.13	--
MW-19I	20.15	13.5	14.15	14.01	13.65	13.6	12.47	13.36	13.1	13.27	13.59	13.77	--	13.4	13.66	13.57	13.55	13.42	--	15.02	14.72	--	14.27	13.34	13.59
MW-20I	21.89	--	14.92	13.35	13.86	13.77	13.53	13.3	13.08	12.69	13.01	13.23	--	13.64	13.73	13.34	13.35	--	--	--	--	--	--	--	--
MW-21I	19.06	9.43	9.89	9.36	9.41	9.36	8.22	8.9	8.44	8.22	8.33	8.17	--	9.68	9.26	8.91	8.87	8.6	--	10.18	9.87	9.76	9.69	--	10.19
RW-8	16.74	--	11.56	11.24	11.04	--	10.74	9.46	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Downgradient Shallow/Intermediate Water-Bearing Zone																									
HC-MW-3	16.94	9.24	9.49	9.46	9.64	9.68	9.56	9.37	9.06	8.86	8.94	8.94	--	--	--	--	--	--	9.3	10.37	9.71	9.61	9.64	--	--
JT-3	13.42	6.92	7.49	7.79	8.03	8.12	7.47	7.72	7.31	7.12	--	--	--	7.94	7.82	7.6	8.07	7.57	7.78	7.88	8.61	8.5	8.47	6.93	7.61
JT-4	13.35	7.83	8.51	9.02	9.35	9.33	9.2	9.03	8.52	8.3	8.03	7.77	--	9.41	9.19	9.02	8.83	8.39	8.55	--	--	9.36	9.35	8.03	8.79
JT-6	12.75	7.45	9.6	8.7	9.04	9.01	8.9	8.69	8.27	8	7.76	7.45	7.34	9.03	8.85	8.61	8.58	8.01	8.19	8.78	9.19	9.07	9.08	7.55	8.29
JT-7	13.47	7.22	8.01	8.37	8.67	8.66	8.49	8.34	7.97	7.68	7.48	7.26	7.2	8.58	8.52	8.2	8.42	7.88	8.11	8.57	9	8.87	8.87	7.39	8.07
JT-8	13.31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.18	--	8.79	8.67	8.63	7.46	7.85
JT-9	13.22	--	--																--	--	--	--	--	--	6.17
IG-1	19.68	13.13	14.03	13.45	12.9	12.76	12.56	12.26	11.97	11.6	11.89	12.09	--	12.55	--	12.27	12.24	--	--	--	13.21	19.68	12.85	11.7	--
IG-2	19.36	13.05	13.48	13.46	13.09	12.95	12.54	12.24	11.94	11.58	11.84	12.01	12.32	--	12.71	12.37	--	12.1	--	13.61	13.47	13.06	13.06	11.86	--
IG-3	19.38	11.28	--	11.07	10.63	10.55	10.35	10.09	9.74	9.52	10.29	10.58	10.96	10.92	10.76	--	10.52	10.09	11.88	11.43	11.09	10.87	10.77	9.58	11.24
IG-4	19.19	11.03	11.45	11.03	10.62	10.56	10.39	10.07	9.73	9.54	10.29	10.56	10.89	10.93	10.83	10.33	--	--	--	11.39	11.13	10.89	--	9.6	--
BR-1	18.74	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.61	7.84	7.71	7.72	6.76	6.89
BR-2	19.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.82	8.01	7.82	7.91	7.23	7.3
Shallow Water-Bearing Zone																									
IW-2S	20.72	13.03	13.34	12.82	12.23	12.03	11.72	11.37	11.04	10.78	11.16	11.23	NM	11.95	11.95	11.56	11.55	11.2	--	13	12.4	12.14	12.04	10.82	13.33
IW-3S	19.32	10.35	10.54	9.95	9.62	9.57	9.47	9.29	9.17	9.02	9.35	9.36	9.6	9.81	9.82	9.57	9.62	9.43	--	10.39	9.89	9.76	9.72	9.05	10.59
IW-4S	19.82	13.95	14.22	13.63	13.03	12.87	12.61	12.22	12.02	11.76	11.92	12.09	12.54	12.61	12.69	12.34	12.32	12.01	--	12.91	13.52	13	12.94	11.79	13.97
IW-5S	18.48	10.63	11.76	11.37	11.09	10.94	10.81	10.56	9.36	10.07	9.43	10.05	10.58	10.5	10.69	10.36	10.39	10.31	--	11.68	9.87	10.75	10.75	10.13	10.55
IW-6S	19.08	9.18	9.53	9	9.12	8.91	8.9	8.28	8.18	8.2	8.35	8.47	8.77	8.93	9.06	8.68	8.78	8.48	8.83	9.29	9.27	9.02	9.11	8.09	9.25
IW-7S	19.36	11.38	11.68	11.23	10.72	10.65	10.44	10.17	9.86	9.65	10.57	10.87	11.33	11.21	11.13	10.61	10.86	10.4	11.88	12.86	11.81	11.26	11.1	9.92	11.48
MW-1S	22.8	16.69	17.12	16.65	16.07	16.02	15.84	15.61	15.37	15.17	15.5	15.7	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	21.96	14.68	14.88	15.27	14.1	14.07	13.73	13.5	13.18	12.99	13.43	13.36	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-11S	20.31	12.74	12.86	12.88	12.73	12.6	12.5	12.36	12.13	11.87	11.87	11.93	--	12.44	12.57	12.42	12.48	12.31	--	--	13.91	--	--	12.68	--
MW-15S	20.01	14.17	14.31	14.38	13.87	13.8	13.65	13.43	13.24	14.02	15.49	14.37	--	--	13.95	13.66	13.83	13.74	--	15.13	14.31	--	14.16	13.41	14.18
MW-18S	22.08	17.36	12.68	16.99	16.63	16.55	16.38	16.16	15.98	15.79	16.13	16.3	--	16.65	16.61	--	16.38	16.1	--	--	16.99	--	16.75	15.93	17.67
TT-1	21.54	15.53	15.85	15.82	15.12	15.1	14.81	14.57	14.42	14.35	14.52	14.66	--	--	--	--	--	--	--	--	--	--	--	--	--
TT-2	21.36	15.65	15.93	15.56	15.13	15.12	14.88	14.91	14.57	14.5	14.72	14.76	--	--	--	--	--	--	--	--	--	--	--	--	--
TT-3	23.16	15.57	15.84	15.49	15.07	15.06	14.71	14.56	14.2	13.36	14.33	14.41	--	--	--	--	--	--	--	--	--	--	--	--	--
TT-MW-7	22.88	17.37	17.64	17.05	16.61	16.57	16.15	15.85	15.46	16.45	15.88	16.06	--	--	--	--	--	--	--	--	--	--	--	--	--
Injection Points																									
IP-1	13.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.27	--	9.03	8.9	8.88	8	8.14
IP-2	13.37	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8	--	8.72	8.55	8.55	7.36	7.73
IP-3	13.62	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.02	--	8.82	8.64	8.65	--	--
IP-4	14.86	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.13	--	8.75	8.56	8.56	7.24	7.89
IP-5	12.81	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.61	--	8.31	8.14	8.14	7.01	7.43
IP-6	13.26	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.12	--	8.84	8.56	8.57	7.45	7.91
IP-7	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.97	--	8.73	8.56	8.54	7.21	--
IP-8	13.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.8	--	8.6	8.42	8.43	--	7.57
IP-9	13.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.83	--	8.66	8.5	8.5	7.13	7.66
IP-10	13.12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.67	--	8.31	8.09	8.09	6.84	7.05
IP-11	12.96	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.33	--	7.96	7.76	7.73	6.73	6.55
IP-12	13.46	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.14	--	--	8.69	8.67	7.3	7.97
IP-13	13.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.97	--	8.64	8.45	8.45	7.13	7.67
IP-14	13.43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.96	--	8.81	8.66	8.6	7.23	7.81
IP-15	13.38	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.92	--	8.7	8.59	8.57	7.4	7.77
IP-16	13.06	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.91	--	8.76	8.56	8.58	7.28	7.78
IP-17	13.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.9	--	8.65	8.98	8.6	7.34	7.8

Table B-4 - Estimated Soil Properties

Parameter	Value	Error (+/-)	Units	Basis
water content	22	3	percent	Laboratory analysis of 3 samples
wet bulk density	1.9	0.1	Mg/m3	Typical for loose to medium dense silty sands
dry bulk density	1.5	0.1	Mg/m3	Calculated from wet bulk density and water content
porosity	0.42	0.05		Calculated based on solid density of 2.65 Mg/m3

Note: porosity listed is total porosity. Effective porosity will be somewhat lower, likely 0.3 to 0.35.

Table B-5 - Chemical Results for Groundwater Samples

Well Name	**JT-3**	**JT-6**	**JT-7**
Sample Date	5/1/2003	5/1/2003	5/1/2003
reened Interval in Feet	11.5 to 16.5	14 to 19	14 to 19
Field Parameters			
solved Oxygen in mg/L	1.7	1.9	1.3
ical Conductivity in mS	200	260	340
pH	6.9	6.9	6.7
ure in degrees Celsius	12.9	13.4	14.3
Volatile Organic			
Chlorinated VOCs			
Vinyl Chlor	0.2 U	0.2 U	25
Chlorobenz	44	740	113
1,3-Dichlor	1 U	15	33
1,4-Dichlor	1 U	12	40
Non-Chlorinated VOCs			
Benzene	14	20	1 U
Ethylbenze	1 U	1.4	1 U
1,2,4-Trim	1 U	1.7	1 U
Naphthale	1 U	63	1 U

Note

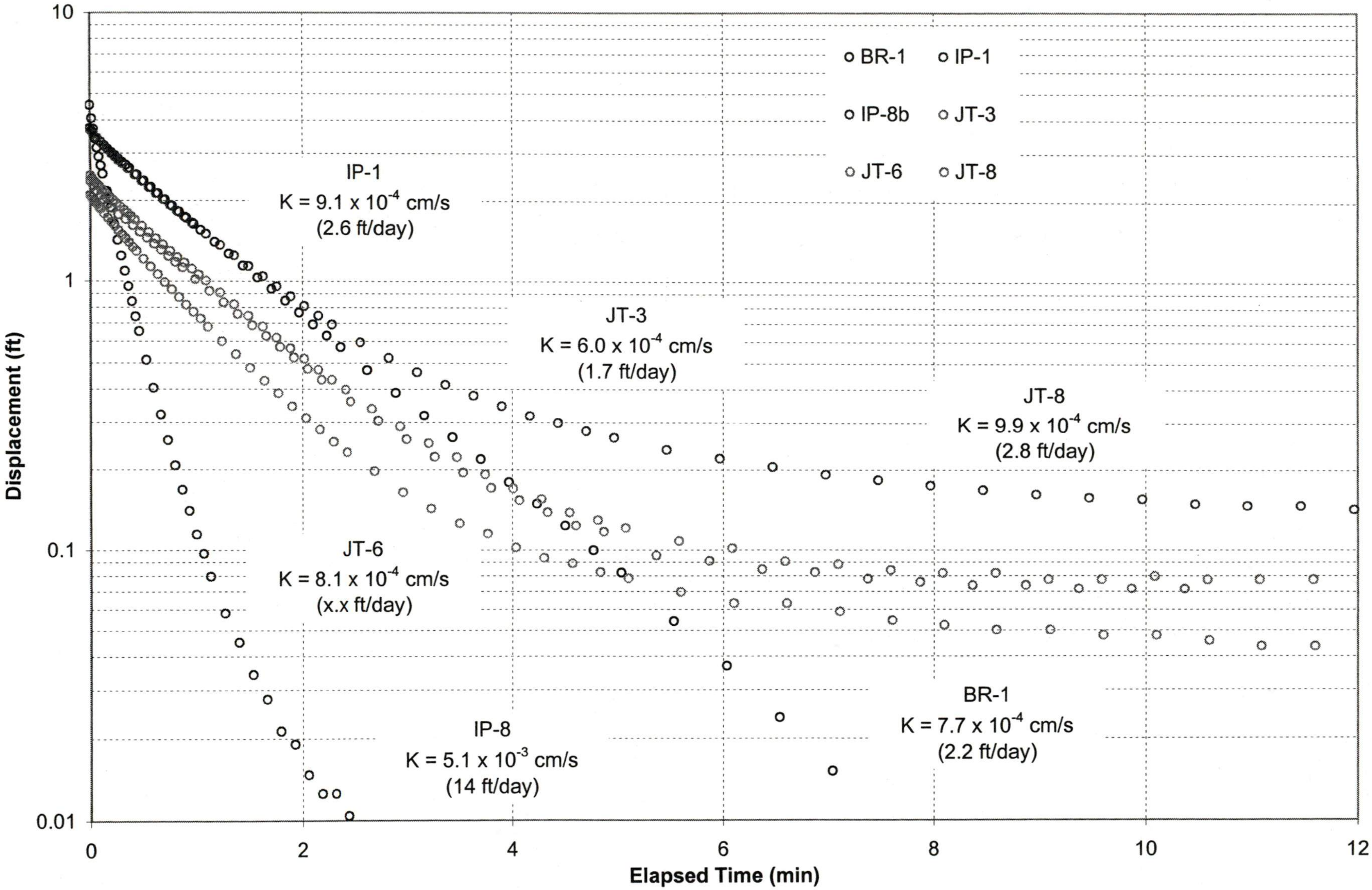
U Not detected at indicated reporting limit

Table B-6 - Chemical Results for Groundwater Samples

Well Name	**JT-11**
Sample Date	6/5/2003
Depth of Screened Interval in Feet	16.5 to 19
Field Parameters	
Dissolved Oxygen in mg/L	0.5
Electrical Conductivity in mS	670
pH	7.2
Temperature in degrees Celsius	15.2
Volatile Organic Compounds in ug/L (8260) - Detected Compounds Only	
Chlorinated VOCs	
Vinyl Chloride	38
cis-1,2-Dichloroethene	57
Chlorobenzene	360
1,3-Dichlorobenzene	90
1,4-Dichlorobenzene	50
1,2-Dichlorobenzene	4.8
Non-Chlorinated VOCs	
Benzene	16

