

**HUMAN HEALTH
AND
ECOLOGICAL RISK ASSESSMENT**

**Brooks Brook
Alaska Highway
Yukon**

Prepared For:
INDIAN and NORTHERN AFFAIRS CANADA
345-300 Main Street
Whitehorse, Yukon
Y1A 2B5

Prepared By:
HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC
V6Z 2K5

EXECUTIVE SUMMARY

Overview

Hemmera Envirochem Inc. (Hemmera) was retained by Indian and Northern Affairs Canada (INAC) to undertake a risk assessment at a portion of the former Alaska Highway construction camp located along the Alaska Highway at Mile Post 830. The property is now used as a native meeting ground and recreational area.

The historical land use of the property has ranged from residential to industrial. Due to the historic land use of the property over the years, INAC retained the Environmental Services Group to conduct an environmental investigation of the property in 1997.

In 1998 INAC retained Lorimer and Associates and Hemmera to complete a Phase I Environmental Investigation to further assess the areas of environmental concern identified in the ESG report. During this investigation hydrocarbons were found to be present in the soil and groundwater at one area of the site known as the "vicinity of Foundation AB." A Detailed Site Investigation was completed in the fall of 2001 to further delineate soil and groundwater hydrocarbon contamination.

The hydrocarbon contamination extends to the vicinity of a brook (Brooks Brook). Due to the close proximity of the brook to the impacted soil and groundwater, INAC requested the possibility of risk managing the contamination in this sensitive area rather than undertaking remedial actions such as excavation.

This risk assessment uses the site data provided by previous investigations and combines the results of an exposure assessment and a toxicity assessment to quantify human health risks. The potential environmental risks are assessed separately on the basis of the defined environmental receptors and existing aquatic and terrestrial toxicity. The results of the risk assessment are summarized by illustration in **Figure I**.

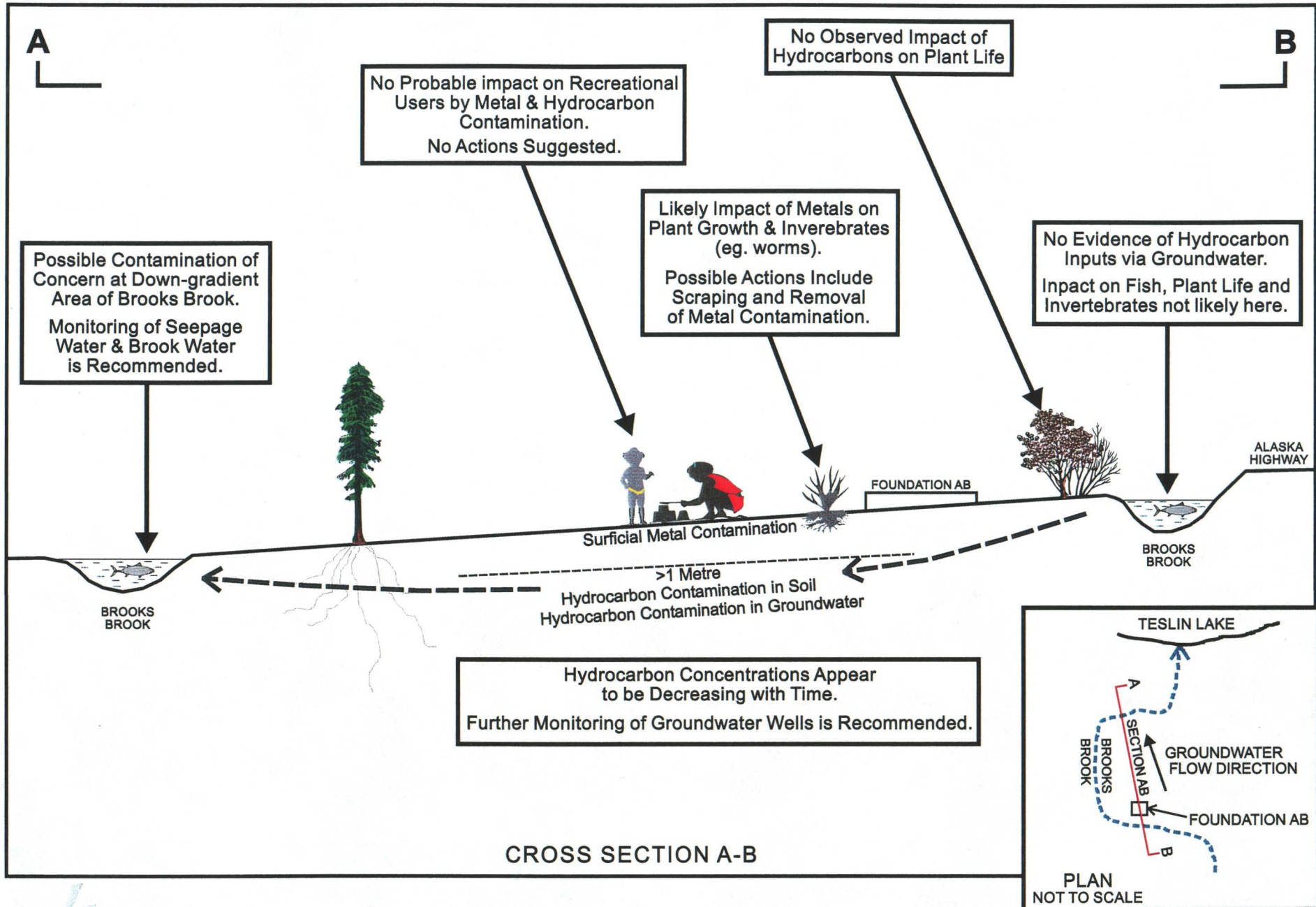


FIGURE I: SUMMARY OF RISK ASSESSMENT RESULTS

Human Health Risk Assessment

The current human health risk assessment was initiated to assess the potential risks to human health in the vicinity of Foundation AB. The risk assessment is based on the current land use of the property as a meeting ground for the Tlingit Band as well as for recreational purposes such as camping and picnics during the summer months.

A review of the previous reports indicate that in addition to hydrocarbons, metals at concentrations in excess of the applicable standards are found in surface soils in the vicinity of Foundation AB. The hydrocarbons are found in soil at a depth ranging from 0.8 meters to 2.5 meters below grade. The groundwater in this area has also been impacted by hydrocarbon contamination.

Contaminants of concern in soil were selected if the 95th percentile concentration of the samples analysed exceeded the applicable Yukon Contaminated Sites Regulation (YCSR) generic or human health protection standards and/or the applicable CCME guidelines, or if the maximum observed concentration is greater than two times any standard or guideline. Groundwater contaminants were not considered for the human health risk assessment, as there are no nearby drinking water wells.

Based on analytical data provided in the previous report, the chemicals selected for the human health risk assessment are summarized in following table:

Chemicals Selected for the Human Health Risk Assessment

Metals	Hydrocarbons
Chromium	Volatile Petroleum Hydrocarbons
Copper	Light Extractable Petroleum Hydrocarbons
Lead	Naphthalene
Zinc	

Once the chemicals were selected, an exposure assessment was conducted. The exposure assessment assesses the pathways that the contaminants could potentially take to come in contact with receptors (humans) on the site.

Three exposure pathways were identified:

1. Dermal
2. Ingestion
3. Inhalation

Dermal exposure, ingestion and inhalation were selected for the surface metals. The possibility of the public being exposed to the soil at depth is unlikely therefore dermal exposure and ingestion were not selected for hydrocarbons. However, inhalation of hydrocarbon vapours was selected as a possible exposure route.

Once the exposure pathways were identified, the quantity of the potential exposure in milligrams per kilogram per day was assessed, i.e. the dose of each chemical for each exposure pathway was calculated. All calculations were very conservative, e.g. it was assumed a member of the public would be present in the area of Foundation AB once every 14 days throughout the year and would confine his/her activities to that area. The estimated doses were then compared to the reference dose (RfD) or tolerable recommended daily intake (TDI) for each chemical of concern. The RfDs and TDIs are based on the toxicity of each of the chemicals. If the estimated dose is greater than the RfD or TDI then there may be potential for human health effects.

None of the estimated doses were found in excess of the RfDs or TDIs for the chemicals of concern. In fact, the calculated estimated doses were well below the RfDs and TDIs. Thus, the current human health risk assessment did not identify any potential risks to human health within the subject area from the metals and hydrocarbon impacted soil and groundwater.

Ecological Risk Assessment

The ecological risk assessment was conducted to assess the potential risks associated with the impacted soil and groundwater to ecological health.

Terrestrial Ecological Risk Assessment

The ecological setting is such that the site-related chemicals of potential concern (COPCs) may contact a wide variety of terrestrial species.

The terrestrial exposure routes and receptors identified in the ecological risk assessment are:

- Root uptake by terrestrial plants of metals and hydrocarbons, and;
- Soil Ingestion and dermal exposure of metals and hydrocarbons by soil invertebrates (e.g. worms).

Ingestion of food with elevated concentrations of the COPCs for small mammals and birds was not considered in the risk assessment due to the small size of the impacted area relative to the large foraging area of small mammals and birds.

Toxicology data for plants and invertebrates were obtained for metals and hydrocarbons in the Subject Area. The chemicals of concern were then selected for the terrestrial ecological risk assessment. These chemicals are listed in the following table.

Summary of Chemicals Selected for the Terrestrial Ecological Risk Assessment

Metals	Hydrocarbons
Chromium	Volatile Petroleum Hydrocarbons (VPH)
Copper	Light Extractable Petroleum Hydrocarbons (LEPH)
Lead	Heavy Extractable Petroleum Hydrocarbons (HEPH)
Zinc	

The toxicity ranges obtained from the literature were then compared to the 95th percentile concentrations observed in the soil. Based on the toxicity assessment of the chemicals of concern, copper and zinc in the surficial soils around the perimeter of Foundation AB appear to have concentrations that pose a potential risk to ecological health. The observed concentrations of copper

and zinc are higher than the recorded LC₅₀ concentrations for soil invertebrates and plants. The LC₅₀ is the concentration of the chemical that causes mortality in 50 % of a particular species.

Aquatic Ecological Risk Assessment

The aquatic ecological risk assessment looked at the potential impact of groundwater contamination on the quality of the water in Brooks Brook. Fish and aquatic invertebrates in Brooks Brook and Teslin Lake were identified as the primary receptors exposed to groundwater contamination. Aquatic plants were not considered receptors based on field observations, which indicated the absence of algae and macrovascular vegetation in the adjacent fast moving brook. In addition, ingestion of food with elevated chemical concentrations by birds and mammals was not considered given the small size of the impacted area relative to a typical feeding area for most birds and mammals that feed on aquatic biota.

The toxicity assessment was conducted for the chemicals in which the 95th percentile of the groundwater samples were in excess of the applicable aquatic life standards and guidelines.

These chemicals in excess of guidelines and standards are listed on the following table:

Metals	Polycyclic Aromatic Hydrocarbons	Petroleum Hydrocarbons
Iron	Naphthalene	LEPH
Manganese	Phenanthrene	HEPH
	Pyrene	
	Toluene	

The toxicity assessment found concentrations in groundwater of manganese, most polycyclic aromatic hydrocarbons, (PAHs), and HEPH well below the referenced toxicology data which included no-effect levels (NOEL), lowest observed effect levels (LOEL), and acute toxicity levels (LC₅₀'s and EC₅₀'s).

The toxicity assessment indicated a potential risk of LEPH and naphthalene to aquatic health.

A comparison of groundwater quality with toxicology data is obviously very conservative as processes (e.g. biodegradation, adsorption, precipitation, dilution etc.) will decrease the concentration of chemicals in groundwater prior to reaching receiving water such as Brooks Brook. The assessment of groundwater impact on Brooks Brook is complicated in that groundwater in the Subject Area directly adjacent to Brooks Brook flows away from this area of the brook. Field data in this area of the brook showed no evidence of any of the potential chemicals of concern in the brook water. However due to "U" shaped flow direction of Brooks Brook, contaminated water may extend to a down-gradient area of the brook.

The extent of down-gradient groundwater contamination could not be evaluated due to dense trees in the area that prevented the drill rig from advancing additional boreholes and wells. As a result, a groundwater model was used to evaluate the likely concentrations of chemical contaminants at two possible points of discharge to the brook. The predicted LEPH and naphthalene concentrations would be significantly less than reported toxicity concentrations to aquatic biota. Further, analytical data from the brook at these locations indicated concentration of LEPH and naphthalene below the method detection limit. As a result, it is predicted there should be no impact on aquatic life in Brooks Brook.

Conclusions and Recommendations

The human health risk assessment did not identify any potential risks to human health within the subject area from the metals and hydrocarbon impacted soil and groundwater.

Based on the soil, groundwater, sediment and surface water sampling, it appears that the brook sediment and the brook water to the east of the Subject Area have not been impacted by the soil and groundwater contamination.

Copper and zinc in the surficial soils around the perimeter of Foundation AB appear to have concentrations that pose a potential risk to ecological health.

Three options are suggested:

- i.) Bioassay tests could be conducted on the soils to evaluate whether actual impacts would occur. If no impact is observed then the soils could be left as is.
- ii.) Metals impacted soils in the vicinity of the foundation could be excavated and removed from the site without further testing.
- iii.) Leave "as is", given that the area of impact is very small and that the area is now densely vegetated.

Hemmera sampled the surface waters to the west and south for metals and hydrocarbons to confirm the quality of the surface water in the down gradient direction of the groundwater plume. The risk assessment and the field data suggest there should be no impact on aquatic life in Brooks Brook.

Based on the elevated concentrations of hydrocarbons observed in the groundwater within the Subject Area, annual monitoring and sampling all of the monitoring wells should be conducted as a component of a risk management approach. This approach would monitor the natural attenuations and biodegradation of the concentrations observed in the groundwater. Such attenuations are suggested in a comparison of historical data. Monitoring could cease upon assurance that the groundwater contamination is of a level that there is little or no potential for environmental impact.

TABLE OF CONTENTS

1	OVERVIEW	1
2	SITE BACKGROUND	3
2.1	SITE LOCATION.....	3
2.2	SITE DESCRIPTION	3
2.2.1	<i>Definition of Subject Area.....</i>	<i>3</i>
2.2.2	<i>Neighbouring Properties</i>	<i>4</i>
2.2.3	<i>Regulatory Permits</i>	<i>4</i>
2.2.4	<i>History of the Site.....</i>	<i>4</i>
2.2.5	<i>Physical Characteristics</i>	<i>5</i>
2.2.5.1	<i>Current Site Topography.....</i>	<i>5</i>
2.2.5.2	<i>Site Geological Conditions</i>	<i>5</i>
2.2.5.2.1	<i>Hydrogeological Conditions</i>	<i>6</i>
2.2.5.2.2	<i>Site Ecology</i>	<i>7</i>
2.2.5.2.3	<i>Receiving Environment</i>	<i>8</i>
2.3	PREVIOUS SITE INVESTIGATIONS	8
2.3.1	<i>Environmental Sciences Group, Royal Military College – An Environmental Assessment, 1997.....</i>	<i>9</i>
2.3.2	<i>Lorimer & Associates/Hemmera Resource Consultants – Phase II Assessment, 1997</i>	<i>11</i>
2.3.3	<i>Hemmera Resource Consultants – Phase III Assessment, 1999.....</i>	<i>15</i>
2.3.4	<i>Hemmera Envirochem – Detailed Site Investigation, 2001</i>	<i>18</i>
2.4	SUMMARY OF PREVIOUS INVESTIGATIONS FOR THE SUBJECT AREA	22
2.4.1	<i>Soil</i>	<i>22</i>
2.4.2	<i>Groundwater</i>	<i>22</i>
2.5	OTHER REPORTS FOR THE BROOKS BROOK PROPERTY	24
2.5.1	<i>Hemmera Resource Consultants – OCP Remediation, 2000.....</i>	<i>24</i>
3	DESCRIPTION OF RISK ASSESSMENT PROCESS.....	25
3.1	GENERAL APPROACH OF A RISK ASSESSMENT.....	25
3.1.1	<i>Description of Development Scenarios.....</i>	<i>25</i>

3.1.2	<i>Scope of Risk Assessment</i>	26
4	HUMAN HEALTH RISK ASSESSMENT	27
4.1	POTENTIAL CONTAMINANTS OF CONCERN.....	27
4.1.1	<i>Selection of Contaminates of Concern</i>	27
4.1.1.1	Cadmium.....	29
4.1.1.2	Chromium	30
4.1.1.3	Copper.....	32
4.1.1.4	Lead.....	34
4.1.1.5	Zinc	35
4.1.1.6	Hydrocarbons in Soil	37
4.1.1.7	Volatile Petroleum Hydrocarbons (VPH or F1).....	37
4.1.1.8	Light Extractable Petroleum Hydrocarbons (LEPHs or F2)	38
4.1.1.9	Heavy Extractable Petroleum Hydrocarbons (HEPH or F3).....	39
4.1.1.10	Naphthalene	40
4.1.2	<i>Summary of Selected Potential Chemical of Concern within the Subject Area</i>	
4.2	EXPOSURE ASSESSMENT – HUMAN HEALTH	43
4.2.1	<i>Type of Risk Characterization</i>	43
4.2.1.1	Characterization of Exposure Setting	43
4.2.1.2	Recreational/Parkland Land	43
4.2.1.3	Identification of Potentially Exposed Population	43
4.2.1.4	Identification of Exposure Routes.....	44
4.2.1.4.1	Ingestion:.....	44
4.2.1.4.2	Dermal Contact:	44
4.2.1.4.3	Inhalation:	44
4.2.1.5	Quantification of Exposure to General Public	45
4.2.1.5.1	Potential Incidental Ingestion Doses.....	45
4.2.1.5.2	Dermal Contact	48
4.2.1.5.3	Inhalation	50
4.2.1.5.4	Inhalation Hydrocarbons	52
4.3	TOXICITY ASSESSMENT – HUMAN HEALTH	53

4.3.1	<i>Selection of Reference Doses (Noncarcinogenic Effects)</i>	53
4.3.2	<i>Toxicity – Chromium</i>	54
4.3.2.1	Reference Dose: RfD	54
4.3.2.2	Carcinogenic Effects	54
4.3.3	<i>Toxicity – Copper</i>	55
4.3.3.1	Reference Dose RfD	55
4.3.3.2	Carcinogenic Effects	55
4.3.4	<i>Toxicity – Lead</i>	55
4.3.4.1	Acute toxicity.....	55
4.3.4.2	Chronic Effects	56
4.3.4.3	Reference Dose (RfD).....	56
4.3.4.4	Carcinogenic Effects	56
4.3.5	<i>Toxicity – Zinc</i>	57
4.3.5.1	Reference Dose RfD	57
4.3.5.2	Carcinogenic Effects	57
4.3.6	<i>Toxicity – Hydrocarbon Vapours</i>	57
4.3.7	<i>Summary of Reference Toxicity Values</i>	57
4.4	RISK CHARACTERIZATION	58
4.5	UNCERTAINTY ANALYSIS	60
4.6	SUMMARY	61
5	ECOLOGICAL RISK ASSESSMENT	63
5.1	CHEMICALS OF POTENTIAL CONCERN.....	63
5.1.1	<i>Soil Concentrations in excess of the YCSR, CCME and CWS</i>	63
5.1.2	<i>Impact of Contaminated Soil on Groundwater</i>	64
5.1.3	<i>Assessment of Sediment Samples</i>	65
5.1.4	<i>Assessment of Surface Water</i>	65
5.1.5	<i>Summary of Selected Chemicals</i>	66
5.1.6	<i>Receptors of Concern</i>	67
5.1.7	<i>Conceptual Model</i>	67
5.2	TERRESTRIAL ECOLOGICAL RISK ASSESSMENT	69

5.2.1	Terrestrial Exposure Assessment.....	69
5.2.1.1	Terrestrial Field Observations.....	69
5.2.1.2	Exposure to Terrestrial Biota.....	70
5.2.1.2.1	Soil Ingestion by Soil Invertebrates	71
5.2.1.2.2	Ingestion of Food With Elevated Concentrations of The COPCs For Small Mammals and Birds	71
5.2.1.3	Toxicity Assessment of Metals in Soil– Soil Invertebrates, Plants, Mammals and Birds	72
5.2.1.3.1	Chromium	72
5.2.1.3.2	Copper.....	73
5.2.1.3.3	Lead.....	73
5.2.1.3.4	Zinc	74
5.2.1.4	Toxicity Assessment of Hydrocarbons in Soil.....	75
5.2.1.5	Assessment of Potential Risk of COCs to Terrestrial Species.....	77
5.2.1.6	Terrestrial Uncertainty Analysis	78
5.2.1.7	Terrestrial – Risk Characterization	78
5.3	AQUATIC ECOLOGICAL RISK ASSESSEMENT.....	79
5.3.1	Aquatic Exposure Assessment.....	79
5.3.1.1	Receiving Environment	79
5.3.1.2	Groundwater	79
5.3.1.3	Exposure to Aquatic Biota.....	80
5.3.1.3.1	Aquatic Invertebrates	80
5.3.1.3.2	Aquatic Plants	80
5.3.1.3.3	Fish.....	80
5.3.1.3.4	Birds.....	81
5.3.1.4	Aquatic Toxicity Assessment of COCs	81
5.3.1.5	Assessment of Potential Risk of COCs to Aquatic Species.....	87
5.3.1.5.1	Direct Comparison of Groundwater Quality with Toxicity Information	88
5.3.1.5.2	Comparison of Calculated Down-gradient Groundwater	

	Quality with Toxicity Information	89
	5.3.1.6 Aquatic Uncertainty Analysis	91
	5.3.1.7 Aquatic – Risk Characterization	92
6	CONCLUSIONS	94
6.1	HUMAN HEALTH RISK ASSESSMENT.....	94
6.2	ECOLOGICAL RISK ASSESSMENT	94
	6.2.1 Terrestrial	94
	6.2.2 Aquatic.....	94
7	RECOMMENDATIONS.....	95
8	RISK MANAGAMENT	96
9	STATEMENT OF LIMITATIONS	98
10	BIBLIOGRAPHY	99
11	REPORT CREDITS	97

List of Figures

Figure I:	Summary of Risk Assessment Results	ii
Figure A:	Human Health Exposure Pathway Diagram	28
Figure B:	Ecological Health Exposure Poathway Diagram	68
Figure 1:	Site Location Map	
Figure 2:	Site layout	
Figure 3:	Cross Sections Indicating Soil Stratigraphy	
Figure 4:	Groundwater Contours	
Figure 5:	Conceptual Diagram of Receiving Environment and Receptors	
Figure 6:	Environmental Sciences Group - Soil Sample Locations and Exceedances	
Figure 7:	Lorimer and Associates/Hemmera Resource Consultants – Exceedances for Hydrocarbons in Soil	
Figure 8:	Lorimer and Associates/Hemmera Resource Consultants – Exceedances for Hydrocarbons in Groundwater	
Figure 9:	Hemmera Resource Consultants – Exceedances for Hydrocarbons in Soil	
Figure 10:	Hemmera Resource Consultants – Exceedances for Hydrocarbons in Groundwater	

- Figure 11: Hemmera Envirochem Inc. – Exceedances for Hydrocarbons in Soil
- Figure 12: Hemmera Envirochem Inc. – Exceedances for Metals and Hydrocarbons in Groundwater
- Figure 13: Horizontal Extent of Impacted Soil
- Figure 14A: Vertical Extent of Impacted Soil – Cross Section A-A'
- Figure 14 B: Vertical Extent of Impacted Soil – Cross Section B-B'
- Figure 15: Approximate Horizontal Extent of Hydrocarbon Contamination in Groundwater

