TIER 1 ECOLOGICAL RISK ASSESSMENT OF A CONTAMINATED RAIL CORRIDOR

by

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ABSTRACT

A screening level ecological risk assessment (ERA) was conducted for a contaminated rail corridor in British Columbia. The purpose of the ERA was to demonstrate the utility of British Columbia Tier 1 ERA methodology for identifying contaminated sites with unacceptable ecological risks requiring remediation and/or risk management. The methodology applies a weight of evidence approach to characterize ecological risks with risk quotients and site observations serving as the two lines of evidence. More weight is placed on field observations because risk quotients are less site-specific and over estimate risk due to multiple conservative assumptions. A major limitation of the provincial Tier 1 method is that the biological survey methodology recommended is too qualitative to provide the information necessary to reliably confirm or refute the presumption of risk indicated by risk quotient results. More quantitative biological survey methods are needed to identify adverse ecological effects and causative links to site contamination.

EXECUTIVE SUMMARY

A screening level (Tier 1) ecological risk assessment (ERA) was conducted to estimate the ecological risks posed by a metal, hydrocarbon and herbicide contaminated rail corridor in coastal British Columbia and to assess the utility of the BC Tier 1 ERA methodology. The receptor groups of concern evaluated in the ERA included terrestrial invertebrates (soil and foliar) and plants, mammals (small omnivores, arboreal insectivores and carnivores), birds (omnivores, cavity-dwellers and raptors) and reptiles.

BC guidance for Tier 1 ERA (BCMELP 1998) recommends the integration of risk quotients and site observations to characterize ecological risks with the more qualitative but site-specific observations of actual field conditions substantiating or refuting the presumption of risk indicated by the risk quotients. The site observation methodology recommended by BC guidance was deemed to be too qualitative to identify adverse ecological effects, particularly to wildlife, and therefore, the results of the site survey were not incorporated into the overall risk characterization. Consequently, the results of the risk assessment were based solely on risk quotients.

The results of the ERA indicate that moderate risks exist for soil and foliar invertebrates, terrestrial plants, small omnivorous mammals, omnivorous birds and reptiles due to site constituents of potential ecological concern (COPECs). Risks posed by site COPECs on mammalian arboreal insectivores, carnivorous mammals, cavity-dwelling birds and

raptors were shown to be low. The uncertainty in the risk estimates were considered to be high but were expected to overestimate actual risk.

To reduce the level of uncertainty in the risk estimates additional assessment activities were recommended including bioassays, direct measurement of tissue concentrations, and a quantitative biological survey to assess COPEC-induced effects.

Overall, the Tier 1 ERA process used in BC was found to be a useful initial step in identifying the potential for chemicals in site media to cause adverse effects on ecological receptors. In addition to the qualitative site observation method recommended, other limitations identified include its failure to consider temporal variations in exposure; its reliance on assumptions, literature data (i.e., lack of site-specific information) and incomplete toxicity data; and, a policy to ignore inhalation and exposure pathways for wildlife.

DEDICATION

For all the patience and support from my wife Jodie.

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ABBREVIATIONS

AW	Aquatic Life Water Use
B(a)P	Benzo(a)pyrene
BC	British Columbia
BCE	British Columbia Environment
BCF	Bioconcentration Factor
BCMELP	British Columbia Ministry of Environment, Lands and Parks
BCMOF	British Columbia Ministry of Forests
BCMWLAP	British Columbia Ministry of Water, Land and Air Protection
COPEC	Constituent of Potential Ecological Concern
CSR	Contaminated Sites Regulation
CWH	Coastal Western Hemlock
DW	Drinking Water Use
EC	Exposure Concentration
EPH	Extractable Petroleum Hydrocarbons
ERA	Ecological Risk Assessment
HEPH	Heavy Extractable Petroleum Hydrocarbons
IW	Irrigation Water Use
LEPH	Light Extractable Petroleum Hydrocarbons
LOAEL	Lowest Observable Adverse Effect Level
LW	Livestock Water Use
NOAEL	No Observable Adverse Effect Level
PAH	Polycyclic Aromatic Hydrocarbons
PCP	Pentachlorophenol
PL	Urban Park Land Use
QA/QC	Quality Assurance/Quality Control
TRV	Toxicity Reference Value
UCL95	Upper 95th percent confidence limit on the arithmetic mean
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

1 GENERAL INTRODUCTION

Since *Silent Spring* (Carson 1962) was published, the impact of man-made chemicals on the environment has garnered increasing concern. More than ever, mankind relies on chemicals for energy production, industrial and commercial processes and various domestic activities. With the use of these chemicals comes their inevitable release into the environment via accidental spills and purposeful disposal. Once in the environment, these chemicals have the potential to cause adverse effects on human health and the environment. As a consequence of a public demand to prevent human effects in particular, programs to remediate contaminated sites have been ongoing for many years. Only relatively recently have ecological risks become important considerations in these remedial decisions (Suter et al. 2000).

Human health risk assessment (HHRA) is the systematic characterisation of potential adverse health effects resulting from human exposures to hazardous waste agents or situations (NRC 1983). HHRA as an organised activity performed by government agencies began in the United States (US) in the 1970s (Klaassen 1996) out of a need to protect citizens from the harmful effects of dietary pesticide residues and food additives. The use of HHRA in the management of contaminated sites began in the US in the early 1980s with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or "Superfund") and the landmark HHRA guidance manual developed by the National Research Council (NRC), *Risk Assessment in the Federal Government: Managing the Process* (NRC 1983). This document provided the framework for human

health risk assessment of contaminated sites as it is applied today. Subsequently, HHRA guidance documents published by the United States Environmental Protection Agency (USEPA) including, *Risk Assessment Guidance for Superfund Volume I, Human Health Evaluation Manual (Part A)* (USEPA 1989a) have been developed and have formed the basis for many of the HHRA methods used today in Canada.

As it pertains to contaminate sites, ecological risk assessment (ERA) is a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to hazardous waste agents. Ecological risk assessment was developed in the United States in the early to mid 1980s from practises in human health risk assessment, environmental hazard assessment and environmental impact assessment to provide a basis for environmental decision making equivalent to human health risk assessment (Suter et al. 2000). Its practise took off after 1992 with the release of an ERA framework by the US Environmental Protection Agency (EPA) (Suter 2000).

Over the past decade, the use of human health and ecological risk assessment in the decision-making process for contaminated sites has become main stream. In British Columbia, contaminated properties are regulated by the Contaminated Sites Regulation (CSR) (BC 1997). According to the CSR, human health/ecological risk assessment is one of two options available for determining the need for and the nature of remediation of a contaminated site. The other option requires the remediation of contaminated site media to the numerical standards and criteria listed in the CSR. This numerical approach can be costly depending on the extent of contamination and therefore is applied most often on

relatively small sites where contamination is not widespread and physical remediation is a cost effective option.

Under the risk assessment option, remediation decisions are based on the risks posed by chemical contamination on human health and the environment (i.e., ecological receptors). If unacceptable risks are identified, remedial actions and/or risk management activities are implemented to reduce risks to levels that are deemed by stakeholders (e.g., property owner, local and provincial governments) to be acceptable. Remediation/risk management may involve the removal of some or all of the contamination or management of the contamination in place. The risk assessment option is particularly applicable at sites where contamination includes chemicals for which provincial standards and criteria do not exist (i.e., the numerical approach is not possible); where cleanup to numerical standards is not feasible (e.g., large contaminated area; contamination beneath existing buildings); where numerical standards and criteria do not seem appropriate given site-specific exposure conditions (e.g., no complete exposure pathways); where significant or sensitive receptors of concern have been identified (e.g., threatened, endangered or culturally important species); and/or, where there is significant public concern (e.g., lead paint in schools) (CCME 1996).

Guidance for conducting ecological risk assessments in BC for properties under provincial jurisdiction is provided by the *Recommended Guidance and Checklist for Tier 1 Ecological Risk Assessment of Contaminated Sites in British Columbia* (BCMELP 1998). According to this guidance manual, there are three tiers of ecological risk

assessment (ERAs) as defined by their complexity: Screening (Tier 1) ERAs, Preliminary Quantitative (Tier 2) ERAs and Detailed Quantitative (Tier 3) ERAs. Tier 1 ERAs are characterized by simple qualitative and or comparative methods, and rely heavily on literature information and previously collected data (CCME 1996). Tier 2 ERAs involve more detailed analysis using techniques such as Monte Carlo simulation and extensive sampling of the site and resident organisms (BCMELP 1998). Tier 3 ERAs typically involve extensive analyses which may entail a series of unrelated chemical stressors, a wide variety of habitat and terrain types and a wide geographical area (BCMELP, 1998). The ERA tier that is required to characterise ecological risk for a site is dictated by the nature and extent of contamination. According to BC guidance (BCMELP 1998), the Tier 1 ERA framework is expected to adequately evaluate approximately 90% of the contaminated sites in BC, with the remaining 10% requiring the additional complexity offered by a Tier 2 or Tier 3 ERA.

This report presents a Tier 1 ERA of a metal, hydrocarbon and herbicide contaminated rail corridor located in an urban area of coastal British Columbia. In addition to demonstrating the performance of a Tier 1 ERA, the strengths and weaknesses of the process will be discussed and recommendations for improvements to the methodology will be provided. The report consists of five primary components: problem formulation, exposure assessment, effects assessment, risk characterization and summary and recommendations.

The problem formulation is the planning phase of the risk assessment, defining the problem to be solved. This component of the ERA discusses the issue(s) to be evaluated and forms the basis of the risk assessment. In this portion of the risk assessment, the site is described, the chemical constituents of potential environmental concern (COPECs) are identified, the ecological receptors of concern are determined and a preliminary conceptual exposure model is developed. The exposure and effects assessments comprise the analysis portion of the risk assessment. In the exposure assessment, the manner in which ecological receptors may come in contact with COPECs is identified and potential exposures are quantified. The effects assessment aims to determine if any adverse environmental effects are currently occurring and to develop appropriate concentration-response relationships to predict if adverse affects will occur in the future (BCMELP 1998). The final component of the risk assessment is risk characterization. The risk characterization integrates the information developed in the exposure and effects assessments to determine the probability of adverse effects (risk) for the receptors of concern.

2 PROBLEM FORMULATION

2.1 Introduction

Problem formulation is the process of defining the nature of an environmental problem and specifying the scope and type of assessment that will be required to solve the problem (Suter et al. 2000). Problem formulation is a critical step in ecological risk assessment because it lays the foundation for the analytical stages of the assessment that follow (i.e., the exposure and effects assessments). Problem formulation begins with a discussion of the site background including its location, history of use, contamination issues and the reason(s) why the risk assessment is being performed. Next, a detailed description of the site is presented consisting of the site dimensions, boundaries, topography, drainage, ecological setting and surrounding land use.

Following the background discussion and site description, analytical data collected during previous site investigations is evaluated to determine which chemical constituents are present in site media at concentrations that warrant their inclusion in the risk assessment as constituents of potential ecological concern (COPECs). Two other important elements of the problem formulation are the identification of the receptors of concern (e.g., populations of resident birds, terrestrial plant communities) and the construction of a conceptual site model. Receptors of concern are those ecological entities to be protected in the ERA and may include species that inhabit or use the site; threatened, endangered or sensitive species; or recreationally, culturally or commercially important species. The

conceptual site model summarizes the information gathered in the problem formulation by illustrating how ecological receptors may come in contact with chemical stressors present in site media. A conceptual model includes descriptions of the contaminant source (e.g., a leaking underground storage tank), the receiving environment (i.e., soil or groundwater) and the processes by which the receptors of concern may come to be exposed directly to the contaminants (e.g., dermal contact, ingestion) and indirectly to the effects of the contaminants on other environmental components (Suter et al. 2000).

2.2 Site Background

2.2.1 Site Location and Use

The subject site is comprised of a 4.2 kilometer rail corridor located in an urban setting in British Columbia (refer to Figure 1). The site was used primarily for rail activities from the early 1900s until the rail-line was decommissioned in the late 1990s. Prior to construction of the rail-line in the early 1900s, the site was undeveloped and forested. In addition to rail activities, walking/biking trails present on portions of the site, are widely used by area residents. Anthropogenic activities that may have resulted in the presence of chemical constituents in site media include general rail activity (e.g., freight transport), routine application of herbicides, placement of fill material of unknown origin and quality, use of creosote-treated rail ties, and, the migration of contaminants from an off-site landfill. Although definitive development plans have not been established, it is understood that the rail corridor will be developed as an urban park in the future.

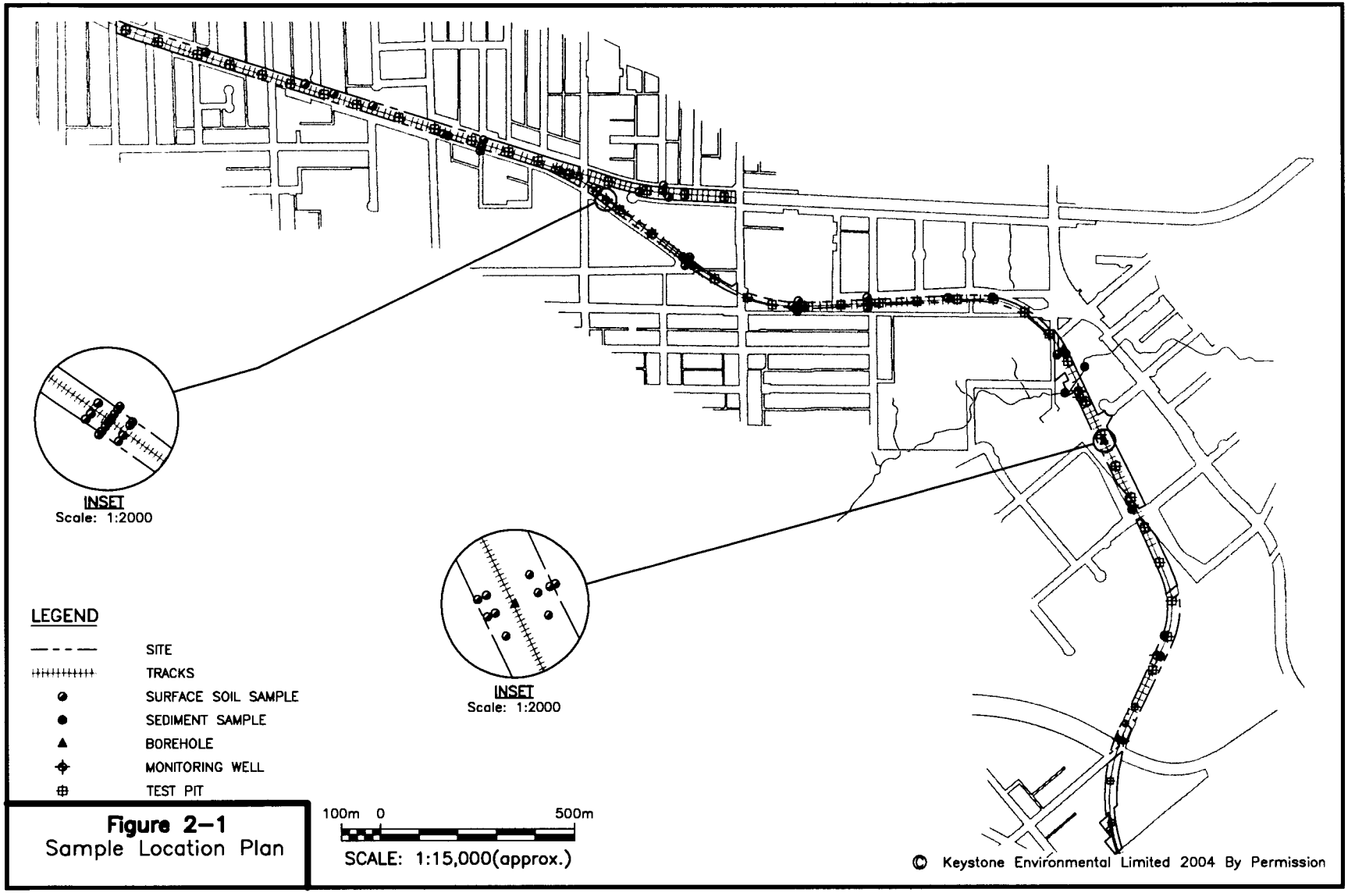

Figure 2–1
Sample Location Plan

2.2.2 Previous Environmental Investigations

Environmental investigations were conducted previously at the site by Golder Associates (2001) and Keystone Environmental Ltd. (Keystone 2004). Sampling locations are identified in Figure 1. During the 2001 investigation, discrete and composite surficial soil samples were collected from the immediate vicinity of the track at several locations along the length of the site. Composite soil samples consisted of three discrete samples; one collected from the track centre line, and two collected at distances of three metres on either side of the track centre-line. Groundwater and sediment samples were not collected during the 2001 investigation. During the 2004 investigation, additional discrete surficial soil samples were collected to further characterize soil quality near the track and to delineate regulatory soil exceedances identified during the 2001 investigation. In addition, soil samples were collected at distances away from the track at regular intervals (approximately 100 metres) in order to characterize soil quality in these areas of the site. Subsurface soils were also collected during the 2004 investigation to vertically characterize soil quality. Sediment samples were collected from a creek, which crosses the site, during the 2004 investigation at locations immediately up and down gradient from the site. Four groundwater wells were also installed and sampled during the 2004 investigation. These groundwater wells were positioned along the length of the site. Surface water samples were not collected during either investigation.

Soil, groundwater and sediment samples were submitted to CANTEST laboratories and analyzed for various chemical constituents. Chemical constituents analyzed included

light and heavy extractable petroleum hydrocarbons (LEPH/HEPH), polycyclic aromatic hydrocarbons (PAH), volatile organic compounds (VOCs), chlorinated phenolic compounds, pesticides, and/or metals. Analytical results from these investigations indicate that several inorganic and organic chemical constituents are present in environmental media at the site at concentrations greater than the standards contained in the BC Contaminated Sites Regulation (BC 1997). Analytical results from these investigations are tabulated in Appendix A and are discussed further in Section 2.4.

2.2.3 Purpose of the Ecological Risk Assessment

The purpose of the ERA is to determine if concentrations of chemical contaminants identified in site media pose unacceptable risks to ecological receptors. The results of the ERA will be used to determine if remedial actions are required to mitigate or manage ecological risks at the site.

2.3 Site Description

2.3.1 Physical Setting

The site varies in width between 15 and 40 metres and comprises an area of approximately 11.2 hectares. Although the site is no longer used for rail-related activities, rail ties, track and ballast remain in place on much of the site. Surface water bodies at the site include a creek, which crosses the central portion of the site within a culvert, and shallow, intermittent drainage ditches, which run parallel to the rail-line on

portions of the site. The site itself is relatively flat-lying. Drainage occurs by infiltration and runoff to the shallow drainage ditches as well as by surface runoff to neighbouring properties. The water table at the site was reported to be between 5 and 17 metres below ground surface.

The site is surrounded by commercial/industrial businesses and/or homes. A walking path is present along sections of the site and on adjacent areas, which is frequently used by pedestrians and cyclists. In general, the area surrounding the site is urban in nature without large green spaces. Nearby areas of high environmental value (i.e., parks, refuges etc.) were not noted in the vicinity of the site.

2.3.2 Ecological Setting

The site is located within the Coastal Western Hemlock (CWH) biogeoclimatic zone and is characterized by cool summers (although hot dry spells can be frequent) and mild winters (BCMOF 1991).

A species/habitat survey was conducted on August 14, 2003. Strips of vegetation of varying widths are present adjacent to the rail ballast. With the exception of Himalayan blackberry (*Rubus discolor*) and red alder (*Alnus rubra*) present in some areas, most areas of the ballast were clear of vegetation. Vegetation adjacent to the rail ballast varied depending on the level of historical disturbance but was largely characterized by opportunistic weeds and mixed grasses (family Poaceae), Himalayan blackberry, and red alder. Other terrestrial plant species observed on the site include black cottonwood

(*Populus balsamifera* ssp. *trichocarpa*), paper birch (*Betula papyrifera*), Douglas fir (*Pseudotsuga menziesii*), western redcedar (*Thuja plicata*), willow species (*Salix* sp.), scotch broom (*Cytisus scoparius*), western hemlock (*Tsuga heterophylla*), bigleaf maple (*Acer macrophyllum*), and choke cherry (*Prunus virginiana*).

Vegetation associated with the shallow drainage ditches running adjacent to the track include mixed grasses (family Poaceae), sedges (family Cyperaceae), and rushes (family Juncaceae). Vegetation associated with the riparian areas of the creek include vine maple (*Acer circinatum*), skunk cabbage (*Lysichiton americanum*), salmonberry (*Rubus spectabilis*), red-osier dogwood (*Cornus stolonifera*), mature western redcedar (*Thuja plicata*), mature black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), mature red alder (*Alnus rubra*), and epiphytes on streambed cobble. Threatened or endangered plant species were not observed at the site.

The avian species observed at the site included American robin (*Turdus migratorius*), northwestern crow (*Corvus caurinus*), rufous-sided towhee (*Pipilo erythrophthalmus*), and sparrows.

The introduced eastern grey squirrel (*Sciurus carolinensis*) was the sole mammalian species observed at the site. The presence of coyotes (*Canis latrans*) at the site was indicated by observations of scat in certain areas. Given the site's urban setting, it is expected that the common raccoon (*Procyon lotor*) also uses the site. Considering the abundance and diversity of vegetation at the site, it is also expected that other small mammalian species including mice, moles, shrews etc. are present, although they were

not observed during the site survey. Three garter snakes (*Thamnophis sirtalis*) were observed at various locations at the site. Threatened or endangered wildlife species were not observed during the site survey.

2.4 Data Screening

Analytical chemistry data obtained during previous investigations (Golder, 2001; Keystone 2004) were screened in order to identify the constituents of potential ecological concern (COPECs) to be evaluated in the ERA.

2.4.1 Methodology

The data considered in the screening process consisted of soil, groundwater and sediment chemistry results from environmental investigations conducted by Golder Associates (2001) and Keystone Environmental Ltd. (Keystone 2004). The screening methods used were based on BC ERA guidance (BCMELP 1998) as well as practices typical of risk assessment practitioners in BC. The data screening process consisted of the following activities:

- Selection of chemical and media-specific screening levels;
- Comparison of soil, groundwater and sediment chemistry data with screening levels;
- Identification of 'preliminary' constituents of potential ecological concern (COPECs) based on direct comparison of chemistry data with screening levels;
- Analysis of summary statistics for each preliminary COPEC data set; and
- Determination of a final list of COPECs to be retained for evaluation in ERA.

2.4.1.1 Data Screening Levels

The first task in the data screening process is to determine concentration thresholds for each chemical for comparison to laboratory analytical results. These thresholds or screening levels are concentrations above which a chemical has the potential to pose unacceptable ecological risk at the site. These values served as the first criteria in the selection of COPECs to be evaluated in the ERA.

The screening levels applied in the ERA were the applicable soil and groundwater standards and sediment criteria contained in the BC Contaminated Sites Regulation (CSR) (BC 1997), the primary legislation containing such standards/criteria in BC. The CSR (BC 1997) contains risk-based numerical soil, water and sediment standards/criteria that are applied according to land use. Generic numerical and matrix numerical soil standards exist for agricultural, residential, urban park, commercial and industrial use. Generic soil standards are available for a range of organic and inorganic constituents and are applicable and protective of all receptors (human and ecological) at a site depending on land use. The matrix soil standards exist for approximately 20 organic and inorganic substances and list separate standards specific to land use and receptor (human and ecological).

Sediment criteria exist for freshwater and marine/estuarine sediments at *sensitive* and *typical* contaminated sites. The criteria for designating a site as sensitive or typical is detailed in the BCMWLAP document, *Criteria for Managing Contaminated Sites in British Columbia, Technical Appendix* (BCMWLAP 2003) and is based on the use of the

site, the presence of important and unique habitat, and the presence of sensitive, threatened and endangered species. Not surprisingly, the sediment criteria for sensitive contaminated sites are more conservative than those for typical contaminated sites.

The water use standards contained in the CSR (BC 1997) are set for comparison to chemical concentrations in groundwater and include standards for aquatic life, irrigation, livestock and drinking water use. The applicability of these water use standards is dependent upon the proximity of the site to these water uses. Details pertaining to the selection of screening levels for comparison to soil, sediment and groundwater data are presented in the following sections.

The intended future use of the site is a park and therefore the soil standards specified for urban park land use were used to screen soil analytical data. Where matrix soil standards were available, the most conservative matrix standards among those specified for *'toxicity to soil invertebrates and plants'* and *'groundwater flow to surface water used by aquatic life'* was adopted as the soil screening level. The matrix soil standards for *'toxicity to soil invertebrates and plants'* was considered because its application is mandatory at all sites (BC 1997). *The 'groundwater flow to surface water used by aquatic life'* matrix soil standards were applied because several aquatic-life bearing water courses are present near the site. In addition to the CSR soil standards, analytical data for inorganic constituents were compared to the CSR regional background soil quality estimates (BC 1997). Where the established regional background estimate for a constituent was greater than the CSR generic or matrix standard, the background concentration was adopted as the final

screening level for that constituent. The soil chemistry data and applicable screening benchmarks are provided in Tables A-1 to A-6 (Appendix A).

In the interest of conservatism, sediment chemistry data was compared to the CSR (BC 1997) sediment (freshwater) criteria for sensitive contaminated sites. The sediment chemistry data and applicable screening benchmarks are provided in Tables A-7 to A-10 (Appendix A).

The CSR (BC 1997) requires that aquatic life standards be applied when a site is located within one kilometre of an aquatic life bearing water body. Given the presence of an aquatic-life bearing creek on the site, the screening benchmarks selected for comparison to groundwater chemistry data were the CSR (BC 1997) water standards for aquatic life water use. If available, standards specific to the protection of freshwater aquatic life were used. Drinking water use standards were not applicable to the site as drinking water wells were not identified within 1.5 kilometer of the site. Similarly, irrigation and livestock water use standards were not applicable to the site as agricultural areas are not present in the vicinity of the site. The groundwater chemistry data and applicable screening benchmarks are provided in Tables A-11 to A-16 (Appendix A).

Many of the constituents measured in site media are not regulated in British Columbia. When selecting COPECs, consideration for the selection of non-regulated constituents was based on concentration comparisons to surrogate screening levels or on the frequency and magnitude of analytical detection. For the non-regulated PAH constituents, the most conservative applicable CSR standard among the regulated PAHs was used as the

surrogate screening benchmark. Generally, non-regulated pesticides and herbicides detected in environmental media at the site were retained as COPECs. Given the ubiquitous nature of many inorganic constituents in environmental media, non-regulated inorganic constituents in site media were not considered to pose a threat to ecological receptors and therefore were not considered in the ERA.

2.4.1.2 COPEC Selection Criteria

If the maximum concentration of a chemical constituent exceeded its screening level in a given medium, that constituent was considered a *preliminary COPEC* in that particular medium. To refine the list of preliminary COPECs to those considered to have a significant potential to cause adverse effects to ecological receptors, BCMWLAP endorses the use of the following additional screening criteria:

- The 95th percent upper confidence limit (UCL95) of the arithmetic mean concentration is greater than the screening benchmark; and,
- The maximum concentration is equal to or greater than two times the screening benchmark.

Applying this approach, only those preliminary COPECs meeting at least one of the above conditions are retained for quantitative evaluation in the ERA. The rationale for the first criterion is based on the notion that the arithmetic mean chemical concentration is the most appropriate and representative value to use as the reasonable maximum exposure (RME) concentration in risk assessments because of the assumption that exposed organisms have an equal chance of exposure to environmental media anywhere

in the exposure area and therefore the spatially averaged concentration is the best estimate of the concentration that would be contacted at the site over time (ADEC 2001). Because the arithmetic average concentration of the samples collected would only be an estimate with some degree of uncertainty of the true average concentration, the 95th percent upper confidence limit (UCL95) of the arithmetic mean is recommended by BC guidance and policy (BCMELP 1998; BCMELP 2000) as the preferred RME concentration term when estimating environmental exposures. Use of the UCL95 provides reasonable confidence that the true site average is not underestimated. It follows then that if the RME concentration of a given COPEC (as estimated by the UCL95) is below the risk-based screening benchmark, the probability that the COPEC will cause adverse effects to ecological receptors is likely low.

UCL95s for the preliminary COPECs were calculated by the non-parametric bootstrap method using a Visual Basic computer program. The bootstrap method was used because it allows the use of non-randomly collected samples and eliminates the requirement for the sample population to meet any particular parametric distribution (normal, lognormal, etc.).

In situations where the UCL95 concentrations for a preliminary COPEC is below the screening benchmark, the second criterion is considered to protect against potential acute effects caused by the few concentrations on a site that may slightly exceed the screening benchmark.

2.4.2 Results

2.4.2.1 Identification of Soil COPECs

Soil analytical results are provided in Tables A-1 through A-6 (Appendix A).

Inorganic Constituents

The regulated inorganic constituents detected in soil at concentrations exceeding screening levels are arsenic, cadmium, chromium, copper, molybdenum and zinc. Summary statistics for these constituents are provided in Table 2-1. Rationale for retaining or excluding these constituents as COPECs in the ERA is provided below.

Arsenic

Soil arsenic concentrations were compared to the CSR matrix standard for groundwater flow to surface water (fresh) used by aquatic life at urban park sites (20 mg/kg). Arsenic was identified in surficial soil at three locations at concentrations exceeding this screening level. Two of the three exceedances exceeded the screening benchmark by at least two times and therefore, arsenic was retained as a COPEC in site soil.

Cadmium

The mean soil pH measured at the site was 6.0. As a result, soil cadmium concentrations were compared to the CSR matrix soil standard for groundwater flow to surface water

Table 2-1. Summary statistics for preliminary constituents of potential ecological concern (COPECs) in soil.