Table B-7 - Chemical Results for Soil Samples

Well Name	**JT-11**
Sample Date	6/4/2003
Depth of Sample Interval in Feet	16.5 to 18
Description Medium dense, wet, gray, slightly silty fine-to-medium SAND	
Volatile Organic Compounds in ug/L (8260) - Detected Compounds Only	
Chlorinated VOCs	
1,3-Dichlorobenzene	400
1,4-Dichlorobenzene	190



Aspect consulting
IN-DEPTH PERSPECTIVE

Slug Test Analysis
(Bouwer and Rice)

Figure xx

Table 4 - Summary of Organic Concentrations Detected in Groundwater
Monitoring Wells and Injection Points

	Depth in		Concentration of Chlorinated Ethene Compounds in ug/L						Concentration of Chlorinated Benzene Compounds in ug/L						Concentration of Other Detected Volatile Organic Compounds in ug/L						Gamma PCB Concentration
Location	Feet	Date	Vinyl Chloride	1,1-DCE	trans-DCE	cis-DCE	TCE	PCE	CB	m-DCB	p-DCB	o-DCB	1,2,4-TCB	1,2,3-TCB	Chloromethane	1,1,2-TCA	Benzene	Toluene	Ethylbenzene	Xylenes	in mg/L - AAroclor1260
	Cleanup Level (1)		*2.92*	*1.93*	*32,800*	*na*	*55.6*	*4.15*	*5,030*	*na*	*4.86*	*4,200*	*227*	*na*	*133*	*25.3*	*43*	*48,500*	*6,910*	*na*	*0.00017*
BR-1	19 to 22	4/15/2002	59	1 U	1 U	1300	400	450	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	36	1.3	1 U	1 U	–
		6/4/2002	130	1 U	9.3	1000	420	400	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	27	1.2	3.7	1 U	–
BR-2	19 to 22	4/15/2002	41	8.9	1 U	660	620	1400	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	89	1 U	1 U	8.7	–
HC-MW-3	6 to 11	12/11/1997	1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	–	–	1 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.0052 U
		4/8/1998	5 U	1 U	1 U	1 U	1 U	1 U	–	–	–	–	–	–	–	1 U	1 U	1 U	1 U	1 U	–
		1/20/2000	5 U	5 U	5 U	5 U	1 U	1 U	5 U	1 U	1 U	1 U	–	–	5 U	1 U	1 U	1 U	1 U	1 U	–
		4/7/2000	5 U	5 U	5 U	5 U	1 U	1 U	5 U	1 U	1 U	1 U	–	–	5 U	1 U	1 U	1 U	1 U	1 U	–
		7/7/2000	5 U	5 U	5 U	5 U	1 U	16	5 U	1 U	1 U	1 U	–	–	5 U	1 U	1 U	1 U	1 U	1 U	–
		10/11/2000	5 U	5 U	5 U	5 U	1 U	1 U	5 U	1 U	1 U	1 U	–	–	5 U	1 U	1 U	1 U	1 U	1 U	–
IP-1	14 to 17	2/20/2001	5 U	5 U	5 U	5 U	1 U	1 U	5 U	140	1300	670	–	–	5 U	1 U	1 U	1 U	1 U	1 U	–
		4/10/2001	4.8	1 U	1 U	7	1 U	1 U	55	100	140	59	850	110	1 U	1 U	1 U	1 U	1 U	1 U	–
		7/10/2001	0.2 U	1 U	1 U	1 U	1 U	1 U	16	44	330	580	1200	1300	1 U	1 U	1 U	1 U	1 U	1 U	–
		10/22/2001	0.2 U	1 U	1 U	2.9	1 U	1 U	23	34	300	550	9000	850	1 U	1 U	3.4	1 U	1 U	1 U	–
		12/17/2001	5.5	1 U	1 U	11	1 U	1 U	16	17	200	230	11000	2500	14	1 U	4.7	1 U	1 U	1 U	–
		6/3/2002	0.2 U	1 U	1 U	1 U	1 U	1 U	6.9	11	160	310	4000	92	1 U	1 U	3.1	1 U	1 U	1 U	–
IP-2	14 to 17	2/20/2001	5 U	5 U	5 U	15	1 U	1 U	120	140	200	54	–	–	5 U	1 U	1 U	1 U	1 U	1 U	–
		4/10/2001	1 U	1 U	1 U	1 U	1 U	1 U	5	14	110	210	4000	590	1 U	1 U	1 U	1 U	1 U	1 U	–
		7/10/2001	16	1 U	1 U	9.3	1 U	1 U	280	200	280	120	2300	300	1 U	1 U	1 U	1 U	1 U	1 U	–
		10/22/2001	2.4	1 U	1 U	1.5	1 U	1 U	3.1	13	33	36	1100	91	1 U	1 U	1 U	1 U	1 U	1 U	–
		12/17/2001							37	190	190	100	1800	140	1 U		1.7	1 U	1 U	1 U	–
		6/3/2002	0.2 U	1 U	1 U	1 U	1 U	1 U	23	47	56	80	4700	270	1 U	1 U	1 U	1 U	1 U	1 U	–
IP-3	14 to 17	2/20/2001	5 U	5 U	5 U	5 U	1 U	1 U	88	19	30	1 U	–	–	5 U	1 U	1 U	1 U	1 U	1 U	–
		4/10/2001	1 U	1 U	1 U	1.2	1 U	1 U	47	7.7	9.4	1.4	19	3.1	1 U	1 U	1 U	1 U	1 U	1 U	–
		7/10/2001	6.7	1 U	1 U	4.7	1 U	1 U	200	23.0	27.0	2.6	16	2.4	1 U	1 U	1 U	1 U	1 U	1 U	–
		10/22/2001	0.2 U	1 U	1 U	1.1	1 U	1 U	11	1.4	2.1	1.0 U	12	1.0 U	1 U	1 U	1 U	1 U	1 U	1 U	–
		6/3/2002	0.2 U	1 U	1 U	1 U	1 U	1 U	1 U	1.0 U	1.0 U	1.0 U	10	1.0 U	1 U	1 U	1 U	1 U	1 U	1 U	–
IP-4	11.5 to 14.5	10/22/2001	81	1 U	1 U	28	1 U	1 U	97	1	4	1 U	4.4	1.0 U	1 U	1 U	14	1 U	1 U	1 U	–
		6/3/2002	74	1 U	1 U	25	1 U	1 U	50	1 U	2.5	1 U	1.0 U	1.0 U	1 U	1 U	1 U	1 U	1 U	1 U	–
IP-5	11.5 to 14.5	1/30/2002	59	1 U	1 U	43	1 U	1 U	75	120	220	24	550	37	1 U	1 U	3.8	1 U	1 U	1 U	–
		6/3/2002	17	1 U	1 U	1 U	1 U	1 U	250	23	62	1 U	300	25	1 U	1 U	11	1 U	1 U	1 U	–
IP-6	11.5 to 14.5	1/30/2002	410	1 U	1 U	170	1 U	1 U	15	4.6	6	1 U	190	21	3.1	1 U	1 U	1 U	1 U	1 U	–
		6/3/2002	650	1 U	1 U	62	1 U	1 U	600	28.0	53	7.2	16	1 U	1 U	1 U	4.7	1 U	1 U	1 U	–
IP-7	11.5 to 14.5	1/30/2002	370	1 U	1 U	120	1 U	1 U	140	170.0	150	75	7500	650	1 U	1 U	1 U	1 U	1 U	1 U	–
		6/3/2002	42	1 U	1 U	17	1 U	1 U	180	180.0	330	37	780	42	1 U	1 U	3.9	1 U	1 U	1 U	–
IP-8	14 to 17	10/22/2001	32	1 U	1 U	14	1 U	1 U	400	160	140	31	200	6.2	1 U	1 U	5	1	1 U	1 U	–
		12/17/2001	500	1 U	1 U	190	1 U	1 U	190	400	320	96	2600	13	4.3	1 U	1 U	1 U	1 U	1 U	–
		6/3/2002	23	1 U	1 U	21	2.2	1 U	120	350	450	1 U	250	16	1 U	1 U	1 U	1 U	1 U	1 U	–
IP-10	14 to 17	10/22/2001	340	1 U	1 U	96	1.3	1 U	370	32	55	7.3	88	6.6	1 U	1 U	11	1 U	1 U	1 U	–
		12/17/2001	300	1 U	1 U	120	4.7	1 U	31	6	15	1.1	13	1.0 U	25	1 U	1 U	1 U	1 U	1 U	–
		6/3/2002	300	1 U	1 U	62	1 U	1 U	230	27	54	6.0	65	5.5	1 U	1 U	11	1 U	1 U	1 U	–
		3/13/03							260	41	83	7.7	9.2	1 J							
IP-11	14 to 17	10/22/2001	68	1 U	1 U	3.4	1 U	1 U	440	160	100	7.4	3	1.0 U	1 U	1 U	17	1	1 U	1 U	–
		12/17/2001	160	1 U	1 U	31	1 U	1 U	210	74	82	6.1	62	4.9	32	1 U	1 U	1 U	1 U	1 U	–
		6/3/2002	55	1 U	1 U	1 U	1 U	1 U	150	82	66	12.0	4.4	1.0 U	1 U	1 U	1 U	1 U	1 U	1 U	–
IP-12	11.5 to 14.5	6/3/2002	32	1 U	1 U	5	1 U	1 U	250.0	12.0	24.0	3.0	4.9	1.0 U	1 U	1 U	4.7	1 U	1 U	1 U	–

Table 4 - Summary of Organic Concentrations Detected in Groundwater
Monitoring Wells and Injection Points

Location	Depth in Feet	Date	Concentration of Chlorinated Ethene Compounds in ug/L						Concentration of Chlorinated Benzene Compounds in ug/L						Concentration of Other Detected Volatile Organic Compounds in ug/L						Gamma PCB Concentration in mg/L - AAroclor1260
			Vinyl Chloride	1,1-DCE	trans-DCE	cis-DCE	TCE	PCE	CB	m-DCB	p-DCB	o-DCB	1,2,4-TCB	1,2,3-TCB	Chloromethane	1,1,2-TCA	Benzene	Toluene	Ethylbenzene	Xylenes	
	Cleanup Level (1)		*2.92*	*1.93*	*32,800*	*na*	*55.6*	*4.15*	*5,030*	*na*	*4.86*	*4,200*	*227*	*na*	*133*	*25.3*	*43*	*48,500*	*6,910*	*na*	*0.00017*
IP-13	11.5 to 14.5	1/30/2002	650	1 U	1 U	240	1 U	1 U	1 U	1 U	1 U	1 U	1800	37	5	1 U	1 U	1 U	1 U	1 U	–
		6/3/2002	380	1 U	1 U	120	1 U	1 U	170	8.6	15	1 U	23	1 U	1 U	1 U	3.8	1 U	1 U	1 U	–
IP-14	14 to 17	6/3/2002	0.2 U	1 U	1 U	1 U	1 U	1 U	5.9	90	100	25	2300	32	1 U	1 U	1 U	1 U	1 U	1 U	–
IP-15	14 to 17	6/3/2002	0.2 U	1 U	1 U	13	1 U	1 U	18.0	120	98	43	950	72	1 U	1 U	1 U	1 U	1 U	1 U	–
IP-16	14 to 17	6/3/2002	0.2 U	1 U	1 U	1 U	1 U	1 U	32.0	14	87	120	4600	450	1 U	1 U	4.5	1 U	1 U	1 U	–
IP-17	14 to 17	6/3/2002	0.2 U	1 U	1 U	1 U	1 U	1 U	38.0	68	26	10	45	1 U	1 U	1 U	1 U	1 U	1 U	1 U	–
JT-3	11.5 to 16.5	3/15/1996	12	4 U	4 U	10 U	4 U	10 U	4 U	5 U	5 U	5 U	5 U	–	–	–	–	–	–	–	–
		3/22/1999	88	5 U	5 U	5 U	1 U	1 U	140	77	44	10	–	–	5 U	1 U	41	1.2	1 U	1.7	–
		7/30/1999	6.4	5 U	5 U	5 U	1 U	1 U	74	25	19	3.2	–	–	5 U	1 U	61	1 U	1 U	1 U	–
		10/15/1999	5 U	5 U	5 U	5 U	1 U	1 U	–	15	8.7	1.4	–	–	5 U	1 U	29	1 U	1 U	1 U	–
		1/20/2000	5 U	5 U	5 U	5 U	1 U	1 U	130	34	25	2.8	–	–	5 U	1 U	47	1.3	1 U	1 U	–
		4/7/2000	5 U	5 U	5 U	5 U	1.5	1 U	100	25	16	2.8	–	–	5 U	1 U	1 U	1 U	1 U	1 U	–
		7/7/2000	5 U	5 U	1.7 J	5 U	1 U	1 U	56	12	10	2	–	–	5 U	1 U	1 U	1 U	1 U	1 U	–
		10/11/2000	5 U	5 U	5 U	5 U	1 U	1 U	45	1 U	1 U	1 U	–	–	5 U	1 U	32	1 U	1 U	1 U	–
		1/16/2001	5 U	5 U	5 U	5 U	1 U	1 U	84	24	19	3.1	–	–	5 U	1 U	33	1	1 U	1 U	–
		4/10/2001	1 U	1 U	1 U	1 U	1 U	1 U	50	6.9	5.6	1 U	1 U	1 U	1 U	1 U	27	1 U	1 U	1 U	0.4 U
		7/10/2001	5 U	5 U	5 U	5 U	1 U	1 U	85	1 U	1 U	1 U	–	–	5 U	1 U	30	1 U	1 U	1 U	–
		10/22/2001	5 U	5 U	5 U	5 U	1 U	1 U	43	1 U	1 U	1 U	–	–	5 U	1 U	55	1 U	1 U	1 U	–
		12/17/2001	0.2 U	1 U	1 U	1 U	1 U	1 U	100	2.1	3.1	1 U	1 U	1 U	1 U	1 U	26	1 U	1 U	1 U	0.017 U
		4/15/2002	5 U	5 U	5 U	5 U	1 U	5.9	81	7.4	1 U	1 U	–	–	5 U	1 U	22	1 U	1 U	1 U	–
		6/4/2002	0.2 U	1 U	1 U	1 U	1 U	1 U	64	2.6	2.7	1 U	1 U	1 U	1 U	1 U	24	1 U	1 U	1 U	1.5