List of Tables

Table 1. Summary of Metals Concentrations in Soil in Subject Area (Environmental Sciences Group, 1997)	10
Table 2. Summary of Soil Hydrocarbon Concentrations in the Subject Area (Lorimer & Associates and Hemmera Resource Consultants, 1997)	13
Table 3. Summary of Hydrocarbon Concentrations in the Groundwater at the Subject Area (Lorimer & Associates and Hemmera Resource Consultants, 1997)	14
Table 4. Summary of Hydrocarbon Concentrations in Soil (Hemmera Resource Consultants, 1999)	16
Table 5. Summary of Hydrocarbon Concentrations in Groundwater (Hemmera Resource Consultants, 1999)	17
Table 6. Summary of Hydrocarbon Concentrations in Soil (Hemmera Envirochem, 2001)	19
Table 7. Summary Groundwater Results (Hemmera Envirochem Inc., 2001)	20
Table 8. Potential Contaminants of Concern	23
Table 9. Carbon Ranges and Sources of Petroleum Hydrocarbons (CWS, 2000)	37
Table 10. Summary of Selected Chemicals for the Human Health Risk Assessment	42
Table 11. Selected Exposure Pathways for The Human Health Risk Assessment	45
Table 12. Estimated Dose – Ingestion for Evaluation of Non-Carcinogenic Effects on Children	47
Table 13. Estimated Dose – Dermal Uptake for Evaluation of Non-Carcinogenic Effects of Children Between The Ages of 0.5 – <5 Years Old	49
Table 14. Estimated Uptake for Evaluation of Metals Inhalation of Children Between the Ages 0.5 – 5 Years Old	52

Table 15. RfD Values For The Human Health Risk Assessment	57
Table 16. Summary of Worst Case Chronic Hazard Index Estimates for Children Between the Ages of 0.5 to 5 Years Old.....	59
Table 17. Summary of Uncertainty for The Human Health Risk Assessment	60
Table 18. Summary of Potential Contaminants of Concern in Soil.....	64
Table 19. Statistical Summary of Potential Contaminants of Concern in Groundwater	65
Table 20. Chemicals Selected For The Ecological Risk Assessment.....	66
Table 21. Vegetation in the Vicinity of Foundation AB.....	69
Table 22. Summary of Substances Selected for the Terrestrial Ecological Risk Assessment	72
Table 23. Metals Toxicity Ranges for the Ecological Receptors.....	75
Table 24. Summary of Hydrocarbon Toxicity as per the CWS	76
Table 25. Terrestrial Ecological Risk Characterization.....	77
Table 26. Summary of Uncertainty.....	78
Table 27. Summary of Aquatic Contaminants of Potential Concern.....	81
Table 28. Toxicity Values for the Potential Aquatic Receptors.....	86
Table 29. Aquatic Ecological Risk Characterization.....	88
Table 30. Summary of Uncertainty.....	91
Table I. Statistical Summary of Chemical Parameters in Excess of the YCSR RL/PL Standards and CCME RL/PL Guidelines for Soil	
Table II. Statistical Summary of Chemical Parameters in Excess of the YCSR AW Standards and CCME FAL Guidelines	
Table III. Summary of Soil Vapour Survey Conducted During the Hemmera Envirochem Detailed Site Investigation	
Table IV. Statistical Summary of Chemical Parameters in Excess of YCSR Soil Standards and CCME Soil Guidelines for Human Health	

List of Appendices

- Appendix A: Table I Terrestrial Plant Species Identified in the ESG 1997 Report Department of
Renewable Resources – Vertebrate Inventory Lists for the Yukon Territory
- Appendix B: Groundwater Contaminant Transport Calculation: Step Injection

List of Photos

- Photo 1: View of the Brooks Brook Property looking west towards the main site area
- Photo 2: View of the Subject Area looking southeast
- Photo 3: View of the topography sloping from the Alaska Highway to Brooks Brook
- Photo 4: View of Brooks Brook flowing into Teslin Lake
- Photo 5: View of heavy vegetation along bank of Brooks Brook

1.0 OVERVIEW

Hemmera Envirochem Inc. (Hemmera) was retained by Indian and Northern Affairs Canada (INAC) to undertake a risk assessment at the former Alaskan Highway construction camp located along the Alaskan Highway at Mile Post 830. The camp has since been decommissioned and the property is now used as a native meeting ground and recreational area.

In 1997, Environmental Sciences Group (ESG) completed an environmental assessment of the Site. Lorimer and Associates Ltd. and Hemmera (formerly Hemmera Resource Consultants) completed several phases of Environmental Site Assessments of the Site in the summer and fall of 1997 and in 1998, based on the ESG report results.

Hydrocarbons and total organochlorine pesticides (OCP) in exceedance of the Yukon Contaminated Sites Regulations (YCSR) and other applicable standards for OCP were detected in the vicinity of a cook shack located on the western portion of the property. In September 1999, Hemmera supervised the remedial excavation of an area of 3900 m² of OCP contaminated soil at the Site. Confirmatory soil samples analyzed by a laboratory indicated that the Site had been remediated to within the remedial criterion of 0.7 parts per million DDT.

Hydrocarbon contamination remained in two areas of the property and a Detailed Site Investigation (DSI) was completed in the fall of 2001 to delineate the hydrocarbon impacted soil and groundwater exceeding the YCSR standard for residential and parkland use and YCSR aquatic life standard, respectively. As one area (Foundation AB) was located near a brook (Brooks Brook), INAC requested the possibility of risk managing the area versus undertaking remedial actions such as excavation. As a result, the DSI also involved collecting information in preparation for completing a risk assessment for the area in the vicinity of Foundation AB.

The current risk assessment was initiated to assess whether human health and ecological exposure to the contaminants could occur in the Foundation AB area ("Subject Area") and if the exposure could result in any risk. It is the understanding of Hemmera that the site is used occasionally as a meeting

ground for the Tlingit Band as well as for recreational purposes such as camping and picnics during the summer months. The risk assessment is based on current land use. If changes to the land use occur, the risk assessment may no longer be applicable and additional procedures may be required for the management of the contaminated soils and groundwater in the Subject Area.

This document constitutes a baseline risk assessment report in accordance with the 1992 "Risk Assessment Guidance" provided by The British Columbia Ministry of Water, Air and Land Protection (MWALP), a 1995 document by Health Canada, and The U.S. Environmental Protection Agency (EPA) Risk Assessment Guidelines. The objectives of the risk assessment are to:

- Provide a consistent process for evaluating and documenting risk at the area in the vicinity of Foundation AB;
- Provide an analysis of baseline risks within current land use: recreation/parkland;
- Provide a basis for determining levels of chemicals that can remain on-site and still be adequately protective of public health and the receiving environment, and
- Provide a basis for comparing potential impacts of various remedial alternatives, if required.

This risk assessment uses the site data provided by previous investigations and combines the results of an exposure assessment and a toxicity assessment to quantify human health risks. The potential environmental risks are assessed separately on the basis of the defined environmental receptors and existing aquatic and terrestrial toxicity information.

2.0 SITE BACKGROUND

2.1 SITE LOCATION

The Brooks Brook property is located in the Yukon Territory at Mile Post 830 on the Alaska Highway.

Latitude 60° 25' 15"

Longitude 133° 11' 00"

The geographical location is shown in **Figure 1**.

2.2 SITE DESCRIPTION

2.2.1 Definition of Subject Area

The Subject Area that this risk assessment addresses is a small portion of the property noted as "Brooks Brook Property" (**Figure 2, Photo 1**). At this time the entire Brooks Brook Property is used as a native recreation and meeting area. Structures currently on the Brooks Brook Property include a wooden framed meeting hall and cook shack, along with numerous tent bases and outhouses. Foundations from former buildings on the Brooks Brook Property are still visible (**Figure 2**).

The Subject Area is defined by the presence of hydrocarbon residue in soil and groundwater at concentrations that exceed YSCR standards. The Subject Area contains a picnic table, bench and garbage can along the west bank of the brook and thus, the Subject Area is occasionally used for recreational purposes. A local resident indicated that the brook is not used for swimming.

The Subject Area is approximately 2000 m² and is located at the extreme southeast end of the Brooks Brook property (**Photo 2**), adjacent to the brook known as Brooks Brook (**Figure 2**). As shown in **Figure 2**, the brook flows around the border of the Subject Area towards Teslin Lake. The Subject Area includes the remains of a concrete foundation referred to as Foundation AB, which is

approximately 30 m northwest of the brook.

2.2.2 Neighbouring Properties

The Brooks Brook Property is bordered to the west by Teslin Lake and to the east by the Alaska Highway. The land to the east of the Alaska Highway is forested. In addition, the properties to the north and south of the property are currently undeveloped and remain forested (**Figure 2**). Approximately 500m northwest of the subject property is one residence.

2.2.3 Regulatory Permits

A review of the previous investigations for the Brooks Brook Property did not indicate any applicable regulatory permits for past or current activities.

2.2.4 History of the Site

The Brooks Brook Property was originally commissioned in 1942 as a line camp for construction of the Alaska Highway. The camp was also used as a telephone relay station for the U.S. Relay Stations network. The stations were used to relay telephone, teletype and radio messages. The camp also functioned as a base for the truck drivers, pipe-layers and construction workers involved in the construction of the Canol (Canadian Oil) project oil pipeline in the vicinity of the Brooks Brook Property. This project was abandoned in 1945.

In 1946, the camp was transferred to the Canadian Army, with the Royal Canadian Air Force (RCAF) being made responsible for the land communications. The relay line was transferred from the RCAF to Canadian National Telegraphs, which was responsible for the actual operation of the line. The Canadian Army continued to supervise the maintenance and road improvements of the Alaska Highway until 1964. This task then became the responsibility of the Federal Department of Public Works. In 1965 the Brooks Brook Property road maintenance station was moved near the Teslin Airport and the repeater station was shut down. The inhabitants of the Brooks Brook Property gradually moved from the site.

Historically, the property contained between 20 to 30 buildings. These buildings included barracks,

married personnel living quarters, a school, a curling rink, at least two powerhouses, fuel storage tanks, at least two fuel dispensing locations, garages, storage sheds, a pumphouse and a relay station building. Sewer lines ran from each building into Brooks Brook. All of the buildings have since been removed. Three landfills were later identified during investigative works in 1997. The landfills were located at the north end of the main property and at the western edge of the property in the woods near Teslin Lake and approximately 2 km south of the main site along the Alaska Highway.

Previous reports speculate that Foundation AB within the Subject Area was the historic location of a gas-operated generator.

As part of the Teslin Tlingit Council land claim agreement, the Brooks Brook Property is now under the jurisdiction of the Teslin Tlingit Council.

2.2.5 Physical Characteristics

2.2.5.1 CURRENT SITE TOPOGRAPHY

The general area slopes steeply down from the Alaska Highway towards Teslin Lake (**Photo 3**), which is southwest of the site as shown in **Figure 1**. Water in Brooks Brook generally flows southwest until it drains into Teslin Lake (**Figure 2, Photo 4**). The brook was rerouted from its original location during the construction of the Alaska Highway (**Figure 2**). The banks of Brooks Brook are approximately sloped 1:1 adjacent to the Subject Area and are on the average 1.5 m in height. During the site visit in September 2001 the brook was observed to be approximately 0.25 m deep and was flowing at approximately 1.2 metres per second.

2.2.5.2 SITE GEOLOGICAL CONDITIONS

Figure 3, obtained from the Hemmera Detailed Site Investigation (December, 2001), indicated the soil stratigraphy in the vicinity of Subject Area is characterized by 2 – 3.5 metres of sand and gravel overlaying silt.

2.2.5.2.1 *Hydrogeological Conditions*

The studies completed by Hemmera indicate groundwater has been observed at a minimum depth of 1.67 m below grade to a maximum depth of 2.08 m below grade. The average depth to groundwater was 1.85 m below grade (Hemmera, 2001).

The relative groundwater elevations and contours, obtained from the Hemmera DSI, for the September 27, 2001 groundwater monitoring event are included on **Figure 4**. Based on the groundwater elevations, an inferred groundwater flow oriented in the southwest direction, away from Brooks Brook was shown. At the time of the collection of hydrogeological data (during the Hemmera DSI), the elevation of the water in Brooks Brook, east of the Subject Area, was also surveyed. It appeared that the water surface in Brooks Brook was at a slightly higher elevation than the piezometric surface in the wells, which suggested that there may be a net flow from Brooks Brook into the highly permeable sand and gravel horizon.

The estimated hydraulic gradient for the Subject Area on September 27, 2001 was 0.034 , as measured between MW01-07 and MW01-04.

On September 25 and 27, 2001, single well response tests were conducted in monitoring wells H97-15 and H98-23, respectively. Hemmera conducted calculations based on the rising head data to determine the hydraulic conductivity of the saturated soils at the Site. Using Hvorslev's method, an estimated hydraulic conductivity of 9.82×10^{-8} m/s was obtained for monitoring well H97-15, which was completed with a screened section in the silt layer only. A hydraulic conductivity of 1.47×10^{-5} m/s was estimated for monitoring well H98-23, which was completed with a screened section across both the sand layer and the silt layer. It should be noted that conducting a rising head test on a well screened across two different stratigraphic units could affect the conductivity value calculated as the different conductivity properties in each layer contributes to the overall value. Based on the calculated conductivity values, approximate groundwater velocities would range from 0.00072 m/day (H97-15) in the silt layer to 0.087 m/day (H98-23) in the sand layer.

2.2.5.2.2 Site Ecology

Brief inspections of terrestrial vegetation at the Subject Area were conducted by Hemmera personnel in September 2001 and August 2002. The inspections found approximately 70% of the Subject Area covered by vegetation with dense vegetation located along both sides of the banks of the brook and in the vicinity of the Foundation AB. No berries or edible plants were observed at the time of the site visit in September 2001, however raspberry plants were observed around the perimeter of Foundation AB during the August 2002 site visit. There were primarily poplar trees in the Subject Area and alder trees were present along the banks of Brooks Brook for the entire length that it crosses the Subject Area (**Photo 5**). Hemmera personnel suspected the alders were placed to maintain slope stability along the brook. A small area of suspect stressed vegetation (i.e. browned leaves, wilted grass) was present east of Foundation AB during the September 2001 site visit. During the August 2002 site visit there was no evidence of stressed vegetation within the Subject Area, this suggests that the "stressed" vegetation observed in September 2001 was likely due to the time of year rather than contaminant impacted stress.

In addition to the Hemmera site inspection, in an Environmental Assessment entitled "*An Environmental Assessment of Brooks Brook, Yukon Territory*", Environmental Sciences Group (ESG) (1997) collected and recorded the terrestrial vegetation on the property. A list of the vegetation observed by ESG is summarized in **Table I**. Approximately 60 different species of terrestrial plants were observed by ESG during their Assessment of the Brooks Brook property.

A detailed inventory of terrestrial plants, soil invertebrate, birds or mammals within the Subject Area has not been conducted. During the site visit in September 2001 no obvious signs of wildlife were visible with the exception of a beaver dam in Brooks Brook located downstream of the site. No mole hills or gopher holes were noted in the area. During the Hemmera DSI, no signs of organic life such as worms, insects or larvae were observed in the soils close to surface. This may have been a result of the time of year in which the site visit occurred. In addition, the soil inspection was limited due to the compactness of the surficial soil. During the site visit in August 2002 obvious signs of wildlife such as animal tracks along the banks of Brooks Brook were observed. In addition, there was a large

abundance of insects observed at the Site in August 2002. Residents of the area have observed fish (graylings) in Brooks Brook seasonally.

Although a detailed evaluation of terrestrial invertebrates and vertebrates was not completed, the Yukon government currently lists 61 mammal species, 4 amphibian species, and 278 bird species within the territory. Many of these of these species likely occupy the subject area at certain times of the year. A list of the terrestrial vertebrates has been included in **Appendix A**.

Given the small size of the Subject Area, it is unlikely that the Subject Area itself would provide an adequate terrestrial feeding area for birds and mammals.

2.2.5.2.3 *Receiving Environment*

The receiving environment for the Subject Area includes Brooks Brook, which borders the Subject Area to the east and south and soil and groundwater in the vicinity of the impacted area. Teslin Lake is also considered part of the receiving environment as Brooks Brook flows into the lake approximately 300 m southeast of the Subject Area.

In addition, humans and all of the terrestrial plants, soil invertebrates, birds and mammals: that utilize the Subject Area are considered receptors within the receiving environment. A conceptual diagram of the receiving environment, and the receptors is included as **Figure 5**.

2.3 PREVIOUS SITE INVESTIGATIONS

Four site investigations and one soil remediation project have been conducted at this site. As the current risk assessment is for the Subject Area in the southeast corner of the Brooks Brook Property, information collected from the previous reports within this area will be reviewed in detail. Analytical results of the previous reports have been compared to the most applicable current guidelines and standards.

2.3.1 Environmental Sciences Group, Royal Military College – An Environmental Assessment, 1997

➤ APPROACH

Environmental Sciences Group (ESG) conducted an assessment of the entire Brooks Brook Property in 1996/1997. The entire study consisted of:

- Cataloguing debris at the site,
- Collection of 108 surficial soil samples for assessment of one or more of the following: Polychlorinated biphenyls (PCBs), Metals, Polycyclic Aromatic Hydrocarbons (PAHs), Total Petroleum Hydrocarbons (TPHs) and Pesticides,
- Collection of one sediment sample from Brooks Brook for the assessment of PCBs and Metals,
- Collection of three surface water samples from Brooks Brook for the assessment of PCBs and Metals concentrations,
- Assessment of 23 plant tissues for concentrations of PCBs and/or Metals,

➤ RESULTS FOR THE SUBJECT AREA– SOILS

Within the Subject Area, ten surficial soil samples were analysed for PCBs and metals, while two samples were analysed for pesticides. The sample locations are indicated on **Figure 6**. All of the PCB and pesticide samples were within the applicable standards and guidelines. Seven of the samples analysed contained concentrations exceeding the CCME RL/PL guidelines and YCSR RL/PL standards for one or more metals. Copper levels in three samples exceeded the CCME guidelines, but only one sample contained concentrations that exceeded the YCSR Toxicity to Soil Invertebrates and Plants guideline. One sample contained a cadmium concentration in exceedance of the CCME RL/PL guideline but within the YCSR RL/PL standards. Zinc concentrations were in exceedance of the CCME RL/PL guideline in five of the soil samples; three of these samples also contained zinc in exceedance of YCSR RL/PL standard. Chromium concentrations were in exceedance of the CCME RL/PL guideline in three of the soil samples and in one of these samples chromium was also in exceedance of the YCSR standard. Lead concentrations were in exceedance of the CCME RL/PL guideline in three of the soil samples and in one of these samples lead was also

in exceedance of the YCSR RL/PL standard. No soil samples were submitted for concentrations of hydrocarbons in the Subject Area. A summary of the metals concentrations in soil are summarized in **Table 1** and sample locations and exceedances are indicated on **Figure 6**.

Table 1. Summary of Metals Concentrations in Soil in Subject Area (Environmental Sciences Group, 1997)

Metal	Number of Samples	Concentration Range mg/kg (ppm)	CCME Residential/ Parkland Guidelines (mg/kg)	YCSR 1996 Standards (mg/kg)
Cadmium (Cd)	10	<1.0 – 11.3	10 [1]	35 [0] (1)
Copper (Cu)	10	23 – 3000	63 [3]	150 [1] (2)
Chromium (Cr)	10	53-263	64 [3]	150 [1] (4)
Lead (Pb)	10	<10 –780	140 [3]	500 [1] (1)
Zinc (Zn)	10	72-2600	200 [5]	450 [3] (2)

[N] Indicates number of samples in exceedance of the guideline or standard

Intake of Contaminated Soil

Toxicity to Soil Invertebrates and Plants

Generic Standards

Groundwater flow to surface water used by aquatic life

➤ RESULTS FOR THE SUBJECT AREA– WATER

There were no surface or groundwater samples collected within the subject area.

➤ RESULTS FOR THE SUBJECT AREA– PLANT TISSUE ANALYSIS

Two plant samples were collected from the Subject Area. PCBs were analysed in one sample. The results indicate concentrations below the method detection limit. Both plant samples were analysed for metals concentrations. Cadmium and zinc had higher concentrations in one of the samples, a *Salix sp.* specimen. This sample was collected in a low area approximately 1 m southeast of the corner of the foundation. Concentrations of cadmium and zinc collected from this specimen were 5.4 µg/g and 241 µg/g respectively where as the concentrations observed in the *Epilobium angustifolium* specimen were <0.5 µg/g and 31 µg/g respectively.

➤ **CONCLUSIONS AND RECOMMENDATIONS OF THE ENVIRONMENTAL SCIENCES GROUP FOR THE SUBJECT AREA**

- Metals impacted soil will need to be delineated and excavated, and;
- Debris should be collected and disposed in an appropriate landfill.

➤ **CONCLUSIONS AND RECOMMENDATIONS OF THE ENVIRONMENTAL SCIENCES GROUP FOR THE ENTIRE BROOKS BROOK PROPERTY**

- None of the soil samples contained concentrations of PCBs in excess of the CCME guideline and/or the YCSR guideline;
- Metals concentrations (cadmium, chromium, copper, lead and zinc) were found in excess of the CCME guidelines and/or YCSR standards;
- Concentrations of PAHs did not exceed either the CCME guidelines or the YCSR standards in any of the soils analysed for PAHs;
- Concentrations of petroleum hydrocarbons were elevated in two soil samples, which was attributed to recent rather than historical activities;
- One soil sample was found to contain concentrations of DDT at levels exceeding the Netherlands Soil Guidelines (guideline adopted for this project);
- ESG estimated that no more than 12 m² of contaminated soil required remediation at the site, and
- ESG recommended that this soil be excavated and placed in an appropriate landfill.

2.3.2 Lorimer & Associates/Hemmera Resource Consultants – Phase II Assessment, 1997

➤ **APPROACH**

Lorimer and Associates in association with Hemmera Envirochem (formerly Hemmera Resource Consultants) completed a Phase II assessment of the Brooks Brook Property in 1997. The Phase II was completed to further assess the presence and/or extent of groundwater and soil contamination at the site. The Phase II consisted of:

- A limited Phase I investigation,
- Limited test pitting and soil sampling around potential areas of concern,

- Limited test pitting and soil sampling around those areas identified in the ESG report as having concentrations of contaminants in excess of either the CMCS or the YCSR guideline in order to confirm the estimated volumes of contaminated soil to be remediated, and
- Installation of monitoring wells upgradient and downgradient of the two identified landfills.

➤ RESULTS FOR THE SUBJECT AREA— SOIL

Boreholes

Seven boreholes were advanced within the Subject Area. The locations of the boreholes and exceedances of the applicable standards and guidelines are indicated on **Figure 7**. Fifteen soil samples were collected and analysed for the following parameters, light extractable petroleum hydrocarbons (LEPH), heavy extractable petroleum hydrocarbons (HEPH), benzene, toluene, ethylbenzene, xylenes (BTEX), and volatile petroleum hydrocarbons (VPH).

For the purpose of this risk assessment the VPH, LEPH and HEPH results have been compared to the 2000 Canada Wide Standards (CWS) for Petroleum Hydrocarbons in soils and the YCSR RL/PL generic standards. The VPH, LEPH, and HEPH were compared to the corresponding 2000 CWS Tier 1 Fraction 1 (F1), Fraction 2 (F2), and Fraction 3 (F3) standards for Residential Eco Soil Contact for coarse-grained surface soils at depths greater than 1.5 meters below grade.