Preliminary COPEC	Sample Count (n)	Concentration Range (mg/kg)	UCL95 (mg/kg)	Screening Benchmark (mg/kg)*
Metals				
Arsenic	66	2.1 - 97.8	11	20
Cadmium	66	0.1 - 2.1	0.5	2
Chromium	66	10.6 - 162.0	26.6	100
Copper	75	10.0 - 684.0	159.6	200
Molybdenum	66	0.2 - 33.0	3.3	10
Zinc	69	18.0 - 1240.0	154.3	150
Pesticides				
Diuron	29	0.025 - 0.25	0.08	n/a
Glyphosate	21	0.015 - 0.91	0.3	n/a
Simazine	29	0.01 - 0.03	0.02	n/a
Petroleum Hydrocarbons				
Acenaphthene	33	0.01 - 0.49	0.07	1
Acenaphthylene	33	0.02 - 0.81	0.1	1
Anthracene	33	0.03 - 2.7	0.3	1
Benzo(a)anthracene	33	0.01 - 3.2	0.4	1
Benzo(b)fluoranthene	33	0.025 - 11	1.2	1
Benzo(g,h,i)perylene	33	0.03 - 1.9	0.3	1
Benzo(k)fluoranthene	16	0.09 - 4.5	1.0	1
Benzo(a)pyrene	33	0.025 - 2.8	0.4	1
Chrysene	33	0.03 - 12	1.3	1
Fluoranthene	33	0.03 - 17	1.9	1
Fluorene	33	0.01 - 0.34	0.05	1
Indeno(1,2,3-cd)pyrene	33	0.025 - 2.9	0.4	1
Pyrene	33	0.05 - 15	2.45	10
LEPH	71	5 - 1000	96.1	1000
HEPH	71	5 - 3300	327.9	1000
Chlorinated Phenolics				
Pentachlorophenol	25	0.0025 - 0.31	0.09	2.5
Ancillary Parameters		Arithmetic Mean		
pH	83	6.0		

*Analytical results for composite soil samples were compared to 1/3 of these screening benchmarks.

used by aquatic life for cadmium for pH values less than 7.0 (2 mg/kg). Cadmium was identified in surficial soil at two locations at concentrations equal to or greater than this screening benchmark. However, a review of the summary statistics for cadmium (Table 2-1) indicates that no concentration measured was equal to or greater than two times the benchmark and that the UCL95 does not exceed the benchmark. As a result, cadmium in site soil was not considered to pose a significant threat to ecological receptors and was not carried forward as a COPEC in the ERA.

Chromium

Soil chromium concentrations were compared to the regional background soil quality estimate (100 mg/kg). A review of the summary statistics for chromium (Table 2-1) indicates that none of the concentrations measured exceed the screening benchmark by at least two times and that the UCL95 concentration is well below the screening value. On this basis, chromium was not retained as a COPEC in soil in the ERA.

Copper

Given the mean soil pH measured at the site (6.0), soil copper concentrations were compared to the CSR matrix standard for groundwater flow to surface water used by aquatic life for copper for pH values between 5.5 and 6.0 (200 mg/kg). Copper was identified in soil at concentrations exceeding this screening benchmark in 15 of 75 samples collected. Considering the number of exceedances and that several exceedances

were in excess of two times the screening benchmark, copper was retained as a COPEC in soil in the ERA.

Molybdenum

Soil molybdenum concentrations were compared to the CSR generic soil standard for urban park sites (10 mg/kg). Molybdenum was detected in a single surficial soil sample at a concentration in excess of two times the benchmark. On this basis, molybdenum was carried forward as a COPEC in soil.

Zinc

Given the mean soil pH measured at the site (6.0), soil zinc concentrations were compared to the CSR matrix soil standard for groundwater flow to surface water used by aquatic life for pH values less than 6.0 (150 mg/kg). Zinc was detected in soil at concentrations in excess of this benchmark in 12 of the 69 samples collected. Considering that several of these exceedances were greater than twice the screening benchmark, zinc was retained as a COPEC in soil in the ERA.

Pesticides/Herbicides

Regulated pesticide/herbicides were not detected in site soil and therefore were not retained as COPECs in soil in the ERA. Pesticides and herbicides detected in site soil that are not regulated in BC included diuron, glyphosate, and simazine. Summary

statistics for these constituents are provided in Table 2-1. Rationale for the inclusion or exclusion of these constituents as COPECs is provided below.

Diuron

Diuron was detected in site soil in 7 of the 30 samples collected at concentrations ranging from 0.05 to 0.25 mg/kg. Given its frequency of detection in soil, diuron was retained as a COPEC in soil in the ERA.

Glyphosate

Glyphosate was detected in site soil in 10 of the 22 samples collected at concentrations ranging from 0.031 to 0.91 mg/kg. Given its frequency of detection, glyphosate was retained as a COPEC in soil in the ERA.

Simazine

Simazine was detected in a single surficial soil sample (out of a total of 29) at a concentration equal to the reported laboratory detection limit (0.03 ppm) (Keystone 2003). Considering that simazine was only detected at a single location, the low concentration detected and the analytical uncertainty at concentrations near the detection limit, simazine was not retained as a COPEC in soil.

Chlorinated Phenols

Pentachlorophenol (penta) was the only chlorinated phenolic constituent (regulated or non-regulated) detected in site soil. Given the mean soil pH measured at the site (6.0), soil penta concentrations were compared to the CSR matrix numerical soil standard for groundwater flow to surface water used by aquatic life for pH values between 5.5 and 6.0 (2.5 mg/kg). As none of the penta concentrations measured exceeded this screening level, penta was not retained as a COPEC in soil in the ERA.

Petroleum Hydrocarbons

The regulated petroleum hydrocarbon constituents detected in soil at concentrations exceeding screening levels are light and heavy extractable petroleum hydrocarbons (LEPH/HEPH), pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene. Summary statistics for these constituents are provided in Table 2-1. Rationale for retaining or excluding these constituents as COPECs in the ERA is provided below.

Light Extractable Petroleum Hydrocarbons (LEPH)

Soil LEPH concentrations were compared to the CSR generic soil standard for urban park sites (1000 mg/kg). LEPH was detected in 31 of 71 soil samples analyzed. A composite soil sample collected contained a concentration of LEPH of 1000 mg/kg, which is equal to the screening benchmark. Because composite samples were screened versus 1/3 of the

screening benchmarks to account for the number of discrete samples comprising them, this sample exceeded the adjusted screening benchmark (333.33 mg/kg) by more than two times. Based on the above, LEPH was retained as a COPEC in soil in the ERA.

Heavy Extractable Petroleum Hydrocarbons (HEPH)

Soil HEPH concentrations were compared to the CSR generic soil standard for urban park sites (1000 mg/kg). HEPH was detected in 53 of 71 samples collected at the site. Several samples analyzed exceeded the screening benchmark by at least two times. On this basis and considering that HEPH was detected in surficial soil across much of the site, HEPH was retained as a COPEC in soil.

Pyrene

Soil pyrene concentrations were compared with the CSR generic soil standard for urban park sites (10 mg/kg). Pyrene was detected in 25 of 33 soil samples analyzed at concentrations ranging from 0.05 to 15 mg/kg. A review of the summary statistics (Table 2-1) indicates that pyrene concentrations in site soil did not exceed the screening benchmark by greater than two times in any sample collected and the UCL95 concentration is less than the screening benchmark. Therefore, pyrene was not retained as a COPEC in soil in the ERA.

Benzo(a)anthracene

Soil benzo(a)anthracene concentrations were compared with the CSR generic soil standard for urban park sites (1 mg/kg). Benzo(a)anthracene was detected in soil in 21 of 33 samples analyzed at concentrations ranging from 0.06 to 3.2 mg/kg. As at least one sample contained benzo(a)anthrancene at concentrations greater than two times the screening benchmark, benzo(a)anthracene was retained as a COPEC in soil in the ERA.

Benzo(b)fluoranthene

Soil benzo(b)fluoranthene concentrations were compared to the CSR generic soil standard for urban park sites (1 mg/kg). Benzo(b)fluoranthene was detected in soil in 27 of 34 soil samples analyzed at concentrations ranging from 0.05 to 11 mg/kg. As at least one sample analyzed contained benzo(b)fluoranthene at concentrations greater than two times the screening benchmark, benzo(b)fluoranthene was retained as a COPEC in soil in the ERA.

Benzo(k)fluoranthene

Soil benzo(k)fluoranthene concentrations were compared to the CSR generic soil standard for urban park sites (1 mg/kg). Benzo(k)fluoranthene was detected in soil in 16 of 16 soil samples analyzed at the site at concentrations ranging from 0.09 to 4.5 mg/kg. As at least one sample contained benzo(k)fluoranthene at concentrations greater than two

times the screening benchmark, benzo(k)fluoranthene was retained as a COPEC in soil in the ERA.

Benzo(a)pyrene

Soil benzo(a)pyrene concentrations were compared to the CSR matrix soil standard for toxicity to soil invertebrates and plants at urban park sites (1 mg/kg). Benzo(a)pyrene was detected in soil in 18 of 33 soil samples analyzed at the site at concentrations ranging from 0.04 to 2.8 mg/kg. Given that at least one sample contained benzo(a)pyrene at concentrations greater than two times the screening benchmark, benzo(a)pyrene was retained as a COPEC in soil.

Indeno(1,2,3-cd)pyrene

Soil indeno(1,2,3-cd)pyrene concentrations were compared with the CSR generic numerical soil standard for urban park sites (1 mg/kg). Indeno(1,2,3-cd)pyrene was detected in soil in 20 of 33 soil samples collected at concentrations ranging from 0.05 to 2.9 mg/kg. Given that at least one sample analyzed contained indeno(1,2,3-cd)pyrene at concentrations greater than two times the screening benchmark, indeno(1,2,3-cd)pyrene was retained as a COPEC in soil in the ERA

Non-Regulated Petroleum Hydrocarbons

Soil concentrations of the non-regulated PAHs were compared to the most conservative CSR soil standard among the regulated PAHs at urban park sites (1 mg/kg). Summary statistics for the non-regulated petroleum hydrocarbon constituents detected in site soils are provided in Table 2-1. Of the non-regulated PAHs detected, anthracene, fluoranthene and chrysene were retained as COPECs in soil because they were detected in at least one sample at concentrations greater than twice the surrogate screening level. The remaining PAHs detected in soil were not carried forward as COPECs in soil in the ERA.

2.4.2.2 Identification of Sediment COPECs

Inorganic Constituents

None of the regulated inorganic constituents analyzed in sediment exceeded their respective CSR sediment criteria and therefore they were not retained as COPECs in sediment in the ERA.

Chlorinated Phenols

Chlorinated phenolic compounds were not detected in site sediment and therefore were not retained as COPECs in this medium.

Petroleum Hydrocarbons

Regulated petroleum hydrocarbon constituents detected in site sediment at the site included the PAH constituents phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, and benzo(a)pyrene. None of these constituents were detected at concentrations greater than their respective CSR sediment criteria and therefore they were not retained as COPECs in sediment in the ERA.

Benzo(b)fluoranthene was the only non-regulated petroleum hydrocarbon constituent detected in sediment at the site. Benzo(b)fluoranthene was detected in both up and down-stream sediment samples at 0.1 and 0.07 mg/kg, respectively. In the absence of a CSR criterion for this constituent, the screening level used was the CSR criterion for dibenz(a,h)anthracene (0.084 mg/kg), the most conservative criterion among the regulated high molecular weight PAHs. Measured benzo(b)fluoranthene concentrations exceeded this benchmark in the up-stream sample only. Given that this sample was collected up-stream from the site, and the presence of several potential sources of hydrocarbon constituents upstream from the site, it was considered unlikely that these detected hydrocarbons originated from the site. Therefore benzo(b)fluoranthene was not retained as a COPEC in sediment in the ERA.

2.4.2.3 Identification of Groundwater COPECs

Inorganic Constituents

None of the regulated inorganic constituents analyzed in groundwater were detected at concentrations exceeding their respective CSR aquatic life water use (AW) standards. Consequently, these constituents were not retained as COPECs in groundwater in the ERA.

Pesticides and Herbicides

Regulated pesticides and herbicides were not retained as COPECs in groundwater as none of the concentrations measured were in excess of their respective CSR AW standards. Non-regulated pesticides and herbicides were not detected in groundwater and consequently were not retained as COPECs in groundwater.

Petroleum Hydrocarbons

None of the regulated petroleum hydrocarbon constituents analyzed in site groundwater exceeded CSR AW standards and therefore they were not retained as COPECs in this medium. Several non-regulated high molecular weight PAHs including chrysene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene and benzo(g,h,i)perylene were detected in site groundwater. In order to evaluate these detections, the CSR AW standard for benzo(a)pyrene, the most conservative screening level among the regulated high molecular weight PAHs, was used as a surrogate

screening level. None of these constituents exceeded the surrogate screening benchmark and therefore they were not retained as COPECs in groundwater in the ERA.

Volatile Organic Compounds (VOCs)

None of the regulated VOCs measured in groundwater were detected at concentrations exceeding CSR AW standards and therefore these constituents were not retained as COPECs in groundwater in the ERA. cis-1,2-Dichloroethene and xylenes were the only non-regulated VOCs detected in groundwater at the site. cis-1-2-Dichloroethene was detected in groundwater at MW04-8 at 0.7 µg/L. Groundwater at this location was approximately 17 metres below ground surface and the nearest aquatic life-bearing water body is located approximately 250 metres to the west. Based on the relatively low concentration detected, the depth to groundwater at this location and the distance to the nearest aquatic life-bearing water body, cis-1-2-dichloroethene detected in groundwater was not considered to pose a significant threat to ecological receptors and therefore was not carried forward as a COPEC in groundwater in the ERA.

Xylenes were detected in a single well location (MW04-7) at 0.6 µg/L. Groundwater at this location was approximately 8 metres below ground surface and the nearest aquatic-life-bearing water body is located approximately 100 metres to the west. Considering the relatively low concentration detected, the depth to groundwater at this location and the distance to nearest aquatic life-bearing water body, xylenes in groundwater were not considered to pose a significant threat to ecological receptors and therefore were not retained as COPECs in groundwater in the ERA.

2.4.2.4 Identification of Surface Water COPECs

Surface water was not sampled at the site and consequently, surface water COPECs could not be identified.

2.4.2.5 Summary of COPECs

The COPECs retained for evaluation in the ERA are summarized in Table 2-2. Each of these constituents has been carried forward in soil only. COPECs were not identified in groundwater or sediment at the site. As site surface water was not sampled, COPECs that may be present in surface water could not be identified.

Table 2-2. Constituents of potential ecological concern (COPECs).

Arsenic	Benzo(k)fluoranthene
Copper	Chrysene
Molybdenum	Fluoranthene
Zinc	Indeno(1,2,3-cd)pyrene
Anthracene	LEPH
Benzo(a)anthracene	HEPH
Benzo(a)pyrene	Diuron
Benzo(b)fluoranthene	Glyphosate

2.5 Ecological Receptors of Concern

Depending on the use of a site, BC ERA guidance (BCMELP 1998) recommends terrestrial and aquatic receptor groups that should be protected as valued ecosystem components (VECs). On commercial and industrial sites, biodiversity is limited largely by the quantity and suitability of the habitat. Consequently, the number of VECs

recommended for these types of sites is small compared to residential or park sites, which may be expected to support a wider range of organisms. For urban park sites, the terrestrial receptor groups recommended by BC guidance (BCMELP 1998) include invertebrates, vegetation, resident or migrant birds (including galliforms, cavity-dwellers, raptors and any threatened, endangered or sensitive species), resident or migrant mammals (including any threatened, endangered or sensitive species), and, reptiles. Aquatic receptor groups recommended for urban park sites include invertebrates, vegetation, resident fish, resident or migrant birds (including any threatened, endangered or sensitive species) and amphibians.

In order to determine if threatened or endangered species may access the site, the British Columbia Conservation Data Centre (CDC) was consulted to conduct a database search for such species in the vicinity of the site. The search did not identify occurrences of threatened or endangered species in the vicinity of the site.

Based on BC guidance (BCMELP 1998), the distribution of COPECs in site media and site observations, the ecological receptor groups of concern considered in the ERA include soil and foliar invertebrates, terrestrial vegetation, terrestrial mammals and birds (including omnivorous, insectivorous and carnivorous species), and reptiles. BC guidance (BCMELP 1998) suggests that galliforms (e.g., quail, pheasants) be considered as avian receptors of concern on urban park sites. Given the narrowness of the site, its urban setting and that there are no other larger green spaces in the area, the site is unlikely to provide sufficient quality habitat capable of supporting populations of galliforms. As a

result, galliforms were not considered as receptors or concern. Because site surface water data has not been collected, aquatic receptors cannot be ruled out as receptors of concern. However, due to the absence of surface water data, risks to aquatic receptors could not be evaluated in the ERA.

2.5.1 Measurement Receptors

Assessing the risks to all species belonging to the receptor groups of concern presented above would be an unreasonable task. In order to assess risks for the receptor groups of concern, surrogate receptors representative of each receptor group were used. These surrogate receptors are called measurement receptors. Where a receptor group of concern is likely represented at the site by species from more than one feeding guild (e.g., carnivores, insectivores), multiple measurement receptors were utilized to account for the multiple pathways by which organisms may be exposed to the COPECs. Additional criteria used to select measurement receptors include the following:

- The measurement receptor does or could use habitat present at the site;
- The measurement receptor is reflective and representative of the receptor group;
- The measurement receptor is known to be either sensitive or highly exposed to COPECs at the site; and
- Adequate toxicological and natural history information is available for the measurement receptor.

The representative measurement receptors utilized in the ERA are presented below in Table 2-3.

Table 2-3. Receptors groups of concern and measurement receptors.

Receptor Group of Concern	Measurement Receptor
Soil Invertebrates	Specific measurement receptor not used
Foliar Invertebrates	Specific measurement receptor not used
Terrestrial Plants	Specific measurement receptor not used
Omnivorous Mammal	Deer Mouse (*Peromyscus maniculatus*)
Carnivorous Mammal	Coyote (*Canis latrans*)
Mammalian Arboreal Insectivore	Little Brown Bat (*Myotis lucifugus*)
Omnivorous Bird	American Robin (*Turdus migratorius*)
Cavity-Dwelling Bird	Pileated Woodpecker (*Dryocopus pileatus*)
Raptor	Red-tailed Hawk (*Buteo jamaicensis*)
Reptile	Common Garter Snake (*Thamnophis sirtalis*)

2.6 Conceptual Model

A conceptual model for the site is provided as Figure 2. The model describes, by way of illustration, the manner in which the ecological receptors of concern may be exposed to the COPECs. Receptor exposures are evaluated in detail in the following section.

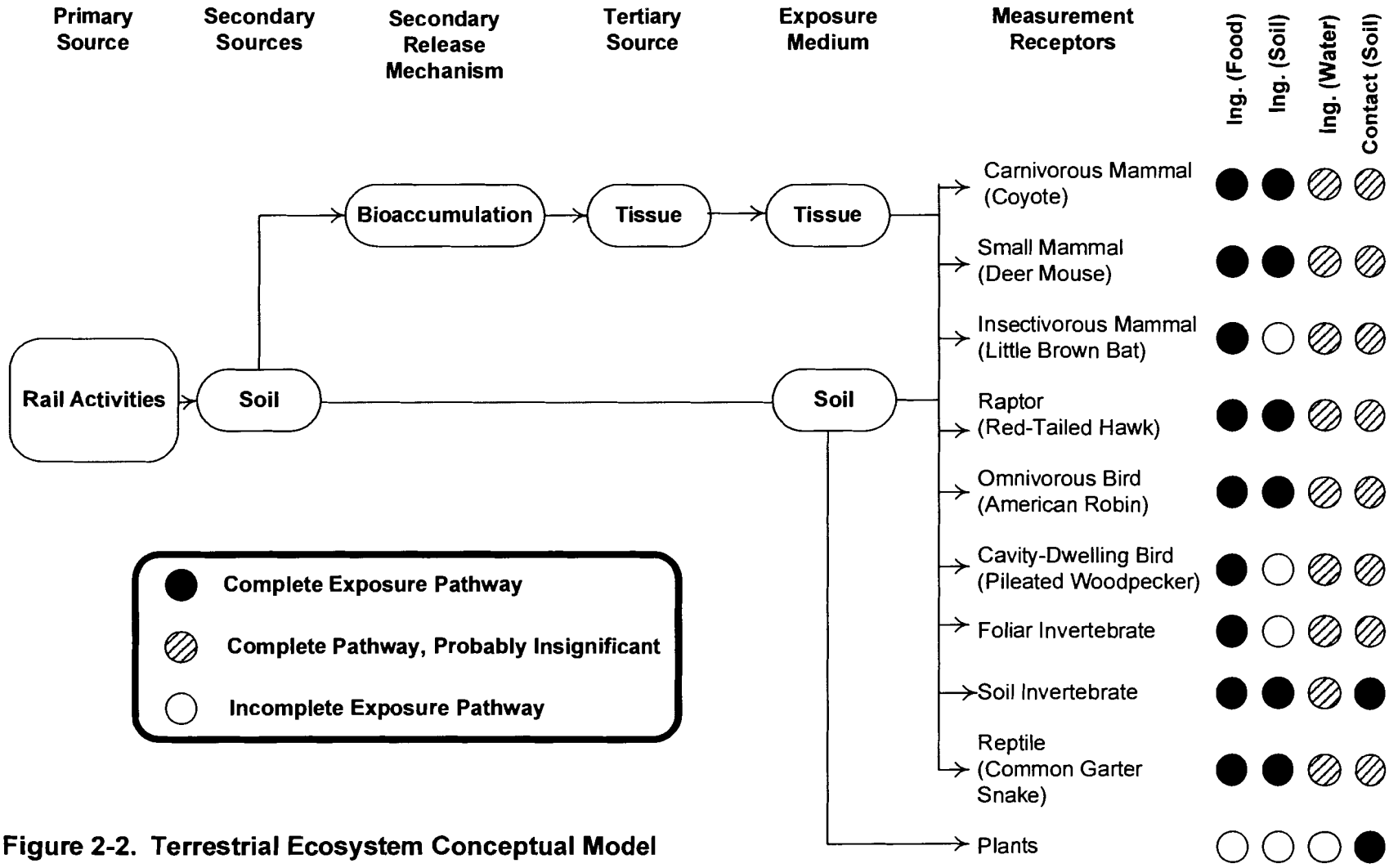

Figure 2-2. Terrestrial Ecosystem Conceptual Model

3 EXPOSURE ASSESSMENT

3.1 Introduction

Exposure is the contact or co-occurrence of a contaminant with a receptor (Suter et al. 2000). Exposure is a key element of risk because toxicant-induced effects cannot occur in the absence of exposure (Klaassen 1996). Exposure assessment is the first of two analysis phases of the ecological risk assessment and attempts to answer the following questions: how may ecological receptors come in contact with toxins at the site; and, what amounts of each toxin are ecological receptors actually or potentially exposed? (CCME 1997).

An exposure pathway is the physical route by which a contaminant moves from a source to a biological receptor (Suter 2000). Exposure can only occur if a complete exposure pathway exists. In order for an exposure pathway to be complete, the following elements must exist: a contaminant source (e.g., creosote treated rail ties); a release mechanism (e.g., leaching); a transport medium for the released contaminants (e.g., soil/groundwater); a point of contact for the receptor (plant root); and, a route of entry into the receptor (e.g., absorption via route).

The first task in the exposure assessment was to identify the complete exposure pathways for each receptor of concern. The second task was to estimate the exposure of each receptor to the COPECs.

3.2 Methodology

3.2.1 Pathways of Exposure

Complete exposure pathways for each receptor were determined based on the distribution of the COPECs in site media, the physicochemical properties of the COPECs and the traits and distribution of ecological receptors at the site.

3.2.2 Exposure Estimation

The methods used to estimate exposures for ecological receptors were consistent with BC guidance for screening level (Tier 1) ERA (BCMELP 1998). Because BC guidance does not provide all of the tools required to estimate ecological exposures, guidance published by the Oak Ridge National Laboratory (ORNL) was also used. The ORNL provides algorithms for estimating contaminant exposures by wildlife which are used widely by professional practitioners of ERA in BC.

BC guidance (BCMELP 1998) allows for the use of direct measurement and/or modeling approaches to estimate exposures by ecological receptors. The primary direct measures used to estimate exposures were the COPEC concentrations measured in environmental media (i.e., soil and sediment). As per BC policy (BCMELP 2000), the 95th percent upper confidence limit (UCL95) of the arithmetic mean COPEC concentrations measured in environmental media were used as exposure point concentrations or estimated environmental concentrations (EECs) in the ERA. The UCL95 concentration was used as

the EEC because it is a conservative, upper-bound estimate of the arithmetic mean concentration, which is generally considered the most appropriate and representative value to use as the EEC concentration in risk assessments (ADEC 2001). The arithmetic mean concentration is considered to be the most appropriate for estimating exposure for two reasons:

- The toxicity estimates used in evaluating risks are based on chronic exposures; and,
- A potentially exposed organism is assumed to have an equal chance of exposure to environmental media anywhere in the exposure area; therefore the spatially averaged concentration is the best estimate of the concentration that would be contacted at the site over time.

Because data from only two sediment samples were available, UCL95s for sediment data sets could not be calculated. Therefore, the maximum COPEC concentrations measured in sediment were used as sediment EECs. This is a conservative approach and likely results in an overestimate of exposure. Soil and sediment EECs were used to estimate COPEC exposures concentrations for the lower trophic level receptors and total daily oral exposures (doses) for the higher trophic level (wildlife) receptors. In addition to media EECs, receptor-specific data from the USEPA's *Wildlife Exposure Factors Handbook* (USEPA 1993) and other literature sources were used in calculations to estimate exposures for the wildlife receptors.

3.2.1.1 Lower Trophic Level Receptors

The lower trophic level receptors of concern considered in the ERA include soil invertebrates, foliar invertebrates and terrestrial plants. In accordance with BC guidance (BCMELP 1998), exposure point concentrations for soil invertebrates and terrestrial plants at the site were assumed to be the EECs (i.e., the UCL95 concentration) calculated for each COPEC in soil, the primary exposure medium of these organisms. Exposure point concentrations for foliar invertebrates were assumed to be equivalent to modelled tissue concentrations (i.e., EEC) of terrestrial vegetation. This is based on the assumption that foliar invertebrates have their greatest exposures through the ingestion of COPECs present in the tissues of terrestrial plants. In order to model terrestrial plant tissue EECs, soil EECs were multiplied by soil-to-plant bioconcentration factors (BCFs) obtained from the scientific literature.

The lower trophic level receptors are food sources for several of the wildlife receptors and therefore, tissue EECs of the lower trophic level receptors were used to calculate dietary exposures for the wildlife receptors that contain these food items in their diets. As described for terrestrial plant tissue, soil invertebrate tissue EECs were modelled by multiplying soil EECs by published soil-to-soil invertebrate BCFs. Aquatic invertebrate and aquatic plant tissue EECs were modelled by multiplying sediment EECs by sediment-to-aquatic invertebrate and aquatic plant BCFs, respectively. Foliar invertebrate tissue EECs were assumed to be equivalent to terrestrial plant tissue concentrations. This approach assumes that 100% of the COPEC present in plant tissue is bioavailable to the

foliar invertebrate. This assumption is very conservative and is expected to overestimate exposure to foliar invertebrates. Soil and sediment EECs and calculated tissue EECs for the lower trophic level 'food sources' are provided in Table B-1 (Appendix B). Bioconcentration factors used to model terrestrial and aquatic invertebrate and plant tissue EECs are provided in Table B-2 (Appendix B).

3.2.1.2 Wildlife Measurement Receptors

The wildlife receptor groups and corresponding measurement receptors (in brackets) considered in the ERA include small omnivorous mammals (deer mouse), arboreal insectivores (little brown bat), carnivorous mammals (coyote), omnivorous birds (American robin), cavity-dwelling birds (pileated woodpecker), raptors (red-tailed hawk), and reptiles (common garter snake). As directed by BC policy (BCMELP 2000), wildlife exposures to COPECs were assumed to occur via the oral pathway only. According to BC policy (BCMELP 2000), the inhalation exposure route is not considered for terrestrial wildlife for three reasons. First, a highly volatile chemical will quickly cause an initial acute exposure, however concentrations are likely to diminish over time thus reducing chronic exposure and risk. Second, there is insufficient scientific data to adequately assess this pathway (i.e., toxicity information, wildlife characteristics affecting potential inhalation exposure, etc.). Also, inhalation in most circumstances is expected to contribute very little to exposure when compared with that via the ingestion pathway. As none of the COPECs considered have appreciable volatility, significant exposures to

COPECs in air and/or soil vapours are unlikely. However, the scientific validity of BC's policy is debateable and is discussed further in Section 6.

It is also BC policy (BCMELP 2000), to ignore the dermal contact exposure pathway for wildlife. The province's rationale for this policy is based on evidence suggesting that many species have pelage characteristics (e.g., fur, scales, feathers) that reduce their exposure to contaminants in the environment to negligible levels when compared to oral exposures (BCMELP 2000). The merits and limitations of this policy are also discussed in Section 6.

As per BC guidance (BCMELP 1998), daily oral doses for each wildlife receptor were estimated by adding modelled tissue COPEC concentrations of each dietary component in ratios that these food items comprise their diets. Receptor-specific data (e.g., body weight, food and water ingestion rates, home range size) and other site-specific data (e.g., contaminated site area) were also used in these calculations. The following equation described by Sample et al. (1997) was used to calculate total oral COPEC exposures for the wildlife receptors:

$$E_j = \frac{A}{HR}\left[\sum_{i=1}^{m}\sum_{k=1}^{n} P_{ik}(I_i \times C_{ijk})\right]$$

where,

E_j = Total oral exposure to contaminant (j) (mg/kg BW/day),

A = Contaminated site area (ha),

HR = Home range size (ha) of the measurement receptor,

m = Total number of ingested media (e.g, food, soil),

I_i = Ingestion rate for medium (i) (kg/kg BW/day or L/kg BW/day),

n = Number of types of medium (i) consumed,

P_{ik} = Proportion of type (k) of medium (i) consumed,

C_{ijk} = Concentration of contaminant (j) in type (k) of medium (i) (mg/kg or mg/L).

Receptor-specific data and exposure assumptions used to estimate daily oral exposures for each wildlife measurement receptor are presented in Tables B-3 to B-9 (Appendix B).