Table 4 - Summary of Organic Concentrations Detected in Groundwater
Monitoring Wells and Injection Points

Location	Depth in Feet	Date	Concentration of Chlorinated Ethene Compounds in ug/L						Concentration of Chlorinated Benzene Compounds in ug/L						Concentration of Other Detected Volatile Organic Compounds in ug/L						Gamma PCB Concentration in mg/L - AAroclor1260		
			Vinyl Chloride	1,1-DCE	trans-DCE	cis-DCE	TCE	PCE	CB	m-DCB	p-DCB	o-DCB	1,2,4-TCB	1,2,3-TCB	Chloromethane	1,1,2-TCA	Benzene	Toluene	Ethylbenzene	Xylenes			
	Cleanup Level (1)		*2.92*	*1.93*	*32,800*	*na*	*55.6*	*4.15*	*5,030*	*na*	*4.86*	*4,200*	*227*	*na*	*133*	*25.3*	*43*	*48,500*	*6,910*	*na*		*0.00017*	
JT-5[3]	26 to 29	3/22/1999	5 U	5 U	5 U	5 U	1 U	5.3	5 U	1 U	1 U	1 U	–	–	5 U	1 U	1 U	1.8	1 U	1 U		–	
		7/30/1999	5 U	5 U	5 U	5 U	1 U	1 U	5 U	1 U	1 U	1 U	–	–	5 U	1 U	1 U	1 U	1 U	1 U		–	
		4/10/2001	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U		0.4 U	
JT-6	14 to 19	3/22/1999	390	5 U	7	140	2.2	1.3	300	570	360	47	–	–	5 U	1 U	8.8	1.2		2.5		–	
		6/17/1999	430	5 U	9.5	160	1.4	1.2	5 U	580	300	31	–	–	5 U	1 U	16	1.4	1 U	1		–	
		7/30/1999	400	5 U	11	160	1.5	1 U	410	400	270	24	–	–	5 U	1 U	20	1.1	1 U	1		–	
		10/15/1999	24	5 U	1 U	58	1 U	1 U	–	240	120	19	–	–	5 U	1 U	20	1 U	1 U	1 U		–	
		10/18/1999	41	5 U	1 U	61	1 U	1 U	–	250	130	9.2	–	–	5 U	1 U	24	1.7	1 U	1 U		–	
		1/21/2000	150	5 U	5 U	49	1 U	1 U	840	260	180	13	–	–	5 U	1 U	37	2.8	1 U	1 U		–	
		4/7/2000	230	5 U	6.4	84	1 U	3.1	610	270	170	17	–	–	5 U	1 U	29	2.8	1 U	3		–	
		7/7/2000	52	20 U	12	120	4 U	4 U	300	220	190	18	–	–	5 U	4 U	18	4 U	4 U	4 U		–	
		10/11/2000	78	5 U	5 U	65	1 U	1 U	550	330	250	1 U	–	–	5 U	41	29	1 U	1 U	1 U		–	
		1/16/2001	94	5 U	5 U	31	1 U	1 U	1100	230	190	18	–	–	5 U	1 U	26	2	1	5.9		–	
		4/10/2001	77	1 U	1 U	54	1 U	1 U	660	260	170	16	1 U	1 U	1 U	1 U	27	1 U	1 U	1 U		0.4 U	
		7/10/2001	20	5	5 U	25	4.8	62	480	220	260	19	–	–	5 U	1 U	18	2.4	1 U	1 U		–	
		7/17/2001	5 U	5 U	5 U	18	1 U	6.8	500	310	220	20	–	–	5 U	1 U	20	2.9	1 U	4.1		–	
		10/22/2001	8.6	5 U	5 U	2.2 J	1 U	1 U	550	130	140	10	–	–	5 U	1 U	36	1 U	1 U	6.9		–	
		12/17/2001	9.4	5 U	5 U	5 U	1 U	1 U	930	28	20	2.5	–	–	5 U	1 U	26	1.7	1 U	3.8		0.017 U	
		1/30/2002	5 U	5 U	5 U	5 U	1 U	1 U	1000	28	32	1 U	–	–	5 U	1 U	24	2.6	1 U	1 U		–	
		4/15/2002	5 U	5 U	5 U	5 U	1 U	1 U	720	55	40	1 U	–	–	5 U	1 U	18	1 U	1 U	1 U		–	
		6/4/2002	20	1 U	1 U	1 U	1 U	1 U	650	100	68	5.5	54	8.4	1 U	1 U	23	2	1 U	1 U		0.2	
JT-7	14 to 19	3/22/1999	64	5 U	5 U	7.2	1 U	1 U	160	190	180	16	–	–	5 U	1 U	2.6	4	1 U	2.7		–	
		7/30/1999	51	5 U	5 U	5 U	1	1 U	240	140	140	16	–	–	5 U	1 U	3.4	1 U	1 U	1.4		–	
		10/15/1999	7	5 U	5 U	3	1 U	1 U	–	110	93	6.8	–	–	5 U	1 U	2.7	2	1 U	1 U		–	
		10/18/1999	10	5 U	5 U	2.1	1 U	1 U	–	97	88	3.3	–	–	5 U	1 U	2.1	1 U	1 U	1 U		–	
		1/21/2000	69	5 U	5 U	6.5	1 U	1 U	140	150	150	9.1	–	–	5 U	1 U	2	1.6	1.3	1.9		–	
		4/7/2000	48	5 U	5 U	5 U	1 U	1 U	140	120	110	6.7	–	–	5 U	1 U	1 U	1 U	1 U	1 U		–	
		7/7/2000	14	10 U	10 U	6.7	2 U	2 U	200	140	200	10	–	–	5 U	2 U	4.6	2 U	2 U	2 U		–	
		10/11/2000	31	5 U	5 U	5 U	1 U	1 U	190	90	110	5.3	–	–	5 U	1 U	2.4	1 U	1 U	1 U		–	
		1/16/2001	5 U	5 U	5 U	5 U	1 U	1 U	26	20	22	1 U	–	–	5 U	1 U	1 U	1 U	1 U	1 U		–	
		4/10/2001	50	1 U	1 U	2.3	1 U	1 U	180	77	82	4.1	1 U	1 U	1 U	1 U	1.4	1 U	1 U	1 U		–	
		7/10/2001	45	5 U	5 U	16	1 U	9.6	240	98	130	7.8	–	–	5 U	1 U	1 U	1 U	1 U	1 U		–	
		10/22/2001	32	5 U	5 U	5 U	1 U	1 U	150	42	74	5.0	–	–	5 U	1 U	1 U	1 U	1 U	1 U		–	
		12/17/2001	30	1 U	1 U	1 U	1 U	1 U	170	86	91	4.7	2.8	1 U	15	1 U	2	1 U	1 U	1 U		–	
		4/15/2002	90	5 U	5 U	5 U	1 U	1 U	140	140	170	5.6	–	–	5 U	1 U	1 U	1.4	1.3	1 U		–	
		6/4/2002	37	1 U	1 U	1 U	1 U	1 U	150	73	82	3.7	85.0	17	1 U	1 U	1 U	1 U	1 U	1 U		–	
JT-8	14 to 17	1/11/2001	86	5 U	5 U	19	1 U	1 U	630	260	160	21	–	–	5 U	1 U	4.4	2	1 U	2.7		–	
		2/20/2001	5 U	5 U	5 U	5 U	1 U	1 U	530	210	200	1 U	–	–	5 U	1 U	1 U	1 U	1 U	1 U		–	
		4/10/2001	20	5.8	1 U	1 U	1 U	1 U	150	660	670	18	250	26	1 U	1 U	1 U	1 U	1 U	1 U		–	
		7/10/2001	42	1 U	1 U	8.7	1 U	1 U	370	210	210	67	1300	87	1 U	1 U	3.4	1 U	1 U	1 U		–	
		10/22/2001	0.2 U	1 U	1 U	1 U	1 U	1 U	46	82	150	120	1300	180	1 U	1 U	1 U	1 U	1 U	1 U		–	
		12/17/2001	0.2 U	1 U	1 U	1 U	1 U	1 U	53	110	340	290	4500	470	1 U	1 U	1 U	1 U	1 U	1 U		–	
		6/4/2002	11	1 U	1 U	1 U	1 U	1 U	260	79	240	220	3900	420	1 U	1 U	1 U	1 U	1 U	1 U		–	

Notes:

(1)	Cleanup level based on Cleanup Action Plan (Hart Crowser 1999) or, if not included, on MTCA Method B Surface Water Cleanup levels
J	Estimated value
U	Not detected at indicated detection limit
–	Not analyzed
CB	Chlorobenzene
m-DCB	m-Dichlorobenzene
p-DCB	p-Dichlorobenzene
o-DCB	o-Dichlorobenzene
1,2,3-TCB	1,2,3-Trichlorobenzene
1,2,4-TCB	1,2,4-Trichlorobenzene
1,2,4-TMB	1,2,4-Trimethylbenzene

Table 5 - Summary of Chemical Concentrations Detected in Soil

Location	Date	Distance from Closest Injection Point in Feet [a]	Sample Depth in Feet	PCB Concentration in mg/kg Aroclor 1260	Concentration of Chlorinated Aliphatic Compounds in ug/kg						Concentration of Chlorinated Benzenes in ug/kg						Concentration of Other Compounds in ug/kg
					Vinyl Chloride	1,1-DCE	trans-DCE	cis-DCE	TCE	PCE	CB	m-DCB	p-DCB	o-DCB	1,2,4-TCB	1,2,3-TCB	Naphthalene
March 2002 Railroad Monitoring Well Installation																	
BR-1	4/11/2002	–	21.5 to 23		50 U	50 U	50 U	380	20 U	330	50 U	50 U	50 U	50 U	50 U	50 U	50 U
BR-2	4/11/2002	–	22 to 23.5		50 U	50 U	50 U	470	620	960	50 U	50 U	50 U	50 U	50 U	50 U	50 U
June 2002 Confirmation Soil Sampling (closest previous sample results in italics)																	
SP-2	*5/22/2001*	–	*12 to 16*	*550*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*50 U*	*840*	*620*	*50 U*	*11,000*	*790*	50 U
SP-2B	*1/15/2002*	*3*	*12 to 16*	*410*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*50 U*	*50 U*	*50 U*	*50 U*	*200*	*300*	50 U
SP-41	6/5/2002	4	12 to 16	290	50 U	50 U	50 U	50 U	20 U	20 U	6,600	5,600	15,000	1,100	84,000	7,200	200
IP-2	*4/11/2001*	–	*Drill Cuttings*	*110*	–	–	–	–	–	–	*260*	*920*	*2,900*	*4700*	*560,000*	*13000*	*50 U*
SP-42	6/5/2002	3	8 to 12	690	50 U	50 U	50 U	1,500	130	20 U	5,000	5,600	14,000	820	14,000	7,800	710
SP-42	6/5/2002	3	12 to 16	2.4	50 U	50 U	50 U	50 U	20 U	20 U	610	970	2,500	130	6,300	180	180
IP-1	*2/20/2001*	–	*Drill Cuttings*	*360 J*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*50 U*	*660*	*2700*	*3200*	*230,000*	*17000*	50 U
IP-1B	*1/15/2002*	*6*	*8 to 12*	*0.2*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*950*	*280*	*790*	*100*	*420*	*50 U*	50 U
SP-43	6/5/2002	4	8 to 12	42	50 U	50 U	50 U	50 U	20 U	20 U	22,000	4,200	4,800	640	27,000	1,000	50 U
IP-1B	*1/15/2002*	*6*	*12 to 16*	*0.2*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*50*	*200*	*170*	*50 U*	*200*	*50 U*	50 U
SP-43	6/5/2002	4	12 to 16	0.2 U	50 U	50 U	50 U	50 U	20 U	20 U	390	700	850	180	6,600	50 U	50 U
SP-4	*5/23/2001*	–	*8 to 12*	*530*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*790*	*250*	*550*	*50 U*	*28,000*	*2,000*	50 U
SP-4B	*1/15/2002*	*6*	*8 to 12*	*210*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*330*	*2,000*	*2,600*	*11,000*	*1,500*	*270,000*	*12,000*	50 U
SP-44	6/5/2002	7	8 to 12	200	50 U	50 U	50 U	50 U	20 U	20 U	880	2,100	7,800	2,100	180,000	26,000	690
SP-44	6/5/2002	7	12 to 16	290	50 U	50 U	50 U	50 U	20 U	20 U	190	1,500	1,000	430	98,000	9,000	50 U
SP-45	6/5/2002	2	4 to 8	0.33	50 U	50 U	50 U	50 U	20 U	20 U	760	290	340	100	3,500	370	50 U
SP-6	*5/23/2001*	–	*8 to 12*	*0.2 U*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*170*	*50 U*	*150*	*50 U*	*50 U*	*50 U*	50 U
SP-45	6/5/2002	2	8 to 12	0.2 U	50 U	50 U	50 U	400	20 U	20 U	110	50 U	210	50 U	1,600	220	50 U
SP-6	*5/23/2001*	–	*12 to 16*	*25*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*50 U*	*930*	*860*	*180*	*45,000*	*2500*	50 U
SP-6B	*1/15/2002*	*7*	*12 to 16*	*800*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*210*	*1900*	*2000*	*500*	*130,000*	*5900*	50 U
SP-45	6/5/2002	2	12 to 16	0.2 U	50 U	50 U	50 U	50 U	20 U	20 U	50 U	940	550	88	3,200	290	50 U
SP-36	*1/29/2002*	–	*12 to 16*	*210*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*150*	*1,500*	*1,200*	*280*	*240,000*	*4500*	50 U
SP-46	6/5/2002	4	12 to 16	0.2 U	50 U	50 U	50 U	50 U	20 U	20 U	50 U	1,600	1,200	190	4,600	190	50 U
SP-47	6/5/2002	3	8 to 12	0.2 U	830	50 U	50 U	4,300	20 U	20 U	50 U	150	200	290	14,000	2,200	50 U
SP-38	*1/29/2002*	–	*13 to 16*	*880*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*420*	*13,000*	*11,000*	*3,200*	*310,000*	*2,400*	50 U
SP-47	6/5/2002	2	12 to 16	250	50 U	50 U	50 U	50 U	20 U	20 U	50 U	1,500	2,000	1,300	360,000	18,000	50 U
SP-48	6/5/2002	7	8 to 12	0.2 U	50 U	50 U	50 U	50 U	20 U	20 U	50 U	1,400	2,000	1,000	170,000	4,000	50 U
SP-38	*1/29/2002*	–	*13 to 16*	*880*	*50 U*	*50 U*	*50 U*	*50 U*	*20 U*	*20 U*	*420*	*13,000*	*11,000*	*3,200*	*310,000*	*2,400*	50 U
SP-48	6/5/2002	7	12 to 16	70	50 U	50 U	50 U	50 U	20 U	20 U	50 U	1,200	1,400	790	33,000	3,000	50 U
SP-49	6/5/2002	6	12 to 16	0.2 U	50 U	50 U	50 U	50 U	20 U	20 U	320	250	300	50 U	2,500	400	50 U