Two of the soil samples submitted for LEPH indicated concentrations in excess of the YCSR RL/PL standard and the F2 CWS. Both of the samples in exceedance of the above referenced standards for hydrocarbons were collected at depths greater than 1.5 meters below grade. All of the soil samples submitted and analyzed for HEPH and BTEX, indicated concentrations within the applicable YCSR standards and CCME guidelines. Of the fifteen soil samples analysed for VPH, only one sample indicated concentrations above the YCSR RL/IL standard while four of the samples exceeded the F1 CSW.

Test Pits

Six testpits were advanced within the Subject Area in the vicinity of Foundation AB. Two samples

collected from the test pits were analysed for metals; these samples indicated concentrations of metals within the applicable YCSR standards and/or CCME guidelines. One of the test pit soil samples was submitted for LEPH/HEPH, PAH and VPH analysis. The analysis indicated concentrations within the YCSR RL/PL standards, CCME RL/PL guidelines and the CWS. The test pit and soil sample locations are indicated on **Figure 7**. The Phase II did not indicate the depths at which the samples were collected within each test pit; however the deepest test pit was advanced to 2.2 meters.

Table 2. Summary of Soil Hydrocarbon Concentrations in the Subject Area (Lorimer & Associates and Hemmera Resource Consultants, 1997)

Parameter	Number Sampled	Concentration Range mg/kg (ppm)	2000 CWS Tier 1 Eco Soil Contact for Coarse Grained Surface Soils <1.5 m (mg/kg)	YCSR 1996 Standards (mg/kg)
VPH (F1)	16	<10 – 730	130 [4]	200 [1]
LEPH (F2)	16	<250 – 3400	450[2]	1000 [2]
HEPH (F3)	16	<250- 300	400 [0]	5000 [0]

[N] Indicates number of samples in exceedance of the guideline or standard

➤ RESULTS FOR THE SUBJECT AREA– GROUNDWATER

Four of the seven boreholes advanced in the subject area were completed as monitoring wells. The locations of the monitoring wells and exceedances are indicated on **Figure 8**. Groundwater samples were collected and analysed for one or more of; TEH, PAHs, and BTEX. Three groundwater samples were collected and submitted for analysis of TEH. The concentrations of TEH ranged from 1000 to 5000 µg/L. Currently, there is no YCSR aquatic life (AW) standard or CCME freshwater aquatic life (FAL) guideline for TEH. TEH consists of LEPH and HEPH fractions. Given the BC Environment standard of 500 µg/L LEPH, there is a strong probability that the LEPH fraction of the observed 1000 – 5000 µg/L TEH is in excess of the BC standard. Each of the four monitoring wells were analysed for concentrations of PAHs. One monitoring well indicated concentrations of naphthalene and phenanthrene in exceedance of the CCME FAL guidelines. A second well also indicated

concentrations in excess of the CCME FAL guideline for pyrene. Analysis of BTEX in the groundwater collected from the four monitoring wells indicated no concentrations in excess of the referenced standards and guidelines.

It should be noted that the CCME FAL guideline is intended for the application to ambient waters for protection of aquatic life, and is discussed in this document for comparison purposes only. The YCSR standards consider a 1:10 fold dilution factor from the groundwater well to a possible exposure of aquatic biota in a waterbody.

**Table 3. Summary of Hydrocarbon Concentrations in the Groundwater at the Subject Area
(Lorimer & Associates and Hemmera Resource Consultants, 1997)**

Parameter	Number of Samples	Concentration Range µg/L (ppm)	CCME FAL Guideline* (µg/L)	YCSR 1996 Standards (µg/L)
TEH	3	1000 – 5000	No Guideline	No Standard
Naphthalene	4	<0.3 – 4.6	1.1 [1]	10 [0]
Phenanthrene	4	<0.05 – 0.44	0.4 [1]	3 [0]
Pyrene	4	<0.02 – 0.04	0.025 [1]	0.2 [0]

[N] Indicates number of samples in exceedance of the guideline or standard

* ambient water quality guideline

➤ CONCLUSIONS AND RECOMMENDATIONS OF THE PHASE II FOR THE SUBJECT AREA

The test pitting and borehole drilling results were successful in determining the vertical extent of hydrocarbon contamination in the Subject Area, however horizontal closure on the hydrocarbon contamination was not obtained. The vertical extent of hydrocarbon contamination in the soil appears to be limited to the sand and gravel layer between 1.5 m and 2 m below grade. Recommendations of the Phase II report were to delineate the horizontal extent of hydrocarbon contamination within the Subject Area.

➤ RECOMMENDATIONS FOR THE ENTIRE BROOKS BROOK PROPERTY

Based on the Lorimer/Hemmera Resource Consultants, Phase II Assessment the recommendations for the entire site included:

- Remediation of the two landfills and annual monitoring of the groundwater wells in the vicinity of the landfills,
- Excavation of the pesticide contaminated soil south of the cook shack,
- Excavation of hydrocarbon contamination in the vicinity of foundation K, and
- Cover areas with localized metals contamination with 0.5 metres of clean backfill.

2.3.3 Hemmera Resource Consultants – Phase III Assessment, 1999

➤ APPROACH

Hemmera conducted a Phase III Assessment in 1998 to further investigate the extent of soil and groundwater contamination in several of the areas identified as areas of concern at the Brooks Brook Property. This assessment focused primarily on the Subject Area as well as the area in the vicinity of the new cook shack. The objectives of the Phase III were to:

- Complete step out boreholes and monitoring wells around existing boreholes and monitoring wells in the vicinity of the Foundation AB (Subject Area),
- Complete hand dug test pits in the vicinity of the new cook shack in order to delineate the extent of OCP and hydrocarbon contamination in this area, and
- Develop remedial options for the contaminated areas at the Brooks Brook Property.

➤ RESULTS FOR THE SUBJECT AREA – SOILS

In August 1998, 10 boreholes were advanced in the Subject Area. The locations of the boreholes and the soil exceedances have been included in **Figure 9**. Fifteen soil samples were submitted for the analysis of LEPH/HEPH, BTEX and VPH. Concentrations of LEPH in four of the soil samples were in exceedance of the YCSR RL/PL standard and the 2000 F2 CWS. HEPH in two of the samples was in exceedance of the F3 CWS. Analysis for VPH concentrations indicated three soil samples in exceedance of the YCSR RL/PL standard while VPH in four of the samples was in exceedance of the 2000 F1 CWS. All of the soil samples were within the applicable standards and guidelines for BTEX.

The results of the soil sampling program indicated the depth of hydrocarbon contamination ranged from 1.22 to 1.98 meters.

Table 4. Summary of Hydrocarbon Concentrations in Soil (Hemmera Resource Consultants, 1999)

Parameter	Number of Samples	Concentration Range mg/kg (ppm)	2000 CWS Tier 1 Eco Soil Contact <1.5 m Depth (mg/kg)	YCSR 1996 Standards (mg/kg)
VPH (F1)	15	<10 – 730	130 [4] 1.2-1.98 m	200 [3] 1.2-1.98 m
LEPH (F2)	15	<250 – 7400	450 [4] 1.2-1.98 m	1000 [4] 1.2-1.98 m
HEPH (F3)	15	<250- 690	400 [2] 1.2-1.98 m	1000 [0]

[N] Indicates number of samples in exceedance of the guideline or standard

(1.2-1.98 m) Indicates the depth range that the concentrations were observed in exceedance

➤ RESULTS FOR THE SUBJECT AREA – GROUNDWATER

Four of the boreholes the Subject Area were completed as monitoring wells. The monitoring wells advanced in 1998 have the prefix H98 associated with them. All eight of the existing and new monitoring wells in the Subject Area were sampled for concentrations of TEH, PAHs, and BTEX. The location of the monitoring wells and the groundwater exceedances are indicated in **Figure 10**.

Although there are no current standards for TEH, concentrations ranged from < 100 µg/L to 30,000 µg/L in the groundwater samples collected.

Three of the monitoring wells and one duplicate indicated concentrations of naphthalene in exceedance of the CCME FAL guideline; two of these wells were also in exceedance of the YCSR AW standard. The PAHs fluorene and phenanthrene were in excess of the CCME FAL guidelines in one or more of the monitoring wells sampled.

There were no concentrations of BTEX in exceedance of the above referenced standards in the groundwater samples collected.

Table 5. Summary of Hydrocarbon Concentrations in Groundwater (Hemmera Resource Consultants, 1999)

Parameter	Number of Samples	Concentration Range µg/L (ppb)	CCME FAL Guidelines * (µg/L)	YCSR 1996 Standards (µg/L)
TEH	8	<100 – 30,000	No Guideline	No Standard
Naphthalene	8	<0.3 – 130	1.1 [4]	10 [2]
Fluorene	8	<0.05 – 0.44	3 [1]	120 [0]
Phenanthrene	8	<0.05 – 1	0.4 [3]	3 [0]

[N] Indicates number of samples in exceedance of the guideline or standard

* ambient water quality guidelines

➤ CONCLUSIONS AND RECOMMENDATIONS FOR THE SUBJECT AREA

The results of the analysis of soil and groundwater samples indicated the presence of hydrocarbon contamination in over a fairly restricted area to the west of Brooks Brook. However, the distribution of monitoring wells in the Subject Area did not allow for closure on the groundwater plume. Hemmera recommended several approaches that INAC could take regarding the impacted soil and groundwater in the Subject Area. The approaches included, excavation, soil vapour extraction, pump and treat, enhanced in-situ chemical oxidation, or risk management. Hemmera indicated that a risk management approach would suggest the need to monitor the surface water quality in Brooks Brook for the presence of elevated concentrations of hydrocarbons. The absence of elevated concentrations would suggest that there would be no need for remediating the hydrocarbons in the soil and groundwater. Hemmera suggested that this approach would be the most cost effective and would require support by an ecological and human health risk assessment.

➤ CONCLUSIONS AND RECOMMENDATIONS FOR THE ENTIRE SITE

Several areas of concern at the Brooks Brook Property were further delineated and volumes of impacted soil were estimated for each of the areas of concern. Based on the volume and extent of the contamination, several remedial options were recommended for each area. A volume approximately 1437 m³ of soil was estimated to be impacted with OCP (organo chlorine pesticides). Due to the elevated concentrations in the vicinity of the cook shack, excavation of the soils was recommended. For a detailed description of the impacted areas delineated during the Phase III assessment, please

refer to the Phase III document.

2.3.4 Hemmera Envirochem – Detailed Site Investigation, 2001

➤ APPROACH

Hemmera Envirochem completed a Detailed Site Investigation (DSI) in the fall of 2001 in the vicinity of Foundation K (northwest of the Subject Area) and Foundation AB (Subject Area). The purpose of the DSI was to confirm that delineation in the area of Foundation K had been completed and to further delineate the hydrocarbon impacted soil and groundwater within the Subject Area. Part of the work program for the DSI included collecting site information required to complete a risk assessment for the Subject Area.

➤ RESULTS OF SOILS ANALYSIS – SUBJECT AREA

A total of eight boreholes were advanced within the subject area. Eleven soil samples were submitted for analysis of EPHs, BTEX and VPH. Six soil samples were also submitted for analysis of PAHs and three soil samples were submitted for analyses of metals.

The results indicated that LEPH concentrations exceeded the F2 CSW in four of the soil samples and in three of these samples LEPH also exceeded YCSR RL/PL standard. HEPH concentrations in four of the soil samples exceeded the F3 CWS and two of these samples also contained HEPH in exceedance of the YCSR RL/PL standard. All of the soil samples submitted for BTEX analysis indicated concentrations below the laboratory method detection limit. Of the eleven soil samples submitted for VPH analysis two samples were in exceedance of both the YCSR RL/PL standard and the F1 CSW. Naphthalene concentrations exceeded the CCME RL/PL guidelines in two of the soil samples submitted. The metals analysis indicated all three of the samples were within both the YCSR RL/PL and CCME RL/PL guidelines for all regulated metal constituents. A summary of the hydrocarbon concentrations is included in **Table 6** and the borehole locations and soil exceedances are indicated on **Figure 11**.

Table 6. Summary of Hydrocarbon Concentrations in Soil (Hemmera Envirochem, 2001)

Parameter	Number of Samples	Concentration Range mg/kg (ppm)	2000 CWS Tier 1 Eco Soil Contact <1.5 m depth (mg/kg)	YCSR 1996 Standards (mg/kg)
VPH (F1)	11	<100 – 270	130 [2] 0.8-2 m	200 [2] 0.8-2 m
LEPH (F2)	11	<250 - 8000	450 [4] 0.8-2.7 m	1000 [3] 0.8-2.7 m
HEPH (F3)	11	<150 – 1000	400 [4] 0.8-2.7 m	1000 [2] 0.8-2.7 m
Naphthalene	6	<0.05 – 0.8	0.6 [2] 2.3-2.7 m	5 [0]

[N] Indicates number of samples in exceedance of the guideline or standard

➤ RESULTS OF SURFICIAL SOIL SAMPLE ANALYSIS – SUBJECT AREA

Three surficial soil samples were collected from the area of the impacted soil plume and analysed for BTEX, VPH and EPHs. One of the samples was submitted for PAH analysis and one sample was submitted for metals analysis. The analytical results indicate concentrations of BTEX, VPH, EPH and PAHs were less than the analytical detection limits. In the sample submitted for metals analysis, all constituents were within the referenced soil standards and guidelines. The surface sample locations are indicated on **Figure 11**.

➤ RESULTS SOIL VAPOUR SURVEY – SUBJECT AREA

Soil vapour surveys were conducted at three locations within the Subject Area and one background location, as indicated on **Figure 11**. Vapour concentrations were determined within small piezometers installed below ground-level. The charcoal tubes from the soil vapour points were submitted for the analysis of BTEX and total hydrocarbons. The results of the soil vapour survey revealed non-detectable concentrations of benzene for all four survey points. Total hydrocarbon concentrations ranged from 0.341 mg/m³ to 0.973 mg/m³. The highest concentration was found in the background sample.

➤ RESULTS OF GROUNDWATER SAMPLES – SUBJECT AREA

Seven of the eight boreholes advanced during the DSI were completed as monitoring wells. The locations of the monitoring wells and groundwater exceedances are indicated on **Figure 12**. 13 of the 15 new and existing monitoring wells were sampled during the DSI. Thirteen groundwater samples and two duplicate samples were submitted for analysis of BTEX, VPH and EPHw. Eight

samples and two duplicates were submitted for analysis of PAHs, while two samples and two duplicates were submitted for metals analysis.

The results of the groundwater samples collected from the Subject Area indicated one sample with a toluene concentration in exceedance of the CCME FAL guideline. Naphthalene concentrations exceeded the YCSR AW standard and the CCME FAL guideline in one of the groundwater samples analysed. Pyrene concentrations exceeded the YCSR AW standard in one of the samples but it was within the CCME FAL guideline. There are no current LEPH/HEPH CCME FAL guidelines or YCSR AW standards for groundwater therefore the analytical results were compared to the BC CSR AW standard. Nine of the groundwater samples were in exceedance of the BC CSR AW standard for LEPH.

Iron concentrations exceeded the YCSR AW standard and the CCME FAL guideline in two of the monitoring wells. One of these wells was also in exceedance of the YCSR AW standard for manganese. The Hemmera DSI attributed the elevated iron and manganese concentrations to naturally occurring background concentrations. **Table 7** summarizes the range of concentrations observed for the parameters in exceedance of the above referenced standards. The locations of the monitoring wells and the exceedances are indicated on **Figure 13**.

Table 7. Summary Groundwater Results (Hemmera Envirochem Inc., 2001)

Parameter	Number of Samples	Concentration Range µg/L (ppb)	CCME FAL 1999 Guidelines * (µg/L)	YCSR AW 1996 Standards (µg/L)	BC CSR 1999 Standards (µg/L)
LEPH	15	<250 – 2500	No Guideline	No Standard	500 [9]
Toluene	10	<0.1 – 24	20 [1]	3000 [0]	3000 [0]
Naphthalene	10	<0.3 - 12	1.1 [1]	10 [1]	10 [1]
Pyrene	10	<0.1 – 0.2	0.025 [1]	0.2 [1]	0.2 [1]
Iron	10	2.46 – 13.1	0.3 [2]	3 [2]	Standard Removed
Manganese	4	0.6 – 1.59	No Guideline	1 [1]	Standard Removed

[N] Indicates number of samples in exceedance of the guideline or standard

* applicable to ambient water for protection of aquatic life

➤ RESULTS – SEDIMENT SAMPLES

Sediment samples were collected at three locations along the west bank of Brooks Brook, (up-gradient, adjacent to and down-gradient of the suspect soil contaminant plume. The sediment samples were analysed for BTEX, VPH and EPH. One sample was also analysed for PAHs and two samples were analysed for metals. All of the samples submitted for the analysis of hydrocarbon were below the laboratory method detection limit. The results of the metals analysis indicated concentrations within the YCSR RL/PL standards and the CCME Interim Freshwater Sediment Quality guidelines.

➤ RESULTS – SURFACE WATER SAMPLES

Surface water samples were collected from the west bank of Brooks Brook at locations upstream and downstream on the eastern border the impacted Subject Area. The samples were analysed for BTEX, VPHw, LEPHw, HEPHw, PAH and total metals.

The results indicated that concentrations of BTEX, VPHw, LEPHw, HEPHw and PAHs were less than the analytical detection limits in both samples tested. Total metal concentrations were within the CCME FAL guidelines for all regulated parameters. No differences were noted in the water quality of brook samples obtained up-gradient and down-gradient of the eastern portion of the Subject Area.

➤ SUMMARY – SUBJECT AREA

Based on the Detailed Site Investigation conducted at Brooks Brook, located in the Yukon, the following conclusions were made:

The assessment of soil contamination in excess of YCSR and/or CCME RL/PL standards/guidelines in the Subject Area has been completed to the extent possible without disturbance to the site area, including removal of trees and vegetation. Hydrocarbon contamination is present northeast, east and southeast of Foundation AB and extends to the west bank of Brooks Brook on the eastern portion of the Subject Area. Contamination was primarily identified in the sand and gravel fill above the silt and was detected at depths ranging from 1.0 m to 2.5 m below grade. **Figures 13 and 14** show the horizontal and vertical extent of impacted soil. A horizontal extent of 400 square meters of impacted

soil was estimated for the Subject Area. Sediment samples collected from the brook had non-detectable levels of the pollutants of concern.

Assessment of groundwater contamination in the Foundation AB area has been completed to the extent possible without disturbance and removal of trees and vegetation in order to install additional wells. Dissolved hydrocarbon contamination in excess of applicable YCSR standards and CCME guidelines was detected east and northeast of the Subject Area, between Foundation AB and the brook. **Figure 15** shows the estimated horizontal extent of hydrocarbon impacted groundwater.

➤ SUMMARY – FOUNDATION K

Minor soil contamination in the Foundation K area is identified by testpit TP6. An area of approximately 70 m² of soil is estimated to be impacted.

2.4 OVERALL SUMMARY OF PREVIOUS INVESTIGATIONS FOR THE SUBJECT AREA

2.4.1 Soil

The previous reports have delineated the vertical and horizontal extent of the hydrocarbon impacted soil on the eastern portion of the Subject Area. **Figures 13, 14A, and 14B** show the extent of impacted soil in this area. The impacted soil ranges from 0.8 m to 2.0 m below grade. The previous reports indicate surficial soils are impacted with metals and are localized around the perimeter of Foundation AB. A summary of the potential contaminants of concern (PCOC) is presented in **Table 8**.

2.4.2 Groundwater

Groundwater appears to be impacted with hydrocarbons to the east of Foundation AB (**Figure 15**). The previous reports indicated the net groundwater flow to be in a west to south west direction. The groundwater in this direction has not been fully delineated due to dense tree growth preventing access of the drill rig. At the request of the client, the trees were not removed to gain access.

Concentrations in excess of the YCSR AW standards and the CCME FAL guidelines for manganese

and iron were observed in the groundwater within the Subject Area.

Table 8 summarizes the contaminants found in exceedance of the standards and guidelines during the previous investigations. A statistical summary of the contaminants of concern in soil has been included in **Table I** and a summary of groundwater contaminants has been included in **Table II**. In addition, **Table III** contains a summary of the soil vapour concentrations collected during the Hemmera DSI. The risk assessment will be based on these findings.

Table 8. Potential Contaminants of Concern

Chemical	Soil	Groundwater
Cadmium	✓	
Chromium	✓	
Copper	✓	
Iron		✓
Lead	✓	
Manganese		✓
Zinc	✓	
Naphthalene	✓	✓
Fluorene		✓
Phenanthrene		✓
Pyrene		✓
Toluene		✓
VPH	✓	✓
LEPH	✓	✓
HEPH	✓	✓
TEH		✓

2.5 OTHER REPORTS FOR THE BROOKS BROOK PROPERTY

2.5.1 Hemmera Resource Consultants – OCP Remediation, 2000

➤ APPROACH

Hemmera Resource Consultants completed the supervision of the remediation of the organochlorine pesticide (OCP) contaminated soils at the Brooks Brook Property. Hemmera's objectives were to provide technical supervision to the remediation contractor for such items as delineation of excavation extent, confirmation sampling, and general contractor's procedures. The scope of work for the project was the remediation of OCP contaminated soil in the vicinity of the new cook shack through excavation and off-site removal.

An area of approximately 3900 m² was removed from the Site and transported by truck to an appropriate landfill in West Edmonton, Alberta. During the excavation, confirmation samples were collected on a 5 metre grid over the base of the excavation area and tested in the field using an immuno assay test kit. A total of 351 samples were tested in the field using the immuno assay kit. In order to provide laboratory confirmation of remediation of OCP contaminated soil to concentrations less than 0.7 ppm DDT, 157 samples were analysed at Cantest Laboratories of Vancouver for concentrations of OCPs. The results of the analysis indicated remediation of the OCP contaminated soil at the Brooks Brook site was completed such that concentrations of DDT are less than 0.7 ppm.

3.0 DESCRIPTION OF RISK ASSESSMENT PROCESS

3.1 GENERAL APPROACH OF A RISK ASSESSMENT

The information summarized in **Section 2** indicates that the Subject Area soil and groundwater contain chemical parameters that are at concentrations in excess of the YCSR, CCME and/or the CWS. INAC requested a risk assessment to determine whether the impacted soil and groundwater can be managed on-site to keep the risks to human health and the ecosystem at a minimum.

A risk assessment is a logical process, whereby all available scientific information is brought together, to produce a description of the nature and magnitude of the potential risk associated with exposure to contamination in a given environmental scenario.

As per the recognized framework procedure, a risk assessment must include:

- Characterization of the chemicals of concern,
- *Exposure assessment*: Based on a given scenario for the subject property, including, the definition of receptors, dose in means of exposure i.e. inhalation, ingestion, skin contact, timing, and duration under which the receptors are exposed to the identified chemicals of concern,
- *Toxicity assessment*: An evaluation of the types of toxicity that the chemicals of concern can produce as well as an evaluation of effects of the identified chemicals of concern,
- *Risk characterization*: An estimation of the risk and uncertainty of the risks based on a comparison of the exposure assessment with information on the toxicity of the chemicals of concern.

3.1.1 Description of Development Scenarios

At this time there are no plans to change the current land use. It is the intention of INAC to continue to use the Brooks Brook Property as a native meeting location and occasional camping and picnicking area. Based on the current land use this risk assessment will assume the following

physical features:

- No excavations or movement of soil are planned.
- The area is only used for occasional recreational purposes and the only facilities on site are a picnic table and garbage can located along the west bank of the brook.
- The only permanent structure remaining on the subject site is the foundation for the former gas powered generator.
- Approximately 50% of the area is covered by vegetation and there is no intent to remove the vegetation.
- Poplar and alder trees are present along the banks of the brook and provide a means for stabilization of the banks.

This risk assessment would not be applicable to any other land use scenario.