To account for the effect of a receptor's home range size on exposure, the above equation contains a 'site-use' term (*A/HR*) made up of the contaminated site area (*A*) and the estimated home range (*HR*) of each measurement receptor. Where the home range of a given receptor is less than the contaminated site area, the entire contaminated area is used to calculate exposure (*A/HR* = 1). This assumption implies that all of the food consumed by such a receptor is from the contaminated site and is therefore contaminated. This would seem to be a highly conservative assumption which may cause overestimation of exposures since some food items may have originated off-site or may not have been exposed to site contaminants. In addition, a site-use factor of one (1) assumes that the entire site area offers suitable habitat for a given receptor, which is seldom true for contaminated sites. Conversely, if the contaminated site area is less than the home range of the receptor, the total exposure to site COPECs is reduced by using the proportion of the contaminated site area to the receptor's home range in the calculation (Sample et al. 1997). The uncertainty in estimating wildlife home ranges causes a high level of

uncertainty in the site use terms and exposure estimates for wildlife receptors whose home ranges are expected to exceed the contaminated site area.

3.3 Results and Discussion

3.3.1 COPEC Distribution and Pathways of Exposure

The only contaminant source identified at the site was surficial soils (soils from the upper metre). COPECs were identified in surficial soils at various locations across the site, although the majority of regulatory exceedances were identified in the immediate vicinity of the track. This is not unexpected considering that most of the historic anthropogenic activity occurred on this portion of the site. The petroleum hydrocarbon COPECs are distributed mainly along the track and immediately adjacent to the track likely the result of leaching from creosoted rail ties. As these areas are largely un-vegetated and covered by ballast, they offer scant foraging opportunities and cover for wildlife and poor substrate for most soil invertebrates and plants. These factors may act to mitigate ecological exposures. The inorganic COPECs, diuron and glyphosate were identified both along the track and in areas lateral to the track, including the slopes and drainage ditches that parallel the track-line. Given the wider distribution of these COPECs in surficial soils, there is expected to be a greater potential for exposure. The following section describes the complete exposure pathways for each receptor of concern. A conceptual model illustrating the inferred pathways of exposure for each ecological receptor of concern is provided as Figure 2.

3.3.1.1 Soil and Foliar Invertebrates and Terrestrial Plants

The exposure pathways that were considered to be complete for soil invertebrates at the site were ingestion and dermal contact with COPECs in surficial soils. Foliar invertebrates have potential exposure to COPECs through the consumption of plant material (e.g., leaves and stems) that have taken up the COPECs from surficial soils via their roots. The root zones of most terrestrial plants are located in the upper 15 centimetres of soil (BCMELP 2000). As such, exposures to COPECs by plants at the site via direct root contact are possible. Considering that COPECs were not identified in site groundwater, contact with groundwater is not a pathway of concern for terrestrial plants and invertebrates at the site.

3.3.1.2 Deer Mouse (*P. maniculatus*)

As an omnivorous mammal often in direct contact with soil, the deer mouse may come in contact with COPECs via ingestion of contaminated food items (e.g., terrestrial invertebrates and terrestrial and aquatic plant material) and via incidental or purposeful ingestion of soil while feeding and/or preening. The species-specific traits and exposure assumptions used to estimate daily oral exposures for the deer mouse are provided in Table B-3 (Appendix B).

3.3.1.3 Little Brown Bat (*M. Lucifugus*)

The little brown bat, an arboreal insectivore, may have contact with COPECs via ingestion of terrestrial and aquatic invertebrates with COPECs in their tissues. The species-specific traits and exposure assumptions used to estimate daily oral exposures for the little brown bat are provided in Table B-4 (Appendix B).

3.3.1.4 Coyote (*C. Latrans*)

As a carnivore, the coyote has the potential for exposure to COPECs at the site via ingestion of contaminated food items such as invertebrates, mammals and birds, and via incidental or purposeful ingestion of soil while feeding and/or preening. The species-specific traits and exposure assumptions used to estimate daily oral exposures for the coyote are provided in Table B-5 (Appendix B).

3.3.1.5 American Robin (*T. migratorius*)

As an omnivorous bird, the American robin may come in contact with COPECs via incidental or purposeful ingestion of soil while feeding and/or preening and via the ingestion of contaminated food items including soil invertebrates and terrestrial vegetation. The species-specific traits and exposure assumptions used to estimate daily oral exposures for the American robin are provided in Table B-6 (Appendix B).

3.3.1.6 Pileated Woodpecker (*D. pileatus*)

The pileated woodpecker, an omnivorous cavity-dwelling bird, may be exposed to COPECs via ingestion of foliar invertebrates and plant tissues. The species-specific traits and exposure assumptions used to estimate daily oral exposures for the pileated woodpecker are provided in Table B-7 (Appendix B).

3.3.1.7 Red-tailed hawk (*B. jamaicensis*)

The red-tailed hawk, a carnivorous bird, may have exposures to COPECs at the site via the ingestion of contaminated food items including various small mammals and birds and via the incidental or purposeful ingestion of soil during feeding and/or preening. The species-specific traits and exposure assumptions used to estimate daily oral exposures for the red-tailed hawk are provided in Table B-8 (Appendix B).

3.3.1.8 Common Garter Snake (*T. sirtalis*)

The carnivorous garter snake may be exposed to COPECs at the site via the ingestion of contaminated food items including amphibians, soil and aquatic invertebrates and birds, and via the incidental or purposeful ingestion of soil during feeding and/or preening. The species-specific traits and exposure assumptions used to estimate daily oral exposures for the common garter snake are provided in Table B-9 (Appendix B).

Wildlife receptors also have the potential for exposure to chemical constituents via ingestion of contaminated site surface water. However, because surface water data was not collected, the significance of this exposure pathway could not be assessed.

3.3.2 Exposure Estimation

Estimated exposure concentrations for the lower trophic level receptors (terrestrial plants, soil and foliar invertebrates) and estimated daily oral doses for the wildlife measurement receptors (deer mouse, little brown bat, coyote, American robin, pileated woodpecker, red-tailed hawk and common garter snake) are provided in Table 3-1. A sample calculation for the total daily oral exposure of the American robin to copper is provided in Appendix C.

For terrestrial plants and soil invertebrates, the highest estimated exposures were to arsenic, copper, zinc, LEPH and HEPH, while copper, LEPH, HEPH and glyphosate exposures were highest for foliar invertebrates. Among the mammalian measurement receptors, the coyote had lower estimated daily oral doses than the deer mouse and little brown bat. For the deer mouse and little brown bat, estimated daily oral doses were highest for copper (deer mouse), LEPH, HEPH and glyposate. Estimated daily oral doses to COPEC were lower for the pileated woodpecker and red-tailed hawk than the American robin. For the American robin, estimated doses were highest for arsenic, copper, molybdenum, zinc, LEPH, HEPH and glyphosate. Estimated daily oral doses for the common garter snake were highest for copper, zinc, LEPH, HEPH and glyphosate.

Table 3-1. Estimated exposure concentrations and daily oral doses

COPEC	Receptor				
	Soil Invertebrates	Foliar Invertebrates	Terrestrial Plants	Deer Mouse	Little Brown Bat
Units	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg BW/day)	(mg/kg BW/day)
Arsenic	1.1E+01	4.0E-01	1.1E+01	1.1E-01	4.7E-02
Copper	1.6E+02	6.4E+01	1.6E+02	1.2E+01	1.6E-01
Molybdenum	3.3E+00	3.3E+00	3.3E+00	6.1E-01	2.5E-02
Zinc	1.5E+02	1.9E-10	1.5E+02	5.9E-01	6.2E-01
Anthracene	2.9E-01	5.9E-03	2.9E-01	2.2E-03	4.2E-04
Benzo(a)anthracene	4.0E-01	8.1E-03	4.0E-01	3.0E-03	9.1E-04
Benzo(a)pyrene	3.5E-01	0.0E+00	3.5E-01	1.3E-03	8.2E-04
Benzo(b)fluoranthene	1.2E+00	1.2E-02	1.2E+00	6.7E-03	1.7E-03
Benzo(k)fluoranthene	9.9E-01	1.0E-02	9.9E-01	5.6E-03	1.3E-05
Chrysene	1.3E+00	2.4E-02	1.3E+00	9.2E-03	7.4E-04
Fluoranthene	1.9E+00	3.8E-02	1.9E+00	1.4E-02	2.0E-03
Indeno(1,2,3cd)pyrene	3.7E-01	1.4E-03	3.7E-01	1.7E-03	4.2E-04
LEPH	9.6E+01	9.6E+01	9.6E+01	1.9E+01	2.2E+00
HEPH	3.3E+02	3.3E+02	3.3E+02	6.1E+01	2.5E+00
Diuron	8.0E-02	1.7E-02	8.0E-02	3.4E-03	1.9E-04
Glyphosate	2.7E-01	1.1E+02	2.7E-01	2.1E+01	1.3E+00

Table 3-1 continued. Estimated exposure concentrations and daily oral doses

COPEC	Receptor				
	Coyote	American Robin	Pileated Woodpecker	Red-Tailed Hawk	Common Garter Snake
Units	(mg/kg BW/day)	(mg/kg BW/day)	(mg/kg BW/day)	(mg/kg BW/day)	(mg/kg BW/day)
Arsenic	1.6E-04	1.3E+00	4.4E-04	9.3E-04	9.4E-02
Copper	1.2E-02	7.6E+01	7.2E-02	7.0E-02	3.4E+00
Molybdenum	6.0E-03	4.9E+00	3.7E-03	3.5E-03	2.7E-01
Zinc	2.1E-03	4.0E+01	2.1E-13	9.2E-03	3.4E+00
Anthracene	3.4E-06	2.5E-02	6.6E-06	2.0E-05	1.7E-03
Benzo(a)anthracene	4.5E-06	2.6E-02	9.1E-06	2.7E-05	1.8E-03
Benzo(a)pyrene	3.0E-05	2.1E-02	00E+00	1.7E-05	1.7E-03
Benzo(b)fluoranthene	1.2E-05	8.3E-02	1.4E-05	6.9E-05	6.0E-03
Benzo(k)fluoranthene	1.0E-05	7.3E-02	1.1E-05	5.7E-05	4.9E-03
Chrysene	1.4E-05	8.6E-02	2.7E-05	8.4E-05	5.3E-03
Fluoranthene	2.2E-05	1.6E-01	4.3E-05	1.3E-04	1.1E-02
Indeno(1,2,3cd)pyrene	3.4E-06	2.5E-02	1.6E-06	1.9E-05	1.9E-03
LEPH	1.8E-02	1.5E+02	1.1E-01	1.1E-01	8.5E+00
HEPH	6.0E-01	5.0E+02	3.7E-01	3.5E-01	2.7E+01
Diuron	3.6E-6	2.7E-02	1.9E-05	2.1E-05	1.5E-03
Glyphosate	2.0E-2	1.7E+02	1.3E-01	1.2E-01	9.4E+00

4 EFFECTS ASSESSMENT

4.1 Introduction

The purpose of the effects or toxicity assessment is to determine if adverse environmental effects are currently occurring at the site and to develop exposure/response relationships for each COPEC/receptor combination to predict if adverse effects will occur in the future (BCMELP 1998). According to BC guidance (BCMELP 1998), the measures used to describe ecological effects in a Tier 1 ERA are toxicity thresholds, which define the COPEC concentrations that cause effects on ecological receptors; qualitative site observations; and, in-situ or laboratory toxicity tests using environmental media from the subject site. The performance of toxicity tests are considered optional by BC guidance (BCMELP 1998).

In the risk calculation section that follows, the effects information developed here is compared with the quantitative exposure estimates calculated in the exposure assessment to characterise the risk of adverse effects to each receptor.

Policy governing the management of contaminated sites in BC does not attempt to protect every potential ecological receptor from adverse effects. Rather the goal is to protect enough individuals to ensure the survival and success of populations and/or communities of organisms. This policy implies some level of acceptable impact. According to BC policy (BCMELP 1998; BC 1997), the level of acceptable impact to ecological resources

is land use based, with less protection given to industrial and commercial properties and greater protection given to residential, urban park and agricultural sites. The rationale for this land use based approach is that the quantity and quality of suitable habitat at commercial and industrial sites is likely the primary factor limiting the abundance and diversity of organisms on these sites. For this reason, less protection is afforded to these types of properties than for agricultural, residential and park sites. According to BC guidance (BCMELP 1998), the maximum level of adverse effect that is deemed acceptable at urban park sites is 20%.

For the purpose of this ERA, the effects assessment consisted of qualitative site observations and development of toxicity thresholds or toxicity reference values (TRVs). Toxicity tests were not conducted. The following section discusses how the two measures of effect (qualitative site observations and toxicity reference values) were used to assess COPEC effects at the site.

4.2 Methodology

4.2.1 Site Observations

The qualitative site survey methodology recommended by BC guidance (BCMELP 1998) is designed to identify whether or not current site conditions are deleterious to plants and animals through a simple site visit. The methodology consists of a simple site walkover and observance of potential COPEC-induced effects including:

- Evidence of phytotoxicity (e.g., bare patches of soil amidst otherwise grassy/vegetated areas; brown/yellow spots on grass and other leafy plants; presence of dead leaves on shrubs, forbs and/or trees);
- Absence of earthworms and other soil invertebrates in soils that would be expected to support communities of such organisms;
- Evidence of toxicity on earthworms and/or other soil invertebrates (e.g., lesions, constrictions and/or growth impairment);
- Wildlife presence/absence.

A site survey was conducted in August 14, 2003 between 10 am and 4 pm. The results of the site survey are provided in Section 4.3.1.

4.2.2 Toxicity Reference Values

Toxicity reference values (TRVs) are threshold effects concentrations that are derived from published toxicity test data. TRVs are used as toxicity threshold for comparison with exposure estimates to estimate the nature and magnitude of effects that a chemical may have on a receptor. In the risk characterization portion of the ERA, these TRVs are compared to exposure estimates from the exposure assessment to calculate risk quotients.

In accordance with BC guidance (BCMELP 1998), the threshold value considered sufficiently protective of terrestrial and aquatic organisms at urban park sites is the EC_{20} (i.e, the chemical concentration that causes a specified effect in 20% of exposed organisms). Consequently, these threshold values were selected for use in the ERA. In cases where EC_{20} values were not available, other comparable or more conservative threshold values were used. In addition, only TRVs with reproductive, growth or survival

endpoints were considered for selection as directed by MWLAP (BCMELP 1998). These endpoints were favoured because effects to these endpoints have a clear impact on the fitness of the organism. Sub-cellular endpoints such as enzyme alterations and DNA breakage were not considered because of the difficulty in linking these effects to toxicant exposures and the uncertainty associated with their relevance to toxic effects or organism fitness.

The primary data sources considered for selection of TRVs were the BC Contaminated Sites Regulation (BC 1997), toxicological benchmarks published by the Oak Ridge National Laboratory (ORNL); and, the grey and peer-reviewed scientific literature. The following section discusses the TRVs selected for each receptor.

4.2.2.1 Terrestrial Plants and Invertebrates

For arsenic, copper, zinc and benzo(a)pyrene, TRVs used were the CSR (BC 1997) matrix soil standards for soil invertebrate and plant protection at urban park sites. As CSR (BC 1997) matrix soil standards do not exist for molybdenum, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, LEPH and HEPH the CSR (BC 1997) the generic soil standards were used as TRVs for these COPECs. Recall that the generic standards are intended to be protective of all receptors, human and ecological and are expected to be overprotective of invertebrates and plants considering the level of protection afforded to humans. In the absence of CSR standards (BC 1997) for chrysene and fluoranthene, the TRV for benzo(a)pyrene was used as a surrogate. The rationale for using the TRV for benzo(a)pyrene is based on an assumption that these three

high molecular weight PAHs have similar potency due to similarities in chemical structure. In the absence of a CSR standard (BC 1997) for anthracene, the CSR generic soil standard for naphthalene was used as a surrogate. The rationale for this approach is based on an assumed structure-activity relationship between these two low molecular weight PAH constituents. Glyphosate TRVs for soil and foliar invertebrates were no-observable adverse effect levels (NOAELs) obtained from a study by Giesy et al. (2000). Quantitative toxicity information on the effects of diuron and glyphosate on terrestrial plants and the effects of diuron on soil invertebrates was unavailable in the literature. Consequently, TRVs for these COPEC/receptor combinations were not developed.

4.2.2.2 Mammalian Measurement Receptors

Toxicity data specific to the deer mouse, little brown bat and coyote were not available in the scientific literature for the COPECs. Consequently, TRVs for these species were derived using toxicity data for other mammalian species (e.g., rat, mink and/or mouse) and physiological scaling factors based on body weight differences. Body weight scaling was conducted using the following equation described by Travis and White (1988), Travis et al. (1990) and EPA (1992):

$$NOAEL_M = NOAEL_T(bw_T/bw_M)^{1/4}$$

where,

$NOAEL_M$ = No Observed Adverse Effects Level for measurement receptor

$NOAEL_T$ = No Observed Adverse Effects Level for test species

bw_T = Body weight of test species

bw_E = Body weight of measurement receptor

According to Sample et al. (1996), this approach is based on studies that show that physiological functions such as metabolic rate and responses to toxic chemicals are a function of body size and that smaller animals are usually more resistant to toxic chemicals due to their higher metabolic and detoxification rates (Sample et al. 1996). EPA uses this scaling methodology in carcinogenicity assessments and reportable quantity documents for adjusting from animal data to an equivalent human dose (Sample et al. 1996).

TRVs for deer mouse, little brown bat and coyote for the inorganic COPECs and benzo(a)pyrene were based on chronic NOAELs and LOAELs for mice, mink and rats published by Sample et al. (1996). Due to the paucity of mammalian toxicological data for the remaining high molecular weight PAH COPECs, TRVs for benzo(a)pyrene were used as surrogates for these constituents. Similarly, toxicological data for mammalian receptors were unavailable for anthracene, the lone low molecular weight PAH COPEC. Consequently, chronic LOAELs developed for acenaphthene (USEPA 1989b), a low molecular weight PAH constituent, were adopted as surrogates for anthracene based on an assumed structure-activity relationship between these two constituents. TRVs for mammalian receptors for LEPH and HEPH were obtained from a study by Foster Wheeler (1997). The details of this study (e.g., test organism, life stage, exposure duration, experimental design) were not reported and therefore an uncertainty factor of 10 was incorporated into the TRV. TRVs for the mammalian receptors for diuron were

based on chronic LOAELs for rats reported by the Weed Science Society of America (WSSA 1994). Mammalian TRVs for glyphosate were based on chronic NOAELs reported by Geisy et al. (2000). The test species used in this study was not reported.

4.2.2.3 Avian Measurement Receptors

Toxicity data specific to the American robin, pileated woodpecker and red-tailed hawk were not available in the scientific literature for the COPECs. Consequently, TRVs for these species were derived using toxicity data for other avian species (e.g., mallard duck, chicken and/or quail) and physiological scaling factors based on body weight differences. Sample et al. (1996) recommends a physiological scaling factor of one (1) for interspecies extrapolation among birds. Thus, interspecies extrapolation among birds is expressed by the following formula:

$$NOAEL_M = NOAEL_T$$

where,

$NOAEL_M$ = No Observed Adverse Effects Level for measurement receptor
$NOAEL_T$ = No Observed Adverse Effects Level for test species

Sample et al. (1996) bases this recommended scaling factor on the findings of a study by Mineau et al. (1996) who calculated scaling factors for birds using LC_{50} data for 37 chemicals.

Avian TRVs for the inorganic COPECs were based on chronic NOAELs and LOAELs for mallard ducks and chickens published by Sample et al. (1996). Avian TRVs for benzo(a)pyrene were based on chronic LOAELs for mallard ducklings published by Patton and Deiter (1980). Due to the paucity of toxicity data for avian receptors for the remaining high molecular PAH constituents, TRVs for benzo(a)pyrene were used as surrogates for these constituents based on an assumed structure-activity relationship. Similarly avian toxicity data was unavailable for anthracene, a low molecular weight PAH constituent. Consequently, TRVs based on a chronic LOAEL for naphthalene (Eisler 1987), a low molecular weight PAH constituent, were adopted as surrogate TRVs for anthracene. Avian TRVs for LEPH and HEPH were obtained from a study by Foster Wheeler (1997). The details of this study (e.g., test organism, life stage, exposure duration, experimental design) were not reported and therefore an uncertainty factor of 10 was incorporated into the TRV. Avian TRVs for diuron were based on an acute LC_{50} for bobwhite quail reported by the Weed Science Society of America (WSSA 1994). In order to approximate an EC_{20}, the LC_{50} value was divided by 20, in accordance with EPA guidance (USEPA 1997). Avian TRVs for glyphosate were based on chronic NOAELs reported by Geisy et al. (2000). The test species used in this study was not reported.

4.2.2.4 Reptiles

Because of the paucity of toxicological information for reptiles, the TRVs used to assess effects to the avian receptors were used as surrogates. Avian TRVs were selected as surrogates due to the relatively close phylogenetic relationship between birds and reptiles.

To account for the toxicological uncertainty associated with using avian TRVs for reptiles, avian TRVs were divided by a factor of 10.

4.3 Results and Discussion

4.3.1 Field Evidence of Toxicant-Induced Effects

In order to assess whether ecological receptors at the site are currently suffering adverse effects due to the presence of COPECs in site media, a qualitative site survey was conducted as per BC guidance (BCMELP 1998). Observations on the apparent health of ecological receptors recorded during the site survey are discussed below.

4.3.1.1 Soil Invertebrates

Earthworms were observed at several locations on the site, particularly in areas where soils were moist and nutrient-rich. Generally, earthworms were not observed in ballasted areas, which is not surprising considering the dry nutrient-poor soils and generally low substrate quality in these areas. Various other soil invertebrate species (e.g., ants and centipedes) were observed at locations across the site, including ballasted areas. Soil invertebrates observed appeared healthy and did not exhibit obvious signs of toxic effects (e.g., lesions, constrictions and/or discolouration). Overall however, COPEC-induced adverse effects could not be ruled out using the qualitative survey methodology recommended by BCMELP (1998).

4.3.1.2 Terrestrial Plants

With the exception of the ballasted areas, the growth of terrestrial plants at the site appeared healthy and did not exhibit obvious signs of toxicant-induced stress (e.g., chlorosis, dieback). As indicated previously, plant species observed in non-ballasted areas were diverse consisting of grasses, forbs, shrubs and trees. The vegetation in some ballasted areas was sparse and was limited mainly to Himalayan blackberry (*R. discolor*) and juvenile red alder (*A. rubra*). As COPEC concentrations detected in soil were generally highest near the rail-bed, apparent impaired plant colonisation could be due to the presence of COPECs in soil in these areas. However, considering the poor substrate quality of the ballast material and the historical rail activity (and associated physical disturbance) in these areas, a thriving plant community would not be expected to be present. In any case, the qualitative survey methodology used was not able to determine if suspected adverse effects were due to site COPECs.

4.3.1.3 Wildlife Receptors

Several avian species were observed at the site including American robin (*T. migratorius*), northwestern crow (*C. caurinus*) and rufous-sided towhee (*P. maculatus*). The lone mammalian species observed during the survey was the eastern grey squirrel (*S. carolinensis*). Observations of coyote droppings indicate that these mammals also use the site. Reptilian species were not observed during the survey.

The limited number of sitings of wildlife species during the survey may be attributable, at least in part, to the fact that the survey was conducted on a warm August day between 10 and 4 pm, the time of day when many wildlife species are least active.

It was not possible to identify COPEC-induced adverse effects on ecological receptors at the site using the qualitative methodology recommended by BCMELP (1998).

4.3.2 Toxicity Reference Values (TRVs)

The TRVs used in the ERA are listed in Table 4-1. As mentioned, TRVs were not developed for diuron and glyphosate for terrestrial plants and for diuron for terrestrial invertebrates.

Table 4-1. Toxicity Reference Values (TRVs)

COPEC	Receptor	TRV	Units	Endpoint	Note / Reference
Arsenic	Plants/Invertebrates	5.0E+01	1	EC20	a / BC 1997
	Deer Mouse	1.4E-01	2	NOAEL	f / Sample et al. 1996
	Little Brown Bat	1.8E-01	2	NOAEL	f / Sample et al. 1996
	Coyote	2.8E-02	2	NOAEL	f / Sample et al. 1996
	Avian	1.3E+01	2	LOAEL	f / Sample et al. 1996
	Garter Snake	1.3E+00	2	LOAEL	f,i / Sample et al. 1996
Copper	Plants/Invertebrates	1.5E+02	1	EC20	a / BC 1997
	Deer Mouse	4.4E+01	2	LOAEL	f / Sample et al. 1996
	Little Brown Bat	5.2E+01	2	LOAEL	f / Sample et al. 1996
	Coyote	8.3E+00	2	LOAEL	f / Sample et al. 1996
	Avian	6.2E+00	2	NOAEL	f / Sample et al. 1996
	Garter Snake	6.2E-01	2	NOAEL	f,i / Sample et al. 1996
Molybdenum	Plants/Invertebrates	1.0E+01	1	NR	b / BC 1997
	Deer Mouse	2.8E-01	2	NOAEL	f / Sample et al. 1996
	Little Brown Bat	3.7E-01	2	NOAEL	f / Sample et al. 1996
	Coyote	5.8E-02	2	NOAEL	f / Sample et al. 1996
	Avian	3.5E+00	2	NOAEL	f / Sample et al. 1996
	Garter Snake	3.5E-01	2	NOAEL	f,i / Sample et al. 1996
Zinc	Plants/Invertebrates	4.5E+02	1	EC20	a / BC 1997
	Deer Mouse	6.5E+02	2	LOAEL	f / Sample et al. 1996
	Little Brown Bat	8.4E+02	2	LOAEL	f / Sample et al. 1996
	Coyote	1.7E+02	2	LOAEL	f / Sample et al. 1996
	Avian	1.3E+02	2	LOAEL	f / Sample et al. 1996
	Garter Snake	1.3E+01	2	LOAEL	f,i / Sample et al. 1996

Table 4-1 continued. Toxicity Reference Values (TRVs)

COPEC	Receptor	TRV	Units	Endpoint	Note / Reference
LEPH	Plants/Invertebrates	1.0E+03	1	NR	b / BC 1997
	Deer Mouse	3.8E+01	2	NR	h / Foster Wheeler
	Little Brown Bat	3.8E+01	2	NR	h / Foster Wheeler
	Coyote	3.8E+01	2	NR	h / Foster Wheeler
	Avian	3.8E+01	2	NR	h / Foster Wheeler
	Garter Snake	3.8E+00	2	NR	h,i / Foster Wheeler
HEPH	Plants/Invertebrates	1.0E+03	1	NR	b / BC 1997
	Deer Mouse	3.8E+01	2	NR	h / Foster Wheeler
	Little Brown Bat	3.8E+01	2	NR	h / Foster Wheeler
	Coyote	3.8E+01	2	NR	h / Foster Wheeler
	Avian	3.8E+01	2	NR	h / Foster Wheeler
	Garter Snake	3.8E+00	2	NR	h,i / Foster Wheeler
Diuron	Plants/Invertebrates	n/a	1	-	n/a
	Deer Mouse	5.1E+02	2	LOAEL	f / WSSA 1994
	Little Brown Bat	6.6E+02	2	LOAEL	f / WSSA 1994
	Coyote	1.0E+02	2	LOAEL	f / WSSA 1994
	Avian	9.6E+00	2	LOAEL	f / WSSA 1994
	Garter Snake	9.6E-01	2	LOAEL	f,i / WSSA 1994
Glyphosate	Plants/Invertebrates	5.9E+01	1	NR	c / Geisy et al. 2000
	Deer Mouse	4.1E+02	2	NOAEL	Geisy et al. 2000
	Little Brown Bat	4.1E+02	2	NOAEL	Geisy et al. 2000
	Coyote	4.1E+02	2	NOAEL	Geisy et al. 2000
	Avian	9.3E+01	2	NOAEL	Geisy et al. 2000
	Garter Snake	9.3E+00	2	NOAEL	i / Geisy et al. 2000

Table 4-1 continued. Toxicity Reference Values (TRVs)

COPEC	Receptor	TRV	Units	Endpoint	Note / Reference
Anthracene	Plants/Invertebrates	5.0E+00	1	EC20	a,e / BC 1997
	Deer Mouse	3.8E+02	2	LOAEL	f,g / USEPA 1989b
	Little Brown Bat	5.0E+02	2	LOAEL	f,g / USEPA 1989b
	Coyote	7.8E+01	2	LOAEL	f,g / USEPA 1989b
	Avian	1.8E+02	2	LOAEL	e,f / Eisler 1987
	Garter Snake	1.8E+01	2	LOAEL	e,f,i / Eisler 1987
Benzo(a) anthracene	Plants/Invertebrates	1.0E+00	1	EC20	a,c / BC 1997
	Deer Mouse	1.1E+00	2	NOAEL	d,f / Sample et al. 1996
	Little Brown Bat	1.4E+00	2	NOAEL	d,f / Sample et al. 1996
	Coyote	7.8E+00	2	NOAEL	d,f / Sample et al. 1996
	Avian	2.4E+02	2	LOAEL	d,f / Patton & Dieter 1980
	Garter Snake	2.4E+01	2	LOAEL	d,f,i / Patton & Dieter 1980
Benzo(a) Pyrene	Plants/Invertebrates	1.0E+00	1	EC20	a / BC 1997
	Deer Mouse	1.1E+00	2	NOAEL	f / Sample et al. 1996
	Little Brown Bat	1.4E+00	2	NOAEL	f / Sample et al. 1996
	Coyote	7.8E+00	2	NOAEL	f / Sample et al. 1996
	Avian	2.4E+02	2	LOAEL	f / Patton & Dieter 1980
	Garter Snake	2.4E+01	2	LOAEL	f,i / Patton & Dieter 1980
Benzo(b) fluoranthene	Plants/Invertebrates	1.0E+00	1	EC20	a,c / BC 1997
	Deer Mouse	1.1E+00	2	NOAEL	d,f / Sample et al. 1996
	Little Brown Bat	1.4E+00	2	NOAEL	d,f / Sample et al. 1996
	Coyote	7.8E+00	2	NOAEL	d,f / Sample et al. 1996
	Avian	2.4E+02	2	LOAEL	d,f / Patton & Dieter 1980
	Garter Snake	2.4E+01	2	LOAEL	d,f,i / Patton & Dieter 1980

Table 4-1 continued. Toxicity Reference Values (TRVs)

COPEC	Receptor	TRV	Units	Endpoint	Note / Reference
Benzo(k) fluoranthene	Plants/Invertebrates	1.0E+00	1	EC20	a,c / BC 1997
	Deer Mouse	1.1E+00	2	NOAEL	d,f / Sample et al. 1996
	Little Brown Bat	1.4E+00	2	NOAEL	d,f / Sample et al. 1996
	Coyote	7.8E+00	2	NOAEL	d,f / Sample et al. 1996
	Avian	2.4E+02	2	LOAEL	d,f / Patton & Dieter 1980
	Garter Snake	2.4E+01	2	LOAEL	d,f,i / Patton & Dieter 1980
Chrysene	Plants/Invertebrates	1.0E+00	1	EC20	a,c / BC 1997
	Deer Mouse	1.1E+00	2	NOAEL	d,f / Sample et al. 1996
	Little Brown Bat	1.4E+00	2	NOAEL	d,f / Sample et al. 1996
	Coyote	7.8E+00	2	NOAEL	d,f / Sample et al. 1996
	Avian	2.4E+02	2	LOAEL	d,f / Patton & Dieter 1980
	Garter Snake	2.4E+01	2	LOAEL	d,f,i / Patton & Dieter 1980
Fluoranthene	Plants/Invertebrates	1.0E+00	1	EC20	a,c / BC 1997
	Deer Mouse	1.1E+00	2	NOAEL	d,f / Sample et al. 1996
	Little Brown Bat	1.4E+00	2	NOAEL	d,f / Sample et al. 1996
	Coyote	7.8E+00	2	NOAEL	d,f / Sample et al. 1996
	Avian	2.4E+02	2	LOAEL	d,f / Patton & Dieter 1980
	Garter Snake	2.4E+01	2	LOAEL	d,f,i / Patton & Dieter 1980
Indeno(1,2,3-cd)pyrene	Plants/Invertebrates	1.0E+00	1	EC20	a,c / BC 1997
	Deer Mouse	1.1E+00	2	NOAEL	d,f / Sample et al. 1996
	Little Brown Bat	1.4E+00	2	NOAEL	d,f / Sample et al. 1996
	Coyote	7.8E+00	2	NOAEL	d,f / Sample et al. 1996
	Avian	2.4E+02	2	LOAEL	d,f / Patton & Dieter 1980
	Garter Snake	2.4E+01	2	LOAEL	d,f,i / Patton & Dieter 1980

Table 4-1 continued. Toxicity Reference Values (TRVs)

Notes:

1 = mg/kg

2 = mg/kg BW/day

a = BC CSR matrix soil standard for soil invertebrate and plant protection for urban park sites

b = BC CSR generic soil standard for human health and environmental protection for urban park sites

c = TRV is for soil and foliar invertebrates only; no toxicity data available for terrestrial plants

d = no toxicity data available; TRV for benzo(a)pyrene used as surrogate

e = no toxicity data available; toxicity data for naphthalene used as surrogate

f = TRV derived by applying a physiological scaling factor to data from other species

g = no toxicity data available; toxicity data for acenaphthene used as surrogate

h = uncertainty factor of 10 applied as details of study not reported

i = derived by applying uncertainty factor of 10 to TRV for raptor (avian receptors)

n/a = toxicity data not available

NR = Not Reported

5 RISK CHARACTERIZATION

5.1 Introduction

Risk characterization finalizes the assessment process by integrating the information from the exposure and effects analyses to determine the probability of an adverse effect to the plant or animal of concern (BCMELP 1998). According to BC guidance (BCMELP 1998), the two means used to integrate exposure and effects information for Tier 1 ERA are the risk quotient method and the site observation method. These two elements serve as lines of evidence to estimate risk for each receptor of concern.