Notes:

J	Estimated value
U	Not detected at indicated detection limit
–	Not analyzed
CB	Chlorobenzene
m-DCB	m-Dichlorobenzene
p-DCB	p-Dichlorobenzene
o-DCB	o-Dichlorobenzene
1,2,3-TCB	1,2,3-Trichlorobenzene
1,2,4-TCB	1,2,4-Trichlorobenzene
1,2,4-TMB	1,2,4-Trimethylbenzene
[a]	At time of sampling
NI	No injection point installed nearby at time of sampling

APPENDIX C

MODELING WORKSHEETS, TABLES AND FIGURES

Text C-1

CALCULATION OF SEQUENTIAL DECAY RATES

Sequential biodegradation can be quantified w/ the following parameters (typical units):

C_{od} = initial daughter product concentration (µg/L)
$C_d(x)$ = daughter product concentration at any location (µg/L)
$C_d(\text{well})$ = daughter product concentration at a downgradient well (µg/L)
C_{op} = initial parent concentration (µg/L)
$C_p(x)$ = parent concentration at any location (µg/L)
$C_p(\text{well})$ = parent concentration at a downgradient well (µg/L)
MW_d = molecular weight of the daughter (g/mole)
MW_p = molecular weight of the parent (g/mole)
λ_p = apparent/actual biodegradation rate of parent (yr^{-1})
λ_d = actual biodegradation rate of daughter (yr^{-1})
α_x = dispersivity (property of soil and hydrogeology) (m)
v_x = average groundwater velocity (m/s)

One of the two biodegradation rates can be quantified immediately:

$$\lambda_p = \frac{v_x}{4\alpha_x}\left[(1-2\alpha_x m_p)^2 - 1\right]; \quad \text{where } m_p = \frac{\ln C_p(well) - \ln C_{op}}{x}$$

This is the Buscheck and Alcantar method, listed in ASTM E1943-98. The method is based upon the solution to the general one-dimensional transport equation with first-order decay of the contaminant (Bear 1979). Assumptions are that the contaminant concentration at the source (C_{op}, C_{od}) is constant, and steady state conditions.

The actual biodegradation rate of the daughter cannot be solved analytically using the general one-dimensional transport equation, as at each point in space some parent is transformed to daughter, and some daughter is further degraded. Further, both parent and daughter undergo dispersion at each point in space. The process of sequential transformation can be approximated numerically, by solving the Bear 1979 equation at successive points along the flowpath:

$$C_p(x'+\Delta x) = C_p(x')\exp\left(\frac{x'}{2\alpha_x}\left[1-\sqrt{1+\frac{4\lambda_p\alpha_x}{v_x}}\right]\right)$$

$$C_d(x'+\Delta x) = C_d(x')\exp\left(\frac{x'}{2\alpha_x}\left[1-\sqrt{1+\frac{4\lambda_d\alpha_x}{v_x}}\right]\right) + \frac{MW_d}{MW_p}\left[C_p(x') - C_p(x')\exp\left(-\frac{\lambda_p x'}{v_x}\right)\right]$$

Beginning with the initial concentrations of the parent and daughter products, and with known values for λ_p and v_x, the above equations can be solved sequentially until $x' + \Delta x$ = well distance. At this point only one value of λ_d provides for $C_d(x' + \Delta x) = C_d(\text{well})$. A utility such as GoalSeek in MS Excel can solve for this λ_d.

REFERENCES:

ASTM 1998. Standard Guide for Remediation of Ground Water by Natural Attenuation at Petroleum Release Sites ASTM Designation E 1943-98.

Bear, J. 1979. Hydraulics of Groundwater, McGraw-Hill, New York, NY.

Table C-1: Best Estimate Steady State Concentrations at Source Edge and POC (Based on monitoring data from before probable effects from Interim Action)

Station	CB	1,4-DCB	1,2,4-TCB
JT-8	150	670	250
JT-6	1100	25	1

Table C-2: Intermediate Well Scenarios, Biodegradation Evaluation

Intermediate Well Scenarios	General TCB/DCB Degradation	TCB Degradation & Dispersion	DCB Degradation & Dispersion	TCB Dispersion Only	DCB Dispersion Only	Dispersivity (m)	TCB Degradation Rate λ (1/yr)	DCB Degradation Rate λ (1/yr)
No Intermediate Well 1	Concurrent	Entire Flowpath	Entire Flowpath	None	None	0.2X	7.63	5.50
Scenario A	Concurrent	First 40 ft	First 40 ft	Second 40 ft	Second 40 ft	0.2X	22.72	13.14
Scenario B	Concurrent	First 20 ft	First 20 ft	Second 60 ft	Second 60 ft	0.2X	97.93	37.36
No Intermediate Well 2	Concurrent	Entire Flowpath	Entire Flowpath	None	None	0.1X	5.61	3.88
Scenario C	Concurrent	First 40 ft	First 40 ft	Second 40 ft	Second 40 ft	0.1X	14.90	9.68
Scenario D	Concurrent	First 20 ft	First 20 ft	Second 60 ft	Second 60 ft	0.1X	57.06	27.00
Scenario E	Disparate	First 40 ft	Entire Flowpath	Second 40 ft	None	0.1X	14.90	3.61
Scenario F	Disparate	First 20 ft	Entire Flowpath	Second 40 ft	None	0.1X	57.06	3.61