3.1.2 Scope of Risk Assessment

Section 2 describes the impacted soil and groundwater within the Subject Area. The previous reports indicated that the foundation within the Subject Area is the location of a former gas generator. It is possible that the gas generator was the source of the hydrocarbon contamination; however this is only speculation. The purpose of the risk assessment is to evaluate whether the impacted soils and groundwater actually constitute any potential risk to human health or the ecosystem, and if so, the risk assessment could be used to develop *in situ* risk management procedures.

Subsequent to a review of the previous soil and groundwater studies (summarized in **Section 2**), and based on the continuation of the current land use. The risk assessment will evaluate the following:

1. The potential impact to the public which may use the Subject Area for recreational purposes (**Section 4**), in particular members of the public (children) who may be in direct contact with the surface soils, and who may inhale hydrocarbon vapours from the hydrocarbon impacted soil and groundwater, and
2. The potential impact of the soil and groundwater on the wildlife, vegetation, and invertebrates (**Section 5**).

4.0 HUMAN HEALTH RISK ASSESSMENT

The human health risk assessment is for the Subject Area identified in **Figure A**. The approach used for the human health risk assessment follows the BC Environment, Health Canada and U.S. EPA Guidelines.

4.1 POTENTIAL CONTAMINANTS OF CONCERN

Section 1 indicates that metals at concentrations in excess of the standards are found in surface soils in the vicinity of Foundation AB, and hydrocarbons are found in soil at a depth of 1 meter or more below grade. In addition, hydrocarbons are also found in excess of the applicable guidelines and standards in groundwater at the Subject Area. This section describes the selection process for the contaminants of concern.

4.1.1 Selection of Contaminants of Concern

For the purpose of this risk assessment, contaminants of concern are defined as those for which the concentration representing the 95th percentile (the value in the range of the data set in which 95 percent of the values lie below) of the samples analysed exceeds the applicable YCSR generic or human health protection standards and/or the applicable CCME guidelines, or if the maximum observed concentration is greater than two times the standards. These criteria have been accepted by the BC MWLAP risk assessment group. The soil standards for comparison in the human health risk assessment are those for the protection of human health (intake of contaminated soil). The impact of groundwater on human health is not considered for the Subject Area since there are no nearby drinking water wells.

A statistical summary of the contaminants of concern in soil is presented in **Table IV**. In addition, a summary of total hydrocarbon vapour concentrations is presented in **Table III**.

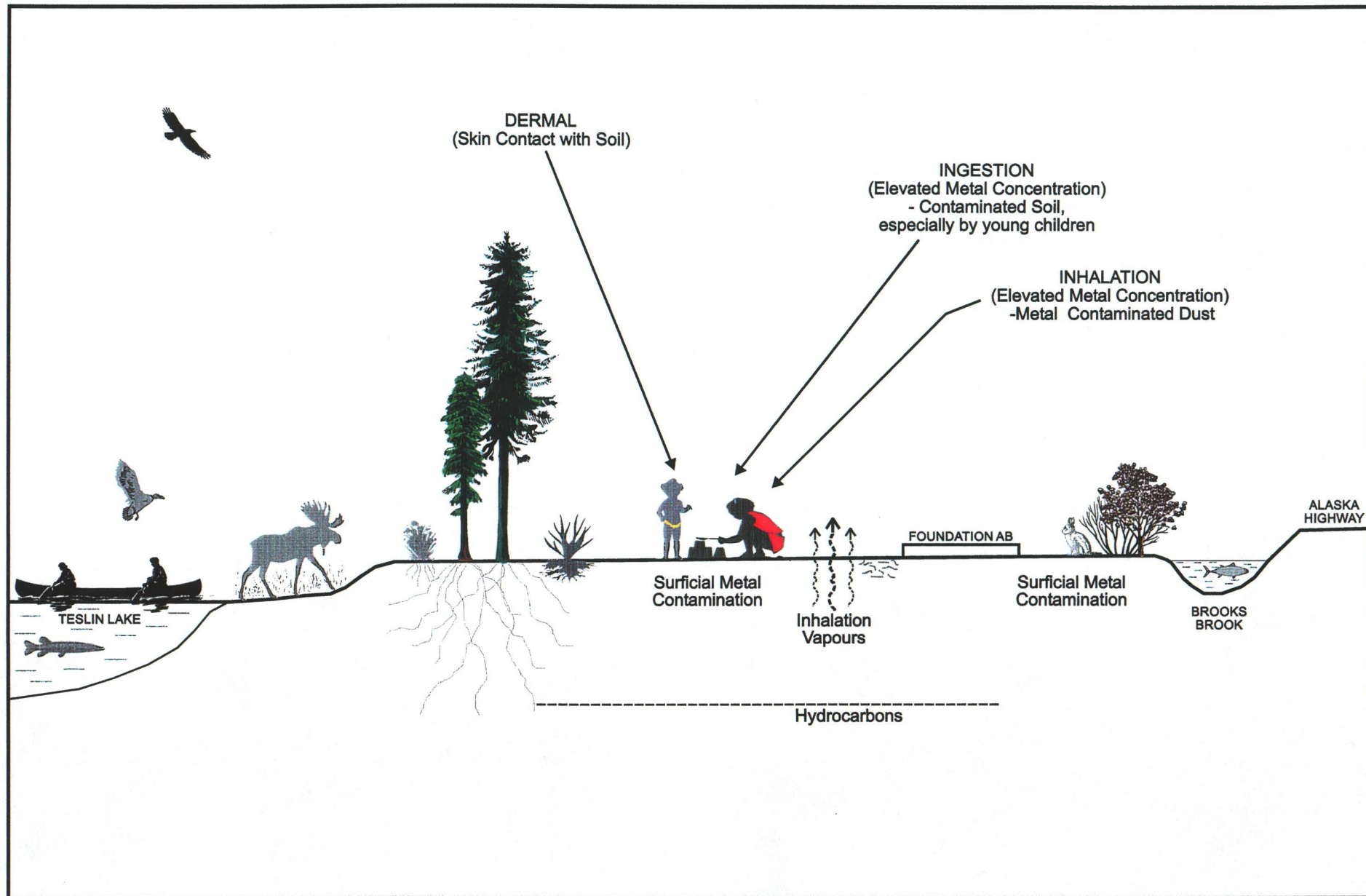


FIGURE A: HUMAN HEALTH EXPOSURE PATHWAY DIAGRAM

4.1.1.1 CADMIUM

The sample location where cadmium exceeded the applicable human health standards is presented on **Figure 6**.

Of the 15 soil samples analyzed for cadmium, none were in exceedance of the YCSR soil standard to protect groundwater flow to surface water used by aquatic life. One sample was in exceedance of the CCME RL/PL guideline of 10 mg/kg. The concentration range was 0.125 to 11.3 mg/kg, with a 95th percentile of 8.43 mg/kg.

➤ USE OF CADMIUM

A large part of the cadmium produced is used in electroplating metals such as iron and steel in the automotive, aircraft and marine equipment industries. It is used as a protective agent against corrosion. Cadmium is also used in plastics, paints, alloys and in the nuclear industry (Sullivan and Krieger 1992).

➤ BACKGROUND LEVELS

Cadmium is found in the rare mineral elements greenockite and otavite. Both forms are found in zinc- and zinc-lead-rich ores (Sullivan and Krieger, 1992). The cadmium content of normal soils is low except in the vicinity of cadmium-bearing deposits (National Research Council Canada, 1981).

➤ SOURCES OF CONTAMINATION

Cadmium contamination is widely distributed in soil, groundwater and air and has become widespread through mining, refining and smelting operations. Other sources include combustion of fossil fuels, municipal waste incineration and agricultural practices of using phosphate fertilizers (Sullivan and Krieger, 1992).

The source of cadmium at this site is speculated to be associated with pipes containing cadmium or a result of emissions from the generator. ESG found pipes near Foundation AB that were assumed to be part of the former gas-operated generator system at this location.

➤ CHEMISTRY

Cadmium is a soft-white, blue tinged, lustrous metal, seldom found as a pure mineral. It occurs in nature a divalent cation (Cd^{2+}). The elemental form of cadmium is insoluble in water, whereas the solubility of cadmium salts varies from 0.00013 to 140 g/100mL (Lide, 1992).

➤ HEALTH IMPACT

Cadmium is a very toxic heavy metal. Human exposure to cadmium has been and continues to be a major concern. Cadmium has been associated with hypertension and carcinogenesis. Acute toxicity from cadmium can occur from either ingestion or inhalation. Acute cadmium exposure is typically most toxic to the tissue to which it is initially exposed i.e. the lung (from inhalation) and gastrointestinal tract (ingestion). Typical symptoms of oral intoxication with cadmium include nausea, vomiting, abdominal cramping and pain, diarrhea, increased salivation, tenesmus and choking (Sullivan and Krieger, 1992). Chronic toxic (non-carcinogenic) effects of cadmium are associated with the pulmonary, kidneys, and skeletal system.

➤ SELECTION

Cadmium in excess of the CCME RL/PL guideline was found in only one of ten soil samples. The 95th percentile concentration was less than the guideline. None of the samples were in excess of the YCSR standard for human health protection. As a result, cadmium is not selected as a chemical of concern.

4.1.1.2 CHROMIUM

The sample locations where chromium concentrations exceeded the applicable human health standards are presented on **Figure 6**.

Of the 15 soil samples analyzed for chromium, one was in exceedance of the YCSR standards of 150 mg/kg for the protection of human health. In addition, 3 of the samples were in exceedance of the generic CCME RL/PL guideline of 64 mg/kg. The concentration range was 19 to 263 mg/kg, with a 95th percentile of 151 mg/kg.

➤ **USE OF CHROMIUM**

Chromium is used for pigments, metal surface plating, leather tanning, textile production, photoic processes, and catalyst production (Geller, 1992).

➤ **BACKGROUND LEVELS**

Background chromium concentrations in Canadian soils are reported to range from 20 to 125 mg/kg. In American soils, a range of 1 to 1500 mg/kg has been reported (NRCC, 1976). 96% of samples from Canadian water systems had dissolved chromium concentrations less than 10 µg/L (ppb) and 99% of the samples had concentrations less than 25 µg/L (NRCC, 1976). Chromium concentrations in food stuffs are typically less than 1 mg/kg fresh weight (NRCC, 1976).

➤ **SOURCES OF CONTAMINATION**

The major sources of chromium emissions into the atmosphere are from ferrochrome production in electric furnaces, refractory processing and coal combustion (NRCC, 1976). Soil and water contamination could potentially originate from all processes where chromium or chromium-containing minerals are used.

The source of chromium contamination at the Subject Area is unknown.

➤ **CHEMISTRY**

Chromium makes up 0.1 to 0.3 ppm of the earth's crust and is primarily associated with ultramafic igneous sedimentary iron ore and phosphorite rock types. Chromium is usually associated with other elements. As well as in metallic form, chromium can exist in oxidation states from +2 to +6, but is most common in the +3 and +6 valences. Chromium III (Cr+3) is the most common form in nature. Chromium VI (Cr+6) rarely occurs in nature and its presence is usually a result of anthropogenic production (Goyer, 1991).

Chromium in biological material is almost always in the trivalent form. Chromium III is also an essential trace nutrient by acting as a cofactor for insulin receptors (Goyer 1991).

➤ **HEALTH IMPACTS**

The most significant adverse health impacts are caused by chromium VI. Chromium is considered an

irritant. Acute dermal exposure may cause hypersensitization and lead to allergic contact dermatitis. Ingested chromium in acute concentrations is likely to cause severe erosive injury in the gastrointestinal tract. Renal failure may result from high concentrations of systemic chromium. Acute inhalation of chromium VI has been linked with lung cancer (Geller, 1992). However chromium VI is unlikely to be present at the site because of its reactivity, the less toxic form of chromium (chromium III) is more likely to be present.

➤ **SELECTION**

Chromium has been selected for the risk assessment as a chemical of concern based on the soil concentrations whereby the 95th percentile exceeds the YCSR standard for protection of human health and the CCME RL/PL guideline.

4.1.1.3 *COPPER*

The sample locations where elevated concentrations of copper were observed is presented on **Figure 6**.

Of the 15 soil samples analysed, none contained copper concentrations in exceedance of the YCSR standard of 15,000 mg/kg for intake of contaminated soil. Copper in three of the samples exceeded the CCME RL/PL guideline of 63 mg/kg. The concentrations ranged from 15 mg/kg to 3000 mg/kg with a 95th percentile of 984 mg/kg.

➤ **USE OF COPPER**

Copper is widely used in the manufacturing of textiles, antifouling paints, electrical conductors, plumbing fixtures and pipes, coins and cooking utensils. Copper compounds are found as an active ingredient in wood preservatives, pesticides, and fungicides. Copper sulphate may be used as a micronutrient in agricultural fertilizers (CCME 1999).

➤ **BACKGROUND LEVELS**

The average concentration of copper in Canadian soil is estimated to be 20 mg/kg with a range between 2 and 100 mg/kg (BC MELP, 1992).

➤ SOURCES OF CONTAMINATION

The source of copper at the site is not known, and may be related to the use of copper piping or paints.

➤ CHEMISTRY

Copper is a metal that occurs in four oxidation states (Cu , Cu^{1+} , Cu^{2+} and Cu^{3+}) with Cu^{2+} being most common (CCME, 1997). Copper occurs in a wide range of mineral deposit types as both primary and secondary mineral. Elemental copper metal does occur in nature, but most copper occurs in the form of sulphide minerals.

➤ HEALTH IMPACT

Copper is an essential element required for good health and proper functioning of biological processes (CCME 1999). However over exposure and deficiency can have serious adverse effects. Estimated total daily copper intake for Canadians ranges from about 22 to 74 $\mu\text{g}/\text{kg}$. Copper is required for many enzymatic reactions. However, doses as low as 0.12 mg/kg body weight (bw) per day may induce nausea and vomiting in some individuals. Acute copper poisoning in humans is rare because of the strong emetic properties of the metal. However, the ingestion of gram quantities of inorganic copper salts is usually fatal in humans and there is considerable variability in individual sensitivities (lethal dose ranges from 50 – 500 mg/kg bw per day (CCME, 1997)). Chronic oral exposure resulting in adverse health effects is rare; however young children, particularly those under 12 months of age have a greater risk due to their limited ability to excrete metals (CCME, 1999). Many factors may affect the toxic potential of copper, including chemical form, interaction with other micro-elements and other components of the diet, health and nutrient status of individuals.

➤ SELECTION

Copper has been selected for the risk assessment as a chemical of concern based on the soil concentrations in exceedance of the CCME RL/PL guidelines. It is noted that the YCSR standard for human health protection is based solely on ingestion, and the risk assessment will enable a more complete evaluation of human health impacts.

4.1.1.4 LEAD

The sample locations where lead exceeded the applicable human health standards are present in **Figure 6**.

Of the 15 soil samples analysed, one contained lead concentrations in exceedance of the YCSR standard for the intake of contaminated soil of 500 mg/kg and three of the samples exceeded the CCME RL/PL guideline of 140 mg/kg. The concentrations ranged from 5 mg/kg to 780 mg/kg with a 95th percentile of 546 mg/kg.

➤ USE OF LEAD

In Canada, the primary use of lead is in the production of acid storage batteries. Other uses include ammunition, radiation shielding, glassware and solders.

➤ BACKGROUND LEVELS

The average lead concentration in the continental crust is approximately 12 mg/kg, and it is estimated Canadian estuarine and coastal sediments contain an average of approximately 20 mg/kg (Garret, 1985). Levels from 24 to 2,000 mg/kg were reported in the Victoria Inner Harbour and 4 to 950 mg/kg were reported in the Brunett River basin (Garret, 1985.)

➤ SOURCE OF CONTAMINATION

Weathering of sulphide ores, mining and smelting, and municipal sewage are sources of lead contamination. It is estimated that anthropogenic inputs of lead to oceans are approximately 10 fold greater than inputs from weathering. (CCME, 1995). Possible sources include solder for piping and lubricating oil.

The source of lead contamination within the Subject Area is unknown; however it appears to be in a fairly localized area around the perimeter of Foundation AB.

➤ CHEMISTRY

Galena (PbS) is the most common lead mineral (CCME, 1995). The divalent form, Pb(II), is the stable form in most of the environment. The speciation of lead as carbonates and hydroxides is

complex and dependent upon factors such as pH, dissolved oxygen, and the presence of co-existing organic and inorganic compounds. Many lead compounds such as lead sulphides and carbonates are insoluble. Free lead ions also readily associate with organic matter, hydrous oxides and clays (CCME, 1995).

➤ HEALTH IMPACTS

Lead can affect most of the body's biological systems, including the blood, kidneys, gastrointestinal tract, nervous system and reproductive system. The potential impacts of lead on human health are of concern and have received considerable attention by regulatory agencies.

➤ SELECTION

Lead has been selected for the risk assessment as a chemical of concern based on the soil concentrations in exceedance of the YCSR intake of contaminated soil standards and the CCME RL/PL guidelines.

4.1.1.5 ZINC

The sample locations where elevated concentrations were observed is presented on **Figure 6**.

Of the 15 soil samples analysed, none contained zinc concentrations in exceedance of the YCSR standard of 10,000 mg/kg for the protection of human health and five of the samples exceeded the CCME RL/PL guideline of 200 mg/kg. The concentrations ranged from 23 mg/kg to 2600 mg/kg with a 95th percentile of 1284 mg/kg.

➤ USE OF ZINC

Zinc is used for galvanizing products for automobiles and structural components in the construction industry (CCME, 1999). It is also used in the manufacture of brass and bronze for plumbing, heating and cooling system components. In addition, zinc is used in the production of zinc oxides, chemicals and zinc dust. Zinc oxide is important in the manufacturing of tires and other rubber products. Zinc powder is also used in batteries (Environment Canada, 1996).

➤ BACKGROUND LEVELS

Zinc constitutes about 0.02 percent of the earth's crust and is widely distributed (Sullivan and Krieger, 1992). The mean concentration of zinc in soils in Canada is 74 mg/kg (McKeague and Wolyntz, 1980).

➤ SOURCES OF CONTAMINATION

Sources of anthropogenic zinc in the environment include electroplaters, smelting and ore processors, mine drainage, domestic and industrial sewage, combustion of solid wastes and fossil fuels, road surface runoff, corrosion of zinc alloy and galvanized surfaces, and erosion of agricultural soils (Environment Canada, 1996).

Source of zinc at this site may be associated with fuel use or use of galvanized siding or culverts.

➤ CHEMISTRY

Zinc is divalent and tends to strongly react with organic and inorganic compounds. Zinc forms stable combinations with many organic substances including humic and fulvic acids and a wide range of biochemical compounds (CCME 1999). Metallic zinc is insoluble, while the solubilities of different zinc compounds range from highly soluble to insoluble (Environment Canada, 1996).

➤ HEALTH IMPACT

Zinc is an essential element required for good health and proper functioning of biological processes. It is a known constituent of over 2000 metalloenzymes and other metabolic compounds (CCME 1999). At high concentrations, zinc may be toxic. Acute symptoms of oral zinc poisoning are primarily gastrointestinal. Symptoms include nausea, vomiting, abdominal pain, diarrhea, and hematemesis. Fever is also reported. The primary organs that are impacted by elevated concentrations of zinc include skin, eyes, respiratory, renal, neurologic and hematologic (chronic ingestion). Other than corneal and lens opacities after ocular zinc salt injury and anaemia from zinc-induced copper deficiency, there are no known chronic effects of zinc toxicity (Sullivan and Krieger, 1992).

➤ SELECTION

Elevated concentrations of zinc were observed in the soil samples collected from around the

perimeter of Foundation AB. Based on the soil concentrations in exceedance of the CCME RL/PL guidelines and the potential toxicological effects of zinc, this metal has been selected as a chemical of concern for the risk assessment.

4.1.1.6 HYDROCARBONS IN SOIL

The Canada Wide Standards for petroleum hydrocarbons consider petroleum hydrocarbons in four fractions (F1 through F4). The fractions F1 through F3 roughly correlate with territorial parameters VPH, LEPH and HEPH. **Table 9** presents the fractions and examples of some associated sources.

Table 9. Carbon Ranges and Sources of Petroleum Hydrocarbons (CWS, 2000)

Fraction	Carbon Range	Source
VPH F1	C ₆ -C ₁₀ C ₆ -C ₁₀	Gasoline/Diesel
LEPH F2	C ₁₀ -C ₁₉ C ₁₀ -C ₁₆	Diesel/Motor Oil (Lubricants)
HEPH F3	C ₁₉ -C ₃₂ C ₁₆ -C ₃₄	Lubricants/Crude Oil
F4	>C ₃₄	Crude Oil/Asphalt

4.1.1.7 VOLATILE PETROLEUM HYDROCARBONS (VPH OR F1)

VPH consists of volatile compounds such as pentane and hexane, which are normally found in fuels such as gasoline. As the compounds are volatile, their concentrations at the Subject Area would be decreasing rapidly from the time that the contamination occurred.

➤ SOIL SUMMARY

Analysis of 44 samples at the site showed concentration ranges of VPH from <100 to 730 mg/kg, versus the Canada Wide Standards (CWS) of 15,000 mg/kg (for ingestion) for VPH (F1) in coarse-grained surface soils. CWS indicates that a standard for dermal contact would be greater than 30,000 mg/kg. There are no structures on the Subject Area, therefore the CWS for inhalation is not applicable. Six VPH samples were in excess of the YCSR generic standard of 200 mg/kg. It is noted that a generic standard is intended to protect human health and the environment, and the scientific basis for the generic standards is weak compared to the CWS and the YCSR matrix standards.

➤ **USE OF VPHs**

VPHs are components of gasoline, solvents, and to some degree jet fuel and diesel.

➤ **BACKGROUND LEVELS**

Normally there would not be background levels of VPHs in a natural soil.

➤ **SOURCE OF CONTAMINATION**

Fuel use at the Subject Area is likely the source of contamination.

➤ **CHEMISTRY**

VPHs are by their name volatile and evaporation is a major fate, along with biodegradation (EPA, 1978).

➤ **HEALTH IMPACTS**

Animal studies indicate effects on blood chemistry after exposure to high concentrations of VPHs. Workplace occupational studies indicate inhalation of high concentrations of VPHs may effect the central nervous system (CWS, 2001).

➤ **SELECTION**

Providing there is a probability of human exposure to VPHs (**Section 4.2.6** of this report), VPHs are selected as a potential chemical of concern. Although the CWS suggests the observed concentrations are much lower than the predicted affect levels, the YCSR is exceeded. The risk assessment, if necessary may have to address the possible risk of the VPH concentrations in excess of the YCSR. It is intended that the vapour monitoring program at the Subject Area would provide a definitive means of evaluating exposure of VPHs to the public.

4.1.1.8 LIGHT EXTRACTABLE PETROLEUM HYDROCARBONS (LEPHs OR F2)

➤ **SOIL SUMMARY**

LEPHs consist of components with more than 10 carbons and less than 16 carbons. Aliphatics such as decane and substituted PAHs are within the LEPH range.

Analysis of 44 samples at the site showed an LEPH range of 125 to 8,000 mg/kg with a 95th

percentile of 5830 mg/kg, versus a CWS of 8000 mg/kg for ingestion of coarse grained soils. The CWS for inhalation is based on exposure of individuals who would live over the contaminated area, and therefore it is not applicable to this site. A total of 9 samples were in excess of the YCSR generic standard of 1000 mg/kg.

➤ **USE OF LEPHS**

LEPHs are components of fuels such as diesel and jet fuel. LEPHs are also found in lubrication oils.

➤ **BACKGROUND LEVELS**

Compounds in the LEPH range may include natural and organic compound such as those found in peat moss and trees. These may be reported as part of the LEPH concentrations but are considered an interference.