This risk quotient method involves the calculation of risk quotients (RQs), which represent the ratio between an exposure estimate and toxicity reference value for a given COPEC/receptor combination. If an RQ is less than unity (1) (i.e., exposure is less than the threshold effects level), the likelihood of unacceptable risk to the receptor is low. Conversely, an RQ greater than unity (i.e., the exposure exceeds the threshold effects level), indicates that the potential for unacceptable risk to the receptor is moderate or high. Given the conservatism incorporated in the estimation of exposure at the screening level, RQs are considered to provide a conservative preliminary estimate of risk (BCMWLAP 2004).

The site observation method recommended by BC guidance provides a qualitative assessment of what actually is happening on the site to support or refute the more

quantitative, but less site-specific, assessment developed through use of the risk quotient method (BCMELP 1998). The site observation method is based on observations of toxic effects on ecological receptors at the site (BCMELP 1998). The intent of this approach is to clearly identify three groups of contaminated sites (BCMELP 1998):

- Those sites with low environmental risk that do not need further review or remediation;
- Those sites with moderate environmental risk that may require further investigation and analysis; and,
- Those sites with high environmental risk that warrant remedial action.

5.2 Methodology

As mentioned, risk quotients and site observations were the two lines of evidence used to characterize risks to ecological receptors at the site.

5.2.1 Risk Quotient Method

Risk quotients served as the first line of evidence in the characterization of ecological risks at the site. RQs were calculated for each COPEC/receptor combination using the following equation (BCMELP 1998):

$$RQ = E/TRV$$

where,

RQ = Risk Quotient

E = Exposure concentration (mg/kg) or total daily oral dose (mg/kg BW/day)

TRV = Toxicity Reference Value (mg/kg or mg/kg BW/day)

Estimated exposure concentrations and total daily oral doses for the receptors of concern are provided in Table 3-1. As discussed in the exposure assessment, exposure concentrations for soil invertebrates and terrestrial plants were the estimated environmental concentrations (EECs) of the COPECs in soil. For foliar invertebrates, exposure concentrations were modelled tissue concentrations of terrestrial plants. Exposure estimates for the wildlife measurement receptors were estimated through food chain modelling. TRVs for each receptor are provided in Table 4-1. For evaluation purposes, RQ results less than unity (1) were considered to indicate low risk, RQs between unity and 100 were considered to indicate moderate risk and RQs greater than 100 were considered to indicate high risk, as suggested by BC guidance (BCMELP 1998).

5.2.2 Site Observation Method

Field observations of toxic effects and overall apparent ecological health served as the second line of evidence in the characterisation of ecological risk at the site. Site observations are reviewed to determine if plants and animals of concern actually occur on site and whether or not these plants and animals show any obvious signs of toxicity (BCMELP 1998). According to BC guidance (BCMELP 1998), the existence of ecological effects may be indicated by:

- Evidence of phytotoxicity (e.g., bare patches of soil amidst otherwise grassy/vegetated areas; brown/yellow spots on grass and other leafy plants; presence of dead leaves on shrubs, forbs and/or trees);
- Presence or absence of earthworms and other soil invertebrates in soils that would be expected to support communities of such organisms;
- Evidence of toxicity on earthworms and/or other soil invertebrates (e.g., lesions, constrictions and/or growth impairment); and,
- Presence or absence of wildlife.

The site observation method also gives consideration to site conditions other than contamination that may be limiting the presence or abundance of certain ecological receptors at the site, such as habitat suitability and abundance. Site observations relevant to the characterization of ecological risk at the site are presented in Section 5.3.2.

5.2.3 Characterization of Ecological Risk

As indicated, risks to the ecological receptors of concern were characterized by considering the results of risk quotient (RQ) calculations and field observations. In addition, the various uncertainties of the risk assessment process were evaluated for their expected influence on risk estimates and are incorporated into the risk characterizations of each receptor of concern. The results of the risk characterization are presented in Section 5.3.3.

5.3 Results and Discussion

5.3.1 Risk Quotients

RQs for each COPEC/receptor combination are summarized in Tables 5-1 through 5-10 and are discussed in detail in Section 5.3.4.

5.3.2 Site Observations

The site observation method recommended by BC guidance (BCMELP 1998) was much too qualitative to identify the presence or absence of adverse effects on ecological receptors at the site. Although birds, mammals and reptiles were observed at the site, simple observation of presence/absence does not allow adverse effects to be detected in wildlife receptors. Furthermore, although obvious evidence of adverse effects could be identified in sessile receptors such as soil invertebrates and plants, more subtle effects, if present, were undoubtedly missed using this methodology. In addition, this method is not sufficiently robust to draw causative links to site COPECs even when apparent effects are observed. Based on the above, effects to the receptors of concern at the site could not be ruled out based on site observations. Consequently, characterization of risk at the site was based solely on the results of risk quotient calculations.

Table 5-1. Soil invertebrate risk quotients

COPEC	Exposure Concentration (mg/kg)	TRV (mg/kg)	Risk Quotient (RQ)	Risk Estimate
Arsenic	1.1E+01	5.0E+01	2.2E-01	Low
Copper	1.6E+02	1.5E+02	1.1E+00	Moderate
Molybdenum	3.3E+00	1.0E+01	3.3E-01	Low
Zinc	1.5E+02	4.5E+02	3.3E-01	Low
Anthracene	2.9E-01	5.0E+00	5.8E-02	Low
Benzo(a)anthracene	4.0E-01	1.0E+00	4.0E-01	Low
Benzo(a)pyrene	3.5E-01	1.0E+00	3.5E-01	Low
Benzo(b)fluoranthene	1.2E+00	1.0E+00	1.2E+00	Moderate
Benzo(k)fluoranthene	9.9E-01	1.0E+00	9.9E-01	Low
Chrysene	1.3E+00	1.0E+00	1.3E+00	Moderate
Fluoranthene	1.9E+00	1.0E+00	1.9E+00	Moderate
Indeno(1,2,3-cd)pyrene	3.7E-01	1.0E+00	3.7E-01	Low
LEPH	9.6E+01	1.0E+03	9.6E-02	Low
HEPH	3.3E+02	1.0E+03	3.3E-01	Low
Diuron	8.0E-02	no TRV	n/c	n/a
Glyphosate	2.7E-01	5.9E+01	4.6E-03	Low

Notes:
n/c = not calculated
n/a = not applicable

Table 5-2. Foliar invertebrate risk quotients

COPEC	Exposure Concentration (mg/kg)	TRV (mg/kg)	Risk Quotient (RQ)	Risk Estimate
Arsenic	4.0E-01	5.0E+01	8.0E-03	Low
Copper	6.4E+01	1.5E+02	4.3E-01	Low
Molybdenum	3.3E+00	1.0E+01	3.3E-01	Low
Zinc	1.9E-10	4.5E+02	4.2E-13	Low
Anthracene	5.9E-03	1.0E+00	5.9E-03	Low
Benzo(a)anthracene	8.1E-03	1.0E+00	8.1E-03	Low
Benzo(a)pyrene	0.0E+00	1.0E+00	0.0E+00	Low
Benzo(b)fluoranthene	1.2E-02	1.0E+00	1.2E-02	Low
Benzo(k)fluoranthene	1.0E-02	1.0E+00	1.0E-02	Low
Chrysene	2.4E-02	1.0E+00	2.4E-02	Low
Fluoranthene	3.8E-02	1.0E+00	3.8E-02	Low
Indeno(1,2,3-cd)pyrene	1.4E-03	1.0E+00	1.4E-03	Low
LEPH	9.6E+01	1.0E+03	9.6E-02	Low
HEPH	3.3E+02	1.0E+03	3.3E-01	Low
Diuron	1.7E-02	no TRV	n/c	n/a
Glyphosate	1.1E+02	5.9E+01	1.9E+00	Moderate

Notes:
n/c = not calculated
n/a = not applicable

Table 5-3. Terrestrial plant risk quotients

COPEC	Exposure Concentration (mg/kg)	TRV (mg/kg)	Risk Quotient (RQ)	Risk Estimate
Arsenic	1.1E+01	5.0E+01	2.2E-01	Low
Copper	1.6E+02	1.5E+02	1.1E+00	Moderate
Molybdenum	3.3E+00	1.0E+01	3.3E-01	Low
Zinc	1.5E+02	4.5E+02	3.3E-01	Low
Anthracene	2.9E-01	1.0E+00	2.9E-01	Low
Benzo(a)anthracene	4.0E-01	1.0E+00	4.0E-01	Low
Benzo(a)pyrene	3.5E-01	1.0E+00	3.5E-01	Low
Benzo(b)fluoranthene	1.2E+00	1.0E+00	1.2E+00	Moderate
Benzo(k)fluoranthene	9.9E-01	1.0E+00	9.9E-01	Low
Chrysene	1.3E+00	1.0E+00	1.3E+00	Moderate
Fluoranthene	1.9E+00	1.0E+00	1.9E+00	Moderate
Indeno(1,2,3-cd)pyrene	3.7E-01	1.0E+00	3.7E-01	Low
LEPH	9.6E+01	1.0E+03	9.6E-02	Low
HEPH	3.3E+02	1.0E+03	3.3E-01	Low
Diuron	8.0E-02	no TRV	n/c	n/a
Glyphosate	2.7E-01	no TRV	n/c	n/a

Notes:
n/c = not calculated
n/a = not applicable

Table 5-4. Deer mouse risk quotients

COPEC	Daily Oral Exposure (mg/kg BW/day)	TRV (mg/kg BW/day)	Risk Quotient (RQ)	Risk Estimate
Arsenic	1.1E-01	1.4E-01	7.9E-01	Low
Copper	1.2E+01	4.4E+01	2.7E-01	Low
Molybdenum	6.1E-01	2.8E-01	2.2E+00	Moderate
Zinc	5.9E-01	6.5E+02	9.1E-04	Low
Anthracene	2.2E-03	3.8E+02	5.8E-06	Low
Benzo(a)anthracene	3.0E-03	1.1E+00	2.7E-03	Low
Benzo(a)pyrene	1.3E-03	1.1E+00	1.2E-03	Low
Benzo(b)fluoranthene	6.7E-03	1.1E+00	6.1E-03	Low
Benzo(k)fluoranthene	5.6E-03	1.1E+00	5.1E-03	Low
Chrysene	9.2E-03	1.1E+00	8.4E-03	Low
Fluoranthene	1.4E-02	1.1E+00	1.3E-02	Low
Indeno(1,2,3-cd)pyrene	1.7E-03	1.1E+00	1.5E-03	Low
LEPH	1.9E+01	3.8E+01	5.0E-01	Low
HEPH	6.1E+01	3.8E+01	1.6E+00	Moderate
Diuron	3.4E-03	5.1E+02	6.7E-06	Low
Glyphosate	2.1E+01	4.1E+02	5.1E-02	Low

Table 5-5. Little brown bat risk quotients

COPEC	Daily Oral Exposure (mg/kg BW/day)	TRV (mg/kg BW/day)	Risk Quotient (RQ)	Risk Estimate
Arsenic	4.7E-02	1.8E-01	2.6E-01	Low
Copper	1.6E-01	5.2E+01	3.1E-03	Low
Molybdenum	2.5E-02	3.7E-01	6.8E-02	Low
Zinc	6.2E-01	8.4E+02	7.4E-04	Low
Anthracene	4.2E-04	5.0E+02	8.4E-07	Low
Benzo(a)anthracene	9.1E-04	1.4E+00	6.5E-04	Low
Benzo(a)pyrene	8.2E-04	1.4E+00	5.9E-04	Low
Benzo(b)fluoranthene	1.7E-03	1.4E+00	1.2E-03	Low
Benzo(k)fluoranthene	1.3E-05	1.4E+00	9.3E-06	Low
Chrysene	7.4E-04	1.4E+00	5.3E-04	Low
Fluoranthene	2.0E-03	1.4E+00	1.4E-03	Low
Indeno(1,2,3-cd)pyrene	4.2E-04	1.4E+00	3.0E-04	Low
LEPH	2.2E+00	3.8E+01	5.8E-02	Low
HEPH	2.5E+00	3.8E+01	6.6E-02	Low
Diuron	1.9E-04	6.6E+02	2.9E-07	Low
Glyphosate	1.3E+00	4.1E+02	3.2E-03	Low

Table 5-6. Coyote risk quotients

COPEC	Daily Oral Exposure (mg/kg BW/day)	TRV (mg/kg BW/day)	Risk Quotient (RQ)	Risk Estimate
Arsenic	1.6E-04	2.8E-02	5.7E-03	Low
Copper	1.2E-02	8.3E+00	1.4E-03	Low
Molybdenum	6.0E-03	5.8E-02	1.0E-01	Low
Zinc	2.1E-03	1.3E+02	1.6E-05	Low
Anthracene	3.4E-06	7.8E+01	4.4E-08	Low
Benzo(a)anthracene	4.5E-06	2.2E-01	2.0E-05	Low
Benzo(a)pyrene	3.0E-05	2.2E-01	1.4E-04	Low
Benzo(b)fluoranthene	1.2E-05	2.2E-01	5.5E-05	Low
Benzo(k)fluoranthene	1.0E-05	2.2E-01	4.5E-05	Low
Chrysene	1.4E-05	2.2E-01	6.4E-05	Low
Fluoranthene	2.2E-05	2.2E-01	1.0E-04	Low
Indeno(1,2,3-cd)pyrene	3.4E-06	2.2E-01	1.5E-05	Low
LEPH	1.8E-02	3.8E+01	4.7E-04	Low
HEPH	6.0E-01	3.8E+01	1.6E-02	Low
Diuron	3.6E-06	1.0E+02	3.6E-08	Low
Glyphosate	2.0E-02	4.1E+02	4.9E-05	Low

Table 5-7. American robin risk quotients

COPEC	Daily Oral Exposure (mg/kg BW/day)	TRV (mg/kg BW/day)	Risk Quotient (RQ)	Risk Estimate
Arsenic	1.3E+00	1.3E+01	1.0E-01	Low
Copper	7.6E+01	6.2E+00	1.2E+01	Moderate
Molybdenum	4.9E+00	3.5E+00	1.4E+00	Low
Zinc	4.0E+01	1.3E+02	3.1E-01	Low
Anthracene	2.5E-02	1.8E+02	1.4E-04	Low
Benzo(a)anthracene	2.6E-02	2.4E+02	1.1E-04	Low
Benzo(a)pyrene	2.1E-02	2.4E+02	8.8E-05	Low
Benzo(b)fluoranthene	8.3E-02	2.4E+02	3.5E-04	Low
Benzo(k)fluoranthene	7.3E-02	2.4E+02	3.0E-04	Low
Chrysene	8.6E-02	2.4E+02	3.6E-04	Low
Fluoranthene	1.6E-01	2.4E+02	6.7E-04	Low
Indeno(1,2,3-cd)pyrene	2.5E-02	2.4E+02	1.0E-04	Low
LEPH	1.5E+02	3.8E+01	3.9E+00	Moderate
HEPH	5.0E+02	3.8E+01	1.3E+01	Moderate
Diuron	2.7E-02	9.6E+00	2.9E-03	Low
Glyphosate	1.7E+02	9.3E+01	1.8E+00	Moderate

Table 5-8. Pileated woodpecker risk quotients

COPEC	Daily Oral Exposure (mg/kg BW/day)	TRV (mg/kg BW/day)	Risk Quotient (RQ)	Risk Estimate
Arsenic	4.4E-04	1.3E+01	3.4E-05	Low
Copper	7.2E-02	6.2E+00	1.2E-02	Low
Molybdenum	3.7E-03	3.5E+00	1.1E-03	Low
Zinc	2.1E-13	1.3E+02	1.6E-15	Low
Anthracene	6.6E-06	1.8E+02	3.7E-08	Low
Benzo(a)anthracene	9.1E-06	2.4E+02	3.8E-08	Low
Benzo(a)pyrene	0.0E+00	2.4E+02	0.0E+00	Low
Benzo(b)fluoranthene	1.4E-05	2.4E+02	5.8E-08	Low
Benzo(k)fluoranthene	1.1E-05	2.4E+02	4.6E-08	Low
Chrysene	2.7E-05	2.4E+02	1.1E-07	Low
Fluoranthene	4.3E-05	2.4E+02	1.8E-07	Low
Indeno(1,2,3-cd)pyrene	1.6E-06	2.4E+02	6.7E-09	Low
LEPH	1.1E-01	3.8E+01	2.9E-03	Low
HEPH	3.7E-01	3.8E+01	9.7E-03	Low
Diuron	1.9E-05	9.6E+00	2.0E-06	Low
Glyphosate	1.3E-01	9.3E+01	1.4E-03	Low

Table 5-9. Red-tailed hawk risk quotients

COPEC	Daily Oral Exposure (mg/kg BW/day)	TRV (mg/kg BW/day)	Risk Quotient (RQ)	Risk Estimate
Arsenic	9.3E-04	1.3E+01	7.2E-05	Low
Copper	7.0E-02	6.2E+00	1.1E-02	Low
Molybdenum	3.5E-03	3.5E+00	1.0E-03	Low
Zinc	9.2E-03	1.3E+02	7.1E-05	Low
Anthracene	2.0E-05	1.8E+02	1.1E-07	Low
Benzo(a)anthracene	2.7E-05	2.4E+02	1.1E-07	Low
Benzo(a)pyrene	1.7E-05	2.4E+02	7.1E-08	Low
Benzo(b)fluoranthene	6.9E-05	2.4E+02	2.9E-07	Low
Benzo(k)fluoranthene	5.7E-05	2.4E+02	2.4E-07	Low
Chrysene	8.4E-05	2.4E+02	3.5E-07	Low
Fluoranthene	1.3E-04	2.4E+02	5.4E-07	Low
Indeno(1,2,3-cd)pyrene	1.9E-05	2.4E+02	7.9E-08	Low
LEPH	1.1E-01	3.8E+01	2.9E-03	Low
HEPH	3.5E-01	3.8E+01	9.2E-03	Low
Diuron	2.1E-05	9.6E+00	2.2E-06	Low
Glyphosate	1.2E-01	9.3E+01	1.3E-03	Low

Table 5-10. Common garter snake risk quotients

COPEC	Daily Oral Exposure (mg/kg BW/day)	TRV (mg/kg BW/day)	Risk Quotient (RQ)	Risk Estimate
Arsenic	9.4E-02	1.3E+00	7.2E-02	Low
Copper	3.4E+00	6.2E-01	5.5E+00	Moderate
Molybdenum	2.7E-01	3.5E-01	7.7E-01	Low
Zinc	3.4E+00	1.3E+01	2.6E-01	Low
Anthracene	1.7E-03	1.8E+01	9.4E-05	Low
Benzo(a)anthracene	1.8E-03	2.4E+01	7.5E-05	Low
Benzo(a)pyrene	1.7E-03	2.4E+01	7.1E-05	Low
Benzo(b)fluoranthene	6.0E-03	2.4E+01	2.5E-04	Low
Benzo(k)fluoranthene	4.9E-03	2.4E+01	2.0E-04	Low
Chrysene	5.3E-03	2.4E+01	2.2E-04	Low
Fluoranthene	1.1E-02	2.4E+01	4.6E-04	Low
Indeno(1,2,3-cd)pyrene	1.9E-03	2.4E+01	7.9E-05	Low
LEPH	8.5E+00	3.8E+00	2.2E+00	Moderate
HEPH	2.7E+01	3.8E+00	7.1E+00	Moderate
Diuron	1.5E-03	9.6E-01	1.6E-03	Low
Glyphosate	9.4E+00	9.3E+00	1.0E+00	Moderate

5.3.3 Uncertainty Analysis

Uncertainty in risk estimates result from assumptions made throughout the risk assessment process, modelling, field and laboratory methodologies, and natural variability in the environment. Tier 1 assessments are more qualitative and therefore rely more heavily on assumptions than the more quantitative Tier 2 and 3 assessments. As a result, Tier 1 assessments inherently have greater uncertainty than Tier 2 and 3 assessments. The uncertainty analysis presents and evaluates the sources of uncertainty in the assessment and attempts to determine whether each source contributes to an under or overestimation of risk as well as whether the overall uncertainty of the assessment is too great to adequately characterize ecological risks. If uncertainty is excessively high, further assessment (e.g., toxicity testing, additional data collection) may be required to reduce uncertainty to a level such that a characterization of risk can be made with reasonable confidence.

Sources of uncertainty in the ERA are evaluated in the following sections and are divided into those that pertain to the assessment of exposure and those that pertain to the assessment of effects. Sources of uncertainty that pertain to exposure include: characterization of chemical concentrations in environmental media; selection of reasonable maximum exposure concentrations for the COPECs; measurement receptors selected to represent the receptor groups of concern; measurement receptor characteristics used to estimate exposures; the use of bioconcentration factors to model tissue concentrations in lower trophic level food sources; and basic exposure modelling

assumptions. Sources of uncertainty pertaining to ecological effects relate mainly to the toxicity reference values selected for use in the assessment.

5.3.3.1 Uncertainty in the Assessment of Exposure

Characterization of Environmental Media Concentrations

The following three elements may have influence the certainty that environmental concentrations were adequately characterized at the site: the sampling program and methodology used; laboratory analytical detection limits; and, laboratory accuracy and precision.

The spatial coverage and quantity of samples collected from environmental media at the site were consistent with the requirements of the BC Contaminated Sites Regulation (BC 1997). Methods used to sample environmental media were consistent with standard methods used in the environmental consulting industry in BC. Samples were placed in appropriate containers and shipped to CANTEST laboratories for analysis. Between samples, sampling equipment was decontaminated to prevent cross-contamination between sampling locations. Based on the above, there is a reasonable level of certainty that the sampling conducted at the site was adequate to characterize COPEC concentrations in environmental media.

In order to evaluate the risk associated with each COPEC it was imperative that laboratory detection limits were lower than the toxicity reference values selected for the

chemicals. The detection limits used in the ERA were sufficiently low to quantify environmental concentrations and complete the risk assessment.

Laboratory precision was measured by calculating the relative percent differences (RPD) in analytical results between samples and blind duplicate samples. According to CANTEST, RPDs calculated were within the acceptable limits for the media and constituents analyzed. Analytical data produced by CANTEST is considered to be accurate based on the laboratory's accreditation with the Standards Council of Canada, the Canadian Association of Environmental Analytical Laboratories (CAEAL), the Canadian Food Inspection Agency and the United States Food and Drug Administration.

Based on the above, there is a reasonable level of certainty that COPEC concentrations were adequately characterized at the site.

Reasonable Maximum Exposure Concentrations

To estimate exposure, the media concentrations measured were reduced to single concentrations (for each COPEC and medium) that represented the reasonable maximum exposure (RME) concentrations. As indicated, BC guidance (BCMELP 1998) and policy (BCMELP 2000) supports the use of the UCL95 of the arithmetic mean concentration to estimate exposures for all receptors based on the assumption that exposures by ecological receptors are averaged over space and time. The rationale for using the UCL95 holds true only for mobile organisms such as terrestrial wildlife, which may move around a site consuming soil, vegetation or animal foods from locations that vary in their degree of

contamination (Suter 2000). For less mobile and sessile organisms such as soil invertebrates and plants, their exposures are not averaged over the site. The reasonable maximum exposure concentration for these receptors is the maximum measured concentration (Suter 2000). In accordance with BC guidance (BCMELP 1998) UCL95 concentrations in soil were used as exposure concentrations for the lower trophic level terrestrial receptors in the ERA. A review of summary statistics for the COPECs (Table 2-1) indicates that maximum COPEC concentrations are approximately 10 times higher than the UCL95 concentrations. Consequently, basing exposures on the UCL95 concentrations rather than maximum concentrations may contribute to an underestimation of exposure by these receptors to some COPECs on certain areas of the site.

Representativeness of Measurement Receptors

Measurement receptors were used as surrogates to estimate risks for the more broad receptors groups of concern. For example, risks to terrestrial mammals were assessed using the deer mouse, little brown bat and coyote. The use of surrogate receptors to evaluate risks has the potential to contribute significant uncertainty to the assessment depending on how representative the selected measurement receptors are of the receptor groups of concern. The measurement receptors are considered to adequately represent the receptor groups of concern for two reasons. First, the measurement receptors selected were all species known to exist at or in the immediate area of the site. Second, where multiple feedings guilds for a given receptor group of concern were expected to use the

site (e.g., omnivorous and carnivorous mammals) a measurement receptor representative of each guild was used.

Measurement Receptor Characteristics

Data on measurement receptor characteristics (e.g., dietary information, body size and home range) used to model wildlife exposures were obtained from sources (USEPA 1993; ORNL 1997) well-known by the risk assessments community in the United States and Canada. Site-specific data was not used in the assessment, which contributes uncertainty to wildlife exposure estimates. It is not certain whether the use of non site-specific information contributes to an under or overestimation of exposures.

Bioconcentration Factors

BC guidance (BCMELP 1998) allows for direct measurement of organisms tissue concentrations and/or the use of modelling for estimating ecological exposures in Tier 1 ERAs. Undoubtedly, measured tissue concentrations have far lower uncertainty than modelled values. Due to financial constraints however, media-to-receptor bioconcentration factors (BCFs) were used to model tissue concentrations in the dietary food sources of the wildlife receptors in this ERA. BCFs used in the ERA were obtained from two peer-reviewed sources: USEPA (1999) and the Oakridge National Laboratory/US Department of Energy (ORNL/DOE) Risk Assessment Information System (RAIS). Where BCFs were unavailable, surrogate values were derived based on structure-activity relationships.

Media-to-receptor BCFs are highly dependent upon media conditions such as chemical concentration, pH, clay content, and organic matter. Consequently, a BCF that is not site-specific is unlikely to be accurate and contributes uncertainty to exposure and risk estimates for wildlife receptors. In addition, the use of structure-activity based surrogate BCFs for COPECs for which BCFs were unavailable contributes uncertainty to exposure estimates for wildlife receptors. The use of literature BCFs and surrogate BCFs could contribute to an under or overestimate of ecological exposures at the site.

Exposure Modelling Assumptions

Two basic assumptions made in the exposure assessment contribute a high level of conservatism to the estimated exposures. First, it was assumed that the entire site area is contaminated. This is a highly conservative assumption because it implies that ecological receptors at the site are exposed to the COPECs and that all media (abiotic and biotic) contacted by ecological receptors are contaminated. In fact, the majority of elevated concentrations measured in environmental media were limited to the track area, areas with relatively low habitat quality. Second, it was assumed that the COPECs are present in environmental media in forms that are 100% bioavailable and are taken up by ecological receptors. This is highly conservative considering the many mechanisms and factors that affect bioavailability (e.g., sorption to abiotic media, geochemistry and chemical form, age and concentration).