Figure C-1: Chlorinated Benzene Contamination

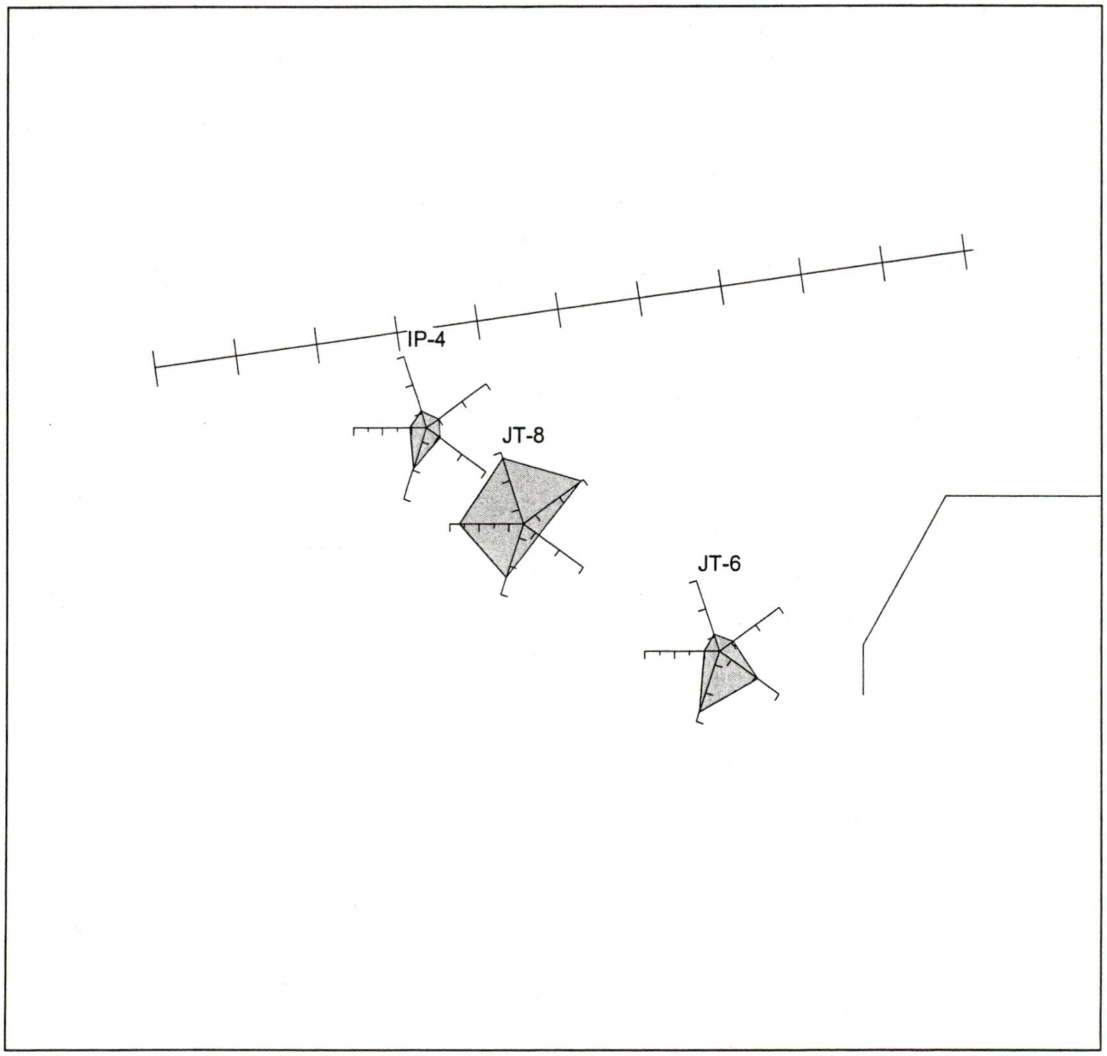


Figure C-1 (con.): IP-4

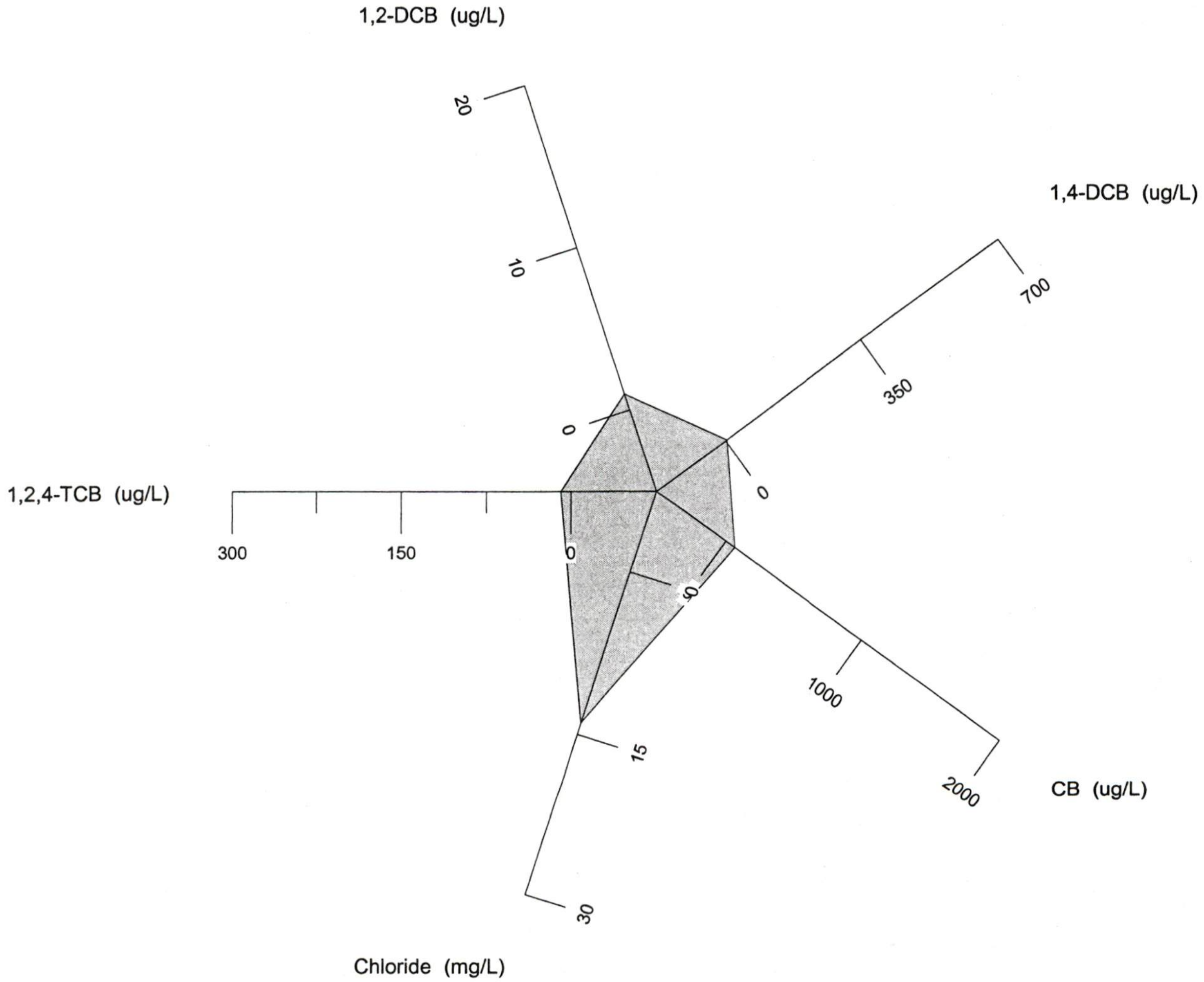


Figure C-1 (con.): JT-8

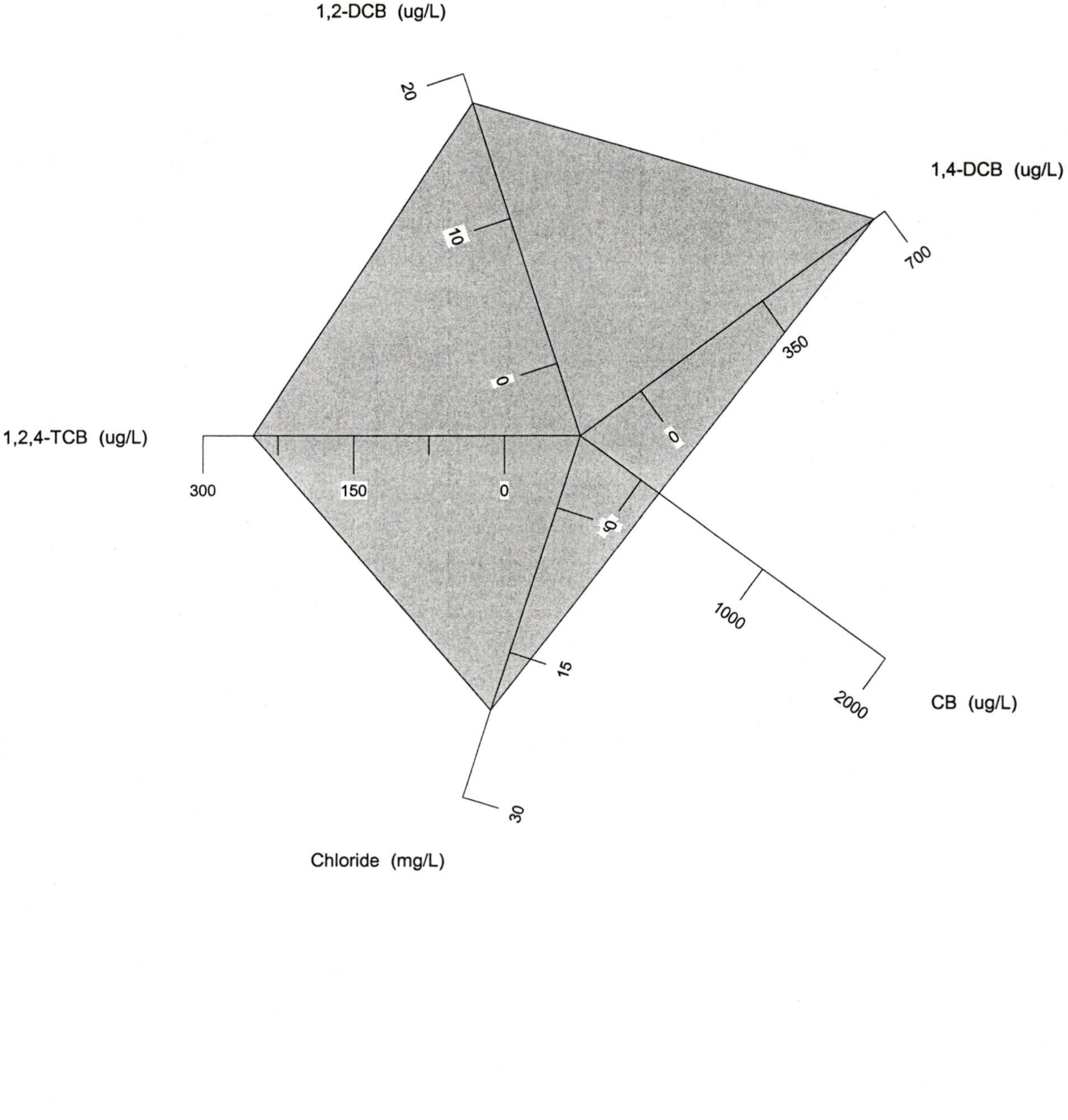


Figure C-1 (con.): JT-6

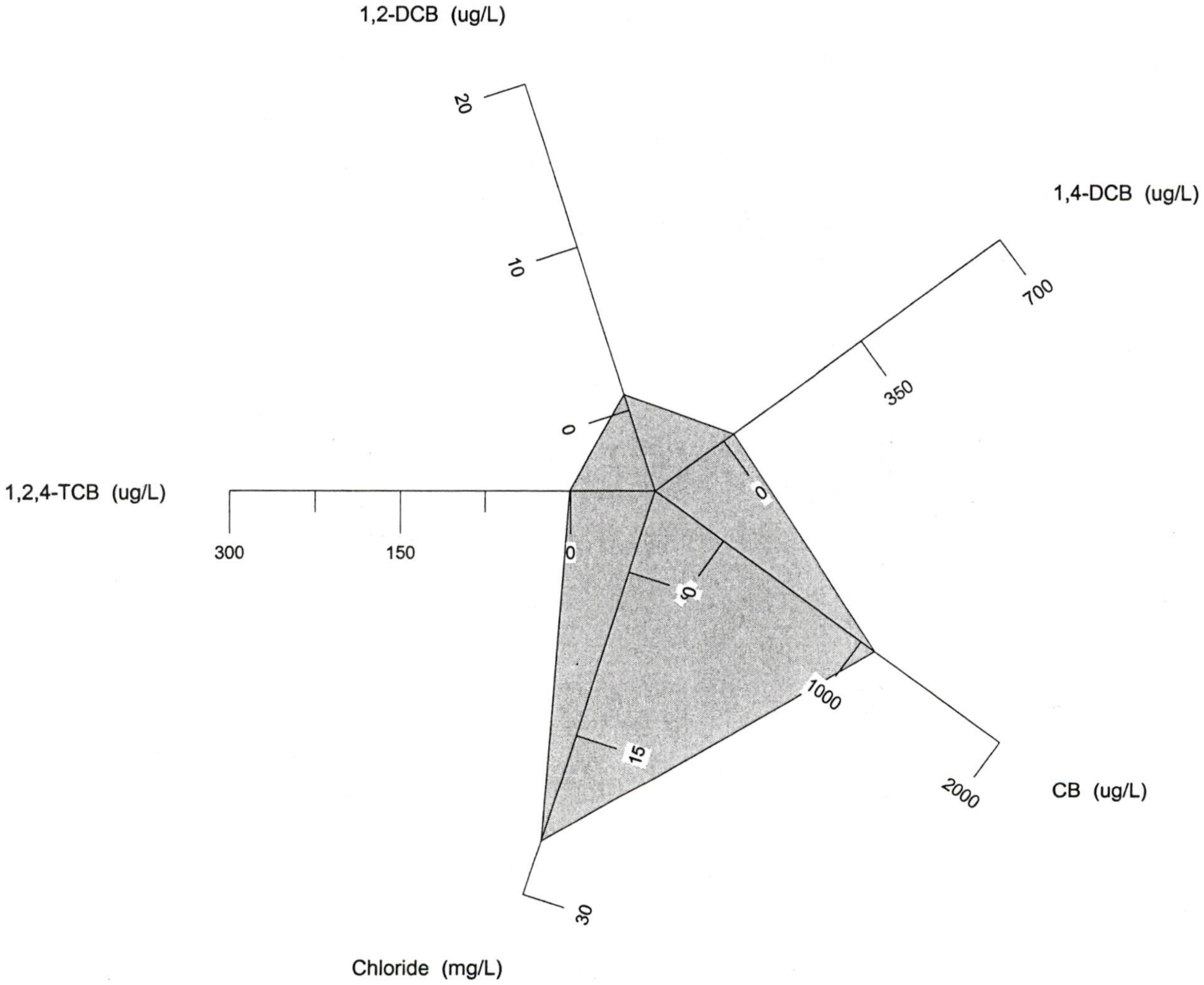
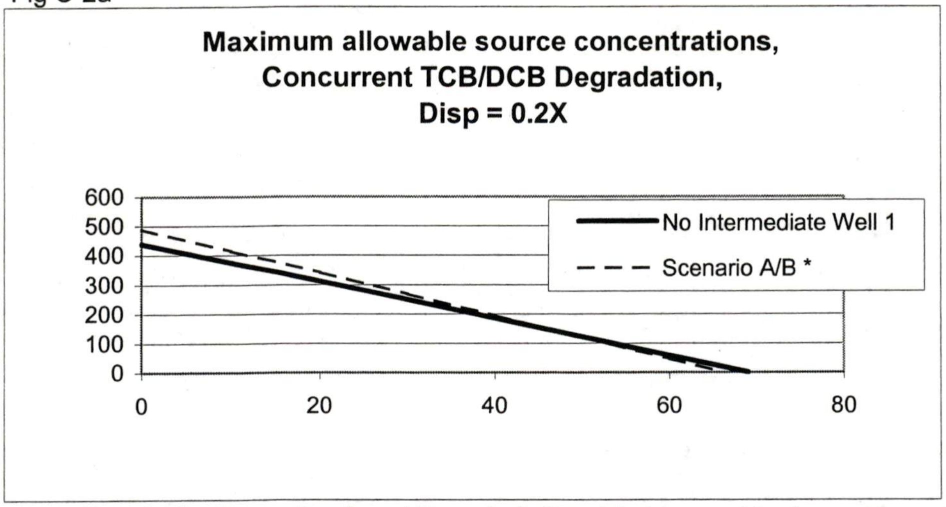


Fig C-2a



Note: Results for Scenarios A and B are indistinguishable graphically, and have been combined.

Figure C-2b

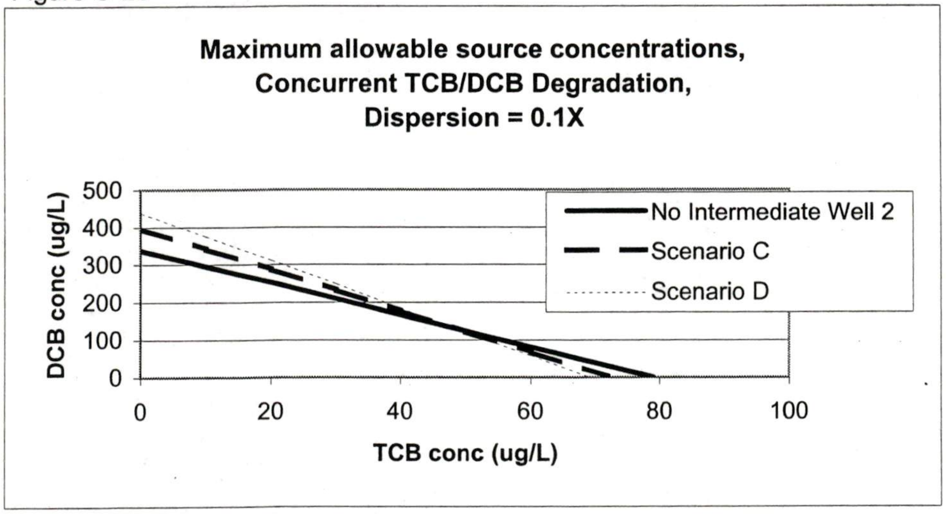
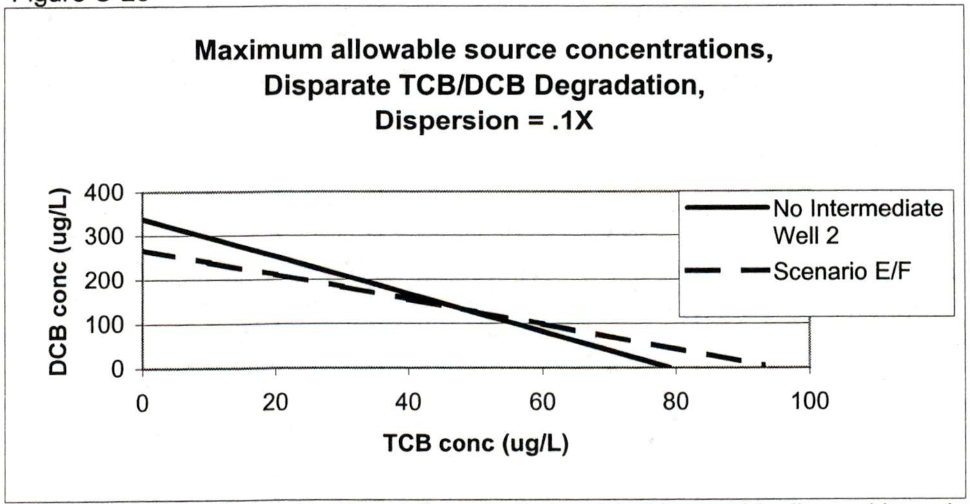
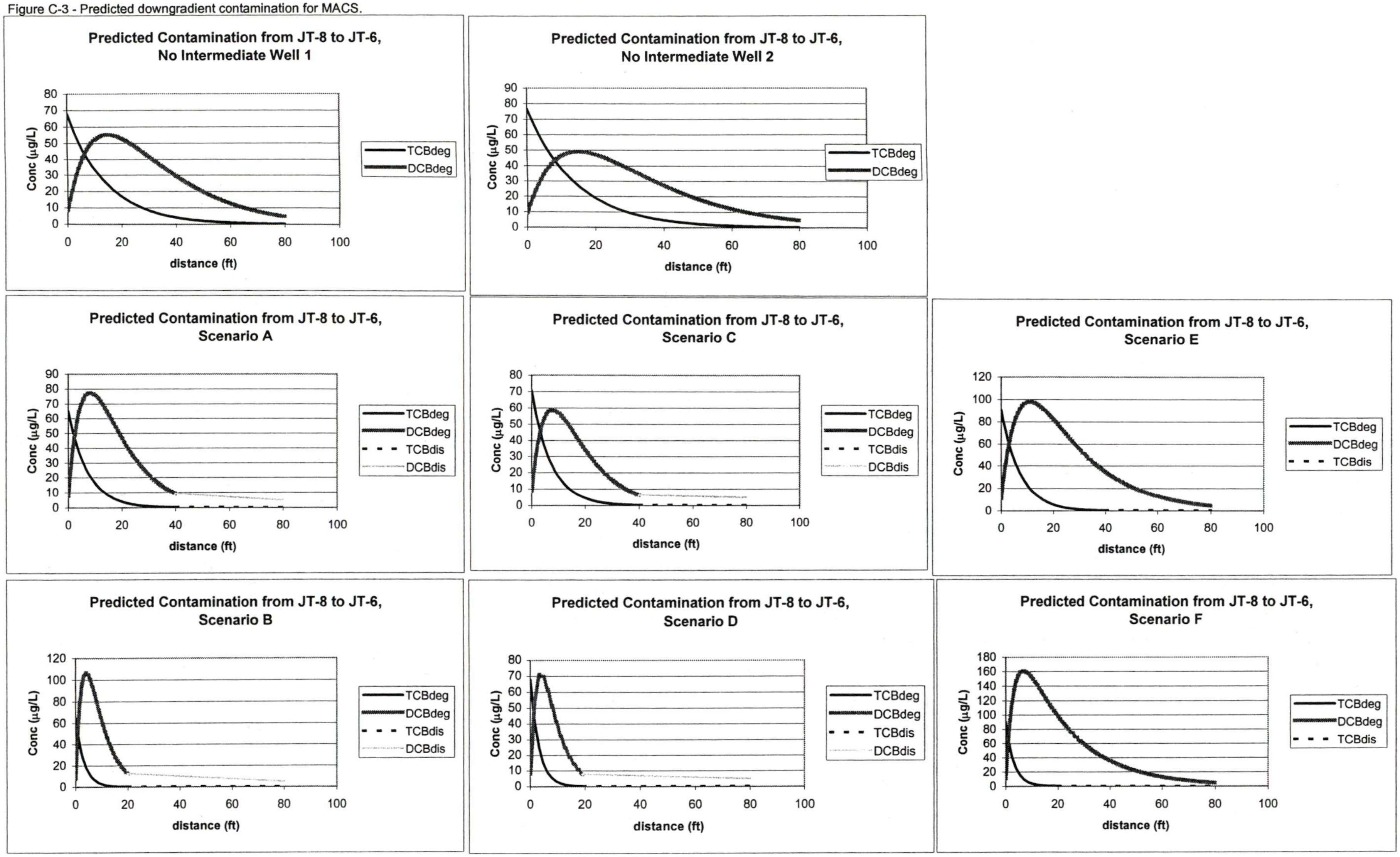