➤ **SOURCE OF CONTAMINATION**

The use of fuel at the Subject Area is likely the source of contamination.

➤ **CHEMISTRY**

LEPHs are normally biodegradable in soil with biodegradation rate dependent upon temperature, oxygen availability, nutrient levels and water levels.

➤ **HEALTH IMPACTS**

Laboratory Studies have exposed animals to elevated levels of LEPH compounds resulting in effects to the liver and blood chemistry (CWS 2000).

➤ **SELECTION**

Providing there is a probability of human exposure to LEPHs (Section 4.2.4 of this report), LEPHs are selected as potential contaminants of concern. Although the observed concentrations are within the 2000 CWS standards for protection of human health, the YCSR is exceeded.

4.1.1.9 *HEAVY EXTRACTABLE PETROLEUM HYDROCARBONS (HEPH OR F3)*

➤ **SOIL SUMMARY**

A range of 125 to 4500 mg/kg petroleum hydrocarbons was reported in the Subject Area, versus the

CWS of 18,000 mg/kg for soil ingestion and a value in excess of 30,000 mg/kg for dermal contact. The YCSR generic standard for HEPH is 1000 mg/kg for urban parks and residential properties. The 95th percentile is 905 mg/kg.

➤ **USE OF HEPHS**

HEPHs are found in lubricating oils and fuels such as Bunker oil and crude oil.

➤ **BACKGROUND LEVELS**

Normally there would be no background levels of HEPH. Extracts from plants may contribute to HEPH levels reported in soil. These would be considered an interference and not part of the HEPH concentration.

➤ **SOURCE OF CONTAMINATION**

Fuel use in the Subject Area and machinery maintenance may be the sources at the Subject Area.

➤ **CHEMISTRY**

HEPH will biodegrade in the environment, however at a rate slower than that for LEPH. The components of HEPH would determine the rate of biodegradation as well as oxygen, bacteria, nutrients and water concentrations in the soil.

➤ **HEALTH IMPACT**

Tests on laboratory animals suggest that frequent exposure to HEPH may affect the functions of the liver and the kidney (CWS 2000).

➤ **SELECTION**

Based on the concentrations of HEPH below the CWS and given that the 95th percentile of the HEPH concentrations is less than the YCSR, HEPH is not selected as a chemical of concern for the human health risk assessment.

4.1.1.10 *NAPHTHALENE*

➤ **SOIL SUMMARY**

The soil sample locations where elevated concentrations were observed is presented on **Figure 13**.

Of the 7 soil samples analysed, none contained naphthalene concentrations in exceedance of the YCSR RL/PL generic standard of 5 mg/kg. Naphthalene in 2 of the samples exceeded the CCME RL/PL guideline of 0.6 mg/kg. The concentrations ranged from 0.025 mg/kg to 0.8 mg/kg with a 95th percentile of 0.77 mg/kg.

➤ USE OF NAPHTHALENE

Naphthalene is used as a moth repellent and is also used in dye manufacturing. It is the most abundant component of coal tar creosote, which is used as a wood preservative, disinfectant and insecticide (CCME, 1999). Naphthalene is also found in gasoline and fuels.

➤ SOURCES OF CONTAMINATION

Anthropogenic sources of naphthalene include emissions from aluminum smelters, steel mills, coal fire generating plants, petroleum refineries, creosote wood preserving facilities, municipal incinerators and leachate from municipal/industrial landfill sites (CCME, 1999). Naphthalene is also released indirectly from creosote-treated telephone poles and railway ties, petroleum spills, waste crank case oil, cigarette smoke, and vehicle exhaust (CCME, 1999). The presence of naphthalene in soil at the Subject Area is likely related to historical use of diesel.

➤ CHEMISTRY

Naphthalene has a chemical formula of C₁₀H₈, it is a white crystalline solid. It is the simplest structured PAH. The persistence of naphthalene in the soil profile increases with increasing depth, because of the decreased volatilization and microbial transformation processes at depth (CCME, 1999).

➤ HEALTH IMPACT

Naphthalene is known to cause acute red blood cell hemolysis and it is also an irritant to the mucous membranes and the eyes (Sullivan and Krieger, 1992). Clinical intoxication syndrome includes eye irritation, headache, confusion, excitement, diaphoresis, nausea, and vomiting. These symptoms can progress to hemolytic anemia with jaundice and acute failure from myoglobinuria (Sullivan and Krieger, 1992). Naphthalene vapour causes mucous membrane and eye irritation at 5 ppm.

➤ SELECTION

Elevated concentrations of naphthalene were observed in the soil and groundwater samples collected within the Subject Area. None exceeded the YCSR and 2 of the 7 samples exceeded the CCME guidelines. Based on the toxicological effects of naphthalene, this chemical has been selected as a potential chemical of concern for the human health risk assessment.

4.1.2 Summary of Selected Potential Chemical of Concern within the Subject Area

Based on previous sampling and analysis of soil within the Subject Area, the following table (Table 10) summarizes the chemicals selected for evaluation of potential recreational human health risks.

Table 10. Summary of Selected Chemicals for the Human Health Risk Assessment

Selected Chemicals For Risk Assessment	Rational
Chromium	3 soil samples > CCME RL/PL soil guideline 1 soil sample > YCSR soil standard 95 th percentile > YCSR and CCME RL/PL soil guideline Sensitive acute and chronic effects
Copper	3 soil samples > CCME RL/PL soil guideline 95 th percentile > CCME RL/PL soil guideline Sensitive acute and chronic effects
Lead	1 soil sample > YCSR soil standard 3 soil samples > CCME RL/PL soil guideline 95 th percentile > YCSR and CCME RL/PL soil guideline Sensitive acute and chronic effects
Zinc	5 soil samples > CCME RL/PL soil guideline 95 th percentile > CCME RL/PL soil guideline Sensitive acute and chronic effects
VPH (F1)	6 of soil samples > YCSR standard 95 th percentile > YCSR standard
LEPH (F2)	9 soil samples > YCSR standard 95 th percentile > CWS and YCSR standard
Naphthalene	2 soil samples > CCME RL/PL guideline 95 th percentile > CCME RL/PL soil standard

4.2 EXPOSURE ASSESSMENT – HUMAN HEALTH

4.2.1 Type of Risk Characterization

The deterministic approach is used for the risk assessment. The deterministic approach provides a conservative risk estimate using statistically defined contaminant concentrations and conservative point estimates for the associated exposure and uptake variables.

4.2.2 Characterization of Exposure Setting

This human health risk assessment is conducted on the basis of the following exposure settings:

- Recreational/Parkland Land
 - Although the impacted soil and groundwater is not uniformly distributed throughout the Subject Area, a worst-case scenario will be assumed for the risk assessment. It will be assumed that persons using the Subject Area in the summer months for recreational purposes would confine their activities to the area with impacted soil and groundwater.

4.2.3 Identification of Potentially Exposed Population

The following human populations are unlikely to be exposed to contamination at the Subject Area:

- Neighbouring residences – The nearest domestic dwelling is approximately 500 m away from the Subject Site.
- Neighbouring workers – The neighbouring properties are undeveloped and will likely remain undeveloped.
- Construction workers – There are no known plans for development or any excavation activities in the Subject Area.

The receptors selected for evaluation of risk associated with the surficial soil contamination on the Subject Site are limited to the general public, specifically incidental exposure to children whom may be playing in the area of the impacted soil.

4.2.4 Identification of Exposure Routes

A generalized exposure pathway flowchart shown in **Figure A** is used to identify human exposure pathways of significance to this study. **Table 11** summarizes the exposure pathways selected for the risk assessment. The following summarizes the evaluation of possible exposure pathways of potential human health impacts in the Subject Area:

- Ingestion:
 - **Surficial Metals** – Ingestion of the metals impacted surficial soils by children in the case of improper hygiene prior to eating and ingestion of berries growing in the vicinity of the metals impacted soils.
 - **Hydrocarbons in Soil** – There is no logical pathway for ingestion of the hydrocarbon impacted soils which are noted to be at greater than 1 meter below grade.
 - **Hydrocarbons in Groundwater** – There are no groundwater wells in the vicinity of the Subject Area; thus there is no logical pathway for ingestion of the hydrocarbon impacted groundwater.
 - **Metals in Groundwater** - There are no groundwater wells in the vicinity of the Subject Area; thus there is no logical pathway for ingestion of the groundwater impacted with metals. Additionally the metals of concern in the soil, are not found in groundwater at concentrations of the Canadian Drinking Water Guidelines.
- Dermal Contact:
 - **Surficial Metals** - By children playing in the impacted soil
 - **Hydrocarbons** - There is no logical pathway for dermal contact of the hydrocarbon impacted soil and groundwater which are at a depth greater than 1 meter below grade, in the Subject Area.
- Inhalation:
 - **Hydrocarbon Vapours** – Inhalation of the hydrocarbon vapours by the general public may occur during the time spent in the Subject Area.
 - **Surficial Metals** – Inhalation of particulates of the impacted soils by children during the handling of the soils is not likely as the soil is comprised of primarily sand and

gravel, however a conservative approach for the risk assessment will be taken and inhalation of metals will be considered.

Table 11 Summarizes the exposure pathways selected for the human health risk assessment.

Table 11. Selected Exposure Pathways for The Human Health Risk Assessment

Exposure Pathway	Exposure	Rational
Ingestion	Surficial Metals	Improper hygiene and ingestion of berries
Dermal Contact	Surficial Metals	Children playing in soil
Inhalation	Hydrocarbon Vapours Metal Particulates	Air breathed while on site Dust breathed in while on site

4.2.5 Quantification of Exposure to General Public

The initial approach of the risk assessment is to undertake the most conservative approach. For example, regular exposures throughout the year are initially assumed. If the calculated risks are found to be in excess of the acceptable risks, then an iterative approach will be undertaken.

4.2.5.1 POTENTIAL INCIDENTAL INGESTION DOSES

Incidental ingestion of soil may occur during incidents such as eating lunch without prior washing of hands, in particular in the case of children. In the deterministic approach, a worst-case scenario is assumed whereby children would have minimal hygiene practices. Additionally, children may deliberately ingest soil. This risk assessment assumes an age group less than 5 years, as this age group is most likely to ingest soil. As well this age group represents the most sensitive sector of the population. Health Canada has recommended the use of 50 mg/day as normal soil intake by children between the ages of 0.5 to <5 years old (Health Canada, 1995).

➤ **NON-CARCINOGENIC DOSES**

Equation 1 provides a means of calculating the potential ingestion of the selected chemical parameters by children between the ages of 0.5 - < 5 years old.

$$\text{Equation 1} \quad \text{ED}_s = \frac{C \times IR \times EF \times BA \times 10^{-6}}{BW}$$

Where:

ED_s = Estimated Dose through eating soil.

C = Concentration of the selected chemical contaminants. The deterministic estimate will use the 95th percentile values as follows:

Metal	95 th Percentile (mg/kg)
Chromium	151
Copper	984
Lead	546
Zinc	1284

IR = Ingestion Rate: The amount of soil a child between the ages of 0.5 - <5 years old eats per day in mg/day (50 mg/day).

EF = Exposure Factor: Indicates how often the individual has been exposed to the contaminant. Based on discussion with local individuals, the frequency of use of the Subject Area for recreational purposes would be "infrequent". For the purposes of this risk assessment 1 day in 14 days will be assumed, i.e. the child may be exposed to the contaminated soils once every two weeks. The unlikely scenario of this occurrence throughout the year is assumed for conservative purposes.

The risk assessment will therefore use a 0.071 exposure factor.

BA = Bioavailability Factor of 1 is assumed. It will be assumed that a contaminant at the site is in the same form as the chemical used in toxicological tests. This assumption is conservative as the soluble forms of metal salts are used for toxicity testing while a metal in soil may be "bound" within a relatively insoluble form.

BW = Body Weight: The average body weight in kilograms (kg) based on a child between the ages of 0.5 - <5 years old. Health Canada recommends using 13 kg as the average weight for this age group (Health Canada, 1995).

Note: The equation includes a conversion factor of 10^{-6} , which is required to convert the concentration of the contaminant in the soil (C) from mg/kg to mg/mg of soil. In this way, the units for soil concentration are the same as those for soil ingestion (both in milligrams of soil) (Health Canada, 1995).

Based on the deterministic approach, **Table 12** summarizes the estimated dosages for potential ingestion of the selected metals by children between the ages of 0.5 - < 5 years old.

Table 12. Estimated Dose – Ingestion for Evaluation of Non-Carcinogenic Effects on Children

Chemical	95 th Percentile Concentration (mg/kg)	Estimated Dose (mg/kg/day)
Chromium	151	4.12×10^{-5}
Copper	984	2.69×10^{-4}
Lead	546	1.49×10^{-4}
Zinc	1284	3.5×10^{-4}

Example: Chromium

$$\begin{aligned} \text{Estimated Dose} &= \frac{151 \text{ mg/kg} \times 50 \text{ mg/day} \times 0.071 \text{ day/days} \times 10^{-6} \text{ kg/mg}}{13 \text{ kg}} \\ &= 4.12 \times 10^{-5} \text{ mg/kg/day} \end{aligned}$$

4.2.5.1.1 Dermal Contact

If a child's skin is exposed to the contamination in the soil, then the chemicals may desorb from the soil with subsequent migration through the skin and into the blood stream.

The dosage of metals resulting from dermal contact would be calculated by **Equation 2**:

$$\text{Equation 2} \quad \text{ED}_{ss} = \frac{C \times A \times BA \times EF \times SF \times 10^{-6}}{BW}$$

Where:

ED_{ss} = Estimated Dose through skin contact with soil (mg/kg/day).

C = Concentration of the contaminant of concern (mg/kg). The risk assessment will use the 95th percentile concentrations

A = Total soil adhered: The amount of soil that will stick to a person, expressed in milligrams per day (mg/day). Health Canada recommends 3,500 mg/day for a child between the ages of 0.5 – <5 years old (Health Canada, 1995). Based on previous risk assessments conducted by Hemmera, this quantity is very conservative. Other means of calculating the soil adhered would result in a much lower adherence factor than the Health Canada recommendation.

BA = Absorption Factor: The percentage of the contaminant in the soil that is actually free to move out of the soil and through the skin (unitless). For the purposes of the risk assessment the following absorption factors for metals are assumed:

Chromium – Most data for skin uptake of chromium is related to chromium VI solutions, which are used in industry. This form of chromium is not expected in the environment and chromium III is likely at the site. Chromium III concentrations may cause the skin lesions, however at very high concentrations, in the order of 26,000 mg/L. This assessment will assume an adsorption factor of 1.0 for chromium.

Copper – The behaviour of copper during dermal adsorption should not be different than similar divalent cations such as cadmium and lead. An adsorption factor of 0.01 is assumed for copper.

Lead – Laug and Kunze (1948) studied the uptake of lead from the application of aqueous lead acetate and a paste of lead ortho arsenic to the skin of rats. A bandage was used to maintain exposure for 24 hours. It was estimated that no more than 1% of the applied lead was taken up by the rat body. This assessment will assume a factor of 0.01 for lead.

Zinc - The behaviour of zinc during dermal adsorption should not be different than similar divalent cations such as, cadmium and lead. An adsorption factor of 0.01 is assumed for zinc.

EF = Exposure Factor: Indicates how often the individual has been exposed to the contaminant. The risk assessment will assume once in 14 days (0.071).

SF = Solubility factor: For skin absorption to occur, the chemicals of concern must be solubilized from soil, possibly by skin sweat. A conservative solubility factor of 1 (100%) is assumed for the soil-associated chemicals.

BW = Body Weight: The average weight in kilograms of a child between the ages of 0.5 – <5 years old (13 kg).

Based on the deterministic approach, **Table 13** summarizes the calculated dosages of the selected metals via dermal uptake by children between the ages of 0.5 – <5 years old.

Table 13. Estimated Dose – Dermal Uptake for Evaluation of Non-Carcinogenic Effects of Children Between The Ages of 0.5 – <5 Years Old

Chemical	95 th Percentile Concentration (mg/kg)	Estimated Dose (mg/kg/day)
Chromium	151	2.9×10^{-5}
Copper	984	1.88×10^{-4}
Lead	546	1.04×10^{-4}
Zinc	1284	2.45×10^{-4}

Example: Lead

$$\begin{aligned}\text{Estimated Dose}_{\text{ss}} &= \frac{546 \text{ mg/kg} \times 3,500 \text{ mg/day} \times 0.01 \times 0.071 \text{ day/days} \times 1 \times 10^{-6} \text{ kg/mg}}{13 \text{ kg}} \\ &= 1.04 \times 10^{-4} \text{ mg/kg/day}\end{aligned}$$

4.2.5.1.2 *Inhalation*

4.2.5.1.2.1 *INHALATION OF METALS*

Metals are found in surface soils near Foundation AB. Given the type of substrate (i.e. sand and gravel), it is unlikely that dust would be generated during recreational use of the Subject Area. Nonetheless, the risk assessment will calculate the potential uptake via inhalation.

The amount of contaminant absorbed into the body through the inhalation of dust can be estimated by the equation:

Equation 3
$$\text{ED}_{\text{dust}} = \frac{\text{C} \times \text{CR} \times \text{RF} \times \text{RR} \times \text{DE} \times \text{EF} \times \text{SF}}{\text{BW}}$$

Where:

ED_{dust} = Estimated dose via inhalation of dust. The dose is expressed as milligrams of contaminant inhaled per kilogram of body weight per day.

C = Concentration of selected chemical contaminants. The deterministic estimate will use the 95th percentile concentrations as follows:

Chemical	95 th Percentile Concentration (mg/kg)
Chromium	151
Copper	984
Lead	546
Zinc	1284

CR = Concentration of respirable dust in air. A dust concentration of 0.6 mg/m^3 as reported by Cowherd et al (1974) at active industrial sites is used for this risk assessment.

RF = Retention Factor (fraction taken up by lungs)

Chromium: For chromium III, a factor of 0.4 based on lead uptake is assumed.

Copper: A factor of 0.4 based on lead uptake is assumed.

Lead: As per the Royal Society of Canada (1989) review, a respiratory uptake factor 0.4 is used for lead.

Zinc: A factor of 0.4 is used for zinc.

RR = Respiration Rate. A point estimate of $5 \text{ m}^3/\text{day}$ is used to assess the respiration rate of a child at the site (Health Canada, 1995).

DE = Length of exposure per day. An exposure of two hours is assumed.

EF = Exposure Factor. An exposure of once per 14 days is assumed, as per the previous assumptions for ingestion and dermal exposure. The exposure factor used is 0.071.

BW = Body Weight. Health Canada (1995) suggests an assumption of an average weight of a child between the ages of 0.5 to 5 years old is 13 kg.

SF = Conversion factor – mg/kg to mg/mg (10^{-6})

Based on the deterministic approach, **Table 14** summarizes the estimated dosages via respiratory uptake of metals by children between the ages of 0.5 to <5 years old.

Table 14. Estimated Uptake for Evaluation of Metals Inhalation of Children Between the Ages 0.5 – 5 Years Old

Chemical	95 th Percentile	Estimated Dose _(dust) (mg/kg/day)
Chromium	151	8.24×10^{-8}
Copper	984	5.3×10^{-7}
Lead	546	2.9×10^{-7}
Zinc	1284	7.0×10^{-7}

Example: Zinc

Estimated Dose_(dust) =

$$\frac{1284 \text{ mg/kg} \times 0.6 \text{ mg/m}^3 \times 0.4 \times 5 \text{ m}^3/\text{day} \times 0.071 \text{ day/days} \times 2 \text{ hours}/24 \text{ hours} \times 10^{-6} \text{ mg/kg}}{13 \text{ kg}}$$

$$= 7.0 \times 10^{-7} \text{ mg/kg/day}$$

4.2.5.1.3 Inhalation Hydrocarbons

Inhalation of hydrocarbon vapours by the general public during time spent in the Subject Area is possible. Field studies described in **Section 2.3.4** of this report were conducted to determine actual soil vapour concentrations (i.e. below surface). This risk assessment will conservatively assume that a recreational user will be exposed to similar concentrations. In reality, soil vapours would be diluted considerably upon exposure to the atmosphere. The amount of contaminant absorbed into the body through inhalation (ED_v) can be estimated with **Equation 4**:

$$\text{Equation 4} \quad \text{ED}_v = \frac{C \times IR \times RF \times DE \times EF}{BW}$$

Where:

ED_v = Estimated Dose of vapour via inhalation: The air inhalation dose is expressed as milligrams of the contaminant inhaled per kilogram of body weight per day (mg/kg/day).

C = Concentration of the contaminant of concern (i.e. petroleum hydrocarbons measured as TPH), in milligrams per cubic meter of air (mg/m³). The highest soil vapour concentration will be used (0.973 mg/m³.)

IR = Inhalation Rate: The amount of air a person breathes in a day, in cubic meters (m^3/day). A point estimate of $5 \text{ m}^3/\text{day}$ is used to assess the respiration rate of a child at the site (Health Canada, 1995).

RF = Retention Factor: It is assumed 100% of the hydrocarbons are retained in the lungs.

DE = Length of exposure per day. An exposure of two hours per day is assumed.

EF = Exposure Factor: Indicates how often the individual has been exposed to the contaminant. For the purposes of the risk assessment an exposure of once per 14 days is assumed as per the previous assumption for ingestion and dermal exposure.

BW = Body Weight: The average body weight in kilograms (kg) of a child between the ages of 0.5 and 5 years old is assumed to be 13 kg.

The dose of petroleum hydrocarbons via air inhalation is therefore:

$$\text{ED}_v = \frac{0.973 \text{ mg/m}^3 \times 5 \text{ m}^3/\text{day} \times 1.0 \times 1\text{day}/14\text{days} \times 2\text{hours}/24\text{hours}}{13 \text{ kg}}$$

$\text{ED}_v = 0.002 \text{ mg/kg/day}$ total petroleum hydrocarbon inhalation

4.3 TOXICITY ASSESSMENT – HUMAN HEALTH

4.3.1 Selection of Reference Doses (Noncarcinogenic Effects)

The human health toxicity values for the contaminants found in the Subject Area are discussed in the U.S. Environmental Protection Agency's Integrated Risk Information System (IRIS), and the general literature. These values will be compared with the exposures calculated in the previous section.

The Reference Doses (RfD) are summarized in the **Table 15** of **Section 4.3.7** of this report. These represent an estimate of a daily exposure level for the human population that is likely to be without an appreciable risk of chronic effects upon exposure to each specific chemical within a particular time frame. The RfDs for the selected chemical apply to the specific route of exposure. In **Section**

4.4, the RfDs for noncarcinogenic compounds will be compared with the exposure dosages calculated previously. If an exposure dosage exceeds the RfD, then a human health effect may be expected.

4.3.2 Toxicity – Chromium

4.3.2.1 REFERENCE DOSE: RfD

Although the analytical data of the previous studies did not differentiate between chromium III (Cr III) and chromium VI, the risk assessment will use the RfD for chromium III as chromium VI readily reduces to chromium III in the environment. As well, historical use of hexavalent chromium at the site is unlikely. Hexavalent chromium is generally found at sites previously used for chrome-plating, wood preservation and maintenance for locomotives that use chromium VI solutions as engine coolants. Such activities did not occur in the Subject Area.

Ivanovik and Pressman (1975) reported reduced absolute weights in rats livers and spleens at a Cr III dose equivalent to 1,400 mg/kg/day. The dose was administered to the rats five days a week for 90 days. Based on this study and others, the EPA has estimated a “No Observed Adverse Effects Level” (NOAEL) of 1,468 mg/kg/day (EPA, 1998). An uncertainty factor of 100 has been applied to the NOAEL based on expected interhuman and interspecies variability to the toxicity of chromium. In addition, a 10 fold modifying factor has also been applied based on the experimental procedures and assumptions made during the studies. With the uncertainty factor and the modifying factor, the EPA recommends a reference dose of 1.5 mg/kg/day for Cr III.