In accordance with BC policy (BCMELP 2000) it was assumed that wildlife exposures to the COPECs were via the oral pathway only. According to BC policy (BCMELP 2000),

inhalation and dermal contact exposures by wildlife are considered negligible and are omitted when estimating total wildlife exposures. According to BC policy (BCMELP 2000), inhalation exposures to volatile constituents are considered negligible for the following three reasons: a highly volatile chemical will quickly cause an initial acute exposure, however concentrations are likely to diminish over time thus reducing chronic exposure and risk; there is insufficient scientific data to adequately assess this pathway (i.e., toxicity information, wildlife characteristics affecting potential inhalation exposure, etc.); and, inhalation in most circumstances is expected to contribute very little to exposure when compared with that via the ingestion pathway. As none of the COPECs have significant volatility, the exclusion of potential inhalation exposures in total exposure estimates for the wildlife receptors is not likely to have resulted in underestimation of exposures.

Dermal exposures by wildlife species were considered to be insignificant, in accordance with BC policy (BCMELP 2000), because feathers and fur are believed to reduce the likelihood of significant dermal contact. Although this rationale may not be valid under every situation, elevated concentrations of the more hydrophobic COPECs were generally confined to the immediate vicinity of the track and ballast, which offers little habitat for nesting and forage and therefore would be unlikely to attract wildlife for extended periods of time. Consequently, the exclusion of dermal exposures in total exposure estimates for the wildlife receptors is not likely to have resulted in an underestimation of exposures.

Overall Uncertainty in the Assessment of Exposure

Based on the analysis presented above, it is concluded that there is significant uncertainty associated with the exposure estimates, attributable mainly to the use of bioconcentration factors to model exposures to wildlife receptors; the absence of site-specific receptor information, and the use of UCL95 values as reasonable maximum exposure concentrations for the sessile and less mobile receptors. However, given the highly conservative assumptions used to model exposures (e.g., all abiotic media and food sources are contaminated and 100% COPEC bioavailability) it is anticipated that actual receptor exposures are overestimated.

5.3.3.2 Uncertainty in the Assessment of Effects

Toxicity Reference Values

TRVs used in the ERA were derived from provincial regulations, the peer-reviewed scientific literature and grey literature sources. For terrestrial invertebrates and plants, TRVs applied were the CSR (BC 1997) matrix soil standards for soil and plant protection or the CSR (BC 1997) generic soil standards for protection of all receptors, human and ecological. The matrix standards correspond to the lowest EC_{20} values among valid studies in the scientific literature at the time the standards were derived and were set to protect 100% of the soil and plant species in BC. Consequently, there is a high degree of certainty that these standards provide the requisite level of protection to the invertebrate and plant species at the site with a tendency to be over-protective of most species. The

CSR (BC 1997) generic standards are protective of human receptors as well as ecological receptors. As the CSR (BC 1997) purposely affords a greater level of protection to humans than ecological receptors, the use of these standards as TRVs in the ERA is expected to over-protect invertebrate and plants species present at the site.

Chronic NOAELs and LOAELs obtained from peer-reviewed literature sources were used to derive TRVs for several constituents for the mammalian and avian receptors. These studies were reviewed for their quality and applicability as well as whether they provide the requisite level of protection for the receptors of concern (EC_{20}). NOAELs and LOAELs presented by Sample et al. (1996), widely used by risk assessment practitioners in BC, were based on a review of the scientific literature and selection of critical studies that met ORNL standards for inclusion. Due to the reputability of this source and that the values used corresponded to EC_{20} level effects or less, there is a reasonable level of certainty that the TRVs developed from this data provide the requisite level of protection for the receptors of concern (EC_{20}).

For some constituents (e.g., benzo(a)pyrene (birds), glyphosate (birds and mammals), diuron (birds and mammals)), little toxicity information was available and therefore, TRVs were developed from toxicity data obtained from individual, published studies. Due to the paucity of available toxicity data for these constituents, there is some uncertainty that the TRVs derived from these data are adequately protective of the receptors of concern.

Due to the lack of toxicological data for wildlife for LEPH and HEPH, a grey literature source was used to derive TRVs for these constituensts. Important details of the study such as the test organism, life stage, exposure duration, exposure route, test endpoint, methodology were not reported and therefore the quality and applicability of these studies could not be evaluated. Consequently an uncertainty factor of 10 was applied in the derivation of TRVs for these COPECs. With the applied uncertainty factors, there is reasonable certainty that the TRVs used for these constituents provide at least the requisite level of protection for the receptors of concern.

As quality toxicological data was unavailable for several of the PAH COPECs, structure-activity relationships were used to assign surrogate values from PAH constituents for which data was available. For example, TRVs for acenaphthene and naphthalene, two low molecular weight PAHs, were used for anthracene. Similarly, TRVs for benzo(a)pyrene, a high molecular weight PAH, were used for other high molecular weight PAH COPECs. Although the surrogate approach facilitates the assessment of effects for these PAH COPECs, there is some uncertainty as to whether the surrogate TRVs adequately protect the receptors of concern, given the limited amount of toxicological data for PAHs. It is not certain whether the surrogate TRVs used under or over-protect the receptors of concern.

Due to the paucity of toxicological data for reptiles, TRVs for raptors (red-tailed hawk) were used as surrogates for the carnivorous common garter snake. To account for the uncertainty of this approach, an uncertainty factor of 10 was applied to the raptor TRVs.

There is considerable uncertainty in the TRVs derived to assess risk to reptiles, however, given the close phylogenetic relationship between reptiles and birds, and that a 10 times uncertainty factor was applied, there is reasonable confidence that the TRVs derived provide at least the requisite level of protection to reptiles at the site.

According to Sample et al. (1996), the physiological scaling methodology used for interspecies extrapolation of TRVs for mammals and birds is consistent with the scaling methodology used in carcinogenicity assessments for adjusting from animal data to an equivalent human dose (EPA 1992). Consequently, there is a reasonable level of certainty that this methodology does not result in the under-protection of the receptors of concern.

Overall Uncertainty in the Assessment of Effects

Overall, the TRVs selected for use the ERA are expected to provide at least the requisite level of protection to the receptors of concern.

5.3.4 Characterization of Ecological Risk

As indicated, confidence in the ability of the site observation method recommended by BCMELP (1998) to identify the presence/absence of COPEC-induced adverse ecological effects at the site was low. Consequently, these observations were not incorporated into the characterization of risk and therefore risk characterizations were based on risk quotients only. The results of the uncertainty analysis indicate that there is considerable

uncertainty in the risk quotients, mainly due to a high degree of uncertainty in exposure estimates. However, based on the conservative assumptions used to estimate exposures and the reasonable confidence that the TRVs selective are adequately protective, the risk quotients are expected to overestimate risk.

RQs were less than unity for the following receptors: little brown bat (arboreal insectivore), coyote (carnivorous mammal), pileated woodpecker (cavity-dwelling bird) and red-tailed hawk (raptor), indicating that site COPECs pose a low risk to these receptor groups.

Receptors with RQs greater than unity included soil and foliar invertebrates, terrestrial plants, deer mouse (small omnivorous mammal), American robin (omnivorous bird) and common garter snake (reptile). Risks to these receptors are discussed further below.

5.3.4.1 Soil Invertebrates and Terrestrial Plants

As indicated in Tables 5-1 and 5-3, RQs for copper (1.1), benzo(b)fluoranthene (1.2), chrysene (1.3) and fluoranthene (1.9) marginally exceed unity for soil invertebrates and plants indicating that these COPECs pose a moderate risk to these receptors. RQs for the remaining COPECs were less than unity indicating low risk.

5.3.4.2 Foliar Invertebrates

As indicated in Tables 5-2, RQs for glyphosate (1.9) marginally exceeded unity for foliar invertebrates indicating moderate risk to foliar invertebrates at the site. RQs for the remaining COPECs were less than unity indicating that they pose a low risk to foliar invertebrates.

5.3.4.3 Deer Mouse

As indicated in Table 5-4, RQs for molybdenum (2.2) and HEPH (1.6) marginally exceeded unity indicating moderate risk to small mammalian species at the site. RQs for the remaining COPECs were less than unity indicating that they pose a low risk to small mammals at the site.

5.3.4.4 American Robin

As indicated in Table 5-7, RQs for copper (12), LEPH (3.9), HEPH (13) and glyphosate (1.8) exceed unity indicating a moderate risk to omnivorous bird species at the site. RQs for the remaining COPECs were less than unity indicating that they pose a low risk to omnivorous bird species at the site.

5.3.4.5 Common Garter Snake

As indicated in Table 5-10, RQs for copper (5.5), LEPH (2.2), HEPH (7.1) and glyphosate (1) exceed unity indicating a moderate risk to reptiles at the site. RQs for the

remaining COPECs were less than unity indicating that they pose a low risk to reptiles at the site.

6 SUMMARY, RECOMMENDATIONS AND PROCESS REVIEW

6.1 Summary and Recommendations

A screening level (Tier 1) ecological risk assessment (ERA) was conducted to estimate the ecological risks posed by a metal, hydrocarbon and herbicide contaminated rail corridor in coastal British Columbia. The results of the ERA were to be used to determine the need for and the nature of remedial/risk management activities at the site and/or the need for additional investigation activities. The receptor groups of concern evaluated in the ERA included terrestrial invertebrates (soil and foliar) and plants, mammals (small omnivores, arboreal insectivores and carnivores), birds (omnivores, cavity-dwellers and raptors) and reptiles. As site surface water data was not available, aquatic receptors could not be ruled out as receptors of concern. Risks to these receptors could not be evaluated as a result of this data gap. It is recommended that a sampling program be conducted at the site to characterise the water quality within the creek and drainage ditches. If analytical results indicate the presence of COPECs in site surface waters, a risk assessment should be conducted to characterize risks to aquatic life receptors.

BC guidance for Tier 1 ERA (BCMELP 1998) recommends the integration of risk quotients and site observations to characterize ecological risks with the more qualitative but site-specific observations of actual field conditions substantiating or refuting the

presumption of risk indicated by the risk quotients. The site observation methodology recommended by BC guidance (BCMELP 1998) was deemed to be much too qualitative to identify adverse ecological effects, particularly to wildlife, and therefore, the results of the site survey were not incorporated into the risk characterization. Consequently, the results of the risk assessment were based solely on risk quotients.

The results of the ERA indicate that moderate risks exist to soil and foliar invertebrates, terrestrial plants, small omnivorous mammals, omnivorous birds and reptiles due to site COPECs. Risks posed by site COPECs on mammalian arboreal insectivores, carnivorous mammals, cavity-dwelling birds and raptors were shown to be low. The uncertainty in these risk estimates is considered to be high due primarily to the modelling approach used to estimate exposures and the inability to identify effects at the site due to an inadequate survey methodology. Analysis of assessment uncertainties indicates that conservative exposure assumptions likely resulted in overestimates of risk using the risk quotient method. Given the relatively low RQs calculated among those indicating moderate risk, it is recommended that further investigation be conducted to reduce uncertainty and refine the characterization of risk at the site. It is recommended that additional data collection and risk re-evaluation precede the consideration of remedial/risk management options.

To reduce the uncertainty in risk estimates for the lower trophic level receptors, it is recommended that laboratory bioassays be conducted using media collected from areas of the site with the highest COPEC concentrations. To determine whether site soils are toxic to soil invertebrates, acute earthworm lethality and chronic growth bioassays are

recommended. For terrestrial plants, seed germination and root elongation bioassays are recommended.

To reduce the uncertainty in risk estimates for the small omnivorous mammals, omnivorous birds and reptiles, it is recommended that tissue concentrations in lower trophic level food items (earthworms, plants, foliar invertebrates) be measured at the site, and that RQs be recalculated using the measured tissue concentrations. Tissue concentrations for these food sources were modelled in the ERA using media-to-receptor bioconcentration factors with high levels of uncertainty as to their accuracy and applicability to site conditions.

To further reduce uncertainties in risk estimates for the wildlife receptors, it is recommended that a quantitative biological survey be conducted to determine whether site COPECs are causing adverse affects on wildlife. Trapping is recommended to collect information on resident wildlife including presence-absence, age structure, growth and fecundity. These data can then be compared to a specified reference site to determine whether site contamination is responsible for the effects.

6.2 Review of Tier 1 ERA Process

The completion of this assessment demonstrates the use of ecological risk assessment as a tool to direct remedial decision making. This tool is particularly applicable for wide area sites, such as the property evaluated here, where regulatory exceedances are widespread making the application of the numerical approach infeasible. Overall, the Tier 1 ERA

process proved to be a useful initial step in identifying the potential for chemicals in site media to cause adverse effects on ecological receptors. In this assessment, the iterative intent of the ERA process was well demonstrated by the recommendation to collect additional site data to reduce assessment uncertainty such that confident risk characterizations can be reached.

Several strengths and limitations in BC's Tier 1 ERA process were identified through the completion of this assessment. A major strength of the process is in its relative ease of application. Generally, the data collected during a typical environmental site investigation (i.e., abiotic media concentrations) is all that is needed to complete a Tier 1 ERA. A second strength is that the process is generally conservative and protective so long as the practitioner ensures that the assumptions made throughout the assessment are conservative.

Several limitations of the BC Tier 1 ERA process were identified. First, the recommended use of a simple site walkover to assess the presence or absence of adverse ecological effects at the subject site and to give these site observations more weight than risk quotients in the overall characterization of risk is not justified. This methodology is far too qualitative to be able to detect COPEC-induced adverse effects in the receptors of concern, particularly on wildlife receptors, whose evaluation is based on simple presence/absence. In addition, even where adverse effects on ecological receptors are observable, the methodology recommended does not have the power to draw causative links to site COPECs. The results of such a qualitative survey are virtually useless in

assessing site-specific COPEC-induced adverse effects and should not be used in characterizing risks. A more rigorous and quantitative site survey method including site-specific measurements and comparison to specified reference sites would be much more informative in identifying effects and drawing causative links.

A second limitation identified is the failure of the process to consider temporal variation in exposure conditions. The process generally relies on data from a single sampling event. In fact, concentrations in environmental media can vary a great deal over time. For instance, chemical concentrations in groundwater and surface water may vary with seasonal runoff. Consequently, screening for constituents of concern and estimating concentrations to be used to estimate exposures may not be accurate based on a data from a single sampling event. To capture potential seasonal variation in exposure conditions, it is recommended that data from at least two sampling events conducted during different seasons be considered.

Another limitation of the Tier 1 ERA process is its inherent uncertainty. Risk assessment practitioners need to be able to identify when uncertainty is too high to reach a decision on risk and when and what additional data may assist in reducing uncertainty. Often Tier 1 assessments are conducted using modelling approaches to estimate exposures which introduce a large portion of the overall uncertainty into the assessment. An effective means of reducing uncertainty at the Tier 1 level is to use measured tissue concentrations in lower trophic level food sources (e.g., invertebrates, vegetation) to model wildlife

exposures, rather than relying on literature based media-to-receptor bioconcentration factors.

A lack of toxicological data for many chemicals and receptors also introduces a large degree of uncertainty into the Tier 1 ERA process through the application of surrogate TRVs from related compounds and extrapolation of values between taxa. Although conservatism can be ensured through the application of uncertainty factors, additional chemical and receptor-specific toxicological data is needed to ensure that risk estimates are not only conservative but approximate actual risk. A general move towards the use of tissue-based toxicological data in ecological risk assessment is recommended so that uncertainties related to chemical bioavailability can be avoided.

A fourth limitation identified is BC's policy (BCMELP 2000) to ignore wildlife exposures via the inhalation and dermal pathways. Although it is unlikely that excluding potential inhalation and dermal exposures in this ERA resulted in underestimates of exposure, BC's policy (BCMELP 2000) that these pathways are negligible is questionable. The policy on inhalation exposures is based on the general notion that volatile constituents dissipate relatively quickly and on the lack of scientific information to characterize this pathway. Although the assumption that significant long-term inhalation exposures to volatiles is plausible in many cases, in some situations this pathway could be significant and should not be dismissed out of hand. Where significant wildlife inhalation exposures are suspected models are available to address exposures via this pathway. BC's policy (BCMELP 2000) on dermal exposures is based on the assumption that wildlife pelage

characteristics limit actual exposures to chemicals. This too is a plausible assumption in most situations. However, where significant dermal exposures are possible, this pathway should be evaluated to ensure that exposures and risks are not underestimated. For example, dermal exposures should be addressed on sites contaminated with highly hydrophobic organic chemicals (e.g., solvents, pesticides) and receptors of concern that may have direct contact (e.g., burrowing mammals).

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APPENDIX A: ANALYTICAL CHEMISTRY DATA

Table A-1: Soil Analytical Results - LEPH/HEPH

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-1C Composite 23-Jul-01	TP01-2C Composite 23-Jul-01	TP01-3C Composite 23-Jul-01	TP01-4M 0.4 - 0.6 23-Jul-01	TP01-4M Duplicate 23-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	<	<	<	<	35	1000	333.3
EPH (C19 - C32)	10	61	93	80	110	170	1000	333.3
LEPH	10	-	-	<	<	35	1000	333.3
HEPH	10	-	-	78	100	170	1000	333.3

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-4C Composite 23-Jul-01	TP01-5C Composite 23-Jul-01	TP01-6C Composite 23-Jul-01	TP01-7C Composite 23-Jul-01	TP01-8M 0.3 - 0.6 23-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	<	23	<	<	<	1000	333.3
EPH (C19 - C32)	10	37	160	69	32	44	1000	333.3
LEPH	10	-	-	-	<	-	1000	333.3
HEPH	10	-	-	-	30	-	1000	333.3

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
EPH	Extractable Petroleum Hydrocarbons uncorrected for PAH.
LEPH	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPH	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
<	Less than reported detection limit
-	Not analyzed
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples comprised of three discrete samples and therefore are compared against 1/3 of the discrete sample screening benchmark

Table A-1 continued: Soil Analytical Results - LEPH/HEPH

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-8C Composite 23-Jul-01	TP01-9C Composite 24-Jul-01	TP01-10C Composite 24-Jul-01	TP01-11M 0.5 - 0.6 24-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	<	11	<	<	1000	333.3
EPH (C19 - C32)	10	68	170	150	51	1000	333.3
LEPH	10	-	-	-	-	1000	333.3
HEPH	10	-	-	-	-	1000	333.3

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-11S 0.0 - 0.2 24-Jul-01	TP01-11C Composite 24-Jul-01	TP01-12C Composite 24-Jul-01	TP01-12C Duplicate 24-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	<	<	<	<	1000	333.3
EPH (C19 - C32)	10	65	25	63	61	1000	333.3
LEPH	10	-	<	-	-	1000	333.3
HEPH	10	-	25	-	-	1000	333.3

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
EPH	Extractable Petroleum Hydrocarbons uncorrected for PAH.
LEPH	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPH	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
<	Less than reported detection limit
-	Not analyzed
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples comprised of three discrete samples and therefore are compared against 1/3 of the discrete sample screening benchmark

Table A-1 continued: Soil Analytical Results - LEPH/HEPH

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-13M 0.5 - 0.7 24-Jul-01	TP01-14N 0.1-0.30 24-Jul-01	TP01-14C Composite 24-Jul-01	TP01-15C Composite 24-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	<	<	<	36	1000	333.3
EPH (C19 - C32)	10	150	89	<	270	1000	333.3
LEPH	10	<	-	-	35	1000	333.3
HEPH	10	140	-	-	270	1000	333.3

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-16C Composite 24-Jul-01	TP01-17C Composite 24-Jul-01	TP01-18C Composite 24-Jul-01	TP01-19C Composite 24-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	<	<	<	470	1000	333.3
EPH (C19 - C32)	10	110	230	440	1100	1000	333.3
LEPH	10	-	-	-	470	1000	333.3
HEPH	10	-	-	-	1100	1000	333.3

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
EPH	Extractable Petroleum Hydrocarbons uncorrected for PAH.
LEPH	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPH	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
<	Less than reported detection limit
-	Not analyzed
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples comprised of three discrete samples and therefore are compared against 1/3 of the discrete sample screening benchmark

Table A-1 continued: Soil Analytical Results - LEPH/HEPH

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-20M 0.0 - 0.1 25-Jul-01	TP01-20C Composite 25-Jul-01	TP01-20C Duplicate 25-Jul-01	TP01-21C Composite 25-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	12	17	14	40	1000	333.3
EPH (C19 - C32)	10	290	300	300	270	1000	333.3
LEPH	10	11	-	-	-	1000	333.3
HEPH	10	280	-	-	-	1000	333.3

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-22C Composite 25-Jul-01	TP01-23C Composite 25-Jul-01	TP01-24M 0.05-0.15 25-Jul-01	TP01-24C Composite 25-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	20	87	21	15	1000	333.3
EPH (C19 - C32)	10	280	330	360	130	1000	333.3
LEPH	10	-	87	20	-	1000	333.3
HEPH	10	-	330	360	-	1000	333.3

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
EPH	Extractable Petroleum Hydrocarbons uncorrected for PAH.
LEPH	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPH	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
<	Less than reported detection limit
-	Not analyzed
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples comprised of three discrete samples and therefore are compared against 1/3 of the discrete sample screening benchmark

Table A-1 continued: Soil Analytical Results - LEPH/HEPH

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-25C Composite 25-Jul-01	TP01-26C Composite 25-Jul-01	TP01-27C Composite 25-Jul-01	TP01-28C Composite 25-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	12	17	29	18	1000	333.3
EPH (C19 - C32)	10	230	140	290	280	1000	333.3
LEPH	10	-	-	29	-	1000	333.3
HEPH	10	-	-	290	-	1000	333.3

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-29C Composite 25-Jul-01	TP01-29C Duplicate 25-Jul-01	TP01-30M 0.05-0.20 25-Jul-01	TP01-30C Composite 25-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	60	80	340	110	1000	333.3
EPH (C19 - C32)	10	300	330	3400	1300	1000	333.3
LEPH	10	-	-	330	-	1000	333.3
HEPH	10	-	-	3300	-	1000	333.3

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
EPH	Extractable Petroleum Hydrocarbons uncorrected for PAH.
LEPH	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPH	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
<	Less than reported detection limit
-	Not analyzed
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples comprised of three discrete samples and therefore are compared against 1/3 of the discrete sample screening benchmark

Table A-1 continued: Soil Analytical Results - LEPH/HEPH

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-31C Composite 26-Jul-01	TP01-32C Composite 26-Jul-01	TP01-33C Composite 26-Jul-01	TP01-34C Composite 26-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	37	22	<	23	1000	333.3
EPH (C19 - C32)	10	230	120	63	190	1000	333.3
LEPH	10	-	22	-	-	1000	333.3
HEPH	10	-	120	-	-	1000	333.3

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-35C Composite 26-Jul-01	TP01-36C Composite 26-Jul-01	TP01-37C Composite 26-Jul-01	TP01-38C Composite 26-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	31	54	27	20	1000	333.3
EPH (C19 - C32)	10	250	270	110	310	1000	333.3
LEPH	10	29	-	-	-	1000	333.3
HEPH	10	240	-	-	-	1000	333.3

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
EPH	Extractable Petroleum Hydrocarbons uncorrected for PAH.
LEPH	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPH	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
<	Less than reported detection limit
-	Not analyzed
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples comprised of three discrete samples and therefore are compared against 1/3 of the discrete sample screening benchmark

Table A-1 continued: Soil Analytical Results - LEPH/HEPH

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-38C Duplicate 26-Jul-01	TP01-39C Composite 26-Jul-01	TP01-40C Composite 26-Jul-01	TP01-41C Composite 27-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	45	31	43	20	1000	333.3
EPH (C19 - C32)	10	340	200	190	150	1000	333.3
LEPH	10	-	-	-	-	1000	333.3
HEPH	10	-	-	-	-	1000	333.3

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-42C Composite 27-Jul-01	TP01-42C Duplicate 27-Jul-01	STP01-1C Composite 27-Jul-01	STP01-2C Composite 27-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	45	59	19	<	1000	333.3
EPH (C19 - C32)	10	1200	1000	130	130	1000	333.3
LEPH	10	-	-	-	<	1000	333.3
HEPH	10	-	-	-	130	1000	333.3

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
EPH	Extractable Petroleum Hydrocarbons uncorrected for PAH.
LEPH	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPH	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
<	Less than reported detection limit
-	Not analyzed
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples comprised of three discrete samples and therefore are compared against 1/3 of the discrete sample screening benchmark

Table A-1 continued: Soil Analytical Results - LEPH/HEPH

Sample ID Sample Depth (m) Date Sampled	RDL	STP01-3C Composite 27-Jul-01	STP01-4C Composite 27-Jul-01	SS03-01 N of tracks surface 11-Aug-03	SS03-02 N of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	1000	<	<	<	1000	333.3
EPH (C19 - C32)	10	110	77	<	<	1000	333.3
LEPH	10	-	-	<	<	1000	333.3
HEPH	10	-	-	<	<	1000	333.3

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-03 S - slope surface 11-Aug-03	SS03-04 Btw tracks surface 11-Aug-03	SS03-05 N of tracks surface 11-Aug-03	SS03-06 S of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
EPH (C10 - C19)	10	<	<	<	<	1000	333.3
EPH (C19 - C32)	10	<	<	<	<	1000	333.3
LEPH	10	<	<	<	<	1000	333.3
HEPH	10	<	<	<	<	1000	333.3

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
EPH	Extractable Petroleum Hydrocarbons uncorrected for PAH.
LEPH	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPH	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
<	Less than reported detection limit
-	Not analyzed
C	Composite sample comprised of three discrete samples
1	Composite samples comprised of three discrete samples and therefore are compared against 1/3 of the discrete sample screening benchmark

Table A-1 continued: Soil Analytical Results - LEPH/HEPH

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-07 N - slope surface 11-Aug-03	SS03-09 N of tracks surface 11-Aug-03	SS03-10 W of tracks surface 11-Aug-03	SS03-14 W of tracks surface 11-Aug-03	SS03-15 E - slope surface 11-Aug-03	SS03-17 W of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark
EPH (C10 - C19)	10	<	<	<	<	<	<	1000
EPH (C19 - C32)	10	<	<	<	<	<	<	1000
LEPH	10	<	<	<	<	<	<	1000
HEPH	10	<	<	<	<	<	<	1000

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-18 E of tracks surface 11-Aug-03	BH03-1 (4') 1.2 13-Aug-03	MW03-2 (22') 6.7 13-Aug-03	MW03-5 (8') 2.4 14-Aug-03	MW03-5 (18') 5.5 14-Aug-03	Discrete Sample Screening Benchmark
EPH (C10 - C19)	10	<	<	<	<	<	1000
EPH (C19 - C32)	10	<	<	<	<	<	1000
LEPH	10	<	<	<	<	<	1000
HEPH	10	<	<	<	<	<	1000

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
EPH	Extractable Petroleum Hydrocarbons uncorrected for PAH.
LEPH	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPH	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
<	Less than reported detection limit
-	Not analyzed
1	Composite samples comprised of three discrete samples and therefore are compared against 1/3 of the discrete sample screening benchmark

Table A-2: Soil Analytical Results - PAHs

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-3C Composite 23-Jul-01	TP01-4M 0.4 - 0.6 23-Jul-01	TP01-7C Composite 23-Jul-01	TP01-11C Composite 24-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Naphthalene	0.01	0.01	0.02	0.05	< 0.01	5	1.67
Acenaphthylene	0.01	< 0.03	0.07	0.06	0.02	1*	0.33*
Acenaphthene	0.01	< 0.03	0.01	0.03	< 0.01	1*	0.33*
Fluorene	0.01	< 0.03	0.02	0.03	< 0.01	1*	0.33*
Phenanthrene	0.01	< 0.26	0.24	0.27	0.10	5	1.67
Anthracene	0.01	< 0.07	0.29	0.18	0.06	1*	0.33*
Fluoranthene	0.01	0.87	1.00	1.10	0.26	1*	0.33*
Pyrene	0.01	0.86	0.87	0.92	0.21	10	3.3
Benzo(a)anthracene	0.01	< 0.11	0.18	0.20	0.05	1	0.33
Chrysene	0.01	< 0.46	1.10	0.55	0.18	1*	0.33*
Benzo(b)fluoranthene	0.01	0.28	1.30	0.46	0.22	1	0.33
Benzo(k)fluoranthene	0.01	0.19	0.59	0.21	0.09	1	0.33
Benzo(a)pyrene	0.01	0.20	0.37	0.18	0.04	1	0.33
Indeno(1,2,3-c,d)pyrene	0.02	0.10	0.47	0.11	0.06	1	0.33
Dibenz(a,h)anthracene	0.02	< 0.02	0.07	< 0.02	< 0.02	1	0.33
Benzo(g,h,i)perylene	0.02	0.13	0.41	0.10	0.04	1*	0.33*

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
<	Less than reported detection limit
-	Not analyzed
*	Most conservative PAH screening benchmark used as surrogate
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-2 continued: Soil Analytical Results - PAHs

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-13M 0.5 - 0.7 24-Jul-01	TP01-15C Composite 24-Jul-01	TP01-19C Composite 24-Jul-01	TP01-20M 0.0 - 0.1 25-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Naphthalene	0.01	0.05	0.09	0.18	0.06	5	1.67
Acenaphthylene	0.01	0.11	0.05	0.12	0.08	1*	0.33*
Acenaphthene	0.01	0.04	0.02	0.03	0.07	1*	0.33*
Fluorene	0.01	0.05	0.03	0.03	0.06	1*	0.33*
Phenanthrene	0.01	0.32	0.30	0.38	0.67	5	1.67
Anthracene	0.01	0.17	0.11	< 0.19	0.23	1*	0.33*
Fluoranthene	0.01	1.10	0.68	0.84	1.00	1*	0.33*
Pyrene	0.01	1.10	0.55	0.79	0.80	10	3.3
Benzo(a)anthracene	0.01	0.32	0.13	0.27	0.36	1	0.33
Chrysene	0.01	1.10	0.43	1.10	0.53	1*	0.33*
Benzo(b)fluoranthene	0.01	1.00	0.37	0.89	0.66	1	0.33
Benzo(k)fluoranthene	0.01	0.47	0.18	0.44	0.30	1	0.33
Benzo(a)pyrene	0.01	0.40	0.13	0.36	0.42	1	0.33
Indeno(1,2,3-c,d)pyrene	0.02	0.34	0.16	0.48	0.41	1	0.33
Dibenz(a,h)anthracene	0.02	0.06	0.03	0.08	0.07	1	0.33
Benzo(g,h,i)perylene	0.02	0.31	0.13	0.50	0.41	1*	0.33*