Figure C-2c



Note: Results for Scenarios E and F are indistinguishable graphically, and have been combined.

Figure C-3 - Predicted downgradient contamination for MACS.



Predicted Contamination from JT-8 to JT-6, No Intermediate Well 1

Predicted Contamination from JT-8 to JT-6, No Intermediate Well 2

Predicted Contamination from JT-8 to JT-6, Scenario A

Predicted Contamination from JT-8 to JT-6, Scenario C

Predicted Contamination from JT-8 to JT-6, Scenario E

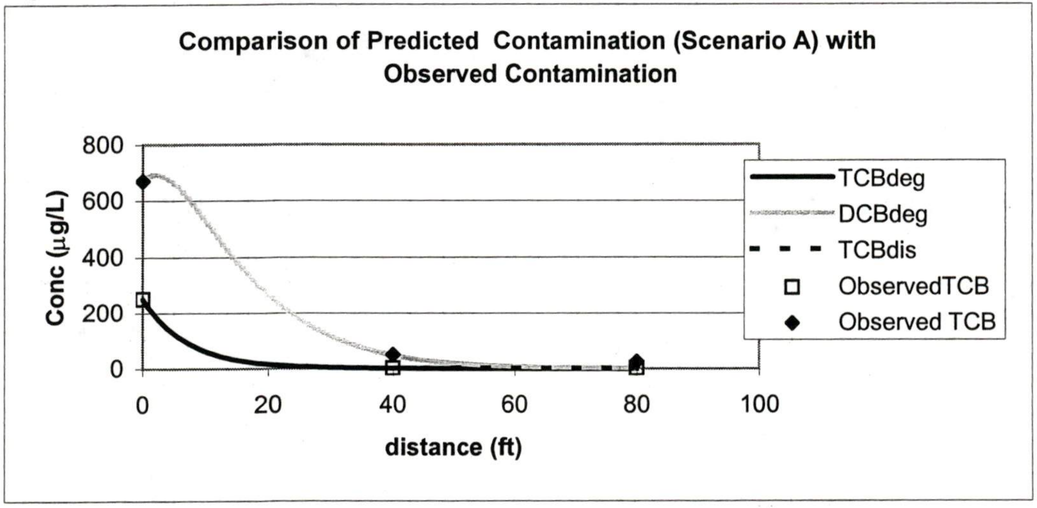
Predicted Contamination from JT-8 to JT-6, Scenario B

Predicted Contamination from JT-8 to JT-6, Scenario D

Predicted Contamination from JT-8 to JT-6, Scenario F

TCBdeg = Degradation and dispersion of TCB
DCBdeg = Degradation and dispersion of DCB
TCBdis = Dispersion of TCB
DCBdis = Dispersion of DCB

Figure C-4


Comparison of Predicted Contamination (Scenario A) with Observed Contamination
Conc (µg/L)
800
600
400
200
0
0
20
40
60
80
100
distance (ft)
TCBdeg
DCBdeg
TCBdis
ObservedTCB
Observed TCB

APPENDIX D

MTCA WORKSHEETS FOR TCB AND 1,4-DCB USING MODEL RESULTS

[redacted]

Worksheet for Calculating Soil Cleanup Levels for Unrestricted & Industrial Land Use

Date:	7/22/2003
Site Name:	Jacobson Terminal
Evaluator:	TriHydro

Refer to WAC 173-340-720, 740, 745, 747 and 750 for details.

A. INPUT PARAMETERS FOR SOIL CLEANUP LEVEL CALCULATIONS

Note: If no data is available for any of the following inputs, then leave the input box blank

Item	Symbol	Value	Units
1. General information			
Name of Chemical:		**1,2,4-TCB (Unsat'd zone)**	
Measured Soil Concentration, if any:	C_s	560	mg/kg
Natural Background Concentration for Soil:	NB_s	0	mg/kg
Practical Quantitation Limit for Soil:	PQL_s	0.05	mg/kg
To evaluate the ingestion and dermal pathways concurrently, check here and input values for ***AF, ABS*** $_d$***, GI***:	☑		
2. Toxicological Properties of the Chemical: Chemical-Specific			
Oral Reference Dose:	RfD_o	0.01	mg/kg-day
Oral Carcinogenic Potency Factor:	CPF_o		kg-day/mg
Inhalation Reference Dose:	RfD_i	0.0571	mg/kg-day
Inhalation Carcinogenic Potency Factor:	CPF_i		kg-day/mg
3. Exposure Parameters			
Inhalation Correction Factor (default = "2" for volatiles; "1" for all others): for target ground water cleanup level	INH	2	unitless
Inhalation Absorption Fraction (default = "1"): for target air cleanup level	ABS_i	1	unitless
Gastrointestinal Absorption Fraction (default = "1"): for ingestion & dermal exposure pathways	$AB1$	1	unitless
Adherence Factor (default = "0.2"): for dermal exposure pathway	AF	0.2	mg/cm^2-day
Dermal Absorption Fraction (chemical-specific or defaults): for dermal exposure pathway	ABS_d	1	unitless
Gastrointestinal Absorption Conversion Factor (chemical-specific or defaults): for dermal exposure pathway	GI	1	unitless
4. Physical and Chemical Properties of the Chemical: Chemical-Specific			
Soil Organic Carbon-Water Partitioning Coefficient: for metals, enter K_d value here and enter "1" for f_{oc} value	K_{oc}	1.659E+03	l/kg
Henry's Law Constant: for the evaluation of ground water and vapor exposure pathway	H_{cc}	5.820E-02	unitless
**If the value for Henry's Law Constant is given in the unit of "atm.m^3/mol", enter value here:*	H		atm.m^3/mol
**Converted unitless form of H_{cc} @13° C: (Enter this converted value into "H_{cc} input Box" above for a calculation)*	H_{cc}	*0.000E+00*	unitless

Solubility of the Chemical in Water: for the calculation of soil saturation limit	***S***	3.000E+02	mg/l

5. Target Ground Water Cleanup Level

Target Ground Water Cleanup Level applicable for a soil cleanup level calculation: **Results from the Ground Water Cleanup Level Worksheet are not automatically transferred into this worksheet.*	C_w	**6.52E+01**	ug/l

6. Site-Specific Hydrogeological Characteristics

Total Soil Porosity (default = "0.43"):	n	0.43	unitless
Volumetric Water Content (default = "0.30"):	Θ_w	0.3	unitless
Volumetric Air Content (default = "0.13"):	Θ_α	0.13	unitless
Dry Soil Bulk Density (default = "1.50"):	ρ_b	1.5	kg/l
Fraction Soil Organic Carbon (default = "0.001"): for metals, enter "1" for f_{oc} value here	f_{oc}	0.035	unitless
Dilution Factor (default = "20" for unsaturated zone soil; "1" for saturated zone soil; or site-specific)	***DF***	20	unitless

7. Vapor Attenuation Factor due to Advection (building structure) & Diffusion (soil layer) Mechanisms

** Vapor Attenuation Factor is the ratio of vapor-phase contaminant concentration within the soil at the source to the air concentration at the exposure point (e.g., within the building)*

Enter Vapor Attenuation Factor: for the evaluation of vapor exposure pathway	***VAF***		unitless

B. SUMMARY OF SOIL CLEANUP LEVEL CALCULATIONS

Chemical of Concern: 1,2,4-TCB (Unsat'd zone)

1. Summary of Results

To calculate a soil cleanup level based on Industrial Land Use (Method C) for Direct Soil Contact, check here: ☑

To calculate a soil concentration based on Method C vapor pathway, check here: ☑

Basis for Soil Concentration	Conc	Units
Most stringent soil concentration based on Soil Direct Contact & Ground Water Protection:	7.598E+01	mg/kg
Natural Background concentration for Soil:	0	mg/kg
Practical Quantitation Limit for Soil:	0.05	mg/kg
Soil Cleanup Level (not considering vapor pathway):	7.598E+01	mg/kg
Warning! Soil Cleanup Level above may not be protective of vapor exposure pathway - evaluate vapor pathway further.		
Soil concentration based on Vapor Pathway (informational purposes only):	0.000E+00	mg/kg

C_{sat} corresponds to the total soil chemical concentration saturated in soil.

R is the ratio of the ground water flow velocity to the

Soil Saturation Limit, C_{sat}:	1.748E+04	mg/kg
Retardation Factor, ***R***:	203.6	unitless

R is the ratio of the ground water flow velocity to the contaminant migration velocity in saturated zone.

2. Summary of Calculation for each Exposure Pathway

<table>
<tr><th colspan="7">Summary by Exposure Pathway</th></tr>
<tr><td rowspan="6">Soil Direct Contact</td><td colspan="2" rowspan="2"></td><td colspan="2">Method B
Unrestricted Land Use
@ HQ=1.0; RISK =1.0E-6</td><td colspan="2">Method C
Industrial Land Use
@ HQ=1.0; RISK =1.0E-5</td></tr>
<tr><td>Ingestion only</td><td>Ingestion & Dermal</td><td>Ingestion only</td><td>Ingestion & Dermal</td></tr>
<tr><td rowspan="2">Under the Current Condition</td><td>HQ? @ Exposure Point</td><td>7.000E-01</td><td>2.240E+00</td><td>1.600E-02</td><td>3.080E-01</td></tr>
<tr><td>RISK? @ Exposure Point</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="2">Target Soil CUL? mg/kg</td><td>@HQ=1.0</td><td>8.000E+02</td><td>2.500E+02</td><td>3.500E+04</td><td>1.818E+03</td></tr>
<tr><td>@RISK =1.0E-6 or 1.0E-5</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="6">Protection of Potable Ground Water</td><td colspan="2"></td><td colspan="2">Method B
@ HQ=1.0; RISK =1.0E-6</td><td colspan="2">Method C
@ HQ=1.0; RISK =1.0E-5</td></tr>
<tr><td rowspan="3">Under the Current Condition</td><td>Predicted Ground Water Conc? ug/l</td><td colspan="4">4.805E+02</td></tr>
<tr><td>HQ? @ Exposure Point</td><td colspan="2">6.007E+00</td><td colspan="2">2.746E+00</td></tr>
<tr><td>RISK? @ Exposure Point</td><td colspan="2">N/A</td><td colspan="2">N/A</td></tr>
<tr><td colspan="2">Target Ground Water CUL? ug/l</td><td colspan="4">6.520E+01</td></tr>
<tr><td colspan="2">Target Soil CUL? mg/kg</td><td colspan="4">7.598E+01</td></tr>
<tr><td rowspan="8">Protection of Air Quality
(for informational purpose only)</td><td colspan="2"></td><td colspan="2">Method B
@ HQ=1.0; RISK =1.0E-6</td><td colspan="2">Method C
@ HQ=1.0; RISK =1.0E-5</td></tr>
<tr><td rowspan="3">Under the Current Condition</td><td>Predicted Air Conc? ug/m^3 @Exposure Point</td><td colspan="4">#DIV/0!</td></tr>
<tr><td>HQ? @ Exposure Point</td><td colspan="2">#DIV/0!</td><td colspan="2">#DIV/0!</td></tr>
<tr><td>RISK? @ Exposure Point</td><td colspan="2">N/A</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="2">Target Air CUL? ug/m^3</td><td>@ HQ=1.0</td><td colspan="2">9.136E+01</td><td colspan="2">1.999E+02</td></tr>
<tr><td>@ RISK=1.0E-6 or 1.0E-5</td><td colspan="2">N/A</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="2">Target Soil CUL? mg/kg</td><td>@ HQ=1.0</td><td colspan="2">0.000E+00</td><td colspan="2">0.000E+00</td></tr>
<tr><td>@ RISK=1.0E-6 or 1.0E-5</td><td colspan="2">N/A</td><td colspan="2">N/A</td></tr>
</table>

NOTES: "CUL" = Cleanup Level; "Conc" = concentration; "HQ" = hazard quotient; "RISK" = carcinogenic risk.