4.3.2.2 CARCINOGENIC EFFECTS

There is currently no data to suggest the potential carcinogenicity of trivalent chromium (chromium III) (IRIS, 1998). Hexavalent chromium (chromium VI) is a known human carcinogen however hexavalent chromium is unlikely to be present at the Subject Area.

4.3.3 Toxicity – Copper

Copper is required in the human diet however the ingestion of gram quantities of inorganic copper salts is usually fatal in humans. There is considerable variability in individual sensitivities (CCME 1999).

4.3.3.1 REFERENCE DOSE RFD

The CCME suggests that the use of NOAEL is inappropriate in the case of copper, as “too many factors may affect the toxic potential of copper i.e. chemical form, potential interaction with other micro elements and other components of the diet, health and nutritional status of individuals” (CCME 1999). The dietary copper requirements that “seem to be adequate and safe” have been adopted by Health Canada for the tolerable daily intake. Health Canada (1995) recommends a tolerable daily intake of 0.05 mg/kg/day – 0.5 mg/kg/day. This range will be used as the RfD for the risk assessment.

4.3.3.2 CARCINOGENIC EFFECTS

Limited data in human and experimental animals indicate that copper does not appear to be teratogenic or carcinogenic (CCME 1999).

4.3.4 Toxicity – Lead

Normal daily intakes of lead from food are estimated to be approximately 70 µg for adults (Royal Society of Canada, 1989). Lead is widely used in industry for uses such as car battery manufacture, solders and ammunition.

4.3.4.1 ACUTE TOXICITY

Symptoms of acute poisoning by inorganic lead include a metallic taste in the mouth, vomiting and cramps. The fatal dose of lead to an adult is estimated to be 0.5 grams (Driesbach, 1983).

4.3.4.2 CHRONIC EFFECTS

Considerable attention has been given to the possibility of adverse health effects from continuous exposure to low levels of lead. Chronic effects at such exposures may include headaches, fatigue, irritability pains in the joints and muscles, stomach cramps and constipation. The symptoms are reversible and complete recovery is possible. More severe exposure that results in wrist drop and severe abdominal pains, may require long-term recovery.

The doses at which adverse human health effects occur, as a result of chronic exposure, have not been unequivocally established. Low blood lead levels can affect certain blood enzymes and aspects of children's neurobehavioural development. Blood-lead (Pb-B) levels are the best indicator of dose regardless of the route of exposure, however the relationship between Pb-B and effects (such as neuropsychological effects in children) are controversial (Royal Society of Canada, 1989). It appears that some of the effects occur at blood lead levels so low as to be essentially without a threshold.

4.3.4.3 REFERENCE DOSE (RfD)

Currently, the U.S. EPA in IRIS, states that the existing health database is not appropriate to develop an RfD for inorganic lead.

Health Canada (1995) has defined a tolerable daily intake of 0.00375 mg/kg/day for lead. This value will be used as the RfD for the risk assessment.

4.3.4.4 CARCINOGENIC EFFECTS

The available human health evidence is considered to be inadequate to refuse or demonstrate any potential carcinogenicity for humans for lead exposure (IRIS, 1996).

There is sufficient information to show that lead is an animal carcinogen and the U.S. EPA classified lead as: B2 probable human carcinogen. Quantitative estimates of carcinogenic risks from oral exposure are not provided by the U.S. EPA because, "estimates derived by standard procedures would not truly describe the potential risk."

4.3.5 Toxicity – Zinc

4.3.5.1 REFERENCE DOSE RfD

Zinc is an essential element in the human diet. Health Canada (1995) has recommended a Tolerable Daily Intake (TDI) of 0.3 – 1.0 mg/kg/day. This value will be used as the RfD in the human health risk assessment.

4.3.5.2 CARCINOGENIC EFFECTS

The U.S. EPA classified zinc as: D, not classifiable as to human carcinogenicity. The human carcinogenicity data for zinc is considered inadequate by the U.S. EPA, as there are no reports on the possible carcinogenicity of zinc in humans (U.S. EPA, 1991).

4.3.6 Toxicity – Hydrocarbon Vapours

The chromatogram of the hydrocarbons in soil vapour indicate the presence of C₈ – C₁₆ compounds hence, the vapour concentrations are in the F2 fraction of the CWS. The CWS (2000) for F2 is based on a TDI of 0.1 mg/kg/day and an RfC of 1.0 mg/m³.

4.3.7 Summary of Reference Toxicity Values

Table 15 summarizes the chronic RfD values, which will be used to evaluate the hazard quotients for the chemicals of concern.

Table 15. RfD Values For The Human Health Risk Assessment

Chemical	Chronic RfD (mg/kg/day)	RfD Source
Chromium	1.5	IRIS, 1998
Copper	0.05 – 0.5	Health Canada, 1995
Lead	0.00357	Health Canada, 1995
Zinc	0.3 – 1.0	Health Canada, 1995
Hydrocarbons in air	0.1	CWS, 2000

4.4 RISK CHARACTERIZATION

The final step in the human health risk assessment consisted of the estimation of risks associated with the predicted exposures. Risks associated with non-cancer health effects from exposure to the selected contaminants of concern were estimated using a Hazard Quotient (HQ) approach. The HQ was calculated by dividing the estimated exposure to chemicals, by the corresponding TDI or RfD, according to the following equation:

$$\text{Equation 5} \quad \text{Hazard Quotient} = \frac{\text{Exposure Estimate (mg/kg/day)}}{\text{Tolerable Daily Intake or Reference Dose (mg/kg/day)}}$$

For hydrocarbons where the estimated exposure limit was expressed as a “safe” air concentration, the Hazard Quotient was calculated as follows:

$$\text{Equation 6} \quad \text{Hazard Quotient} = \frac{\text{Estimated Air Concentration } (\mu\text{g/m}^3)}{\text{Reference Concentration } (\mu\text{g/m}^3)}$$

The worst-case hazard quotients, as calculated by the deterministic assessment, are summarized in **Table 16**. Each of the hazard quotients for each chemical and exposure were added to get a total hazard index. For example, the total dermal, ingestion and inhalation HQ's for copper were summed to determine the total copper hazard index. A total hazard index in excess of 1.0 would imply potential for adverse health effects. However, due to the large number of conservative factors typically employed in the deterministic approach, HQs that are greater than 1 do not necessarily indicate that adverse health effects will occur. Instead, HQs that are greater than 1 suggest that the results of the risk assessment should be closely examined before concluding on the possibility of health effects.

Table 16. Summary of Worst Case Chronic Hazard Index Estimates for Children Between the Ages of 0.5 to 5 Years Old

Chemicals	Exposure (mg/kg/day)	TDI or RfD (mg/kg/day)	Hazard Quotient Maximum
Copper (Dermal)	1.88×10^{-4}	0.05 – 0.5	3.8×10^{-4}
Copper (Ingestion)	2.69×10^{-4}	0.05	2.75×10^{-5}
Copper (Inhalation)	5.3×10^{-7}	0.05	1.06×10^{-5}
Total Copper Chronic Hazard Index:			4.18×10^{-4}
Chromium (Dermal)	2.9×10^{-5}	1.5	1.9×10^{-5}
Chromium (Ingestion)	4.12×10^{-5}	1.5	2.3×10^{-3}
Chromium (Inhalation)	8.24×10^{-8}	1.5	5.47×10^{-8}
Total Chromium Chronic Hazard Index:			2.3×10^{-3}
Lead (Dermal)	1.04×10^{-4}	0.00357	2.9×10^{-2}
Lead (Ingestion)	1.49×10^{-4}	0.00357	5.37×10^{-3}
Lead (Inhalation)	2.98×10^{-7}	0.00357	8.3×10^{-5}
Total Lead Chronic Hazard Index:			3.4×10^{-2}
Zinc (Dermal)	2.45×10^{-4}	0.3 – 1.0	8.2×10^{-4}
Zinc (Ingestion)	3.5×10^{-4}	0.3	4.2×10^{-2}
Zinc (Inhalation)	7.0×10^{-7}	0.3	2.33×10^{-6}
Total Zinc Chronic Hazard Index:			4.3×10^{-2}
Hydrocarbon (Inhalation)	0.002	0.1	0.02
Total Hydrocarbon Chronic Index:			0.02
CHILDREN BETWEEN THE AGES OF 0.5 TO 5 WORST-CASE TOTAL CHRONIC HAZARD INDEX Regulatory Limit = 1.0			0.1

4.5 UNCERTAINTY ANALYSIS

The purpose of an uncertainty analysis is to enable the reader to determine the likelihood that a risk estimate might overestimate or underestimate the true risk. It is noted by BC Environment that for a deterministic risk estimate (based on conservative default factors), which result in significantly less than regulatory levels of concern, a qualitative uncertainty analysis would provide very little information value. Nonetheless an uncertainty analysis is provided in this report.

Table 17 presents a summary of the uncertainty analysis.

Table 17. Summary of Uncertainty for The Human Health Risk Assessment

Assumption	Uncertainty	Rational
Contaminant Distribution		
Evaluation of contaminant Distribution (Metals)	Low to Moderate – Possible underestimate of risk	Previous investigations did not adequately delineate extent of contamination
Evaluation of contaminant Distribution (Hydrocarbons)	Low	Soil contamination fully delineated
Exposure Pathway		
Frequency of exposure	Moderate to High – Possible overestimate of risk	Uncertain how often the site would be used for recreational purposes – assumed exposure all year
Dermal exposure	Moderate to High • Probable overestimate of risk • Assumption of 100% availability of metals in soil	• Area of surficial metals contamination is covered with plants • Health Canada exposure parameter much greater than literature estimates
Inhalation	Moderate overestimate of vapour exposure • Moderate possible over estimate of dust inhalation	Soil vapour concentrations above area of contamination are less than at the background sampling location – no risk assumed based on background data • Dust levels based on levels at construction sites where fine grained soils were located, versus sand/gravel at the Subject Area

Ingestion	High overestimate	Assumed that soil contaminants have same availability as chemicals used in toxicity tests
<i>Reference Dose</i>		
RFDs	Moderate – possible overestimate for some metals High – uncertainty for toxicity of hydrocarbons	High uncertainty factor for Chromium – 1000 fold safety factor applied from animal studies

4.6 SUMMARY

The human health risk assessment identified seven contaminants of concern based on the concentrations in soil within the subject area and their toxicity to human health.

The next part of the human health risk assessment identified the potential population exposed to the contaminants in the soil. The general public was identified as the exposed population, in particular, young children who may be playing in the area of the impacted soil.

The exposure assessment of the risk assessment identified three exposure pathways in which the contaminants could potentially impact children: dermal, ingestion, and inhalation. The previous investigations identified hydrocarbons in soil at a depth of 0.8 meters or more below grade. Dermal and ingestion exposure to the soil at this depth by humans was not considered in the human health risk assessment. Inhalation of hydrocarbon vapours was considered.

Because there are no groundwater wells in the vicinity of the Subject Area, and no logical pathway for humans to be exposed to the contaminants in groundwater, groundwater was not considered in the human health risk assessment.

Based on the three exposure pathways (dermal, ingestion and inhalation), models were used to calculate the most conservative exposure levels to which the population would potentially be subjected. Dermal, ingestion, and inhalation calculations were completed for the metals, cadmium, copper, chromium, lead, and zinc. Inhalation calculations were also completed for total hydrocarbons.

The final step in the human health risk assessment consisted of the estimation of hazard quotient associated with the predicted exposure levels. If the hazard quotients were in excess of 1, it would imply the potential for adverse human health effects. None of the potential contaminants of concern identified in the human health risk assessment indicated a hazard quotient greater than one. The total hazard index values ranged from for copper 4.18×10^{-4} to 0.02 for hydrocarbon inhalation.

For the current land use as parkland, even with the use of very conservative assumptions, the human health risk assessment did not identify any potential risks to human health within the subject area from the metals and hydrocarbons that impacted the quality of the soil and groundwater at the Subject Area.

5.0 ECOLOGICAL RISK ASSESSMENT

Based on prior site investigations and the information summarized in **Section 1**, the chemicals which represent a potential risk to the environment within the Subject Area are metals and hydrocarbons. The current and future land use of the Subject Area is parkland. At this time, there are no proposed development plans for the subject site other than maintaining it as a recreational area. The current ecological risk assessment was based on this land use.

BC Environment has developed guidelines for ecological risk assessments (BC Environment 1998). This assessment will include the required information outlined in this guideline and furthermore will be in the format of the BC Environment guidelines document. Modifications to the guidelines are made where appropriate.

5.1 CHEMICALS OF POTENTIAL CONCERN

The YCSR and CCME soil and groundwater standards will be used to select the potential chemicals of ecological concern. In addition, known effect levels of contaminants in water will be summarized to evaluate whether the observed groundwater concentrations have any potential for impacts on plant growth or aquatic biota.

5.1.1 Soil Concentrations in excess of the YCSR, CCME and CWS

The majority of the metal contamination is located around the perimeter of Foundation AB. The extent of the metals contamination in the soil appears to be within a 0.2 to 0.3 meter surface layer.

The hydrocarbon impacted soil is located on the eastern portion of the Subject Area. Contamination was primarily in the sand-gravel fill above the silt layer and was detected at depths ranging from 1.0 to 2.5 meters below grade.

The analytical data for the metals and hydrocarbons in soil that exceed the applicable standards and guidelines for ecological protection are summarized in **Table 18**.

Table 18. Summary of Potential Contaminants of Concern in Soil

Parameters	Samples (n)	Range (mg/kg) Min / Max		YCSR (mg/kg)	Number >YCSR	CCME RL/PL or CWS (mg/kg)	Number >CCME or CWS	95 th Percentile (mg/kg)
Chromium	15	19	263	250 ⁽¹⁾ 60 ⁽²⁾	1 3	64	3	151
Copper	15	15	3000	150 ⁽¹⁾ 30,000 ⁽²⁾	1 0	63	3	984
Lead	15	5	780	1000 ⁽¹⁾ 40,000 ⁽²⁾	0 0	300 ⁽³⁾	2	546
Zinc	15	23	2600	450 ⁽¹⁾ 550 ⁽²⁾	4 3	200	5	1284
Naphthalene	7	0.025	0.8	5	0	0.6	2	0.77
VPH (F1)	44	5	730	200	6	350 ⁽⁴⁾ 230 ⁽⁵⁾	6 6	532
LEPH (F2)	44	125	8000	1000	9	1500 ⁽⁴⁾ 150 ⁽⁵⁾	8 9	5830
HEPH (F3)	44	125	4500	1000	2	2500 ⁽⁴⁾ Na ⁽⁵⁾	1	906

⁽¹⁾ YCSR Toxicity to soil invertebrates and plants

⁽²⁾ YCSR Groundwater flow to surface water used by aquatic life

⁽³⁾ CCME Environmental Health Guidelines

⁽⁴⁾ CWS generic level for PHC coarse grained subsoil (>1.5 m) for protection of groundwater for aquatic life

⁽⁵⁾ CWS generic levels for PHC in coarse grained subsoil (>1.5m) for agricultural eco soil contact

Note: The pH values in soils collected during the Hemmera Envirochem DSI (2001) ranged from 6.8 to 7.9.

5.1.2 Impact of Contaminated Soil on Groundwater

Groundwater in the Subject Area appears to be impacted with metals and hydrocarbons. Table 19 presents a statistical summary of the potential contaminants of concern in groundwater.

Table 19. Statistical Summary of Potential Contaminants of Concern in Groundwater

Parameters	Samples (n)	Range (µg/L) Min / Max		YCSR (µg/L)	Number >YCSR	CCME FAL* (µg/L)	Number >CCME	95 th Percentile (µg/L)
Iron	4	11,100	13,100	3	4	300	4	13,100
Manganese	4	600	1,170	1	1	50,000	0	1,167
Naphthalene	24	0.15	130	10	4	1.1	6	16
Phenanthrene	24	0.025	1	3	0	0.4	5	0.69
Pyrene	24	0.01	0.2	0.2	1	0.025	2	0.09
Toluene	24	0.05	24	3,000	0	2	4	2.48
TEH	27	50	30,000	ns	na	ng	na	19,390
LEPH	15	125	2,500	500 ⁽¹⁾	10	ng	na	2080
HEPH	15	125	420	ns	na	ng	na	322

⁽¹⁾ BC Contaminated Sites generic numerical standard for groundwater

* Guideline applicable to receiving waters with aquatic biota

It was observed that iron and manganese were found at levels in excess of the groundwater standards and guidelines. The iron and manganese observed in the groundwater may be a product of anaerobic conditions in the hydrocarbon impacted soil and groundwater, drawing the iron and manganese out of their naturally occurring states.

Although there are no current Yukon or Federal applicable petroleum hydrocarbon standards or guidelines, the concentrations appear elevated. The BC CSR guidelines for LEPH have been included strictly for comparison purposes.

5.1.3 Assessment of Sediment Samples

Sediment soil samples were collected at three locations along the west bank of Brooks Brook, upgradient, adjacent to and downgradient of the suspect soil contaminant plume. The samples were analysed for BTEX, VPH and EPH. The results indicated concentrations less than the laboratory method detection limit.

5.1.4 Assessment of Surface Water

Surface water samples were collected from the bank of Brooks Brook at locations upstream and

downstream of the impacted soil and groundwater within the Subject Area. The samples were analysed for one or more of the following: BTEX, VPH, LEPH, HEPH, PAHs, and total metals. The results indicated concentrations of BTEX, VPH, LEPH, HEPH and PAHs below the laboratory method detection limits in each the surface water samples analysed. Total metal concentrations were within the CCME FAL guidelines for all regulated parameters with the exception of two minor exceedances for aluminium and one exceedance for copper. In general no differences were noted in the water quality of stream samples obtained up-gradient and down-gradient of the Subject Area.

5.1.5 Summary of Selected Chemicals

Based on soil, groundwater, sediment and surface water monitoring, it appears that the brook sediment and surface water to the west of the Subject Area have not been impacted by the soil and groundwater contamination within the Subject Area. No samples of the sediment or surface water have been collected from the brook to the south and southwest of the Subject Area.

The selected chemicals for the ecological risk assessment are metals and hydrocarbons in the soil and groundwater.

Table 20 provides a summary of the initial set of chemicals selected chemicals for the ecological risk assessment based on comparison with existing standards and guidelines. The following sections will describe the rational for final selection of the possible chemicals of concern.

Table 20. Chemicals Selected For The Ecological Risk Assessment

Metals	Hydrocarbons
Chromium (soil)	Naphthalene (groundwater)
Copper (soil)	Phenanthrene (groundwater)
Lead (soil)	Pyrene (groundwater)
Iron (groundwater)	Toluene (groundwater)
Manganese (groundwater)	VPH (soil)
Zinc (soil)	LEPH (soil and groundwater)
	HEPH (soil and groundwater)
	TEH (soil and groundwater)

5.1.6 Receptors of Concern

The ecological setting of the Subject Area is such that site-related COPC may contact a wide variety of terrestrial and aquatic species. Site visits conducted during the previous investigations have outlined the ecological resources present on the site and the adjacent areas. Two general habitat types were identified:

- Terrestrial
- Aquatic

A regional species list has been included in **Appendix A**. An inventory of site vegetation is also included in **Appendix A**. The vegetation was identified during the ESG assessment of the Brooks Brook Property.

5.1.7 Conceptual Model

The conceptual model of the Subject Area regarding the potential exposure pathways for site receptors is shown on **Figure B**. This model is used as a guideline for the terrestrial risk assessment. The exposure routes presented on **Figure B** include:

Terrestrial:

- Root uptake by terrestrial plants of COPCs in soil.
- Soil ingestion and dermal exposure of COPCs in soil for soil invertebrates.
- Ingestion of food with elevated concentrations of the COPCs for small mammals and songbirds.

Aquatic:

- For aquatic invertebrates, direct exposure to groundwater-borne COPCs in surface water and porewater.
- For aquatic plants, direct exposure to groundwater-borne COPCs in surface water and porewater.

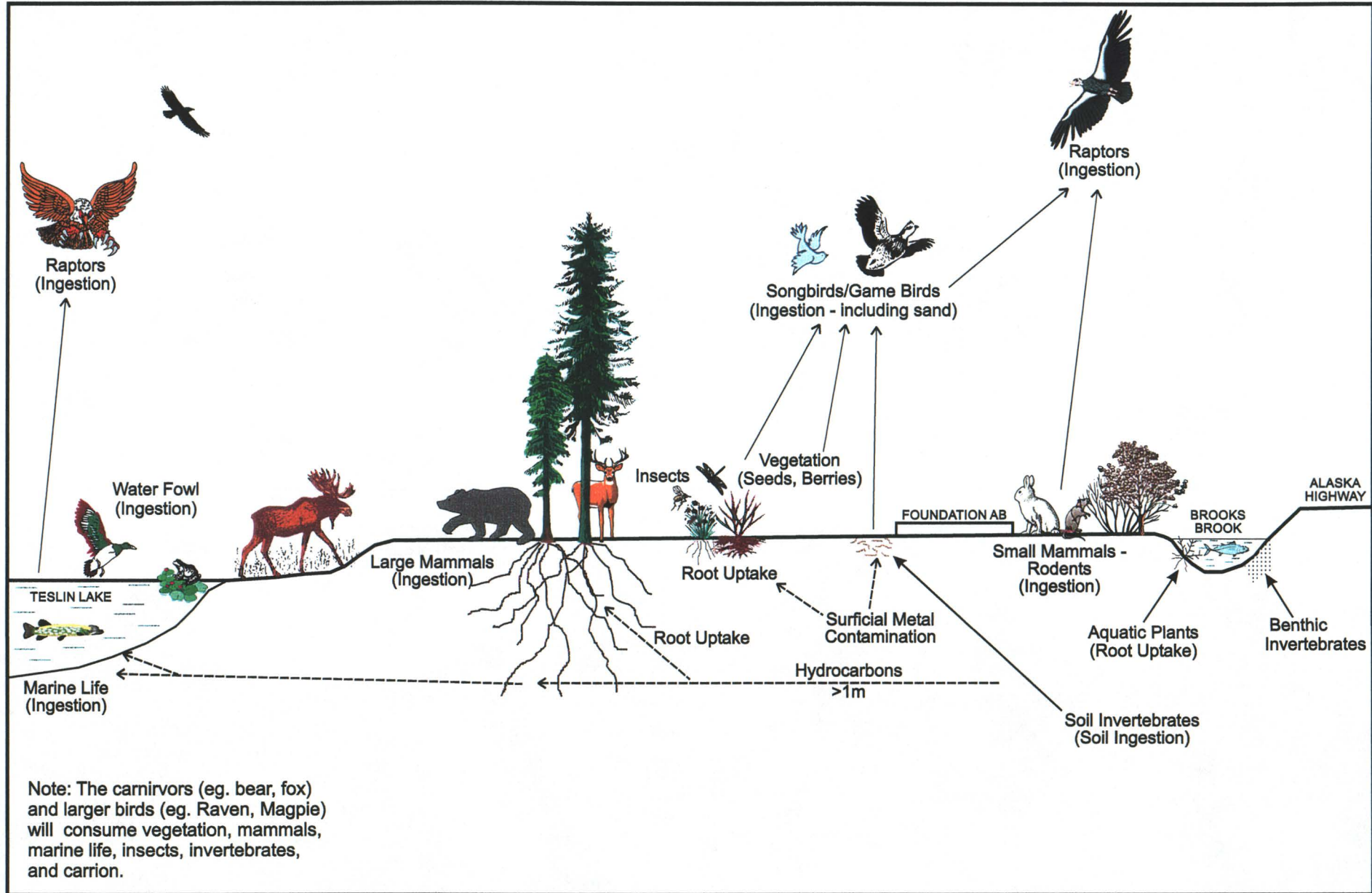


FIGURE B: ECOLOGICAL HEALTH EXPOSURE PATHWAY DIAGRAM

- For bottomfish, direct exposure to groundwater-borne COPCs in surface water and porewater
- and ingestion of food with elevated chemical concentrations.
- For birds, ingestion of food with elevated chemical concentrations.