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
<	Less than reported detection limit
-	Not analyzed
*	Most conservative PAH screening benchmark used as surrogate
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-2 continued: Soil Analytical Results - PAHs

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-23C Composite 25-Jul-01	TP01-24M 0.05-0.15 25-Jul-01	TP01-27C Composite 25-Jul-01	TP01-30M 0.05-0.20 25-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Naphthalene	0.01	0.15	0.13	0.03	0.68	5	1.67
Acenaphthylene	0.01	0.06	0.11	0.07	0.81	1*	0.33*
Acenaphthene	0.01	0.01	0.02	0.01	0.49	1*	0.33*
Fluorene	0.01	0.02	0.02	0.02	0.34	1*	0.33*
Phenanthrene	0.01	0.18	0.33	0.16	4.3	5	1.67
Anthracene	0.01	0.08	0.19	0.16	2.7	1*	0.33*
Fluoranthene	0.01	0.25	0.51	0.31	17	1*	0.33*
Pyrene	0.01	0.2	0.41	0.27	15	10	3.3
Benzo(a)anthracene	0.01	0.07	0.15	0.1	3.2	1	0.33
Chrysene	0.01	0.22	0.63	0.22	12	1*	0.33*
Benzo(b)fluoranthene	0.01	0.24	0.53	0.25	11	1	0.33
Benzo(k)fluoranthene	0.01	0.1	0.24	0.1	4.5	1	0.33
Benzo(a)pyrene	0.01	0.08	0.21	0.15	2.8	1	0.33
Indeno(1,2,3-c,d)pyrene	0.02	0.11	0.29	0.19	2.9	1	0.33
Dibenz(a,h)anthracene	0.02	< 0.02	0.06	0.03	0.44	1	0.33
Benzo(g,h,i)perylene	0.02	0.11	0.35	0.2	1.9	1*	0.33*

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
<	Less than reported detection limit
-	Not analyzed
*	Most conservative PAH screening benchmark used as surrogate
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-2 continued: Soil Analytical Results - PAHs

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-32C Composite 26-Jul-01	TP01-35C Composite 26-Jul-01	STP01-2C Composite 27-Jul-01	SS03-01 N of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Naphthalene	0.01	0.09	0.08	0.17	<	5	1.67
Acenaphthylene	0.01	0.06	0.08	0.03	<	1*	0.33*
Acenaphthene	0.01	0.02	0.21	0.01	<	1*	0.33*
Fluorene	0.01	0.02	0.14	0.02	<	1*	0.33*
Phenanthrene	0.01	0.23	1.80	0.26	<	5	1.67
Anthracene	0.01	0.08	0.27	0.05	<	1*	0.33*
Fluoranthene	0.01	0.42	5.30	0.40	0.18	1*	0.33*
Pyrene	0.01	0.33	4.40	0.35	0.17	10	3.3
Benzo(a)anthracene	0.01	0.09	0.59	0.15	0.1	1	0.33
Chrysene	0.01	0.32	2.10	0.44	0.1	1*	0.33*
Benzo(b)fluoranthene	0.01	0.32	1.20	0.43	0.09	1	0.33
Benzo(k)fluoranthene	0.01	0.19	0.73	0.36	-	1	0.33
Benzo(a)pyrene	0.01	0.1	0.50	0.17	<	1	0.33
Indeno(1,2,3-c,d)pyrene	0.02	0.17	0.46	0.14	<	1	0.33
Dibenz(a,h)anthracene	0.02	0.03	0.05	0.03	<	1	0.33
Benzo(g,h,i)perylene	0.02	0.2	0.36	0.13	<	1*	0.33*

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
<	Less than reported detection limit
-	Not analyzed
*	Most conservative PAH screening benchmark used as surrogate
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-2 continued: Soil Analytical Results - PAHs

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-02 N of tracks surface 11-Aug-03	SS03-03 S - slope surface 11-Aug-03	SS03-04 Btw tracks surface 11-Aug-03	SS03-05 N of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Naphthalene	0.01	<	<	<	<	5	1.67
Acenaphthylene	0.01	<	<	<	<	1*	0.33*
Acenaphthene	0.01	<	<	<	<	1*	0.33*
Fluorene	0.01	<	<	<	<	1*	0.33*
Phenanthrene	0.01	<	<	<	0.07	5	1.67
Anthracene	0.01	<	<	<	<	1*	0.33*
Fluoranthene	0.01	0.07	0.07	<	0.1	1*	0.33*
Pyrene	0.01	0.05	0.07	<	0.11	10	3.3
Benzo(a)anthracene	0.01	<	0.06	<	0.08	1	0.33
Chrysene	0.01	<	0.06	<	0.08	1*	0.33*
Benzo(b)fluoranthene	0.01	0.07	0.05	<	0.06	1	0.33
Benzo(k)fluoranthene	0.01	-	-	-	-	1	0.33
Benzo(a)pyrene	0.01	<	<	<	<	1	0.33
Indeno(1,2,3-c,d)pyrene	0.02	<	<	<	<	1	0.33
Dibenz(a,h)anthracene	0.02	<	<	<	<	1	0.33
Benzo(g,h,i)perylene	0.02	<	<	<	<	1*	0.33*

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
<	Less than reported detection limit
-	Not analyzed
*	Most conservative PAH screening benchmark used as surrogate
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-2 continued: Soil Analytical Results - PAHs

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-06 S of tracks surface 11-Aug-03	SS03-07 N - slope surface 11-Aug-03	SS03-09 N of tracks surface 11-Aug-03	SS03-10 W of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Naphthalene	0.01	<	<	<	<	5	1.67
Acenaphthylene	0.01	<	<	<	<	1*	0.33*
Acenaphthene	0.01	<	<	<	<	1*	0.33*
Fluorene	0.01	<	<	<	<	1*	0.33*
Phenanthrene	0.01	0.57	<	<	0.06	5	1.67
Anthracene	0.01	0.15	<	<	<	1*	0.33*
Fluoranthene	0.01	1.1	<	<	0.12	1*	0.33*
Pyrene	0.01	1	<	<	0.12	10	3.3
Benzo(a)anthracene	0.01	0.91	<	<	0.14	1	0.33
Chrysene	0.01	0.87	<	<	0.13	1*	0.33*
Benzo(b)fluoranthene	0.01	0.98	0.06	<	0.16	1	0.33
Benzo(k)fluoranthene	0.01	-	-	-	-	1	0.33
Benzo(a)pyrene	0.01	0.37	<	<	0.05	1	0.33
Indeno(1,2,3-c,d)pyrene	0.02	0.29	<	<	0.05	1	0.33
Dibenz(a,h)anthracene	0.02	0.08	<	<	<	1	0.33
Benzo(g,h,i)perylene	0.02	0.25	<	<	0.05	1*	0.33*

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
<	Less than reported detection limit
-	Not analyzed
*	Most conservative PAH screening benchmark used as surrogate
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-2 continued: Soil Analytical Results - PAHs

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-14 W of tracks surface 11-Aug-03	SS03-15 E - slope surface 11-Aug-03	SS03-17 W of tracks surface 11-Aug-03	SS03-18 E of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Naphthalene	0.01	<	<	<	<	5	1.67
Acenaphthylene	0.01	<	<	<	<	1*	0.33*
Acenaphthene	0.01	<	<	<	<	1*	0.33*
Fluorene	0.01	<	<	<	<	1*	0.33*
Phenanthrene	0.01	<	0.07	0.06	<	5	1.67
Anthracene	0.01	<	<	<	<	1*	0.33*
Fluoranthene	0.01	<	0.11	0.09	<	1*	0.33*
Pyrene	0.01	0.07	0.11	0.08	<	10	3.3
Benzo(a)anthracene	0.01	<	<	0.11	<	1	0.33
Chrysene	0.01	<	<	0.1	<	1*	0.33*
Benzo(b)fluoranthene	0.01	0.07	0.14	0.12	<	1	0.33
Benzo(k)fluoranthene	0.01	-	-	-	-	1	0.33
Benzo(a)pyrene	0.01	<	<	<	<	1	0.33
Indeno(1,2,3-c,d)pyrene	0.02	<	0.06	0.05	<	1	0.33
Dibenz(a,h)anthracene	0.02	<	<	<	<	1	0.33
Benzo(g,h,i)perylene	0.02	<	0.06	0.05	<	1*	0.33*

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
<	Less than reported detection limit
-	Not analyzed
*	Most conservative PAH screening benchmark used as surrogate
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-2 continued: Soil Analytical Results - PAHs

Sample ID Sample Depth (m) Date Sampled	RDL	BH03-1 (4') 1.2 13-Aug-03	MW03-2 (22') 6.7 13-Aug-03	MW03-5 (8') 2.4 14-Aug-03	MW03-5 (18') 5.5 14-Aug-03	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Naphthalene	0.01	<	<	<	<	5	1.67
Acenaphthylene	0.01	<	<	<	<	1*	0.33*
Acenaphthene	0.01	<	<	<	<	1*	0.33*
Fluorene	0.01	<	<	<	<	1*	0.33*
Phenanthrene	0.01	<	<	<	<	5	1.67
Anthracene	0.01	<	<	<	<	1*	0.33*
Fluoranthene	0.01	<	<	<	<	1*	0.33*
Pyrene	0.01	<	<	<	<	10	3.3
Benzo(a)anthracene	0.01	<	<	<	<	1	0.33
Chrysene	0.01	<	<	<	<	1*	0.33*
Benzo(b)fluoranthene	0.01	<	<	<	<	1	0.33
Benzo(k)fluoranthene	0.01	-	-	-	-	1	0.33
Benzo(a)pyrene	0.01	<	<	<	<	1	0.33
Indeno(1,2,3-c,d)pyrene	0.02	<	<	<	<	1	0.33
Dibenz(a,h)anthracene	0.02	<	<	<	<	1	0.33
Benzo(g,h,i)perylene	0.02	<	<	<	<	1*	0.33*

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
<	Less than reported detection limit
-	Not analyzed
*	Most conservative PAH screening benchmark used as surrogate
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-3: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-4M 0.05 - 0.25 23-Jul-01	TP01-4C Composite 23-Jul-01	TP01-8C Composite 23-Jul-01	TP01-10M 0.5 - 0.7 24-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Antimony	2	< 2	< 2	3	< 2	20	6.7
Arsenic	0.2	2.8	2.1	4.4	2.2	20	6.7
Barium	0.1	68.3	37.1	49	64.3	500	166.7
Beryllium	0.1	0.1	0.1	0.1	< 0.1	4	1.3
Cadmium	0.2	< 0.2	0.5	0.7	< 0.2	2 - 70a	0.67-23.3a
Chromium (total)	0.2	17.1	10.6	13.6	12.4	100	33.3
Cobalt	0.3	9.3	4.3	5.9	5.9	50	16.6
Copper	0.5	39.5	33.2	142	23.5	90 - 150a	30-50
Lead	2	16	6	24	10	150 - 1000a	50-333a
Mercury	0.05	< 0.05	< 0.05	< 0.05	< 0.05	100	33.3
Molybdenum	0.4	< 0.4	< 0.4	< 0.4	1.9	10	3.3
Nickel	0.8	16.1	8.9	13.9	9.3	100	33.3
Selenium	0.5	< 0.5	< 0.5	< 0.5	< 0.5	4	1.3
Silver	1	< 1	< 1	< 1	< 1	20	6.7
Tin	2	< 2	< 2	4	< 2	50	16.6
Vanadium	0.3	37.3	26.2	33.5	34.5	200	66.7
Zinc	0.5	51.2	59.9	67.8	32.7	150 - 450a	50-150a
pH	0.1	5.9	6	7	6.1	n/s	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-12C Composite 24-Jul-01	TP01-16C Composite 24-Jul-01	TP01-20M 0 - 0.1 27-Jul-01	TP01-20C Composite 27-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Antimony	2	< 2	< 2	3	3	20	6.7
Arsenic	0.2	7.7	3.5	8.9	6.5	20	6.7
Barium	0.1	58	69.6	77	63.9	500	166.7
Beryllium	0.1	0.2	0.2	0.1	0.2	4	1.3
Cadmium	0.2	< 0.2	< 0.2	0.9	0.8	2 - 70a	0.67-23.3a
Chromium (total)	0.2	23.6	14.9	37.1	21.8	100	33.3
Cobalt	0.3	7.8	7	8.4	6.8	50	16.6
Copper	0.5	50.6	170	134	79.2	90 - 150a	30-50
Lead	2	6	23	301	152	150 - 1000a	50-333a
Mercury	0.05	< 0.05	< 0.05	0.07	0.07	100	33.3
Molybdenum	0.4	0.4	< 0.4	6.7	2.7	10	3.3
Nickel	0.8	22.2	13.6	27.8	18.6	100	33.3
Selenium	0.5	< 0.5	< 0.5	< 0.5	< 0.5	4	1.3
Silver	1	< 1	< 1	< 1	< 1	20	6.7
Tin	2	< 2	10	4	< 2	50	16.6
Vanadium	0.3	36.7	36.4	36.5	34.5	200	66.7
Zinc	0.5	78	65	166	155	150 - 450a	50-150a
pH	0.1	6.1	6.1	8.1	7.6	n/s	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-24C Composite 27-Jul-01	TP01-26M 0.05 - 0.2 27-Jul-01	TP01-28C Composite 25-Jul-01	TP01-32C Composite 26-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Antimony	2	2	3	2	2	20	6.7
Arsenic	0.2	9.1	8.4	5.6	5.9	20	6.7
Barium	0.1	68.3	73.8	58.1	46.2	500	166.7
Beryllium	0.1	0.2	0.2	0.2	0.1	4	1.3
Cadmium	0.2	0.6	2.1	1.2	0.5	2 - 70a	0.67-23.3a
Chromium (total)	0.2	27.5	32.9	26.2	15.7	100	33.3
Cobalt	0.3	9.1	8.3	6.7	6.1	50	16.6
Copper	0.5	245	178	72.7	416	90 - 150a	30-50
Lead	2	36	65	92	34	150 - 1000a	50-333a
Mercury	0.05	< 0.05	0.06	< 0.05	< 0.05	100	33.3
Molybdenum	0.4	2.5	4.1	3	0.9	10	3.3
Nickel	0.8	29.3	29.8	21.7	17.4	100	33.3
Selenium	0.5	< 0.5	< 0.5	< 0.5	< 0.5	4	1.3
Silver	1	< 1	< 1	< 1	< 1	20	6.7
Tin	2	7	3	< 2	18	50	16.6
Vanadium	0.3	39.7	38.6	35.3	27.5	200	66.7
Zinc	0.5	74.2	123	137	50.5	150 - 450a	50-150a
pH	0.1	6.6	6.4	6.9	6.3	n/s	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-36C Composite 26-Jul-01	STP01-1C Composite 27-Jul-01	SS03-01 N of tracks surface 11-Aug-03	SS03-02 N of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Antimony	2	< 2	< 2	<	<	20	6.7
Arsenic	0.2	4.3	4.4	<	<	20	6.7
Barium	0.1	71	63.2	83	69	500	166.7
Beryllium	0.1	0.2	0.2	<	<	4	1.3
Cadmium	0.2	0.4	0.6	0.2	1.5	2 - 70a	0.67-23.3a
Chromium (total)	0.2	20.1	15	31	35	100	33.3
Cobalt	0.3	7.5	6.8	8	6	50	16.6
Copper	0.5	102	44.9	52	476	90 - 150a	30-50
Lead	2	14	27	13	27	150 - 1000a	50-333a
Mercury	0.05	< 0.05	< 0.05	0.03	0.04	100	33.3
Molybdenum	0.4	2.2	< 0.4	<	<	10	3.3
Nickel	0.8	18.2	13.1	26	33	100	33.3
Selenium	0.5	< 0.5	< 0.5	<	<	4	1.3
Silver	1	< 1	< 1	<	8	20	6.7
Tin	2	4	< 2	<	<	50	16.6
Vanadium	0.3	37.7	36.6	46	48	200	66.7
Zinc	0.5	48.7	65	69	244	150 - 450a	50-150a
pH	0.1	6	6.4	6.1	5.8	n/s	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit
N	Discrete sample collected 3m north of track midline
M	Discrete sample collected from track midline
S	Discrete sample collected from 3m south of track midline
C	Composite sample comprised of three discrete samples
1	Composite samples compared against 1/3 of the discrete sample screening benchmark

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-03 S - slope surface 11-Aug-03	SS03-04 Btw tracks surface 11-Aug-03	SS03-05 N of tracks surface 11-Aug-03	SS03-07 N - slope surface 11-Aug-03	SS03-09 N of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark
Antimony	2	<	<	<	<	<	20
Arsenic	0.2	<	<	<	<	<	20
Barium	0.1	66	121	107	92	87	500
Beryllium	0.1	<	<	<	<	<	4
Cadmium	0.2	<	<	<	<	0.2	2 - 70a
Chromium (total)	0.2	25	28	24	18	27	100
Cobalt	0.3	5	9	6	6	7	50
Copper	0.5	90	37	177	464	32	90 - 150a
Lead	2	12	9	14	21	5	150 - 1000a
Mercury	0.05	0.02	0.03	0.02	0.04	0.02	100
Molybdenum	0.4	<	<	<	<	<	10
Nickel	0.8	13	20	15	14	19	100
Selenium	0.5	<	<	<	<	<	4
Silver	1	<	<	<	<	<	20
Tin	2	<	<	6	13	<	50
Vanadium	0.3	42	58	45	44	50	200
Zinc	0.5	31	47	34	56	73	150 - 450a
pH	0.1	5.6	5	5.5	4.9	5.5	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-12 E of tracks surface 11-Aug-03	SS03-13 W of tracks surface 11-Aug-03	SS03-14 W of tracks surface 11-Aug-03	SS03-17 W of tracks surface 11-Aug-03	SS03-18 E of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark
Antimony	2	<	<	<	<	<	20
Arsenic	0.2	<	<	<	<	<	20
Barium	0.1	58	62	59	118	75	500
Beryllium	0.1	<	<	<	<	<	4
Cadmium	0.2	<	<	<	0.2	0.3	2 - 70a
Chromium (total)	0.2	20	19	24	25	14	100
Cobalt	0.3	5	6	8	11	5	50
Copper	0.5	320	105	24	426	41	90 - 150a
Lead	2	24	9	<	54	<	150 - 1000a
Mercury	0.05	0.02	0.02	0.02	0.03	0.01	100
Molybdenum	0.4	<	<	<	<	<	10
Nickel	0.8	11	17	18	27	10	100
Selenium	0.5	<	<	<	0.2	<	4
Silver	1	<	<	<	<	<	20
Tin	2	13	<	<	29	<	50
Vanadium	0.3	55	42	54	55	43	200
Zinc	0.5	41	51	36	65	78	150 - 450a
pH	0.1	4.9	5	7	4.9	5.2	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-20 S - ditch surface 11-Aug-03	SS03-21 S - slope surface 11-Aug-03	MW03-2 (22') 6.7 13-Aug-03	BH03-4 (3') 0.9 14-Aug-03	MW03-5 (8') 2.4 14-Aug-03	Discrete Sample Screening Benchmark
Antimony	2	<	<	<	<	<	20
Arsenic	0.2	<	<	<	<	<	20
Barium	0.1	151	156	51	45	71	500
Beryllium	0.1	<	<	<	<	<	4
Cadmium	0.2	<	<	<	<	<	2 - 70a
Chromium (total)	0.2	27	17	16	15	15	100
Cobalt	0.3	11	7	4	4	4	50
Copper	0.5	33	128	10	17	14	90 - 150a
Lead	2	6	15	<	<	<	150 - 1000a
Mercury	0.05	0.03	0.03	<	<	0.01	100
Molybdenum	0.4	<	<	<	<	<	10
Nickel	0.8	18	14	5	7	8	100
Selenium	0.5	<	<	<	<	<	4
Silver	1	<	<	<	<	<	20
Tin	2	<	<	<	<	<	50
Vanadium	0.3	57	57	51	54	49	200
Zinc	0.5	59	51	21	18	22	150 - 450a
pH	0.1	5.2	4.7	6	6.2	5.3	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	MW03-5 (18') 5.5 14-Aug-03	SS03-25 N - slope surface 14-Aug-03	SS03-26 N - ditch surface 14-Aug-03	MW03-6 (5') 1.5 14-Aug-03	SS03-30 Slope surface 24-Oct-03	Discrete Sample Screening Benchmark
Antimony	2	<	<	<	<	<	20
Arsenic	0.2	<	<	<	<	<	20
Barium	0.1	103	79	128	118	49	500
Beryllium	0.1	<	<	<	<	<	4
Cadmium	0.2	<	<	0.5	<	0.6	2 - 70a
Chromium (total)	0.2	24	23	24	17	27	100
Cobalt	0.3	7	7	8	10	10	50
Copper	0.5	21	191	62	51	189	90 - 150a
Lead	2	<	20	91	18	30	150 - 1000a
Mercury	0.05	0.04	0.04	0.1	0.02	0.03	100
Molybdenum	0.4	<	<	<	<	<	10
Nickel	0.8	14	14	54	12	28	100
Selenium	0.5	0.2	0.3	0.3	0.2	0.2	4
Silver	1	<	<	<	<	<	20
Tin	2	<	7	<	<	10	50
Vanadium	0.3	60	53	48	56	44	200
Zinc	0.5	36	58	162	113	76	150 - 450a
pH	0.1	4.7	4.6	5.1	6.4	6.4	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-31 Ditch surface 24-Oct-03	SS03-32 Slope surface 24-Oct-03	SS03-33 Ditch surface 24-Oct-03	SS03-34 Slope surface 24-Oct-03	SS03-35 Ditch surface 24-Oct-03	Discrete Sample Screening Benchmark
Antimony	2	<	<	<	<	<	20
Arsenic	0.2	<	<	<	<	<	20
Barium	0.1	38	47	52	34	33	500
Beryllium	0.1	<	<	<	<	<	4
Cadmium	0.2	0.8	<	0.5	<	2.0	2 - 70a
Chromium (total)	0.2	18	20	19	14	30	100
Cobalt	0.3	6	6	6	5	7	50
Copper	0.5	73	229	128	190	167	90 - 150a
Lead	2	25	20	30	15	24	150 - 1000a
Mercury	0.05	0.05	0.04	0.05	0.01	0.04	100
Molybdenum	0.4	<	<	<	<	<	10
Nickel	0.8	16	16	15	12	31	100
Selenium	0.5	0.4	0.2	0.4	<	0.3	4
Silver	1	<	<	<	<	<	20
Tin	2	<	6	<	11	<	50
Vanadium	0.3	37	46	39	38	37	200
Zinc	0.5	147	42	246	34	491	150 - 450a
pH	0.1	6.2	6	6.2	6.1	6.3	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-39 N - ditch surface 24-Oct-03	SS03-40 N - ditch surface 24-Oct-03	SS03-41 S- slope surface 24-Oct-03	SS03-42 S - ditch surface 24-Oct-03	SS03-43 S - slope surface 24-Oct-03	Discrete Sample Screening Benchmark
Antimony	2	<	<	<	<	<	20
Arsenic	0.2	<	<	<	<	<	20
Barium	0.1	57	49	69	72	57	500
Beryllium	0.1	<	<	<	<	<	4
Cadmium	0.2	0.2	0.3	0.2	0.3	0.3	2 - 70a
Chromium (total)	0.2	18	20	17	22	16	100
Cobalt	0.3	8	8	7	8	8	50
Copper	0.5	303	480	159	62	684	90 - 150a
Lead	2	29	48	18	16	29	150 - 1000a
Mercury	0.05	0.03	0.03	0.03	0.04	0.02	100
Molybdenum	0.4	<	<	<	<	<	10
Nickel	0.8	16	20	15	17	17	100
Selenium	0.5	0.2	0.2	0.2	0.4	0.2	4
Silver	1	<	<	<	<	<	20
Tin	2	8	18	<	<	11	50
Vanadium	0.3	49	45	47	54	43	200
Zinc	0.5	52	68	53	75	57	150 - 450a
pH	0.1	6.1	5.8	6	5.8	6.3	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-44 S - ditch surface 24-Oct-03	SS03-45 Slope surface 24-Oct-03	SS03-46 Ditch surface 24-Oct-03	SS03-47 Ditch surface 24-Oct-03	SS03-48 W - slope surface 24-Oct-03	Discrete Sample Screening Benchmark
Antimony	2	<	<	<	<	<	20
Arsenic	0.2	<	<	<	<	<	20
Barium	0.1	98	49	59	56	52	500
Beryllium	0.1	<	<	<	<	<	4
Cadmium	0.2	<	0.3	0.5	0.3	0.3	2 - 70a
Chromium (total)	0.2	33	22	18	20	19	100
Cobalt	0.3	10	8	7	6	7	50
Copper	0.5	41	366	242	60	87	90 - 150a
Lead	2	9	78	92	26	17	150 - 1000a
Mercury	0.05	0.07	0.05	0.08	0.03	0.03	100
Molybdenum	0.4	<	<	<	6	<	10
Nickel	0.8	22	25	17	15	16	100
Selenium	0.5	0.2	0.3	0.3	0.2	0.3	4
Silver	1	<	<	<	<	<	20
Tin	2	<	19	9	<	<	50
Vanadium	0.3	62	48	42	44	42	200
Zinc	0.5	65	77	109	86	59	150 - 450a
pH	0.1	6	5.8	5.7	6.4	6.3	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-49 E - slope surface 24-Oct-03	SS03-50 Slope surface 24-Oct-03	SS03-51 Slope base surface 24-Oct-03	SS03-52 Ditch surface 24-Oct-03	SS03-53 Ditch surface 24-Oct-03	Discrete Sample Screening Benchmark
Antimony	2	<	<	<	<	<	20
Arsenic	0.2	<	<	<	<	<	20
Barium	0.1	69	38	39	69	35	500
Beryllium	0.1	<	<	<	<	<	4
Cadmium	0.2	0.2	<	<	0.2	<	2 - 70a
Chromium (total)	0.2	16	14	14	22	22	100
Cobalt	0.3	6	6	6	6	6	50
Copper	0.5	99	67	48	61	42	90 - 150a
Lead	2	11	8	8	26	18	150 - 1000a
Mercury	0.05	0.02	0.02	0.02	0.03	0.02	100
Molybdenum	0.4	<	<	<	33	<	10
Nickel	0.8	14	9	10	18	15	100
Selenium	0.5	<	<	<	0.3	0.3	4
Silver	1	<	<	<	<	<	20
Tin	2	<	<	<	<	<	50
Vanadium	0.3	42	48	51	37	44	200
Zinc	0.5	43	31	32	53	46	150 - 450a
pH	0.1	6.4	6.2	5.9	5.8	5.6	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-54 Slope surface 24-Oct-03	SS03-55 Ditch surface 24-Oct-03	SS03-56 Slope surface 24-Oct-03	SS03-57 Ditch surface 24-Oct-03	SS03-58 Ditch surface 24-Oct-03	Discrete Sample Screening Benchmark
Antimony	2	<	<	<	<	<	20
Arsenic	0.2	<	15	66	38	<	20
Barium	0.1	52	73	45	46	79	500
Beryllium	0.1	<	<	<	<	<	4
Cadmium	0.2	<	0.4	0.9	0.6	1.2	2 - 70a
Chromium (total)	0.2	15	25	17	16	162	100
Cobalt	0.3	5	9	6	6	9	50
Copper	0.5	53	179	118	100	216	90 - 150a
Lead	2	8	26	52	29	104	150 - 1000a
Mercury	0.05	0.02	0.06	<	0.01	0.11	100
Molybdenum	0.4	<	<	<	<	<	10
Nickel	0.8	10	18	8	10	20	100
Selenium	0.5	<	0.3	<	<	0.4	4
Silver	1	<	<	<	<	<	20
Tin	2	<	6	<	<	26	50
Vanadium	0.3	48	65	48	50	51	200
Zinc	0.5	44	155	540	249	206	150 - 450a
pH	0.1	5.7	5.8	6.5	6.5	6.5	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-59 Slope surface 24-Oct-03	SS03-60 N - ditch surface 24-Oct-03	SS03-62 Slope surface 24-Oct-03	SS03-63 Slope surface 13-Nov-03	SS03-64 S - slope surface 13-Nov-03	Discrete Sample Screening Benchmark
Antimony	2	<	<	<	-	-	20
Arsenic	0.2	<	<	<	-	-	20
Barium	0.1	55	48	47	-	-	500
Beryllium	0.1	<	<	<	-	-	4
Cadmium	0.2	0.4	0.3	0.2	-	1.1	2 - 70a
Chromium (total)	0.2	29	21	19	-	-	100
Cobalt	0.3	8	7	7	-	-	50
Copper	0.5	272	89	71	28	59	90 - 150a
Lead	2	50	26	16	-	-	150 - 1000a
Mercury	0.05	0.06	0.03	0.03	-	-	100
Molybdenum	0.4	<	<	<	-	-	10
Nickel	0.8	18	15	15	-	-	100
Selenium	0.5	0.3	<	0.2	-	-	4
Silver	1	<	<	<	-	-	20
Tin	2	10	<	<	-	-	50
Vanadium	0.3	52	48	45	-	-	200
Zinc	0.5	89	63	52	-	769	150 - 450a
pH	0.1	6.1	5.8	6.2	6.2	6.1	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
-	Constituent not analyzed
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-67 N of tracks surface 13-Nov-03	SS03-68 S of tracks surface 13-Nov-03	SS03-69 S of tracks surface 13-Nov-03	SS03-70 N - ditch surface 13-Nov-03	SS03-72 S - slope surface 13-Nov-03	Discrete Sample Screening Benchmark
Antimony	2	-	-	-	-	-	20
Arsenic	0.2	-	-	-	-	-	20
Barium	0.1	-	-	-	-	-	500
Beryllium	0.1	-	-	-	-	-	4
Cadmium	0.2	-	-	-	-	-	2 - 70a
Chromium (total)	0.2	-	-	-	-	-	100
Cobalt	0.3	-	-	-	-	-	50
Copper	0.5	35	79	43	45	44	90 - 150a
Lead	2	-	-	-	-	-	150 - 1000a
Mercury	0.05	-	-	-	-	-	100
Molybdenum	0.4	-	-	-	-	-	10
Nickel	0.8	-	-	-	-	-	100
Selenium	0.5	-	-	-	-	-	4
Silver	1	-	-	-	-	-	20
Tin	2	-	-	-	-	-	50
Vanadium	0.3	-	-	-	-	-	200
Zinc	0.5	-	-	-	-	-	150 - 450a
pH	0.1	7.5	6.2	7.3	5.3	6.5	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
-	Constituent not analyzed
<	Less than reported detection limit