CAUTION: The requirements and procedures for establishing soil cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-740, 173-340-745, 173-340-747 and 173-340-7490 through 173-340-7494). The use of this Workbook is not sufficient to establish soil cleanup levels under the regulation. Specifically, the soil cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-740(3)(b)(i) and 173-340-745(5)(b)(i));
- Soil residual saturation (see WAC 173-340-747(10));
- Ecological impacts (see WAC 173-340-7490 through 7494); and
- Total site risk (see WAC 173-340-740(5)(a) and 173-340-745(6)(a)).

Other exposure pathways may also need to be evaluated on a site-specific basis to establish soil cleanup levels.

CAUTION: The requirements and procedures for establishing air cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-750). The use of this Workbook may not be sufficient to establish air cleanup levels under the regulation. Specifically, the air cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-750(3)(b)(i) and (4)(b)(i));
- Concentrations based on natural background and the practical quantitation limit (see WAC 173-340-750(5)(c));
- Total site risk (see WAC 173-340-750(5)(a)).

Worksheet for Calculating Soil Cleanup Levels for Unrestricted & Industrial Land Use

Date:	7/22/2003
Site Name:	Jacobson Terminal
Evaluator:	TriHydro

Refer to WAC 173-340-720, 740, 745, 747 and 750 for details.

A. INPUT PARAMETERS FOR SOIL CLEANUP LEVEL CALCULATIONS

Note: If no data is available for any of the following inputs, then leave the input box blank

Item	Symbol	Value	Units
1. General information			
Name of Chemical:		**1,2,4-TCB (Sat'd zone)**	
Measured Soil Concentration, if any:	C_s	560	mg/kg
Natural Background Concentration for Soil:	NB_s	0	mg/kg
Practical Quantitation Limit for Soil:	PQL_s	0.05	mg/kg
To evaluate the ingestion and dermal pathways concurrently, check here and input values for AF, ABS_d, GI:	☑		
2. Toxicological Properties of the Chemical: Chemical-Specific			
Oral Reference Dose:	RfD_o	0.01	mg/kg-day
Oral Carcinogenic Potency Factor:	CPF_o		kg-day/mg
Inhalation Reference Dose:	RfD_i	0.0571	mg/kg-day
Inhalation Carcinogenic Potency Factor:	CPF_i		kg-day/mg
3. Exposure Parameters			
Inhalation Correction Factor (default = "2" for volatiles; "1" for all others): for target ground water cleanup level	INH	2	unitless
Inhalation Absorption Fraction (default = "1"): for target air cleanup level	ABS_i	1	unitless
Gastrointestinal Absorption Fraction (default = "1"): for ingestion & dermal exposure pathways	$AB1$	1	unitless
Adherence Factor (default = "0.2"): for dermal exposure pathway	AF	0.2	mg/cm^2-day
Dermal Absorption Fraction (chemical-specific or defaults): for dermal exposure pathway	ABS_d	1	unitless
Gastrointestinal Absorption Conversion Factor (chemical-specific or defaults): for dermal exposure pathway	GI	1	unitless
4. Physical and Chemical Properties of the Chemical: Chemical-Specific			
Soil Organic Carbon-Water Partitioning Coefficient: for metals, enter K_d value here and enter "1" for f_{oc} value	K_{oc}	1.659E+03	l/kg
Henry's Law Constant: for the evaluation of ground water and vapor exposure pathway	H_{cc}	5.820E-02	unitless
**If the value for Henry's Law Constant is given in the unit of "atm.m^3/mol", enter value here:*	H		atm.m^3/mol
**Converted unitless form of H_{cc} @13° C: (Enter this converted value into "H_{cc} input Box" above for a calculation)*	H_{cc}	*0.000E+00*	unitless

Solubility of the Chemical in Water: for the calculation of soil saturation limit	***S***	3.000E+02	mg/l

5. Target Ground Water Cleanup Level

Target Ground Water Cleanup Level applicable for a soil cleanup level calculation: **Results from the Ground Water Cleanup Level Worksheet are not automatically transferred into this worksheet.*	C_w	**6.52E+01**	ug/l

6. Site-Specific Hydrogeological Characteristics

Total Soil Porosity (default = "0.43"):	n	0.43	unitless
Volumetric Water Content (default = "0.30"):	Θ_w	0.43	unitless
Volumetric Air Content (default = "0.13"):	Θ_α	0.00	unitless
Dry Soil Bulk Density (default = "1.50"):	ρ_b	1.5	kg/l
Fraction Soil Organic Carbon (default = "0.001"): for metals, enter "1" for f_{oc} value here	f_{oc}	0.035	unitless
Dilution Factor (default = "20" for unsaturated zone soil; "1" for saturated zone soil; or site-specific)	***DF***	1	unitless

7. Vapor Attenuation Factor due to Advection (building structure) & Diffusion (soil layer) Mechanisms

** Vapor Attenuation Factor is the ratio of vapor-phase contaminant concentration within the soil at the source to the air concentration at the exposure point (e.g., within the building)*

Enter Vapor Attenuation Factor: for the evaluation of vapor exposure pathway	***VAF***		unitless

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B. SUMMARY OF SOIL CLEANUP LEVEL CALCULATIONS

Chemical of Concern: 1,2,4-TCB (Sat'd zone)

1. Summary of Results

To calculate a soil cleanup level based on Industrial Land Use (Method C) for Direct Soil Contact, check here: ☑

To calculate a soil concentration based on Method C vapor pathway, check here: ☑

Basis for Soil Concentration	Conc	Units
Most stringent soil concentration based on Soil Direct Contact & Ground Water Protection:	3.805E+00	mg/kg
Natural Background concentration for Soil:	0	mg/kg
Practical Quantitation Limit for Soil:	0.05	mg/kg
Soil Cleanup Level (not considering vapor pathway):	3.805E+00	mg/kg
Warning! Soil Cleanup Level above may not be protective of vapor exposure pathway - evaluate vapor pathway further.		
Soil concentration based on Vapor Pathway (informational purposes only):	0.000E+00	mg/kg

C_{sat} corresponds to the total soil chemical concentration saturated in soil.

R is the ratio of the ground water flow velocity to the

Soil Saturation Limit, C_{sat}:	1.751E+04	mg/kg
Retardation Factor, ***R***:	203.6	unitless

R is the ratio of the ground water flow velocity to the contaminant migration velocity in saturated zone.

2. Summary of Calculation for each Exposure Pathway

Summary by Exposure Pathway

			Method B *Unrestricted Land Use* @ HQ=1.0; RISK =1.0E-6		*Method C* *Industrial Land Use* @ HQ=1.0; RISK =1.0E-5	
			Ingestion only	Ingestion & Dermal	Ingestion only	Ingestion & Dermal
Soil Direct Contact	Under the Current Condition	HQ? @ Exposure Point	7.000E-01	2.240E+00	1.600E-02	3.080E-01
		RISK? @ Exposure Point	N/A	N/A	N/A	N/A
	Target Soil CUL? mg/kg	@HQ=1.0	8.000E+02	2.500E+02	3.500E+04	1.818E+03
		@RISK =1.0E-6 or 1.0E-5	N/A	N/A	N/A	N/A

			Method B @ HQ=1.0; RISK =1.0E-6	*Method C* @ HQ=1.0; RISK =1.0E-5
Protection of Potable Ground Water	Under the Current Condition	Predicted Ground Water Conc? ug/l	9.597E+03	
		HQ? @ Exposure Point	1.200E+02	5.484E+01
		RISK? @ Exposure Point	N/A	N/A
	Target Ground Water CUL? ug/l		6.520E+01	
	Target Soil CUL? mg/kg		3.805E+00	

			Method B @ HQ=1.0; RISK =1.0E-6	*Method C* @ HQ=1.0; RISK =1.0E-5
Protection of Air Quality *(for informational purpose only)*	Under the Current Condition	Predicted Air Conc? ug/m^3 @Exposure Point	#DIV/0!	
		HQ? @ Exposure Point	#DIV/0!	#DIV/0!
		RISK? @ Exposure Point	N/A	N/A
	Target Air CUL? ug/m^3	@ HQ=1.0	9.136E+01	1.999E+02
		@ RISK=1.0E-6 or 1.0E-5	N/A	N/A
	Target Soil CUL? mg/kg	@ HQ=1.0	0.000E+00	0.000E+00
		@ RISK=1.0E-6 or 1.0E-5	N/A	N/A

NOTES: "CUL" = Cleanup Level; "Conc" = concentration; "HQ" = hazard quotient; "RISK" = carcinogenic risk.

CAUTION: The requirements and procedures for establishing soil cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-740, 173-340-745, 173-340-747 and 173-340-7490 through 173-340-7494). The use of this Workbook is not sufficient to establish soil cleanup levels under the regulation. Specifically, the soil cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-740(3)(b)(i) and 173-340-745(5)(b)(i));
- Soil residual saturation (see WAC 173-340-747(10));
- Ecological impacts (see WAC 173-340-7490 through 7494); and
- Total site risk (see WAC 173-340-740(5)(a) and 173-340-745(6)(a)).

Other exposure pathways may also need to be evaluated on a site-specific basis to establish soil cleanup levels.

CAUTION: The requirements and procedures for establishing air cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-750). The use of this Workbook may not be sufficient to establish air cleanup levels under the regulation. Specifically, the air cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-750(3)(b)(i) and (4)(b)(i));
- Concentrations based on natural background and the practical quantitation limit (see WAC 173-340-750(5)(c));
- Total site risk (see WAC 173-340-750(5)(a)).

Worksheet for Calculating Soil Cleanup Levels for Unrestricted & Industrial Land Use

Date: 7/22/2003
Site Name: Jacobson Terminal
Evaluator: TriHydro

Refer to WAC 173-340-720, 740, 745, 747 and 750 for details.

A. INPUT PARAMETERS FOR SOIL CLEANUP LEVEL CALCULATIONS

Note: If no data is available for any of the following inputs, then leave the input box blank

Item	Symbol	Value	Units
1. General information			
Name of Chemical:		**1,4-DCB Unsat'd zone**	
Measured Soil Concentration, if any:	C_s	15	mg/kg
Natural Background Concentration for Soil:	NB_s	0	mg/kg
Practical Quantitation Limit for Soil:	PQL_s	0.05	mg/kg
To evaluate the ingestion and dermal pathways concurrently, check here and input values for AF, ABS_d, GI:	☑		
2. Toxicological Properties of the Chemical: Chemical-Specific			
Oral Reference Dose:	RfD_o		mg/kg-day
Oral Carcinogenic Potency Factor:	CPF_o	0.024	kg-day/mg
Inhalation Reference Dose:	RfD_i	0.228571	mg/kg-day
Inhalation Carcinogenic Potency Factor:	CPF_i		kg-day/mg
3. Exposure Parameters			
Inhalation Correction Factor (default = "2" for volatiles; "1" for all others): for target ground water cleanup level	INH	2	unitless
Inhalation Absorption Fraction (default = "1"): for target air cleanup level	ABS_i	1	unitless
Gastrointestinal Absorption Fraction (default = "1"): for ingestion & dermal exposure pathways	$AB1$	1	unitless
Adherence Factor (default = "0.2"): for dermal exposure pathway	AF	0.2	mg/cm^2-day
Dermal Absorption Fraction (chemical-specific or defaults): for dermal exposure pathway	ABS_d	1	unitless
Gastrointestinal Absorption Conversion Factor (chemical-specific or defaults): for dermal exposure pathway	GI	1	unitless
4. Physical and Chemical Properties of the Chemical: Chemical-Specific			
Soil Organic Carbon-Water Partitioning Coefficient: for metals, enter K_d value here and enter "1" for f_{oc} value	K_{oc}	6.160E+02	l/kg
Henry's Law Constant: for the evaluation of ground water and vapor exposure pathway	H_{cc}	9.960E-02	unitless
**If the value for Henry's Law Constant is given in the unit of "$atm.m^3/mol$", enter value here:*	H		$atm.m^3/mol$
**Converted unitless form of H_{cc} @13°C: (Enter this converted value into "H_{cc} input Box" above for a calculation)*	H_{cc}	*0.000E+00*	unitless

Solubility of the Chemical in Water: for the calculation of soil saturation limit	***S***	7.380E+01	mg/l

5. Target Ground Water Cleanup Level

Target Ground Water Cleanup Level applicable for a soil cleanup level calculation: **Results from the Ground Water Cleanup Level Worksheet are not automatically transferred into this worksheet.*	C_w	**8.10E+00**	ug/l

6. Site-Specific Hydrogeological Characteristics

Total Soil Porosity (default = "0.43"):	n	0.43	unitless
Volumetric Water Content (default = "0.30"):	Θ_w	0.3	unitless
Volumetric Air Content (default = "0.13"):	Θ_α	0.13	unitless
Dry Soil Bulk Density (default = "1.50"):	ρ_b	1.5	kg/l
Fraction Soil Organic Carbon (default = "0.001"): for metals, enter "1" for f_{oc} value here	f_{oc}	0.035	unitless
Dilution Factor (default = "20" for unsaturated zone soil; "1" for saturated zone soil; or site-specific)	***DF***	20	unitless

7. Vapor Attenuation Factor due to Advection (building structure) & Diffusion (soil layer) Mechanisms

* *Vapor Attenuation Factor is the ratio of vapor-phase contaminant concentration within the soil at the source to the air concentration at the exposure point (e.g., within the building)*

Enter Vapor Attenuation Factor: for the evaluation of vapor exposure pathway	***VAF***		unitless

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B. SUMMARY OF SOIL CLEANUP LEVEL CALCULATIONS

Chemical of Concern: 1,4-DCB Unsat'd zone

1. Summary of Results

To calculate a soil cleanup level based on Industrial Land Use (Method C) for Direct Soil Contact, check here: ☑

To calculate a soil concentration based on Method C vapor pathway, check here: ☑

Basis for Soil Concentration	Conc	Units
Most stringent soil concentration based on Soil Direct Contact & Ground Water Protection:	3.527E+00	mg/kg
Natural Background concentration for Soil:	0	mg/kg
Practical Quantitation Limit for Soil:	0.05	mg/kg
Soil Cleanup Level (not considering vapor pathway):	3.527E+00	mg/kg
Warning! Soil Cleanup Level above may not be protective of vapor exposure pathway - evaluate vapor pathway further.		
Soil concentration based on Vapor Pathway (informational purposes only):	0.000E+00	mg/kg

C $_{sat}$ corresponds to the total soil chemical concentration saturated in soil.