5.2 TERRESTRIAL ECOLOGICAL RISK ASSESSMENT

5.2.1 Terrestrial Exposure Assessment

5.2.1.1 TERRESTRIAL FIELD OBSERVATIONS

A description of the site ecology is included in **Section 2.2.5.2.2** of this report. The field observations were conducted during the DSI in September of 2001 and during a site visit conducted in August 2002. The field observations concluded that 70 % of the Subject Area was covered by vegetation with dense vegetation occurring along the bank of Brooks Brook (**Photo 2 and Photo 5**) and in the vicinity of Foundation AB. A plant species inventory was conducted during the ESG 1997 field investigation. This report suggests that the trees along the bank of Brooks Brook include lodge pole pine, black cottonwood, white spruce, Alaska willow and trembling aspen. Vegetation observed in the vicinity of Foundation AB is summarized in **Table 21**. A complete list of vegetation observed during the ESG field investigation has been included in **Appendix A**.

Table 21. Vegetation in the Vicinity of Foundation AB

Common Name	Genus Species Name
Fireweed	Epilobium angustifolium
Yarrow	Achillea millefolium
Slender Wheatgrass	Elymus trachycaulus
Common Dandelion	Taraxacum officinale
Prickly Rose	Rosea acicularis
Vetch	Vicia spp.
Bentgrass	Agrostis
Northern Scouring Rush	Equisetum variegatum

Tall Bluebells	Mertensia paniculata
Narrow-leaved Cotton Grass	Eriophorum angustifolium
Horsetail	Equisetum scirpoides
Mushrooms	
Mosses	
Grasses	

A detailed inventory of invertebrates, terrestrial mammals, and birds has not been conducted for the Subject Area. During the Hemmera DSI (2001), a limited inspection of the surface soils for soil invertebrates was conducted. The DSI found no signs of worms, insects or larvae. It is the opinion of the risk assessor that the findings during the field investigation for soil invertebrates is not necessarily representative of the species diversity in the soil at the Subject Area. In addition, the DSI found no signs of terrestrial mammals or birds, with the exception of a beaver dam located downstream from the Brooks Brook property. Given the location of the Subject Area and the species listed for the Yukon Territory it is likely that several species of mammals and birds may be present on the Subject Area at certain times of the year. This was confirmed during the site visit in August 2002 in which visual indication of terrestrial mammals were observed (tracks in sediment). However, given the small area of the site, it is unlikely that the site by itself could provide an adequate terrestrial foraging area for birds and mammals. A list of the birds and mammals found in the Yukon obtained from the Yukon Government web page has been included in **Appendix A**.

5.2.1.2 EXPOSURE TO TERRESTRIAL BIOTA

Heavy tree growth along the bank of Brooks Brook is evident, (**Photo 5**) while the central portions of the Subject Area contains primarily grasses, shrubs and herbs. The following means of terrestrial community exposure to the potential contaminants may occur:

Root Uptake: The hydrocarbon impacted soil and groundwater are at 1 or meters below grade and the roots of most plants at the site are not likely to extend to this depth. There is no visual evidence of an impact on vegetation in the area. It is suggested that exposure for root uptake of hydrocarbons at this

depth is minimal. Root uptake of the surficial metals impacted soil in the vicinity of Foundation AB may occur.

5.2.1.2.1 Soil Ingestion by Soil Invertebrates

The hydrocarbon impacted soil and groundwater are at 1 or meters below grade. Therefore, the pathway of soil ingestion by invertebrates is probably of minor concern for hydrocarbons at this site. Metals in the vicinity of Foundation AB have the potential for uptake by invertebrates.

5.2.1.2.2 Ingestion of Food With Elevated Concentrations of The COPCs For Small Mammals and Birds

Given that the pathways for hydrocarbon exposure to plants and soil invertebrates at this site are minimal, it is suggested that ingestion of food with elevated concentrations of hydrocarbons by small mammals and songbirds is not of concern.

Surficial soils impacted with metals may be taken up by plants and invertebrates, and in turn small mammals and songbirds may be exposed to elevated concentrations of metals in the plants in the vicinity of soil impacted with metals. The exposure of small mammals and birds to elevated food concentrations would likely be minimized based on the relatively small area impacted with metals and the relatively large foraging areas of the small mammals and birds likely found at the Subject Area. For example, the home range of a red tailed hawk is in the order of a few hundred hectares to over 1500 hectares, while the range for foxes varies from 50 to 3000 hectares (U.S. EPA, 1993). Ranges of deer mice would be much less, however evidence of such species were not observed at the site.

Although there does not appear to be an exposure pathway for the hydrocarbon impacted soil, the Canada Wide Standards for Petroleum Hydrocarbons in soils specify hydrocarbon standards for coarse and fine-grained soils at depths to 1.5 m and at depths beyond 1.5 meters. As a result the risk assessment will consider potential impacts of the subsurface petroleum hydrocarbons to terrestrial species via each of the exposure pathways. With reference to **Table 20**, **Table 22** provides a

summary of the substances selected for the ecological risk assessment. It is noted that TEH as referenced in **Table 20**, comprises LEPH and HEPH.

Table 22. Summary of Substances Selected for the Terrestrial Ecological Risk Assessment

Metals	Hydrocarbons
Chromium	VPH
Copper	LEPH
Lead	HEPH
Zinc	

5.2.1.3 *TOXICITY ASSESSMENT OF METALS IN SOIL– SOIL INVERTEBRATES, PLANTS, MAMMALS AND BIRDS*

5.2.1.3.1 *Chromium*

Receptor – Terrestrial Plants

Breeze (1973) found chromium (III) increased plant mortality at 10 ppm in a solution culture. A review of several studies of plant-chromium toxicity indicate that 1-5 ppm of chromium in an available form in the soil is the toxic threshold for a number of plant species (NRCC, 1981).

Receptor – Soil Invertebrates

Data on toxicity of chromium to terrestrial invertebrates are sparse (Eisler, 1986). Studies conducted in India showed that a concentration of 10 to 15 ppm of chromium VI in irrigation water, when applied to soils for agricultural purposes, was lethal in two species of earthworms in 58 to 60 days (Eisler, 1986; Soni and Abbasi 1981; Abbasi and Soni 1983).

Receptor – Small Mammals and Birds

Rabbits given chromium concentrations of 1.7 mg/kg body weight daily for six weeks had adversely affected blood and serum chemistry and significant morphological changes in the liver (Tandon et al. 1978). Toxic concentrations of chromium in the diet of poultry range from 1,000 to 5000 ppm (Puls, 1988).

5.2.1.3.2 Copper

Receptor – Terrestrial Plants

Effect levels on plants (e.g. growth impairment and seed emergence), resulting from copper exposure were noted to range from 31 mg/kg to 500 mg/kg in various species of terrestrial plants (BC MELP, 1996).

Receptor – Soil Invertebrates

Lowest observed effects concentrations from copper exposure were noted to range from 27 mg/kg to 370 mg/kg in various species of earthworms (BC MELP, 1996). Lethal effect levels (e.g. LC₅₀'s) ranged from 100 to 2760 mg/kg of copper.

Receptor – Small Mammals and Birds

Toxic copper concentrations in the diets of rabbits occur at concentrations greater than 300 ppm (Puls, 1988). Rabbits are reported to be very susceptible to copper toxicity. Concentrations ranging from 300–600 ppm have been reported to be toxic to geese. Signs of copper toxicity in geese include feather loss, reduced weight gain and egg production, and an increase in the incidence of tibial dischondroplasia (Puls, 1988).

5.2.1.3.3 Lead

Receptor – Terrestrial Plants

Lead inhibits plant growth, reduces photosynthesis, and reduces mitosis and water absorption. Adverse effects have been observed in roadside weeds (*Cassia* spp.) at lead concentrations of 12 to 312 mg/kg in soil (Krishnayya and Bedi 1986). Non-lethal effect levels were reported at 1200 mg/kg (lead in soil) for species such as pine. The same concentration resulted in an EC₅₀ in raddishes.

Receptor – Soil Invertebrates

No observed effect concentrations from lead exposure were noted in the range of 1480 mg/kg, and lethal doses were in the range of 2500 mg/kg in various species of earthworms (BC MELP, 1996).

Receptor – Small Mammals and Birds

Puls (1998), in his review of the literature, noted chronic toxicity levels of 25 mg/kg/day in rabbits.

Chronic toxicity signs of lead in rabbits include reduced appetite, reduced weight, lethargy, and reduced immune responses. The chronic toxic dose of lead for ducks is 12 mg Pb/kg body wt/day (Puls, 1988). Lead toxicity signs in water fowl include behavioural changes, lethargy, anorexia, anemia, flaccid paralysis and prostration, emaciation, impaction of proventriculus (Puls, 1988).

5.2.1.3.4 Zinc

Receptor – Terrestrial Plants

Uptake of zinc from soils by plants is dependent on soil type; for example, uptake is lower in coarse loamy soils than in fine loamy soils (Chang et al. 1983). In 1996, the British Columbia Ministry of Environment held a CSR review workshop, which outlined the methodology for the CSR standards for soil invertebrates and plants. The workshop provided an overview of the lethal and non-lethal effect levels for several metals to plants as documented in the literature. A wide range of effect levels were noted, ranging from no effect on seed emergence of lettuce at concentrations of 1000 mg/kg zinc to in soil, to 50% effect levels on turnip seed emergence at zinc concentrations of 25 mg/kg in soil.

Receptor - Invertebrates

Among terrestrial invertebrates, adverse effects on earthworm survival were documented to range from 470 to 662 mg/kg of soil. Slugs had reduced food consumption at 300 mg Zn/kg diet and reduced growth at 1,000 mg Zn/kg diet (Chang et al. 1983). The BCMELP (1996) indicated zinc toxicity values (LC₅₀ concentrations) for invertebrates ranging from 80 mg/kg to 1010 mg/kg.

Receptor – Small Mammals and Birds

Puls (1988) found dietary toxicity levels of zinc to be greater than 1,500 ppm in mink. Concentrations above 1,500 ppm caused toxicity signs such as impaired reproductive performance and reduced hematocrit values. Toxicity occurred in mallards (*Anas platyrhynchos*) when fed 3,000 mg Zn/kg for 30 days (Eisler, 1993); at this concentration many deaths occurred. Other zinc toxicity signs include leg paralysis, depressed hemoglobin and hematocrit levels, reduced food intake, reduced body weight and egg production, and reduction in pancreas size (Puls, 1988).

Table 23 summarizes the metals chosen for the ecological risk assessment and the associated

toxicity concentration ranges for the selected receptors.

Table 23. Metals Toxicity Ranges for the Ecological Receptors

Parameter	95 th Percentile mg/kg Soil Concentrations at Subject Area	Reported Toxicity Ranges mg/kg	
		Terrestrial Plants and Invertebrates Soil Concentrations	Small Mammals and Birds Diet Concentrations
Chromium	151	EC ₅₀ – 250 LC ₂₀ – 800	1.7 - 5000
Copper	984	27 – 2760 EC ₅₀ – 150 LC ₂₀ – 250	300-600
Lead	546	12 – 3070 EC ₅₀ – 1000 LC ₂₀ – 2000	12-25
Zinc	1284	20 – 1010 LC ₂₀ – 450 EC ₅₀ – 600	1500 - 3000

LC₂₀ = Lethal Concentration – The concentration at which mortality occurs in 20% of the test subjects

EC₅₀ = Effective Concentration – The concentration at which 50% of the test subjects experience some kind of adverse effect, i.e. behaviour, growth, reproduction.

The data suggest that copper and zinc in the soils near Foundation AB are at levels that may impact plant growth and invertebrate survival.

5.2.1.4 TOXICITY ASSESSMENT OF HYDROCARBONS IN SOIL

Literature on toxicity of petroleum hydrocarbons to terrestrial plants and invertebrates is received within the CWS support documentation for the petroleum hydrocarbon criteria. **Table 24** provides an overview of the CWS findings.

Table 24. Summary of Hydrocarbon Toxicity as per the CWS

Hydrocarbon	95 th Percentile (mg/kg) Soil Concentrations at Site	Soil Toxicity (mg/kg)		CWS Standard
		Plants	Invertebrates	
Fraction 2 >C ₁₀ – C ₁₆ (LEPH equivalent for this study)	2080	• EC₅₀ endpoint 1800 mg/kg • Alfalfa shoot 21 day EC₅₀ 1, 370 mg/kg (CCME 2000) • Northern wheatgrass 14 day EC₅₀ 1,370 mg/kg (CCME 2000)	LC ₅₀ endpoint 600 mg/kg LC ₅₀ worm mortality 7 day 1100 mg/kg (CCME 2000) LC ₅₀ worm mortality 14 day 1100 mg/kg (CCME 2000)	900 mg/kg fine grained soil 450 mg/kg coarse grained soil 2200 mg/kg fine grained soil >1.5 m 1500 mg/kg coarse grained soil > 1.5 m
Fraction 3 >C ₁₆ – C ₃₄ (HEPH equivalent for this study)	322	EC ₅₀ endpoint 2000 mg/kg Alfalfa shoot 26 day EC ₅₀ 2100 mg/kg	• LC₅₀ endpoint 800 mg/kg • LC₅₀ worm mortality 57 days 810 mg/kg	800 mg/kg fine grained soil 400 mg/kg coarse grained soil 3500 mg/kg fine grained soil > 1.5 m 2500 mg/kg coarse grained soil > 1.5 m
Fresh Diesel			• LC₅₀ worms 1000 mg/kg	
Weathered Diesel		EC ₅₀ endpoint 20,000 mg/kg		

LC₂₀ = Lethal Concentration – The concentration at which mortality occurs in 20% of the test subjects

EC₅₀ = Effective Concentration – The concentration at which 50% of the test subjects experience some kind of adverse effect, i.e. behaviour, growth, reproduction.

The data show that weathering of a petroleum product such as diesel results in a reduced toxicity of the product in soil. CWS states that the existing database is very limited, and “at face value, the data suggests that weathered diesel is substantially less toxic to plants than fresh diesel”.

5.2.1.5 ASSESSMENT OF POTENTIAL RISK OF COCS TO TERRESTRIAL SPECIES

Table 25 compares the toxicity information provided in **Section 5.2.1.4** with the concentrations of contaminants observed in the site soils. The potential risks to terrestrial species that may be exposed to the contaminants of concern are evaluated.

Table 25. Terrestrial Ecological Risk Characterization

Contaminant of Concern	Concern/Risk	Comparison with toxicity information	Field Observations
Chromium	Minimal – Likely not of concern	95 th percentile within EC ₅₀ and less than most reported chronic and lethal concentrations to plants	Some areas with metals contamination have evident vegetation. Field data inconclusive for vegetation and invertebrates.
Copper	Likely of concern	95 th percentile concentrations > most reported chronic and lethal concentrations to plants	
Lead	Likely not of concern	95 th percentile concentrations within EC ₅₀ and LC ₂₀ 's for plants and invertebrates	
Zinc	Likely of concern	Concentrations > than most reported chronic and lethal concentrations to plants and invertebrates	
Hydrocarbons	Probably not of concern	Soils contain LEPH > reported toxicity levels in laboratory studies for plants and invertebrates. However LEPH < reported toxicity levels for weathered diesel Hydrocarbons are at subsurface depths that are not generally accessed by roots and invertebrates	No effect on vegetation noted in areas with elevated hydrocarbons.

5.2.1.6 TERRESTRIAL UNCERTAINTY ANALYSIS

Table 26 summarizes the uncertainty in the assumptions made during the ecological risk assessment.

Table 26. Summary of Uncertainty

Assumption	Uncertainty	Rational
Contaminants Distribution		
Metals	Moderate to High	Insufficient samples submitted for analysis. The dispersion is not well defined.
Hydrocarbons	Low	Sufficient samples submitted for analysis.
Contaminant Concentrations		
Metals and Hydrocarbons in soil, sediment and water	Low	Relative percent difference between samples and duplicates are low. Laboratory results appear reliable.
Hydrocarbon Receptors		
Soil Invertebrates	Moderate	Invertebrate populations to depth of hydrocarbon contamination not well defined.
Terrestrial Plants	Moderate	Root growth to hydrocarbon concentration depth is not known. No effects visibly evident.
Small Mammals and Birds	Low	No logical pathway for exposure to hydrocarbons.
Bioavailability		
Soil Invertebrates	Moderate	No bioassay completed
Terrestrial Plants	High	Limited visual observations and limited bioassay data
Toxicity		
Toxicity Ranges for Metals	Moderate	Toxicity ranges based on species that may not be present on site

5.2.1.7 TERRESTRIAL – RISK CHARACTERIZATION

The primary goal of the deterministic ecological assessment was to determine the impacts, if any, resulting from metals in surface soils around Foundation AB and the presence of hydrocarbons in the subsurface. Based on the toxicity assessment of the metals in **Section 5.2.8.3** and the observed concentrations of copper and zinc, it appears that there is a potential risk to ecological health (**Table 22**) on a localized basis, i.e. to the vegetation and invertebrates.

5.3 AQUATIC ECOLOGICAL RISK ASSESSEMENT

5.3.1 Aquatic Exposure Assessment

5.3.1.1 RECEIVING ENVIRONMENT

Brooks Brook borders the south and east side of the Subject Area. This portion of the brook was re-routed from its historical location during the construction of the Alaska Highway (**Figure 2**). As mentioned in **Section 2.2.5.1** of this report, the banks are sloped 1:1 and on average 1.5 m in height. The bank and stream bottom consist primarily of gravel. The flow is rapid and there was little evidence of settled fine material within the gravel bed. During September 2001, the brook was approximately 0.25 m deep and had an estimated flow-rate of 1.2 m/s. The water was clear, with no evidence of algal growth. No vegetation was present from the top of the bank to the stream bed. Brooks Brook drains to Teslin Lake, which is located approximately 300 meters west of the Subject Area.

Based on the analysis of Brook's Brook water there is no evidence of PCOC presence in the stream. As there is no evidence of a PCOC loading to Teslin Lake, the risk assessment should not consider risk to Teslin Lake.

5.3.1.2 GROUNDWATER

Key to this risk assessment is the possible impact of groundwater contamination on the quality of water in Brooks Brook. As described in **Section 2.2.5.2.1** of this report, two studies of groundwater flow (March 1999 and September 2001) indicated that there may a net flow from Brooks Brook into the highly permeable sand and gravel horizon, and that the net flow of groundwater is southwest, away from Brooks Brook. With reference to **Figure 2** it is observed that Brooks Brook follows a "U" shaped pathway. Although the net flow of groundwater from the area of soil contamination is away from the eastern section of the brook, the flow proceeds in the direction of the brook at a distance which may range from 10 to 100 meters, dependent upon the groundwater flow pattern. Large tree

growths restricted further access of the drill rig to the south of the Subject Area, and further delineation of groundwater flow patterns could not occur without destruction of the trees. Destruction of the trees would have been contrary to the intent of the clients, who wish to maintain the current tree growth on the property. As a result, a risk assessment of groundwater impacts on the quality of Brooks Brook water may be limited in its conclusions, pending additional field information.

5.3.1.3 *EXPOSURE TO AQUATIC BIOTA*

Within Brooks Brook, the following exposures are evaluated for consideration within the risk assessment:

5.3.1.3.1 *Aquatic Invertebrates*

Typically, a risk assessment would consider aquatic invertebrates in streams, such as *Daphnia magna* (water flea). Although aquatic invertebrate populations have not been assessed for this area, this risk assessment will consider the possible impact to aquatic invertebrates as a result of direct exposure to groundwater-borne COPCs that may migrate to surface water.

5.3.1.3.2 *Aquatic Plants*

Given the field observations of the absence of algae and macrovascular vegetation in the brook, aquatic plants are not considered receptors of direct exposure to groundwater-borne COPCs that migrate to surface water.

5.3.1.3.3 *Fish*

Graylings are noted to inhabit the brook. The risk assessment will first consider direct exposure to groundwater-borne COPCs that migrate to surface water and porewater. Ingestion of food will only be considered if there is evidence of elevated chemical concentrations in the brook water. Given the shallow depth of the brook in September, i.e. 25 cm, and the likelihood of a complete freeze-over, it is unlikely that the stream is a major habitat for resident fish. Fish in Teslin Lake would encounter more long-term exposure if contamination extended to that distance.

5.3.1.3.4 Birds

Ingestion of food with elevated chemical concentrations by birds is not considered a major concern given the small area of the Subject Area, relative to a typical feeding area for most bird species.

5.3.1.4 AQUATIC TOXICITY ASSESSMENT OF COCs

Table 27 summarizes the aquatic contaminants of potential concern in terms of the contaminant toxicity to aquatic invertebrates and fish as selected in the previous section of this report.