Table A-3 continued: Soil Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-74 S - slope surface 13-Nov-03	SS03-76 N of tracks surface 13-Nov-03	SS03-78 S of tracks surface 13-Nov-03	SS03-79 E of tracks surface 13-Nov-03	SS03-80 W - slope surface 13-Nov-03	Discrete Sample Screening Benchmark
Antimony	2	-	-	-	-	-	20
Arsenic	0.2	-	-	-	97.8	-	20
Barium	0.1	-	-	-	-	-	500
Beryllium	0.1	-	-	-	-	-	4
Cadmium	0.2	-	-	-	-	-	2 - 70a
Chromium (total)	0.2	-	24	-	-	-	100
Cobalt	0.3	-	-	-	-	-	50
Copper	0.5	65	56	35	-	-	90 - 150a
Lead	2	-	-	-	-	-	150 - 1000a
Mercury	0.05	-	-	-	-	-	100
Molybdenum	0.4	-	-	-	-	0.7	10
Nickel	0.8	-	-	-	-	-	100
Selenium	0.5	-	-	-	-	-	4
Silver	1	-	-	-	-	-	20
Tin	2	-	-	-	-	-	50
Vanadium	0.3	-	-	-	-	-	200
Zinc	0.5	-	-	-	1240	-	150 - 450a
pH	0.1	6.0	6.1	6.4	7.9	4.9	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
-	Constituent not analyzed
<	Less than reported detection limit

Table A-4: Soil Analytical Results - Chlorinated Phenols

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-6C Composite 23-Jul-01	TP01-16C Composite 24-Jul-01	TP01-26C Composite 25-Jul-01	TP01-38C Composite 26-Jul-01	STP01-3C Composite 27-Jul-01	Discrete Sample Screening Benchmark	Composite Sample Screening Benchmark[1]
Pentachlorophenol	0.025	0.028	0.31	0.17	0.15	0.13	0.15 - 20a	0.05 - 6.67a
2,3,4-Trichlorophenol	0.025	<	<	<	<	<	0.5	0.167
2,3,5-Trichlorophenol	0.025	<	<	<	<	<	0.5	0.167
2,3,6-Trichlorophenol	0.025	<	<	<	<	<	0.5	0.167
2,4,5-Trichlorophenol	0.025	<	<	<	<	0.006	0.5	0.167
2,4,6-Trichlorophenol	0.025	<	<	<	<	<	0.5	0.167
3,4,5-Trichlorophenol	0.025	<	<	<	<	<	0.5	0.167
2,3,4,5-Tetrachlorophenol	0.025	<	<	<	<	<	0.5	0.167
2,3,4,6-Tetrachlorophenol**	0.025	<	0.016	0.011	0.034	0.009	0.5	0.167
2-chlorophenol	0.25	<	<	<	<	<	0.5	0.167
3-chlorophenol	0.25	<	<	<	<	<	0.5	0.167
4-chlorophenol	0.25	<	<	<	<	<	0.5	0.167
2,3-Dichlorophenol	0.025	<	<	<	<	<	0.5	0.167
2,4 & 2,5-Dichlorophenol	0.025	<	<	<	<	<	0.5	0.167
2,6-Dichlorophenol	0.025	<	<	<	<	<	0.5	0.167
3,4-Dichlorophenol	0.025	<	<	<	<	<	0.5	0.167
3,5-Dichlorophenol	0.025	<	<	<	<	<	0.5	0.167
pH		-	6.1	-	-	-	n/s	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
a	Screening benchmark is pH dependent
<	Less than reported detection limit
-	Not analyzed
**	includes 2,3,5,6-tetrachlorophenol
C	Composite sample comprised of three discrete samples
1	Composite samples comprised of three discrete aliquots and therefore are compared against 1/3 of the discrete sample screening benchmark

Table A-4 continued: Soil Analytical Results - Chlorinated Phenols

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-01 N of tracks surface 11-Aug-03	SS03-02 N of tracks surface 11-Aug-03	SS03-03 S - slope surface 11-Aug-03	SS03-04 Btw tracks surface 11-Aug-03	SS03-05 N of tracks surface 11-Aug-03	SS03-06 S of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark
Pentachlorophenol	0.01	<	0.036	0.014	<	0.071	0.023	0.15 - 20a
2,3,4-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,5-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,6-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,4,5-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,4,6-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
3,4,5-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,4,5-Tetrachlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,4,6-Tetrachlorophenol*	0.01	<	<	<	<	<	<	0.5
Total Trichlorophenol	0.01	<	<	<	<	<	<	n/s
Total Tetrachlorophenols	0.01	<	<	<	<	<	<	n/s
Total Chlorinated Phenols	0.01	<	0.036	0.014	<	0.071	0.023	n/s
pH	0.1	6.1	5.8	5.6	5	5.5	4.8	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
a	Screening benchmark is pH dependent
<	Less than reported detection limit
*	includes 2,3,5,6-tetrachlorophenol

Table A-4 continued: Soil Analytical Results - Chlorinated Phenols

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-07 N - slope surface 11-Aug-03	SS03-08 N of tracks surface 11-Aug-03	SS03-09 N of tracks surface 11-Aug-03	SS03-10 W of tracks surface 11-Aug-03	SS03-14 W of tracks surface 11-Aug-03	SS03-16 W of tracks surface 11-Aug-03	Discrete Sample Screening Benchmark
Pentachlorophenol	0.01	0.011	0.082	0.04	0.056	<	0.008	0.15 - 20a
2,3,4-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,5-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,6-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,4,5-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,4,6-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
3,4,5-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,4,5-Tetrachlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,4,6-Tetrachlorophenol*	0.01	<	<	<	<	<	<	0.5
Total Trichlorophenol	0.01	<	<	<	<	<	<	n/s
Total Tetrachlorophenols	0.01	<	<	<	<	<	<	n/s
Total Chlorinated Phenols	0.01	0.011	0.082	0.04	0.056	<	0.008	n/s
pH	0.1	4.9	5	5.5	5.3	7	5	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
a	Screening benchmark is pH dependent
<	Less than reported detection limit
*	includes 2,3,5,6-tetrachlorophenol

Table A-4 continued: Soil Analytical Results - Chlorinated Phenols

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-17 W of tracks surface 11-Aug-03	SS03-18 E of tracks surface 11-Aug-03	SS03-20 S - ditch surface 11-Aug-03	SS03-21 S - slope surface 11-Aug-03	SS03-24 Btw tracks surface 14-Aug-03	SS03-25 N - slope surface 14-Aug-03	Discrete Sample Screening Benchmark
Pentachlorophenol	0.01	0.006	0.011	<	0.03	0.25	0.063	0.15 - 20a
2,3,4-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,5-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,6-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,4,5-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,4,6-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
3,4,5-Trichlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,4,5-Tetrachlorophenol	0.01	<	<	<	<	<	<	0.5
2,3,4,6-Tetrachlorophenol*	0.01	<	<	<	<	0.011	<	0.5
Total Trichlorophenol	0.01	<	<	<	<	<	<	n/s
Total Tetrachlorophenols	0.01	<	<	<	<	0.011	<	n/s
Total Chlorinated Phenols	0.01	0.006	0.011	<	0.03	0.26	0.063	n/s
pH	0.1	4.9	5.2	5.2	4.7	4.6	4.6	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
a	Screening benchmark is pH dependent
<	Less than reported detection limit
•	includes 2,3,5,6-tetrachlorophenol

Table A-4 continued: Soil Analytical Results - Chlorinated Phenols

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-26 N - ditch surface 14-Aug-03	MW03-6 (5') 1.5 14-Aug-03	Discrete Sample Screening Benchmark
Pentachlorophenol	0.01	0.013	<	0.15 - 20a
2,3,4-Trichlorophenol	0.01	<	<	0.5
2,3,5-Trichlorophenol	0.01	<	<	0.5
2,3,6-Trichlorophenol	0.01	<	<	0.5
2,4,5-Trichlorophenol	0.01	<	<	0.5
2,4,6-Trichlorophenol	0.01	<	<	0.5
3,4,5-Trichlorophenol	0.01	<	<	0.5
2,3,4,5-Tetrachlorophenol	0.01	<	<	0.5
2,3,4,6-Tetrachlorophenol*	0.01	<	<	0.5
Total Trichlorophenol	0.01	<	<	n/s
Total Tetrachlorophenols	0.01	<	<	n/s
Total Chlorinated Phenols	0.01	0.013	<	n/s
pH	0.1	5.1	6.4	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
a	Screening benchmark is pH dependent
<	Less than reported detection limit
*	includes 2,3,5,6-tetrachlorophenol

Table A-5: Soil Analytical Results - Pesticides/Herbicides

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-01 N of tracks surface 11-Aug-03	SS03-02 N of tracks surface 11-Aug-03	SS03-03 S - slope surface 11-Aug-03	SS03-04 Btw tracks surface 11-Aug-03	SS03-05 N of tracks surface 11-Aug-03	SS03-07 N - slope surface 11-Aug-03	Screening Benchmark
Atrazine	0.02	<	<	<	<	<	<	n/s
Atrazine desethyl	0.02	<	<	<	<	<	<	n/s
Diuron	0.05	0.06	0.06	0.06	<	<	0.24	n/s
Bromacil	0.05	<	<	<	<	<	<	n/s
Butylate	0.02	<	<	<	<	<	<	n/s
Chlorpropham	0.05	<	<	<	<	<	<	n/s
Hexazinone	0.08	<	<	<	<	<	<	n/s
Metalachlor	0.08	<	<	<	<	<	<	n/s
Metribuzin	0.02	<	<	<	<	<	<	n/s
Prometryn	0.02	<	<	<	<	<	<	n/s
Propazine	0.02	<	<	<	<	<	<	n/s
Simazine	0.03	<	<	<	<	<	<	n/s
Terbutryn	0.03	<	<	<	<	<	<	n/s
Triadimefon	0.07	<	<	<	<	<	<	n/s
Trifluralin	0.05	<	<	<	<	<	<	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
<	Less than reported detection limit

Table A-5 continued: Soil Analytical Results - Pesticides/Herbicides

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-09 N of tracks surface 11-Aug-03	SS03-14 W of tracks surface 11-Aug-03	SS03-17 W of tracks surface 11-Aug-03	SS03-18 E of tracks surface 11-Aug-03	SS03-30 Slope surface 24-Oct-03	SS03-31 Ditch surface 24-Oct-03	Screening Benchmark
Atrazine	0.02	<	<	<	<	<	<	n/s
Atrazine desethyl	0.02	<	<	<	<	<	<	n/s
Diuron	0.05	<	<	0.08	<	0.05	<	n/s
Bromacil	0.05	<	<	<	<	<	<	n/s
Butylate	0.02	<	<	<	<	<	<	n/s
Chlorpropham	0.05	<	<	<	<	<	<	n/s
Hexazinone	0.08	<	<	<	<	<	<	n/s
Metalachlor	0.08	<	<	<	<	<	<	n/s
Metribuzin	0.02	<	<	<	<	<	<	n/s
Prometryn	0.02	<	<	<	<	<	<	n/s
Propazine	0.02	<	<	<	<	<	<	n/s
Simazine	0.03	<	<	<	<	<	<	n/s
Terbutryn	0.03	<	<	<	<	<	<	n/s
Triadimefon	0.07	<	<	<	<	<	<	n/s
Trifluralin	0.05	<	<	<	<	<	<	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
<	Less than reported detection limit

Table A-5 continued: Soil Analytical Results - Pesticides/Herbicides

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-32 Slope surface 24-Oct-03	SS03-33 Ditch surface 24-Oct-03	SS03-34 Slope surface 24-Oct-03	SS03-35 Ditch surface 24-Oct-03	SS03-36 S - ditch surface 24-Oct-03	SS03-45 Slope surface 24-Oct-03	Screening Benchmark
Atrazine	0.02	<	<	<	<	<	<	n/s
Atrazine desethyl	0.02	<	<	<	<	<	<	n/s
Diuron	0.05	<	<	<	<	<	<	n/s
Bromacil	0.05	<	<	<	<	<	<	n/s
Butylate	0.02	<	<	<	<	<	<	n/s
Chlorpropham	0.05	<	<	<	<	<	<	n/s
Hexazinone	0.08	<	<	<	<	<	<	n/s
Metalachlor	0.08	<	<	<	<	<	<	n/s
Metribuzin	0.02	<	<	<	<	<	<	n/s
Prometryn	0.02	<	<	<	<	<	<	n/s
Propazine	0.02	<	<	<	<	<	<	n/s
Simazine	0.03	<	<	<	<	<	<	n/s
Terbutryn	0.03	<	<	<	<	<	<	n/s
Triadimefon	0.07	<	<	<	<	<	<	n/s
Trifluralin	0.05	<	<	<	<	<	<	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
<	Less than reported detection limit

Table A-5 continued: Soil Analytical Results - Pesticides/Herbicides

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-46 Ditch surface 24-Oct-03	SS03-50 Slope surface 24-Oct-03	SS03-51 Slope Base surface 24-Oct-03	SS03-58 Ditch surface 24-Oct-03	SS03-59 Slope surface 24-Oct-03	SS03-60 N - ditch surface 24-Oct-03	Screening Benchmark
Atrazine	0.02	<	<	<	<	<	<	n/s
Atrazine desethyl	0.02	<	<	<	<	<	<	n/s
Diuron	0.05	<	<	<	<	0.25	0.06	n/s
Bromacil	0.05	<	<	<	<	<	<	n/s
Butylate	0.02	<	<	<	<	<	<	n/s
Chlorpropham	0.05	<	<	<	<	<	<	n/s
Hexazinone	0.08	<	<	<	<	<	<	n/s
Metalachlor	0.08	<	<	<	<	<	<	n/s
Metribuzin	0.02	<	<	<	<	<	<	n/s
Prometryn	0.02	<	<	<	<	<	<	n/s
Propazine	0.02	<	<	<	<	<	<	n/s
Simazine	0.03	0.03	<	<	<	<	<	n/s
Terbutryn	0.03	<	<	<	<	<	<	n/s
Triadimefon	0.07	<	<	<	<	<	<	n/s
Trifluralin	0.05	<	<	<	<	<	<	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
<	Less than reported detection limit

Table A-5 continued: Soil Analytical Results - Pesticides/Herbicides

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-6C Composite 23-Jul-01	TP01-16C Composite 24-Jul-01	TP01-26C Composite 25-Jul-01	TP01-38C Composite 26-Jul-01	STP01-3C Composite 27-Jul-01	Screening Benchmark
Atrazine	0.02	<0.04	<	<	<	<	n/s
Diuron	0.2	<	<	<	<	<	n/s
Linuron	0.05	<	<	<	<	<	n/s
Simazine	0.02	<0.04	<	<	<	<	n/s
Tebuthiuron	0.02	<	<	<	<	<	n/s
Bromacil	0.01	<0.02	< 0.05	< 0.05	< 0.05	< 0.05	n/s
Hexachlorobenzene	0.02	< 0.04	-	-	-	-	n/s
Glyphosate	0.5	<	<	<	0.58	<	n/s
AMPA	0.5	<	<	<	<	<	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
<	Less than reported detection limit

Table A-5 continued: Soil Analytical Results - Pesticides/Herbicides

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-6C Composite 23-Jul-01	Screening Benchmark
Atrazine	0.02	< 0.04	n/s
De-ethyl Atrazine	0.03	< 0.06	n/s
Butylate	0.05	< 0.10	n/s
Cyanazine	0.05	< 0.10	n/s
Desmetryn	0.03	< 0.06	n/s
Diphenylamine	0.01	< 0.02	n/s
Diuron	0.2	<	n/s
Eptam	0.05	< 0.10	n/s
Ethalfluralin	0.05	< 0.10	n/s
Hexazinone	0.01	< 0.02	n/s
Linuron	0.05	<	n/s
Metalaxyl	0.03	< 0.06	n/s
Metribuzin	0.01	< 0.02	n/s
Metolachlor	0.02	< 0.04	n/s
Pirimicarb	0.01	< 0.02	n/s
Profluralin	0.05	< 0.10	n/s
Prometryn	0.02	< 0.04	n/s
Propazine	0.01	< 0.02	n/s
Simazine	0.02	< 0.04	n/s
Tebuthiuron	0.02	<	n/s
Terbuthylazine	0.01	< 0.02	n/s
Terbutryn	0.02	< 0.04	n/s
Triallate	0.01	< 0.02	n/s
Triadimefon	0.03	< 0.06	n/s
Trifluralin	0.01	< 0.02	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
<	Less than reported detection limit

Table A-5 continued: Soil Analytical Results - Pesticides/Herbicides

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-6C Composite 23-Jul-01	Screening Benchmark
Alachlor	0.05	< 0.10	n/s
Aldrin	0.03	< 0.06	n/s
BHC, alpha-	0.03	< 0.06	n/s
BHC, beta-	0.03	< 0.06	n/s
Captan	0.1	< 0.20	n/s
Chlorbenside	0.01	< 0.02	n/s
Chlordane, alpha-	0.05	< 0.10	n/s
Chlordane, gamma-	0.05	< 0.10	n/s
Chlorfenson	0.02	< 0.04	n/s
Chlorothalonil	0.1	< 0.20	n/s
Chlorpropham	0.02	< 0.04	n/s
Dacthal (DCPA)	0.01	< 0.02	n/s
DDE, p,p'-	0.01	< 0.02	n/s
DDT, o,p'-	0.02	< 0.04	n/s
DDT, p,p'-	0.02	< 0.04	n/s
Diallate(e)	0.05	< 0.10	n/s
Diallate(z)	0.05	< 0.10	n/s
Dichlobenil	0.02	< 0.04	n/s
Dichloran	0.05	< 0.10	n/s
Dichlofluanid	0.05	< 0.10	n/s
Dicofol	0.02	< 0.04	n/s
Dieldrin	0.05	< 0.10	n/s
Endosulfan I	0.05	< 0.10	n/s
Endosulfan II	0.05	< 0.10	n/s
Endosulfan Sulphate	0.05	< 0.10	n/s
Endrin	0.05	< 0.10	n/s
Folpet	0.1	< 0.20	n/s
Heptachlor	0.05	< 0.10	n/s
Lindane, BHC, gamma-	0.05	< 0.10	n/s
Methidathion	0.03	< 0.06	n/s
Methoxychlor	0.01	< 0.02	n/s
Mirex	0.03	< 0.06	n/s
Nitrofen	0.02	< 0.04	n/s
Permethrin, cis	0.02	< 0.04	n/s
Permethrin, trans	0.01	< 0.02	n/s
Procymidone	0.02	< 0.04	n/s
Pronamide	0.02	< 0.04	n/s
Quintozene	0.05	< 0.10	n/s
Tecnazene	0.05	< 0.10	n/s
Tetradifon	0.02	< 0.04	n/s
Tolylfluanid	0.05	< 0.10	n/s
Vinclozolin	0.05	< 0.10	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
<	Less than reported detection limit

Table A-5 continued: Soil Analytical Results - Pesticides/Herbicides

Sample ID Sample Depth (m) Date Sampled	RDL	TP01-6C Composite 23-Jul-01	Screening Benchmark
Acephate	0.1	< 0.20	n/s
Aspon	0.02	< 0.04	n/s
Azinphos Ethyl	0.05	< 0.10	n/s
Azinphos Methyl	0.1	< 0.2	n/s
Bromacil	0.01	< 0.02	n/s
Benfluralin	0.01	< 0.02	n/s
Bromophos	0.01	< 0.02	n/s
Bromophos Ethyl	0.03	< 0.06	n/s
Carbophenothion	0.03	< 0.06	n/s
Chlorfenvinphos(e)	0.05	< 0.10	n/s
Chlorfenvinphos(z)	0.01	< 0.02	n/s
Chlormephos	0.05	< 0.10	n/s
Chlorpyrifos	0.02	< 0.04	n/s
Chlorpyrifos Methyl	0.01	< 0.02	n/s
Chlorthiophos	0.03	< 0.06	n/s
Cyanophos	0.02	< 0.04	n/s
Demeton	0.05	< 0.10	n/s
Diazinon	0.03	< 0.06	n/s
Dichlofenthion	0.02	< 0.04	n/s
Dichlorvos	0.01	< 0.02	n/s
Dicrotophos	0.05	< 0.10	n/s
Dimethoate	0.05	< 0.10	n/s
Dioxathion	0.05	< 0.10	n/s
Disulfoton	0.05	< 0.10	n/s
EPN	0.05	< 0.10	n/s
Ethion	0.02	< 0.04	n/s
Fenchlorphos(Ronnel)	0.01	< 0.02	n/s
Fenitrothion	0.05	< 0.10	n/s
Fonofos	0.01	< 0.02	n/s
Iodofenphos	0.01	< 0.02	n/s
Isofenphos	0.03	< 0.06	n/s
Malaoxon	0.03	< 0.06	n/s
Malathion	0.05	< 0.10	n/s
Mevinphos-cis	0.01	< 0.02	n/s
Pirimiphos-methyl	0.02	< 0.04	n/s
Profenophos	0.05	< 0.10	n/s
Pyrazophos	0.01	< 0.02	n/s
Quinalphos	0.03	< 0.06	n/s
Sulfotep	0.01	< 0.02	n/s
Terbufos	0.03	< 0.06	n/s
Tetrachlorvinphos	0.02	< 0.04	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
<	Less than reported detection limit

Table A-6: Soil Analytical Results - Glyphosate

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-01 N of tracks surface 11-Aug-03	SS03-02 N of tracks surface 11-Aug-03	SS03-03 S - slope surface 11-Aug-03	SS03-04 Btw tracks surface 11-Aug-03	SS03-05 N of tracks surface 11-Aug-03	SS03-07 N - slope surface 11-Aug-03	Screening Benchmark
Glyphosate	0.03	0.1	0.069	<	<	0.4	0.11	n/s

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-09 N of tracks surface 11-Aug-03	SS03-14 W of tracks surface 11-Aug-03	SS03-17 W of tracks surface 11-Aug-03	SS03-18 E of tracks surface 11-Aug-03	SS03-A Duplicate of SS03-18 11-Aug-03	SS03-22 W - slope surface 13-Aug-03	Screening Benchmark
Glyphosate	0.03	0.031	0.049	0.048	<	<	<	n/s

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-23 W - slope surface 14-Aug-03	MW03-3 (5') 1.5 14-Aug-03	SS03-47 Ditch surface 24-Oct-03	SS03-48 W - slope surface 24-Oct-03	SS03-48A Duplicate of SS03-48 24-Oct-03	SS03-49 E - slope surface 24-Oct-03	Screening Benchmark
Glyphosate	0.03	<	<	<	0.78	0.91	0.42	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
<	Less than reported detection limit

Table A-7: Sediment Analytical Results - LEPH/HEPH

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-11 D/S - creek - 11-Aug-03	SS03-19 U/S - creek - 11-Aug-03	Screening Benchmark
EPH (C10 - C19)	250	<	<	n/s
EPH (C19 - C32)	250	<	<	n/s
LEPH	250	<	<	n/s
HEPH	250	<	<	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
EPH	Extractable Petroleum Hydrocarbons uncorrected for PAH.
LEPH	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPH	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
U/S	Sample collected upstream of site
D/S	Sample collected downstream of site
n/s	No screening benchmark for this constituent
<	Less than reported detection limit
-	Not analyzed

Table A-8: Sediment Analytical Results - PAHs

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-11 D/S - creek - 11-Aug-03	SS03-19 U/S - creek - 11-Aug-03	Screening Benchmark
Naphthalene	0.05	<	<	0.24
Acenaphthylene	0.05	<	<	0.08
Acenaphthene	0.05	<	<	0.055
Fluorene	0.05	<	<	0.089
Phenanthrene	0.05	<	0.06	0.32
Anthracene	0.05	<	<	0.15
Fluoranthene	0.05	0.08	0.12	1.5
Pyrene	0.05	0.09	0.13	0.54
Benzo(a)anthracene	0.05	<	0.06	0.24
Chrysene	0.05	<	0.05	0.53
Benzo(b)fluoranthene	0.05	0.07	0.1	0.084*
Benzo(k)fluoranthene		-	-	n/s
Benzo(a)pyrene	0.05	<	0.05	0.48
Indeno(1,2,3-c,d)pyrene	0.05	<	<	0.084*
Dibenz(a,h)anthracene	0.05	<	<	0.084
Benzo(g,h,i)perylene	0.05	<	<	0.084*

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
LMW	Low Molecular Weight
HMW	High Molecular Weight
U/S	Sample collected upstream of site
D/S	Sample collected downstream of site
n/s	No screening benchmark for this constituent
<	Less than reported detection limit
-	Not analyzed
*	Most conservative HMW PAH screening benchmark used as surrogate

Table A-9: Sediment Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-11 D/S - creek - 11-Aug-03	SS03-19 U/S - creek - 11-Aug-03	Screening Benchmark
Antimony	10	<	<	n/s
Arsenic	10	<	<	11
Barium	1	38	41	n/s
Beryllium	1	<	<	n/s
Cadmium	0.2	<	0.2	2.2
Chromium (total)	2	20	11	56
Cobalt	1	4	4	n/s
Copper	1	24	21	120
Lead	5	28	30	57
Mercury	0.01	0.02	0.03	0.3
Molybdenum	4	<	<	n/s
Nickel	2	10	9	n/s
Selenium	0.2	<	<	n/s
Silver	2	<	<	n/s
Tin	5	<	<	n/s
Vanadium	1	38	28	n/s
Zinc	1	84	105	200
pH	0.1	5.7	6	n/s

NOTES:

All concentrations in micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
U/S	Sample collected upstream of site
D/S	Sample collected downstream of site
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit

Table A-10: Sediment Analytical Results - Metals

Sample ID Sample Depth (m) Date Sampled	RDL	SS03-11 D/S - creek - 11-Aug-03	SS03-19 U/S - creek - 11-Aug-03	Screening Benchmark
Pentachlorophenol	0.005	<	<	0.4
2,3,4-Trichlorophenol	0.01	<	<	n/s
2,3,5-Trichlorophenol	0.01	<	<	n/s
2,3,6-Trichlorophenol	0.01	<	<	n/s
2,4,5-Trichlorophenol	0.01	<	<	n/s
2,4,6-Trichlorophenol	0.01	<	<	n/s
3,4,5-Trichlorophenol	0.01	<	<	n/s
2,3,4,5-Tetrachlorophenol	0.005	<	<	n/s
2,3,4,6-Tetrachlorophenol*	0.005	<	<	n/s
Total Trichlorophenol	0.01	<	<	n/s
Total Tetrachlorophenols	0.005	<	<	n/s
Total Chlorinated Phenols	0.005	<	<	n/s
pH	0.1	5.7	6	n/s

NOTES:

Sample results reported as micrograms per gram (µg/g) [parts per million (ppm)]

RDL	Reported Detection Limit
U/S	Sample collected upstream of site
D/S	Sample collected downstream of site
n/s	No standard for this constituent
<	Less than reported detection limit
-	Not analyzed
**	includes 2,3,5,6-tetrachlorophenol

Table A-11: Groundwater Analytical Results - LEPHw/HEPHw

Sample ID Date Sampled	RDL	MW03-6 05-Feb-04	MW04-7 01-Apr-04	MW04-8 01-Apr-04	Screening Benchmark
EHw (C10 - C19)	250	<	350	<	500
EHw (C19 - C32)	250	<	<	<	n/s
LEPHw	250	<	350	<	500
HEPHw	250	<	<	<	n/s

NOTES:

Sample results reported as micrograms per litre (µg/L) [parts per billion (ppb)]

RDL	Reported Detection Limit
EHw	Extractable Petroleum Hydrocarbons uncorrected for PAH
LEPHw	Light Extractable Petroleum Hydrocarbons corrected for PAHs
HEPHw	Heavy Extractable Petroleum Hydrocarbons corrected for PAHs
n/s	No screening benchmark for this constituent
<	Less than reported detection limit
-	Not analyzed

Table A-12: Groundwater Analytical Results - PAHs

Sample ID Date Sampled	RDL	MW03-6 05-Feb-04	MW04-7 01-Apr-04	MW04-8 01-Apr-04	Screening Benchmark
Naphthalene	0.3	<	<	<	10
Acenaphthylene	0.1	<	<	<	n/s
Acenaphthene	0.1	<	<	<	60
Fluorene	0.05	<	<	<	120
Phenanthrene	0.05	<	<	<	3
Anthracene	0.01	0.11	<	<	1
Acridine	0.05	<	<	<	0.5
Fluoranthene	0.04	0.07	<	<	2
Pyrene	0.02	0.08	<	<	0.2
Benzo(a)anthracene	0.01	0.02	<	<	1
Chrysene	0.01	0.02	<	<	0.1*
Benzo(b)fluoranthene	0.01	0.09	<	<	0.1*
Benzo(k)fluoranthene		-	-	-	0.1*
Benzo(a)pyrene	0.01	0.03	<	<	0.1
Indeno(1,2,3-c,d)pyrene	0.01	0.03	<	<	0.1*
Dibenz(a,h)anthracene	0.01	0.01	<	<	0.1*
Benzo(g,h,i)perylene	0.01	0.03	<	<	0.1*
Quinoline	0.5	<	<	<	34

NOTES:

Sample results reported as micrograms per litre (µg/L) [parts per billion (ppb)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
<	Less than reported detection limit
-	Not analyzed
*	Most conservative PAH screening benchmark used as surrogate