R is the ratio of the ground water flow velocity to the

Soil Saturation Limit, C_{sat}:	1.607E+03	mg/kg
Retardation Factor, ***R***:	76.2	unitless

R is the ratio of the ground water flow velocity to the contaminant migration velocity in saturated zone.

2. Summary of Calculation for each Exposure Pathway

Summary by Exposure Pathway

			Method B *Unrestricted Land Use* @ HQ=1.0; RISK =1.0E-6		*Method C* *Industrial Land Use* @ HQ=1.0; RISK =1.0E-5	
Soil Direct Contact			Ingestion only	Ingestion & Dermal	Ingestion only	Ingestion & Dermal
	Under the Current Condition	HQ? @ Exposure Point	N/A	N/A	N/A	N/A
		RISK? @ Exposure Point	3.600E-07	1.152E-06	2.743E-08	5.280E-07
	Target Soil CUL? mg/kg	@HQ=1.0	N/A	N/A	N/A	N/A
		@RISK =1.0E-6 or 1.0E-5	4.167E+01	1.302E+01	5.469E+03	2.841E+02
Protection of Potable Ground Water			*Method B* @ HQ=1.0; RISK =1.0E-6		*Method C* @ HQ=1.0; RISK =1.0E-5	
	Under the Current Condition	Predicted Ground Water Conc? ug/l	3.445E+01			
		HQ? @ Exposure Point	N/A		N/A	
		RISK? @ Exposure Point	1.890E-05		1.890E-05	
	Target Ground Water CUL? ug/l		8.100E+00			
	Target Soil CUL? mg/kg		3.527E+00			
Protection of Air Quality *(for informational purpose only)*			*Method B* @ HQ=1.0; RISK =1.0E-6		*Method C* @ HQ=1.0; RISK =1.0E-5	
	Under the Current Condition	Predicted Air Conc? ug/m^3 @Exposure Point	#DIV/0!			
		HQ? @ Exposure Point	#DIV/0!		#DIV/0!	
		RISK? @ Exposure Point	N/A		N/A	
	Target Air CUL? ug/m^3	@ HQ=1.0	3.657E+02		8.000E+02	
		@ RISK=1.0E-6 or 1.0E-5	N/A		N/A	
	Target Soil CUL? mg/kg	@ HQ=1.0	0.000E+00		0.000E+00	
		@ RISK=1.0E-6 or 1.0E-5	N/A		N/A	

NOTES: "CUL" = Cleanup Level; "Conc" = concentration; "HQ" = hazard quotient; "RISK" = carcinogenic risk.

CAUTION: The requirements and procedures for establishing soil cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-740, 173-340-745, 173-340-747 and 173-340-7490 through 173-340-7494). The use of this Workbook is not sufficient to establish soil cleanup levels under the regulation. Specifically, the soil cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-740(3)(b)(i) and 173-340-745(5)(b)(i));
- Soil residual saturation (see WAC 173-340-747(10));
- Ecological impacts (see WAC 173-340-7490 through 7494); and
- Total site risk (see WAC 173-340-740(5)(a) and 173-340-745(6)(a)).

Other exposure pathways may also need to be evaluated on a site-specific basis to establish soil cleanup levels.

CAUTION: The requirements and procedures for establishing air cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-750). The use of this Workbook may not be sufficient to establish air cleanup levels under the regulation. Specifically, the air cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-750(3)(b)(i) and (4)(b)(i));
- Concentrations based on natural background and the practical quantitation limit (see WAC 173-340-750(5)(c));
- Total site risk (see WAC 173-340-750(5)(a)).

Worksheet for Calculating Soil Cleanup Levels for Unrestricted & Industrial Land Use

Date: 7/22/2003
Site Name: Jacobson Terminal
Evaluator: TriHydro

Refer to WAC 173-340-720, 740, 745, 747 and 750 for details.

A. INPUT PARAMETERS FOR SOIL CLEANUP LEVEL CALCULATIONS

Note: If no data is available for any of the following inputs, then leave the input box blank

Item	Symbol	Value	Units
1. General information			
Name of Chemical:		**1,4-DCB Sat'd zone**	
Measured Soil Concentration, if any:	C_s	15	mg/kg
Natural Background Concentration for Soil:	NB_s	0	mg/kg
Practical Quantitation Limit for Soil:	PQL_s	0.05	mg/kg
To evaluate the ingestion and dermal pathways concurrently, check here and input values for AF, ABS_d, GI:	☑		
2. Toxicological Properties of the Chemical: Chemical-Specific			
Oral Reference Dose:	RfD_o		mg/kg-day
Oral Carcinogenic Potency Factor:	CPF_o	0.024	kg-day/mg
Inhalation Reference Dose:	RfD_i	0.228571	mg/kg-day
Inhalation Carcinogenic Potency Factor:	CPF_i		kg-day/mg
3. Exposure Parameters			
Inhalation Correction Factor (default = "2" for volatiles; "1" for all others): for target ground water cleanup level	INH	2	unitless
Inhalation Absorption Fraction (default = "1"): for target air cleanup level	ABS_i	1	unitless
Gastrointestinal Absorption Fraction (default = "1"): for ingestion & dermal exposure pathways	$AB1$	1	unitless
Adherence Factor (default = "0.2"): for dermal exposure pathway	AF	0.2	mg/cm^2-day
Dermal Absorption Fraction (chemical-specific or defaults): for dermal exposure pathway	ABS_d	1	unitless
Gastrointestinal Absorption Conversion Factor (chemical-specific or defaults): for dermal exposure pathway	GI	1	unitless
4. Physical and Chemical Properties of the Chemical: Chemical-Specific			
Soil Organic Carbon-Water Partitioning Coefficient: for metals, enter K_d value here and enter "1" for f_{oc} value	K_{oc}	6.160E+02	l/kg
Henry's Law Constant: for the evaluation of ground water and vapor exposure pathway	H_{cc}	9.960E-02	unitless
**If the value for Henry's Law Constant is given in the unit of "atm.m^3/mol", enter value here:*	H		atm.m^3/mol
**Converted unitless form of H_{cc} @13° C: (Enter this converted value into "H_{cc} input Box" above for a calculation)*	H_{cc}	*0.000E+00*	unitless

Solubility of the Chemical in Water: for the calculation of soil saturation limit	***S***	7.380E+01	mg/l

5. Target Ground Water Cleanup Level

Target Ground Water Cleanup Level applicable for a soil cleanup level calculation: **Results from the Ground Water Cleanup Level Worksheet are not automatically transferred into this worksheet.*	C_w	**8.10E+00**	ug/l

6. Site-Specific Hydrogeological Characteristics

Total Soil Porosity (default = "0.43"):	n	0.43	unitless
Volumetric Water Content (default = "0.30"):	Θ_w	0.43	unitless
Volumetric Air Content (default = "0.13"):	Θ_α	0.00	unitless
Dry Soil Bulk Density (default = "1.50"):	ρ_b	1.5	kg/l
Fraction Soil Organic Carbon (default = "0.001"): for metals, enter "1" for f_{oc} value here	f_{oc}	0.035	unitless
Dilution Factor (default = "20" for unsaturated zone soil; "1" for saturated zone soil; or site-specific)	***DF***	1	unitless

7. Vapor Attenuation Factor due to Advection (building structure) & Diffusion (soil layer) Mechanisms

** Vapor Attenuation Factor is the ratio of vapor-phase contaminant concentration within the soil at the source to the air concentration at the exposure point (e.g., within the building)*

Enter Vapor Attenuation Factor: for the evaluation of vapor exposure pathway	***VAF***		unitless

B. SUMMARY OF SOIL CLEANUP LEVEL CALCULATIONS

Chemical of Concern: 1,4-DCB Sat'd zone

1. Summary of Results

To calculate a soil cleanup level based on Industrial Land Use (Method C) for Direct Soil Contact, check here: ☑

To calculate a soil concentration based on Method C vapor pathway, check here: ☑

Basis for Soil Concentration	Conc	Units
Most stringent soil concentration based on Soil Direct Contact & Ground Water Protection:	1.770E-01	mg/kg
Natural Background concentration for Soil:	0	mg/kg
Practical Quantitation Limit for Soil:	0.05	mg/kg
Soil Cleanup Level (not considering vapor pathway):	1.770E-01	mg/kg
Warning! Soil Cleanup Level above may not be protective of vapor exposure pathway - evaluate vapor pathway further.		
Soil concentration based on Vapor Pathway (informational purposes only):	0.000E+00	mg/kg

C $_{sat}$ corresponds to the total soil chemical concentration saturated in soil.

R is the ratio of the ground water flow velocity to the

Soil Saturation Limit, C_{sat}:	1.612E+03	mg/kg
Retardation Factor, R:	76.2	unitless

R is the ratio of the ground water flow velocity to the contaminant migration velocity in saturated zone.

2. Summary of Calculation for each Exposure Pathway

Summary by Exposure Pathway

Soil Direct Contact			*Method B* Unrestricted Land Use @ HQ=1.0; RISK =1.0E-6		*Method C* Industrial Land Use @ HQ=1.0; RISK =1.0E-5	
			Ingestion only	Ingestion & Dermal	Ingestion only	Ingestion & Dermal
	Under the Current Condition	HQ? @ Exposure Point	N/A	N/A	N/A	N/A
		RISK? @ Exposure Point	3.600E-07	1.152E-06	2.743E-08	5.280E-07
	Target Soil CUL? mg/kg	@HQ=1.0	N/A	N/A	N/A	N/A
		@RISK =1.0E-6 or 1.0E-5	4.167E+01	1.302E+01	5.469E+03	2.841E+02

Protection of Potable Ground Water			*Method B* @ HQ=1.0; RISK =1.0E-6	*Method C* @ HQ=1.0; RISK =1.0E-5
	Under the Current Condition	Predicted Ground Water Conc? ug/l	6.866E+02	
		HQ? @ Exposure Point	N/A	N/A
		RISK? @ Exposure Point	3.767E-04	3.767E-04
	Target Ground Water CUL? ug/l		8.100E+00	
	Target Soil CUL? mg/kg		1.770E-01	

Protection of Air Quality *(for informational purpose only)*			*Method B* @ HQ=1.0; RISK =1.0E-6	*Method C* @ HQ=1.0; RISK =1.0E-5
	Under the Current Condition	Predicted Air Conc? ug/m^3 @Exposure Point	#DIV/0!	
		HQ? @ Exposure Point	#DIV/0!	#DIV/0!
		RISK? @ Exposure Point	N/A	N/A
	Target Air CUL? ug/m^3	@ HQ=1.0	3.657E+02	8.000E+02
		@ RISK=1.0E-6 or 1.0E-5	N/A	N/A
	Target Soil CUL? mg/kg	@ HQ=1.0	0.000E+00	0.000E+00
		@ RISK=1.0E-6 or 1.0E-5	N/A	N/A

NOTES: "CUL" = Cleanup Level; "Conc" = concentration; "HQ" = hazard quotient; "RISK" = carcinogenic risk.

CAUTION: The requirements and procedures for establishing soil cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-740, 173-340-745, 173-340-747 and 173-340-7490 through 173-340-7494). The use of this Workbook is not sufficient to establish soil cleanup levels under the regulation. Specifically, the soil cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-740(3)(b)(i) and 173-340-745(5)(b)(i));
- Soil residual saturation (see WAC 173-340-747(10));
- Ecological impacts (see WAC 173-340-7490 through 7494); and
- Total site risk (see WAC 173-340-740(5)(a) and 173-340-745(6)(a)).

Other exposure pathways may also need to be evaluated on a site-specific basis to establish soil cleanup levels.

CAUTION: The requirements and procedures for establishing air cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation (see WAC 173-340-750). The use of this Workbook may not be sufficient to establish air cleanup levels under the regulation. Specifically, the air cleanup levels derived using this Workbook do not account for the following:

- Concentrations based on applicable state and federal laws (see WAC 173-340-750(3)(b)(i) and (4)(b)(i));
- Concentrations based on natural background and the practical quantitation limit (see WAC 173-340-750(5)(c));
- Total site risk (see WAC 173-340-750(5)(a)).