Table A-13: Groundwater Analytical Results - VOCs

Sample ID Date Sampled	RDL	MW04-7 03/31/04	MW04-8 03/31/04	Screening Benchmark
Benzene	0.1	<	<	4000
Bromodichloromethane	0.1	<	<	n/s
Bromoform	0.2	<	<	n/s
Bromomethane	0.8	<	<	n/s
2-Butanone	5	<	<	n/s
Carbon Tetrachloride	0.1	<	<	130
Chlorobenzene	0.1	<	<	13
Chloroethane	0.4	<	<	n/s
Chloroform	0.3	<	<	20
Chloromethane	0.4	<	<	n/s
Dibromochloromethane	0.1	<	<	n/s
1,2-Dibromoethane	0.1	<	<	n/s
Dibromomethane	0.2	<	<	n/s
Dichlorodifluoromethane	0.2	<	<	n/s
1,2-Dichlorobenzene	0.1	<	<	7
1,3-Dichlorobenzene	0.1	<	<	1500
1,4-Dichlorobenzene	0.1	<	<	260
1,1-Dichlorethane	0.1	<	<	n/s
1,2-Dichlorethane	0.4	<	<	1000
1,1-Dichlorethene	0.1	<	<	n/s
cis-1,2-Dichloroethene	0.1	<	0.7	n/s
trans-1,2-Dichloroethene	0.1	<	<	n/s
1,2-Dichloropropane	0.1	<	<	n/s
cis-1,3-Dichlorpropene	0.1	<	<	n/s
trans-1,3-Dichlorpropene	0.1	<	<	n/s
Ethylbenzene	0.1	<	<	2000
2-Hexanone	5	<	<	n/s
4-Methyl-2-pentanone	2	<	<	n/s
Methylene Chloride	6	<	<	980
Styrene	0.1	<	<	720
1,1,2,2-Tetrachloroethane	0.2	<	<	n/s
Tetrachloroethene	0.1	<	<	1100
Toluene	0.1	0.7	<	390
1,1,1-Trichloroethane	0.1	<	<	n/s
1,1,2-Trichloroethane	0.1	<	<	n/s
Trichloroethene	0.1	<	0.9	200
Trichlorofluoromethane	0.2	<	<	n/s
Vinyl Chloride	0.2	<	<	n/s
Xylenes	0.1	0.6	<	n/s

NOTES:

Sample results reported as micrograms per litre (µg/L) [parts per billion (ppb)]

RDL	Reported Detection Limit
n/s	No standard for this constituent
<	Less than reported detection limit
-	Not analyzed

Table A-14: Groundwater Analytical Results - Chlorinated Phenols

Sample ID Date Sampled	RDL	MW03-3 28-Aug-03	MW03-6 04-Feb-04	MW04-7 01-Apr-04	MW04-8 31-Mar-04	Screening Benchmark
Pentachlorophenol	0.05	<	0.08	<	0.07	1-27.5a
2,3,4-Trichlorophenol	0.1	<	<	<	<	1-270a
2,3,5-Trichlorophenol	0.1	<	<	<	<	1-270a
2,3,6-Trichlorophenol	0.1	<	<	<	<	1-270a
2,4,5-Trichlorophenol	0.1	<	<	<	<	1-270a
2,4,6-Trichlorophenol	0.1	<	<	<	<	1-270a
3,4,5-Trichlorophenol	0.1	<	<	<	<	1-270a
2,3,4,5-Tetrachlorophenol	0.05	<	<	<	<	2-180a
2,3,4,6-Tetrachlorophenol*	0.05	<	<	<	<	2-180a
pH	-	7.08	5.98	6.40	6.70	n/s

NOTES:

Sample results reported as micrograms per litre (µg/L) [parts per billion (ppb)]

RDL	Reported Detection Limit
n/s	No standard for this constituent
a	Screening benchmark is pH and temperature dependent
<	Less than reported detection limit
-	Not analyzed
*	includes 2,3,5,6-tetrachlorophenol

Table A-15: Groundwater Analytical Results - Pesticides/Herbicides

Sample ID Date Sampled	RDL	MW03-3 28-Aug-03	MW03-6 04-Feb-04	MW03-6 27-Apr-04	MW04-7 02-Apr-04	MW04-8 31-Mar-04	Screening Benchmark
Diuron	0.5	<	-	<	<	<	n/s
Alachlor	0.2	<	-	<	<	<	n/s
Atrazine	0.1	<	-	<	<	<	20
Bromacil	0.2	<	-	<	<	1.7	50
Butylate	0.2	<	-	<	<	<	n/s
Chlorpropham	1	< 2	-	<	<	<	n/s
Hexazinone	0.8	<	-	<	<	<	n/s
Metolachlor	0.8	<	-	<	<	<	80
Propazine	0.1	<	-	<	<	<	n/s
Simazine	0.1	<	-	<	<	<	100
Glyphosate	35	<	<	-	<	<	650
AMPA	35	<	-	-	<	<	n/s

NOTES:

Sample results reported as micrograms per litre (µg/L) [parts per billion (ppb)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is pH dependent
<	Less than reported detection limit
-	Not analyzed

Table A-16: Groundwater Analytical Results - Dissolved Metals

Sample ID Date Sampled	RDL	MW03-3 21-Nov-03	MW03-6 04-Feb-04	MW04-7 01-Apr-04	MW04-8 31-Mar-04	Screening Benchmark
Aluminum	5	14	23	17	51	n/s
Antimony	1	<	<	<	<	200
Arsenic	1	<	<	2	<	50
Barium	1	35	18	36	29	10000
Beryllium	1	<	<	<	<	53
Boron	50	<	<	<	110	n/s
Cadmium	0.2	<	<	<	<	0.1-1.3a
Calcium	50	20200	14900	35000	60200	n/s
Chromiun (total)	1	<	<	<	<	10
Cobalt	1	<	<	15	4	20
Copper	1	<	1	<	1	20-90a
Iron	50	<	70	18900	<	n/s
Lead	1	<	<	<	<	40-160a
Magnesium	50	2330	2670	8150	16200	n/s
Manganese	1	13	3	2510	920	n/s
Mercury	0.02	<	<	<	<	1
Molybdenum	0.5	<	1.3	<	1.3	10000
Nickel	1	<	<	4	8	250-1500a
Phosphorus	10	120	410	< 150	< 150	n/s
Potassium	10	1060	1210	1500	3700	n/s
Selenium	1	<	<	<	<	10
Silicon	50	11000	26800	17700	33100	n/s
Silver	0.1	<	<	< 0.25	< 0.25	0.5-15a
Sodium	50	6230	7360	11500	15200	n/s
Strontium	1	110	45	440	310	n/s
Tellurium	1	<	<	<	<	n/s
Thallium	0.1	<	<	<	<	3
Thorium	0.5	<	<	<	<	n/s
Tin	1	<	2	<	<	n/s
Titanium	1	<	2	1	3	1000
Uranium	0.5	<	<	<	0.8	3000
Vanadium	1	<	1	<	2	n/s
Zinc	5	<	<	6	<	75-3150a
Zirconium	10	<	<	<	<	n/s
pH		-	5.98	6.40	6.7	n/s
Hardness (Total-D)(mg/L)	1	60	48	121	217	n/s

NOTES:

All concentrations in micrograms per litre (µg/L) [parts per billion (ppb)]

RDL	Reported Detection Limit
n/s	No screening benchmark for this constituent
a	Screening benchmark is hardness dependent
<	Less than reported detection limit
-	Not analyzed

APPENDIX B: ENVIRONMENTAL CONCENTRATIONS AND RECEPTOR CHARACTERISTICS

Table B-1: Estimated Environmental Concentrations (EECs)

COPEC	Soil EECs (ppm)	Sediment EECs (ppm)	Aquatic Vegetation EECs (ppm)[b]	Terrestrial Plant EECs (ppm)[c]	Soil Invertebrate EECs (ppm)[c]	Foliar Invertebrate EECs (ppm)[d]
Arsenic	1.10E+01	5.00E+00	1.80E-01	3.95E-01	1.21E+00	3.95E-01
Copper	1.60E+02	2.40E+01	9.60E+00	6.38E+01	6.38E+00	6.38E+01
Molybdenum	3.26E+00	2.00E+00	2.00E+00	3.26E+00	3.26E+00	3.26E+00
Zinc	1.54E+02	1.05E+02	1.26E-10	1.85E-10	8.64E+01	1.85E-10
Anthracene	2.90E-01	2.50E-02	5.05E-04	5.86E-03	2.32E-02	5.86E-03
Benzo(a)anthracene	4.00E-01	6.00E-02	1.21E-03	8.08E-03	1.20E-02	8.08E-03
Benzo(a)pyrene	3.50E-01	5.00E-02	0.00E+00	0.00E+00	2.45E-02	0.00E+00
Benzo(b)fluoranthene	1.19E+00	1.00E-01	1.01E-03	1.20E-02	8.33E-02	1.20E-02
Benzo(k)fluoranthene	9.90E-01	0.00E+00	0.00E+00	1.00E-02	7.92E-02	1.00E-02
Chrysene	1.29E+00	5.00E-02	9.35E-04	2.41E-02	5.16E-02	2.41E-02
Fluoranthene	1.90E+00	1.20E-01	2.42E-03	3.84E-02	1.52E-01	3.84E-02
Indeno(1,2,3-c,d)pyrene	3.70E-01	2.50E-02	9.75E-05	1.44E-03	2.96E-02	1.44E-03
LEPH	9.61E+01	1.25E+02	1.25E+02	9.61E+01	9.61E+01	9.61E+01
HEPH	3.28E+02	1.25E+02	1.25E+02	3.28E+02	3.28E+02	3.28E+02
Diuron	8.00E-02	8.00E-02	1.68E-02	1.68E-02	1.68E-02	1.68E-02
Glyphosate	2.70E-01	2.70E-01	1.13E+02	1.13E+02	1.13E+02	1.13E+02

NOTES:

Soil EECs are the 95th percent upper confidence limit (UCL95) of the arithmetic mean concentration of each COPEC

Sediment EECs are maximum concentrations detected. UCL95 could not be calculated due to small samples size (n=2)

b - EECs estimated by multiplying sediment EECs by media-to-receptor bioconcentrations factors (BCFs)

c - EECs estimated by multiplying soil EECs by media-to-receptor bioconcentration factors (BCFs)

d - Foliar invertebrate EECs assumed to equal terrestrial plant tissue concentrations (a conservative assumption)

e - EECs assumed to equal sum of all dietary food concentrations. Assumes 100% bioavailability (a conservative assumption)

Table B-1 continued: Estimated Environmental Concentrations

COPEC	Aquatic Invertebrate EECs (ppm)[b]	Deer Mouse EECs (ppm)[e]	American Robin EECs (ppm)[e]	Pileated Woodpecker EECs (ppm)[e]	Pacific Treefrog EECs (ppm)[e]
Arsenic	4.50E+00	5.97E-01	8.25E-01	3.95E-01	6.14E-01
Copper	7.20E+00	6.36E+01	5.02E+01	6.38E+01	5.97E+01
Molybdenum	2.00E+00	3.21E+00	3.26E+00	3.26E+00	3.20E+00
Zinc	5.99E+01	3.09E+00	2.65E+01	1.85E-10	5.06E+00
Anthracene	4.03E-02	1.13E-02	1.62E-02	5.86E-03	7.96E-03
Benzo(a)anthracene	8.70E-02	1.56E-02	1.70E-02	8.08E-03	1.20E-02
Benzo(a)pyrene	7.95E-02	7.00E-03	1.36E-02	0.00E+00	4.46E-03
Benzo(b)fluoranthene	1.61E-01	3.51E-02	5.49E-02	1.20E-02	2.10E-02
Benzo(k)fluoranthene	0.00E+00	2.92E-02	4.83E-02	1.00E-02	1.13E-02
Chrysene	6.90E-02	4.85E-02	5.69E-02	2.41E-02	2.70E-02
Fluoranthene	1.93E-01	7.42E-02	1.06E-01	3.84E-02	4.87E-02
Indeno(1,2,3-c,d)pyrene	4.03E-02	8.76E-03	1.64E-02	1.44E-03	4.03E-03
LEPH	2.01E+02	9.72E+01	9.61E+01	9.61E+01	1.01E+02
HEPH	2.01E+02	3.20E+02	3.28E+02	3.28E+02	3.22E+02
Diuron	1.68E-02	1.81E-02	1.81E-02	1.68E-02	1.68E-02
Glyphosate	1.13E+02	1.11E+02	1.11E+02	1.13E+02	1.13E+02

NOTES:

Soil EECs are the 95th percent upper confidence limit (UCL95) of the arithmetic mean concentration of each COPEC

Sediment EECs are maximum concentrations detected. UCL95 could not be calculated due to small samples size (n=2)

b - EECs estimated by multiplying sediment EECs by media-to-receptor bioconcentrations factors (BCFs)

c - EECs estimated by multiplying soil EECs by media-to-receptor bioconcentration factors (BCFs)

d - Foliar invertebrate EECs assumed to equal terrestrial plant tissue concentrations (a conservative assumption)

e - EECs assumed to equal sum of all dietary food concentrations. Assumes 100% bioavailability (a conservative assumption)

Table B-2

Media-to-Receptor Bioconcentration Factors

COPEC	Soil to Soil Invertebrate*	Soil to Plant*	Sediment to Invertebrate*	Sediment to Aquatic Plant*
Arsenic	0.11	0.036	0.9	0.036
Copper	0.04	0.4	0.3	0.4
Molybdenum	1c	1c	1c	1c
Zinc	0.56	1.2E-12	0.57	1.2E-12
Anthracene	0.08c	0.0202c	1.61c	0.0202c
Benzo(a)anthracene	0.03	0.0202	1.45	0.0202
Benzo(a)pyrene	0.07	0	1.59	0
Benzo(b)fluoranthene	0.07	0.0101	1.61	0.0101
Benzo(k)fluoranthene	0.08	0.0101	1.61	0.0101
Chrysene	0.04	0.0187	1.38	0.0187
Fluoranthene	0.08c	0.0202c	1.61c	0.0202c
Indeno(1,2,3-c,d)pyrene	0.08	0.0039	1.61	0.0039
LEPH	1c	1c	1.61c	1c
HEPH	1c	1c	1.61c	1c
Diuron	0.21b	0.21a	0.21b	0.21a
Glyphosate	420b	420a	420b	420a

NOTES:

BCF = Bioconcentration Factor

* US EPA. 1999. Screening Level Ecological Risk Assessment Protocol For Hazardous Waste Combustion Facilities, Peer Review Draft. Office of Solid Waste.

a - Obtained from the Oak Ridge National Laboratory (ORNL) Risk Assessment Information System (RAIS) - soil to wet plant uptake

b - No data available. Soil to wet plant uptake factor used as surrogate

c - No COPEC-specific BCF available. Conservative assumption.

Table B-3: Measurement Receptor Characteristics - Deer Mouse (*P. maniculatus*)

Receptor Characteristics[a]	Deer Mouse	
Body weight (kg)	0.021	b
Food consumption rate (kg/day)	0.0040	c
Home range (hectares)	0.0595	e
Dietary Composition[a]	**Percentages**	g
Soil	2%	f
Beetles	15%	h
Grasshoppers	5%	h
Leafhoppers	5%	h
Lepidopterans	10%	h
Spiders	2%	h
Seeds	47%	j
Forbs and grasses	7%	j
Sedges	4%	k
Shrubs	2%	j

NOTES:

a = General receptor characteristics and dietary consumption for *P. maniculatus* are from US EPA (1993). Diet normalized to 100%.

b = Value selected is average of males and females from a study of North American deer mice (US EPA 1993).

c = Based on food ingestion rate of 0.19 kg/kg-day and a BW of 0.021 kg (US EPA 1993).

d = Water consumption rate based on 0.19 kg/kg-day and a BW of 0.021 kg (US EPA 1993).

e = Value selected is the average of mean home ranges for males and females in a Virginia mixed deciduous forest (US EPA 1993).

f = Recommended percentage of soil ingestion for wildlife (BCMELP 2000).

g = Diet normalized to equal 100% including ingestion of 2% soil.

h = EECs for these organisms were assumed to equal those of the foliar invertebrate receptor.

Rationale: Grasshoppers and leafhoppers are primarily herbivorous, most Lepidopteran larvae are phytophagus, and many spiders consume herbivorous species.

j = EECs for terrestrial plants used for these food sources.

k = EECs for aquatic vegetation used for sedges.

US EPA. 1993. Wildlife Exposure Factors Handbook. Office of Research and Development. EPA/600/R-93/187.

BCMELP. 2000. Tier 1 Ecological Risk Assessment Policy Decision Summary. Environment and Resource Management Department, Pollution Prevention and Remediation Branch, Risk Assessment and Integrated Pesticide Management. Victoria, BC.

Table B-4: Measurement Receptor Characteristics - Little Brown Bat (*M. lucifugus*)

Receptor Characteristics[a]	Little Brown Bat	
Body weight (kg)	0.0074	b
Food consumption rate (kg/day)	0.0024	
Home range (hectares)	314	c
Dietary Composition	**Percentages**	
Aerial Invertebrates:		d
Coleopterans (foliar invert)	7%	f
Trichopterans (aquatic invert)	33%	e
Chironomidae (aquatic invert)	56%	e
Other insects	4%	f

NOTES:

a = Receptor characteristics for *Myotis lucifugus* are from Sample et al. (1997).

b = Value selected represents mean of reported literature values (ORNL 1997).

c = Little information is available on the home range of *Myotis lucifugus*. The literature reviewed indicates that the Little Brown Bat may travel up to several kilometers while foraging for food. Assuming 3 kilometers as a home range radius, the home range is approximatley 314 hectares.

d = Literature data considered consists of 28 adult specimens collected in Nova Scotia, and percentages were normalized to equal 100% of diet.

e = EECs for aquatic invertebrates used for these aquatic species.

f = EECs for foliar invertebrates used for coleopterans. 'Other insects' assumed to be terrestrial foliar insects.

Sample, B.E., M.S. Aplin, R.A. Efroymson, G.W. Suter II, and C.J.E. Welsh. 1997. Methods and Tools for the Estimation of Exposure of Terrestrial Wildlife to Contaminants. ORNL/TM-13391.

Table B-5: Measurement Receptor Characteristics - Coyote (*C. latrans*)

Receptor Characteristics[a]	Coyote	
Body weight (kg)	12	b
Food consumption rate (kg/day)	0.68	
Home range (hectares)	3010	
Dietary Composition[d]	**Percentages**	
Soil ingestion (direct)	2%	e
Lagomorph	53%	j
Livestock	12%	k
Mice	7%	
Other mammals	5%	l
Birds	17%	h
Insects	1%	f
Plants	2%	g
Miscellaneous	2%	m

NOTES:

a = Receptor characteristics for *Canis latrans* are from Sample et al. (1997)

b = Value selected is average of male and female reported literature values for coyotes in Alaska (ORNL 1997).

c = Using Eqn. 21 (Sample et al. 1997) and a body weight of 12 kg.

d = Data taken from a study of coyotes in Nebraska where carrion diet was divided by species group to allow more accurate determination of diet percentages. Percentages normalized to total 100% including 2% direct soil ingestion.

e = Recommended percentage of soil ingestion for wildlife (BCMELP 2000).

f = 'Insects' were assumed to be 50% foliar and 50% soil invertebrates.

h = 'Birds' were assumed to consist of 100% omnivores (robins).

j = Small mammal (deer mice) EECs were used as an estimate of lagomorph EECs.

k = Livestock has been excluded since the home range of coyote greatly exceeds the site area, (therefore, 12.25% of their diet is considered to be assumed elsewhere where livestock may be present).

l = EECs for 'other mammals' were assumed to consist of 100% small mammals (deer mice)

m = The 'miscellaneous' category was assumed to consist of small mammals (deer mice).

Sample, B.E., M.S. Aplin, R.A. Efroymson, G.W. Suter II, and C.J.E. Welsh. 1997. Methods and Tools for the Estimation of Exposure of Terrestrial Wildlife to Contaminants. ORNL/TM-13391.

BCMELP. 2000. Tier 1 Ecological Risk Assessment Policy Decision Summary. Environment and Resource Management Department, Pollution Prevention and Remediation Branch, Risk Assessment and Integrated Pesticide Management. Victoria, BC.

Table B-6: Measurement Receptor Characteristics - American Robin (*T. migratorius*)

Receptor Characteristics[a]	American Robin	
Body weight (kg)	0.077	b
Food consumption rate (kg/day)	0.11704	f
Home range (hectares)	0.42	c
Dietary Composition[a]	**Percentages**	
Soil ingestion (direct)	2%	d
Insects	54%	e,g
Seeds & Fruit	44%	e,h

NOTES:

a = General receptor characteristics and dietary consumption for *Turdus migratorius* are from US EPA (1993).

b = Value selected is average of males and females across all seasons (US EPA 1993).

c = Home range selected is mean value cited for a campus habitat (US EPA 1993).

d = Recommended percentage of soil ingestion for wildlife (BCMELP 2000).

e = Values selected were for adult specimens from western United States of America, and have been normalized to incorporate 2% direct soil ingestion.

f = Food consumption rate based on food ingestion rate of 1.52 kg/kg-day and body weight of 0.077kg (US EPA 1993).

g = 'Insects' were assumed to be 50% foliar and 50% soil invertebrates.

h = EECs for seeds and fruit assumed to equal that of terrestrial plants.

EEC = Estimated Environmental Concentration

US EPA. 1993. Wildlife Exposure Factors Handbook. Office of Research and Development. EPA/600/R-93/187.

BCMELP. 2000. Tier 1 Ecological Risk Assessment Policy Decision Summary. Environment and Resource Management Department, Pollution Prevention and Remediation Branch, Risk Assessment and Integrated Pesticide Management. Victoria, BC.

Table B-7: Measurement Receptor Characteristics - Pileated Woodpecker (*D. pileatus*)

Receptor Characteristics	Pileated Woodpecker	
Body weight (kg)	0.291	a
Food consumption rate (kg/day)	0.03	f
Home range (hectares)	893	b
Dietary Composition	**Percentages**	
Foliar insects	70%	c
Fruit & seeds	30%	c, e

NOTES:

a = Average of body weight range reported by Bonar (1999).

b = Average of territory range reported in Bull and Holthausen (1993).

c = Diet percentages from DeGraaf et al. (1983).

e = EECs for seeds and fruit assumed to equal those of terrestrial plants.

f = Food consumption rate based on allometric formula presented in US EPA (1993) for 'all birds'.

Bonar, R.L. 1999. Pileated Woodpecker Winter Habitat. Habitat Suitability Index Model. Weldwood of Canada Ltd. October 1999.

Bull, E.L. and R.S. Holthausen. 1993. Habitat use and management of pileated woodpeckers in northeastern Oregon. Journal of Wildlife Management. 57:335-345.

DeGraaf, R.M., V.E. Scott, R.H. Hamre, L. Ernst, and S.H. Anderson. 1983. Forest and Rangeland Birds of the Unites States. U.S. Department of Agriculture, Washington, DC.

US EPA. 1993. Wildlife Exposure Factors Handbook. Office of Research and Development. EPA/600/R-93/187.

Table B-8: Measurement Receptor Characteristics - Red-Tailed Hawk (*B. jamaicensis*)

Receptor Characteristics[a]	Red-Tailed Hawk	
Body weight (kg)	1.134	b
Food consumption rate (kg/day)	0.112	c
Home range (hectares)	859	e
Dietary Composition[k]	**Percentages[l]**	
Direct soil ingestion	2%	l
Lagomorphs	25%	f
Squirrels	35%	f
Voles & mice	5%	f
Other mammals	8%	f
Waterfowl	16%	g
Grouse (galliform)	4%	h
Other birds	6%	j

NOTES:

a = General receptor characteristics and dietary consumption for *Buteo jamaicensis* are from US EPA (1993)

b = Value selected is average of males and females for BWs reported for adults (US EPA 1993).

c = Based on average food ingestion rate of 0.0987 kg/kg-day and a BW of 1.134 kg (US EPA 1993).

d = Water consumption rate based on 0.057 kg/kg-day and BW of 1.134 kg (US EPA 1993).

e = Home range based on average of home ranges reported (US EPA 1993).

f = Exposure to COPCs in lagomorphs, squirrels, voles, mice, and 'other mammals' was estimated using the EEC calculated for deer mice.

g = Exposure to COPCs in waterfowl were not included as waterfowl are not expected to occur at the Site in significant numbers.

h = Exposure to COPCs in galliforms was estimated using the EEC calculated for the american robin.

j = Exposure to COPCs in 'other birds' was estimated using the average of EECs calculated for robins and pileated woodpeckers.

k = Dietary composition is based on 10 years of data collected from Alberta farms and woodlands, and reported in US EPA (1993).

l = Diet percentages have been normalized to 100% to incorporate 2% soil ingestion (BCMELP 2000).

US EPA. 1993. Wildlife Exposure Factors Handbook. Office of Research and Development. EPA/600/R-93/187.

BCMELP. 2000. Tier 1 Ecological Risk Assessment Policy Decision Summary. Environment and Resource Management Department, Pollution Prevention and Remediation Branch, Risk Assessment and Integrated Pesticide Management. Victoria, BC.

Table B-9: Measurement Receptor Characteristics - Common Garter Snake (*T. sirtalis*)

Receptor Characteristics[a]	Common Garter Snake	
Body weight (kg)	0.0354	b
Food consumption rate (kg/day)	0.00496	c
Home range (hectares)	18.5	d
Dietary Composition[e]	**Percentages[j]**	
Soil (direct ingestion)	2%	
Amphibians	57%	f
Earthworms & Misc. Invertebrates	39%	
Birds	1%	g
Leeches	1%	h

NOTES:

a = General receptor characteristics and dietary consumption for *Thamnophis sirtalis* are from Cal EPA (1999).

b = Value selected is the average of measurements for adult males and females collected in Canada (Cal EPA 1999).

c = Based on 14% of their body mass ingested per day (based on ingestion of frogs) and estimated from metabolic rate (Cal EPA 1999).

d = Home range based on average of adult male/female reported values (Cal EPA).

e = Dietary composition from Canadian studies (based on species collected on Vancouver Island). Percentages were normalized to sum 100% for identified components (Cal EPA 1999).

f = Exposure to COPCs in amphibians was estimated using the EECs calculated for Pacific tree frogs.

g = Exposure to COPCs in birds was estimated using the EECs calculated for robins.

h = Exposure to COPCs in leeches was estimated using the EECs calculated for aquatic invertebrates.

j = Diet normalized to 100% to incorporate 2% direct soil ingestion (BCMELP 2000).

Cal/EPA. 1999. California Wildlife Exposure Factor and Toxicity Database. Office of Environmental Health Hazard Assessment. http://www.oehha.org/cal_ecotox/default.htm

BCMELP. 2000. Tier 1 Ecological Risk Assessment Policy Decision Summary. Environment and Resource Management Department, Pollution Prevention and Remediation Branch, Risk Assessment and Integrated Pesticide Management. Victoria, BC.

APPENDIX C: SAMPLE CALCULATIONS

Total Daily Oral Exposure

This section provides a sample calculation for determining total oral exposures to copper by the American robin. Total oral copper exposure by the American robin was estimated using the following equation (Sample et al. 1997):

$$E_j = \frac{A}{HR}\left[\sum_{i=1}^{m}\sum_{k=1}^{n} P_{ik}(I_i \times C_{ijk})\right]$$

where,

E_j = Total oral exposure to contaminant (j) (mg/kg/d)
m = Total number of ingested media (e.g, food, soil)
I_i = Ingestion rate for medium (i) (kg/kg-BW/d or L/kg-BW/d)
n = Number of types of medium (i) consumed
P_{ik} = Proportion of type (k) of medium (i) consumed
C_{ijk} = Concentration of contaminant (j) in type (k) of medium (i) (mg/kg or mg/L)
A = Contaminated Site area (ha)
HR = Home range size (ha) of the measurement receptor

The following are the pertinent variable values used for the calculation of copper exposure to the American robin:

Csoil	= 159.59 mg/kg (copper)
Cinsect*	= 35.11 mg/kg (copper)
Cseed/fruit	= 63.84 mg/kg (copper)
A	= 11.2 ha
HR	= 0.42 ha
I	= 0.1170 (kg/d)
BW	= 0.077 kg-BW
Psoil	= 0.02
Pinsect	= 0.54
Pseed/fruit	= 0.44

Note: The home range of the American robin is smaller than the contaminated Site area. For modeling purposes, the American robin was assumed to use the entire Site area: A/HR=1.

*Insect consumption by the American robin was assumed to consist of 50% soil and 50% foliar insects.

The following calculations estimate copper exposures by the American robin resulting from dietary intake of soil, insects and seeds/fruit at the Site.

$$Esoil = 1(0.02)\left(\frac{0.1170kg/d}{0.077kgBW} \times 159.59mg/kg\right) = 4.83mg/kg-bw/day$$

$$Einsect = 1(0.54)\left(\frac{0.1170kg/d}{0.077kgBW} \times 35.11mg/kg\right) = 28.8mg/kg-bw/day$$

$$Eseed/fruit = 1(0.44)\left(\frac{0.1170kg/d}{0.077kgBW} \times 63.84mg/kg\right) = 42.4mg/kg-bw/day$$

The sum of exposures estimated above gives the total oral exposure of the American robin to copper at the Site.

$$Ej = Esoil + Einsect + Eseed/fruit = 4.83 + 28.8 + 42.4 = 76.0mg/kg-bw/day$$

Risk Quotient Calculation

This section provides a sample calculation for determining the risk quotient (RQ) for American robin exposure to copper.

$$RQ = \frac{E}{TRV}$$

where,

RQ = Risk quotient (unitless)
E = Exposure concentration (mg/kg) or total oral exposure (mg/kg-bw/day)
TRV = Toxicity reference value (mg/kg or mg/kg-bw/day)

The following are the pertinent variable values used for the calculation of risk to the American robin resulting from copper exposure at the Site:

E = 76.0 mg/kg-bw/day
TRV = 61.7 mg/kg-bw/day

$$RQ = \frac{E}{TRV} = \frac{76.0mg/kg-bw/day}{61.7mg/kg-bw/day} = 1.2$$

The risk quotients were assessed as indicators of potential risk based on BC ERA guidance (BCMELP 1998):

RQ < 1 = low risk
1 < RQ < 100 = moderate risk
RQ > 100 = high risk

Based on this approach, the potential (based solely on RQ results) for adverse effects to the American robin resulting from exposure to copper at the Site, was moderate.

References

BCMELP (British Columbia Ministry of Environment, Lands and Parks). 1998. Guidance and Checklist for Tier 1 Ecological Risk Assessment of Contaminated Sites in British Columbia. British Columbia Ministry of Environment, Lands and Parks.

Sample, B.E., M.S. Aplin, R.A. Efroymson, G.W. Suter, II, and C.J.E. Welsh. 1997. Methods and tools for estimation of the exposure of terrestrial wildlife to contaminants. Oak Ridge National Laboratory, Oak Ridge TN. ORNL/TM-13391.