Table 27. Summary of Aquatic Contaminants of Potential Concern

COPC	Assessment of COPC
Iron	<i>Properties</i> Iron occurs naturally, and the level of its presence in water is dependent upon many factors. Mostly present in surface water in ferric state (Fe^{+3}), but occurs in low concentrations in the water column as ferric salts, has a low solubility in aerobic waters. Ferrous iron (Fe^{+2}) persists and is found in high concentrations in reducing waters where sulphide and carbonate anions are absent (i.e. in a landfill). Also occurs as inorganic or organic ferrous and ferric complexes, or as stable colloids (CCREM, 1997). Concentrations in water are influenced by: oxidation-reduction reactions, pH, and other inorganic and organic complexing agents. Ferrous iron predominates at low pH in anoxic environments such as groundwater and ferric iron is most abundant in oxygenated water. Hydroxide complexes form at neutral and alkaline pH. Release of groundwater to surface waters will result in oxidation of ferrous iron to the ferric form. The elevated levels in groundwater at the subject site may be due to natural concentrations and/or due to natural degradation of the hydrocarbon residues in soil. Areas of groundwater seepage to surface waters are generally characterized by a red colour; no such colouration was observed in Brooks Brook.
	<i>Toxicity</i> Ferric iron precipitates in high concentration may result in the coating of gills of fish and settled iron precipitates may be detrimental to fish eggs and bottom dwelling fish food organisms. A 72 hr LC_{50} of greater than 500,000 $\mu\text{g/l}$ for the channel fish was recorded by Clemens and Sneed in 1959. 96 hr LC_{50} values for invertebrates (mayflies, stoneflies and caddis flies) are in the

	order of 320 µg/L iron (NC, 1974). Gerhart (1995) found a 42 day EC₅₀ of 23,410 µg/L for <i>Leptophlebia marginata</i> (mayfly).
	<i>Guidelines</i>
	1000 µg/L iron was deemed adequately protective for freshwater aquatic life (U.S. EPA, 1976). 96 hr LC₅₀ values for fish range from 300 to 500,000 µg/L iron. The European Inland Fisheries Advisory Commission recommends that iron should not exceed 1000 µg/L to manage aquatic life. The CCME total iron in the receiving environment is 300 µg/L while the YCSR standard for dissolved iron in groundwater is 3,000 µg/L. The concentrations observed in groundwater from the Subject Area range from 11,100 to 13,100 µg/L.
Manganese	<i>Properties</i>
	Manganese occurs naturally and its chemical behaviour is very similar to that of iron. It is frequently found in association with iron. Soluble manganese may be elevated in area of anaerobic decomposition, and the levels observed at the subject site may be due to degradation of hydrocarbon residuals in soil. Adverse effects of manganese on freshwater aquatic organisms have been reported in a number of studies, although the cause-effect evidence is not extensive (Reimer, 1999). A review of the literature on manganese toxicity conducted by Reimer (1999), found aquatic toxicity values of manganese to vary with the water hardness.
	<i>Toxicity</i>
	A 96 h LC₅₀ for rainbow trout was found at manganese concentrations of 4.83 mg/L with a pH of 7.53 and a water hardness of 34 mg/L. An IC₂₅ (statistically derived concentration at which 25% of organisms are inhibited for the exposure endpoint in the study, i.e. growth, reproduction, hatching success vs. controls) of 5.59 mg/L was found during a 62 day chronic toxicity test on Brown trout. The pH of the water was 7.9 while the hardness was 150 mg/L. Trenel and Kuhn (1982) found a 48 h LC₅₀ of 4.7-56.1 mg/L in <i>Daphnia magna</i>.
	<i>Guidelines</i>
	Manganese freshwater aquatic life values of 0.1-1 mg/L was recommended by the United States EPA (Reimer, 1999). A review of the EPA guideline for manganese found that the description of the effects of manganese on aquatic life "is inadequate, of little value to aquatic biologists generally out of date, lacks completeness and seldom cites the available literature" (Reimer 1999). The current YCSR standard for groundwater is 1mg/L while there is no current CCME guideline for manganese. Reimer (1999) proposed hardness dependent guidelines for manganese. The concentrations of manganese in groundwater at the Subject Area range from

	0.6 – 1.17 mg/L.
Naphthalene	<i>Properties</i>
	Naphthalene is found in petroleum products. It is readily biodegraded by soil and aquatic micro-organisms (IEDA, 1974). When exposed to sunlight, photolysis may occur.
	<i>Toxicity</i>
	Fish – Moles (1980) found a 96h LC ₅₀ of 3220 µg/L in <i>Oncorhynchus kisutch</i> (coho salmon). A CCME review reported 96h LC ₅₀ ranges of 1990 to 7900 µg/L for fathead minnows. Chronic effects to rainbow trout embryo larvae stages were reported at ranges from 8 – 46 µg/L (mean of 11 µg/L) at 4 day exposures.
	Invertebrates - A CCME review reposted 48h LC ₅₀ 's of 2160 to 4663 µg/L for <i>Daphnia magna</i> .
	<i>Guidelines</i>
	The CCME FAL guideline for surface water is 1.1 µg/L while the YCSR groundwater standard is 10 µg/L. Concentrations of naphthalene at the Subject Area range from 0.15 – 130 µg/L.
Phenanthrene	<i>Properties</i>
	The source of phenanthrene at the Subject Area is likely a petroleum product. Biodegradation is an important fate process along with photolysis when dissolved in water.
	<i>Toxicity</i>
	Fish – In continuous-flow toxicity tests with embryo-larval stages of rainbow trout and largemouth bass (<i>Micropterus salmoides</i>), the LC ₅₀ values for phenanthrene were 40 and 180 µg/L (CWQG, 1996). Call et al. (1986) conducted chronic tests with rainbow trout and embryos exposed to phenanthrene. The LOEC and NOEC for mortality were 8 µg/L and 5 µg/L. The same study found 96h LC ₅₀ of 375 and 234 µg/L and 96h EC ₅₀ s (loss of equilibrium) of 50 and 49 µg/L for rainbow trout and sunfish, respectively.
	Invertebrates - Call et al. (1986) reported a 48h EC ₅₀ (immobilization) of 117 µg/L for <i>D. magna</i> . Call et al. (1986) also reported 96h EC ₅₀ s of 96 µg/L (shortened tentacles and body column for hydroids) (marine species) and 126 µg/L (immobilization) for amphipods (<i>Gammarus pseudolimnaeus</i>) exposed to phenanthrene.
	Plants - The CWQG suggests that the effect of polycyclic aromatic hydrocarbons on aquatic plants is variable (CWQG, 1996).
	<i>Guidelines</i>
	The interim water quality guideline for phenanthrene for the protection of freshwater life is 0.4 µg/L. It was derived by multiplying the chronic LOEL of 4

	µg/L for rainbow trout (corresponding to the control-adjusted 93% survival of the trout) (Black et. al. 1983) by a safety factor of 0.1 (CCME 1991). The YCSR groundwater standard is 3 µg/L for phenathrene. Concentrations at the Subject Area range from 0.025 to 1 µg/L. The CWQG suggests that the effect of polycyclic aromatic hydrocarbons on aquatic plants is variable (CWQG, 1996).
Pyrene	Properties - Pyrene is found in petroleum products, and natural sources such as forest fires also produce pyrene. - Pyrene would biodegrade in the environment but at a slower rate than naphthalene. Dissolved pyrene can undergo photolysis. Some PAHs, such a pyrene have, been shown to be severely toxic to aquatic organisms when the dissolved PAHs are exposed to sunlight or UV light (BCE, 1993).
	Toxicity
	Fish — Phototoxic effects of pyrene to fish have been demonstrated at concentrations as low as 25.6 µg/L (Oris and Giesy, 1987). In the absence of UV light, acute effects have not been observed at 2000 µg/L in several test species (coho salmon, rainbow trout, chinook salmon, sea lamprey, fathead minnow, northern squawfish). Invertebrates - A number of tests have been conducted with freshwater species and most of these address phototoxic endpoints (Kagan et al., 1985; Oris and Giesy, 1987; Borovsky et al., 1987; Newsted and Giesy, 1987). Reported LC₅₀s range from 4 to 60 µg/L. The lowest effects concentration from a non-phototoxic endpoint is for freshwater daphnids have also been observed below 100 µg/L in the absence of UV light (Abernethy et al., 1986).
	Guidelines
	The YCSR groundwater standard for pyrene (0.2 µg/L) was derived using the freshwater phototoxic ambient water quality guideline of 0.02 µg/L (BCE, 1999c). The ambient water quality guideline was based on consideration of the relative phototoxic potentials of pyrene and anthracene (i.e., pyrene assumed to be 4.7 times more phototoxic to fathead minnow (<i>Pimephales promelas</i>), the phototoxicity of anthracene to fathead minnows (Oris and Giesy, 1987), and by application of a safety factor of 0.01 to the fathead minnow LOEC (12 µg/L) (BCE, 1993). In other words, the pyrene criterion was derived from surrogate chemical toxicity information, rather than from studies conducted specifically with pyrene. Due to a lack of data, no water quality criterion for protection of aquatic life from chronic (non-phototoxic) effects was developed. There is a high degree of uncertainty with the ambient water guideline for pyrene and in turn for the YCSR standard. Based on other PAHs, it is expected that pyrene

	would have a large difference in relative potency between phototoxic and non-phototoxic exposures. The apparent conservatism of the standard, coupled with its assumption of an exposure scenario eliciting phototoxic effects, warranted closer investigation. The BC guideline, upon which the YCSR is based, was developed over seven years ago. Pyrene concentrations in groundwater at the site have ranged from 0.01 to 0.2 µg/L.		
Toluene	<i>Properties</i>		
	Petroleum products such as gasoline and solvents contain toluene. Volatilization is a major fate process for toluene. Toluene in water would have a half-life of approximately 5.2 hours (EPA, 1979).		
	<i>Toxicity</i>		
	Fish - Concentrations of toluene causing acute toxicity to fish species ranged from 5,460 µg/L for coho salmon to 1,340,000 µg/L for mosquito fish (CWQG, 1996). The threshold concentration for sublethal effects of toluene on the growth of coho salmon fry was between 0.02 and 5.8 µg/L. Invertebrates -Chronic toxicity of toluene to aquatic invertebrates may occur at concentrations below 4,300 µg/L.		
	<i>Guidelines</i>		
	The 1996 Canadian Water Quality Guidelines (CWQG) set the guideline for toluene at 300 µg/L. This guideline is based on a review of literature regarding toxicity of toluene to various aquatic organisms. The guideline for the protection of aquatic life was derived using the LC₅₀ value of 5,460 µg/L for coho salmon and an application factor of 0.05 (CWQG, 1996). Toluene concentrations in groundwater at this site have ranged from 0.05 to 24 µg/L.		
Hydrocarbons	<i>Properties</i>		
	Hydrocarbons degrade in the environment. However the rates of degradation depend upon factors such as temperature, bacteria populations, nutrient levels and the types of hydrocarbons (i.e. light hydrocarbons from products such as diesel degrade faster than heavy hydrocarbons from products such as lubrication oil or Bunker oil). Aging of hydrocarbons in soil has been observed to result in lower toxicity and lower ecological impacts.		
	<i>Toxicity</i>		
	<u>Product</u>	<u>Organism</u>	<u>LC₅₀ (µg/L)</u>
	Fuel Oil # 2	Rainbow trout (eggs)	1.2 x 10 ⁴ – 2.0 x 10 ⁴
	Gasoline	Rainbow trout	4.0 x 10 ⁴ – 1.0-x 10 ⁵
	Diesel	Daphnia magna	7.2 x 10 ³
	Diesel	Salmo gairderi	2.5 x 10 ³

	(Oncorhynchus mykiss)	
New crankcase oil	Daphnia magna	3.8×10^2
Used crankcase oil	Daphnia magna	4.2×10^4
Guidelines		
There are no current ambient water quality guidelines for petroleum hydrocarbons. There are no YCSR or CCME groundwater standards or guidelines. The BC CSR groundwater standard for LEPH (F2) is 500 µg/L. TEH levels in groundwater at this site have ranged from 50 to 30,000 µg/L and LEPH concentrations have ranged from 125 to 2,500 µg/L. The TEH concentrations would represent concentrations of product such as diesel, which is likely the source of hydrocarbon contamination at the Subject Area. Until approximately 1998, the BC ministry of Environment required reporting of TEH "as diesel".		

Table 28 summarizes the contaminants of potential concern and the associated toxicity concentrations for the selected receptors.

Table 28. Toxicity Values for the Potential Aquatic Receptors

Parameters	95 th Percentile Concentrations in Groundwater	Reported Toxicity Ranges in Surface Waters	
		Aquatic Invertebrates	Fish
Iron	13.1 mg/L	96 hrLC ₅₀ of 0.32 mg/L in mayflies and stoneflies	< 1 mg/L to maintain fish populations
Manganese	1.167 mg/L	48 h LC ₅₀ of 4.7-56.1 mg/L in <i>Daphnia magna</i> 48 h EC ₅₀ of 40 mg/L in <i>Daphnia magna</i>	96 h LC ₅₀ of 4.83 mg/L @ 34 mg/L CaCO ₃ in rainbow trout 62 day IC ₅₀ of 5.59 mg/L @ 150 mg/L CaCO ₃ in Brown Trout
Naphthalene	16 µg/L	24 h EC ₅₀ 15,000 µg/L in <i>Daphnia magna</i>	96 h LC ₅₀ 3220 µg/L in Coho Salmon Lowest reported chronic effects: 8-46 µg/L
Phenanthrene	0.69 µg/L	96 h EC ₅₀ of 117 µg/L in <i>Daphnia magna</i> (immobilization)	96 h LC ₅₀ of 375 µg/L in rainbow trout 96 h EC ₅₀ of 49 µg/L Lowest reported effect level (LOEL): 8 µg/L No observed effect level (NOEL): 5 µg/L

Pyrene	0.09 µg/L	In the presence of UV light, LC ₅₀ 's ranges from 4-60 µg/L in <i>Daphnia magna</i> In absence of UV light, EC ₅₀ for <i>Daphnia magna</i> has been reported to be less than 100 µg/L	Observed effects of pyrene on fish in the absence of UV from light occur at concentrations in excess of 2000 µg/L. In the presence of UV light toxicity (LT ₅₀) occurs in the range of 26 µg/L.
Toluene	2.48 µg/L	EC ₅₀ 's for <i>Daphnia magna</i> range from 7,000 to 310,000 µg/L. Chronic toxicities range from 3,750 µg/L (16 day LC ₅₀) for <i>Daphnia magna</i> to 173,000 µg/L (6 day EC ₄₀)	Acute toxicity for fish range from 5460 µg/L (96h LC ₅₀) for coho salmon to 1,340,000 µg/L in mosquito fish. Chronic Toxicity ranges from 20 µg/L in rainbow trout to 68,300 µg/L in guppies.
LEPH	2080 µg/L	LC ₅₀ of 7200 µg/L in <i>Daphnia magna</i> (diesel)	LC ₅₀ of 2,500 µg/L in <i>Salmo gairderi</i> (diesel)
HEPH	322 µg/L	LC ₅₀ of 42,000 µg/L in <i>Daphnia magna</i> (used crankcase oil)	LC ₅₀ of 2,500 µg/L in <i>Salmo gairderi</i> (diesel)

5.3.1.5 ASSESSMENT OF POTENTIAL RISK OF COCS TO AQUATIC SPECIES

The assessment of potential risk to aquatic species is dependent upon likely exposure levels. Two iterative conservative scenarios are used in this risk assessment.

Assumption that aquatic life is exposed to chemicals at the 95th percentile concentrations observed in groundwater. It is assumed there are no retarding factors such as biodegradation, adsorption or dilution between a well (where high concentrations were observed) and the receiving water body. Additionally it is assumed, no dilution occurs within the stream. It is noted that the Fisheries Act is applied to discharges to a water body without any consideration for dilution within the water body. It is noted that brook water quality adjacent to the subject area has no detectable concentrations of the PCOC's.

If a comparison of groundwater concentrations with the toxicity values noted in **Tables 27 and 28** show a potential impact, then the iterative approach of assessing potential impacts of groundwater on

down-gradient stream water quality will be used. A one dimensional chemical transport in groundwater modelling will be used to predict possible concentrations at the point of discharge to a down-gradient portion of the brook. It is recognized that the down-gradient groundwater flow is not fully characterized because of site limitations, and conservative assumption will be made for pathways of transport.

5.3.1.5.1 *Direct Comparison of Groundwater Quality with Toxicity Information*

The first comparison of groundwater concentrations with toxicity information eliminates all chemicals of concern except for iron, naphthalene and LEPH. Iron is removed from consideration as it is considered to be a background concentration. The following section will provide a further evaluation to groundwater transport.

Table 29 provides an assessment of the aquatic ecological risk based on the prior toxicity information.

Table 29. Aquatic Ecological Risk Characterization

Contaminant of Concern	Concern/Risk	Comparison with toxicity information	Field Observations
Iron	Possibly (could be background)	95 th percentile greater than LC ₅₀ concentrations	No visual indications of red staining along Brooks Brook
Manganese	Not Likely	95 th percentile well within EC ₅₀ and LC ₅₀ concentrations	
Naphthalene	Possibly	95 th percentile well within EC ₅₀ and LC ₅₀ concentrations for invertebrates and fish 95 th percentile (16 µg/L) greater than lowest range (8 µg/L) of chronic effects to fish but lower than upper range number (46µg/L).	
Phenanthrene	Not Likely	95 th percentile concentrations well within EC ₅₀ and LC ₅₀ 's for fish and invertebrates 95 th percentile (0.69 µg/L) lower than reported No	

		observed effects level (5 µg/L)	
Pyrene	Not Likely	95 th percentile concentrations well within EC ₅₀ and LC ₅₀ 's for fish and invertebrates, including toxicity values reported in presence of UV light.	
Toluene	Not Likely	95 th percentile concentrations well within EC ₅₀ and LC ₅₀ 's for fish and invertebrates	
LEPH	Possibly	95 th percentile concentrations near the reported LC ₅₀ concentrations for fish and above 0.05 safety factor typically used by CCME.	Hydrocarbon sheen and odour observed in groundwater samples.
HEPH	Not Likely	95 th percentile concentrations well within LC ₅₀ 's for fish and aquatic invertebrates	

5.3.1.5.2 Comparison of Calculated Down-gradient Groundwater Quality with Toxicity Information

The route of Brooks Brook is such that there are two scenarios by which contaminated groundwater could influence the water quality of Brooks Brook:

A portion of Brooks Brook is directly adjacent to hydrocarbon contamination in the Subject Area. Previous discussions in this report indicate that groundwater at the Subject Area moves away from this portion of Brooks Brook and that Brooks Brook may in part be a source of groundwater in the subject area. Water quality samples showed no impacts of groundwater in this area of Brooks Brook. No further consideration of the impact of the PCOC's for this area of Brooks Brook is necessary. Due to the "U" shaped configuration of Brooks Brook, contaminated groundwater may move towards down-gradient areas of the brook as discussed in **Section 2.3.3** of this report. Within this section it is also noted that down-gradient groundwater flow patterns have not been defined because of limitations of access to down-gradient areas, and points of entry to Brooks Brook of water from the well with the most contaminated groundwater may vary from 20 to more than 100 meters. To estimate the possible concentrations of the two contaminants, LEPH and naphthalene, at down-gradient areas, a one dimensional model was used to simulate transport of the chemicals in a confined groundwater aquifer.

The calculation considers:

- Advection – chemical movement via groundwater flow due to the groundwater gradient
- Dispersion – longitudinal (forward and backward) spreading of the contaminant
- Retardation – adsorption of the chemicals to the soil will cause the chemical velocity to be slower than groundwater velocity. It should be noted the equation makes no allowances for biodegradation.

The equations and the assumptions used for estimating contaminant movement at the Subject Area are provided in **Appendix B**. The results are illustrated in **Figure B** where it is assumed the observed worst-case concentration of 2.5mg/L LEPH represents the initial concentration prior to movement in the groundwater regime. The model predicts that the plume enters Brooks Brook 20 meters down-gradient of the “worst-case” LEPHs observed in groundwater well MW01-03, the LEPH concentration at the point of entry to Brooks Brook would be no greater than 0.06 mg/L. The 0.06 mg/L concentrations would be observed after 8 months of transport. If the point of entry of the plume was 40 meters from the area of “worst case” groundwater the LEPH concentration would be approximately 0.03 mg/L, and observed after approximately 18 months transport.

The 0.06 mg/L concentration is 40 fold less than the LC₅₀ reported for diesel and 700 fold less than the LC₅₀ reported for aged diesel.

To calculate guideline concentrations of chemicals on the basis of LC₅₀ concentrations, CCME has used a 20-fold application factor (0.05 multiplier) for non-persistent organic compounds (CCME, 1999). The predicted LEPH concentrations at a 20 meter down-gradient distance at the Subject Area, are well within the application (or protection) factors used by CCME if applied to reported LC₅₀'s for diesel and aged diesel, e.g. LC₅₀ mg/L x 0.05 = 0.125 mg/L versus the predicted 0.06 mg/L. As a result it is predicted the observed LEPH concentrations in groundwater at the site would not be of concern to Brooks Brook.

A similar decrease would be predicted for naphthalene, where the maximum value of 130 µg/L would decrease to approximately 3 µg/L within a distance of 40 meters. The resulting concentration is less than the lowest reported chronic effect level of 8 µg/L.

Overall the mathematic model predicts there would be no impact on down-gradient portions of Brooks Brook. Support for the model was obtained during the site visit on August 1, 2002 in which three surface water samples were collected along the southern "U" shaped portion of the Brook. Each of the three surface water samples collected indicated concentrations of LEPH and naphthalene below the method detection limits. Further, no evidence of iron staining was observed along the banks of the brook.

5.3.1.6 AQUATIC UNCERTAINTY ANALYSIS

Table 30 summarizes the uncertainty in the assumptions made during the aquatic ecological risk assessment.

Table 30. Summary of Uncertainty

Assumption	Uncertainty	Rational
<i>Contaminants Distribution</i>		
Metals	Moderate to High	Insufficient samples submitted for analysis. A real dispersion is not well defined.
Hydrocarbons	High	Hydrocarbon plume not completely delineated due to dense vegetation (trees) to the west of the Subject Area
<i>Contaminant Concentrations</i>		
Metals and Hydrocarbons in groundwater	Low	Relative percent difference between samples and duplicates are low. Laboratory results appear reliable.
<i>Hydrocarbon Receptors</i>		
Aquatic Invertebrates and Fish Species	Moderate to High	Existence of an exposure pathway of contaminants in groundwater to the receptors in Brooks Brook or Teslin Lake does not appear likely due to the August 2002 observations. Populations are not defined in the brook
Aquatic Plants	Low	No aquatic plants observed in Brooks Brook
Birds	Low	Area of site smaller than typical feeding area of birds

<i>Toxicity data</i>		
Aquatic Invertebrates	Moderate	Limited bioassay data particularly for LEPH/HEPH.
Fish Species	Moderate	Limited bioassay data particularly for LEPH/HEPH. Toxicity ranges based on species that may not be present in the area of the site.

5.3.1.7 AQUATIC – RISK CHARACTERIZATION

The primary goal of the aquatic ecological risk assessment was to determine the impacts, if any, resulting from metals and hydrocarbons in the groundwater of the Subject Site. Based on the toxicity assessment of the contaminants in **Section 5.2.1.4** it appears that light extractable petroleum hydrocarbons are the only contaminants of potential concern. Iron is not selected on the basis that the elevated concentrations may be representative of background levels. With respect to the observed concentrations of light extractable petroleum hydrocarbons it is quite likely that there is no potential risk to aquatic health. As summarized in **Section 5.2.1.5**, the uncertainty of this risk is high due to the concentrations of hydrocarbons in the groundwater not being fully delineated and the uncertainty in the groundwater flow patterns. The dense tree growth to the west of the hydrocarbon plume prevented the drill rig from advancing additional boreholes to the west of the hydrocarbon impacted area. Further, Brooks Brook (to the east of the Subject Area) has prevented the advancement of additional boreholes and monitoring wells to the east of the hydrocarbon plume.

A mathematical model suggests that there should be no impacts to Brooks Brook. To verify the model, Hemmera sampled the surface water in August 2002 in the brook at down-gradient locations west and south west of the property to assess the status of the brook and seepage water entering the creek. Three surface water samples were collected and analysed for LEPH/HEPH, PAHs and total metals. Each of the three surface water samples indicated LEPH/HEPH and PAHs concentrations below the method detection limit. In addition, during the site visit the brook was surveyed for evidence of red staining due to elevated iron in the groundwater, there was no visual indication of red staining along the brook. Therefore, the mathematical model, analytical data, and visual observations suggest that the plume is not influencing the brook to the south or west of the Subject Area.

6.0 CONCLUSIONS

6.1 HUMAN HEALTH RISK ASSESSMENT

The human health risk assessment identified: chromium, copper, lead, zinc and hydrocarbons as potential contaminants of concern. The exposure assessment found ingestion, dermal, and inhalation as possible pathways of exposure to humans as the Subject Area is used occasionally for recreational purposes. Possible inhalation of hydrocarbon vapours was also considered in the human health risk assessment.

The exposure estimate calculated the estimated daily intake of each of the above mentioned chemicals. The estimated daily intake values were then compared to the reference doses and tolerable daily intake values found in the literature. All of the estimated daily intake values were well within the recommended RfDs and TDIs. Thus, human health risk assessment did not identify any potential risks to human health within the Subject Area from the metals and hydrocarbon impacted soil and groundwater.

6.2 ECOLOGICAL RISK ASSESSMENT

6.2.1 Terrestrial

The terrestrial risk characterization, based on the toxicity assessment of metals, found copper and zinc at concentrations that may be a potential ecological health risk to soil invertebrates and plants on a localized basis. The metals of concern appear to be localized around the perimeter of Foundation AB.

6.2.2 Aquatic

The aquatic risk characterization suggests there is no risk to aquatic biota from groundwater impacted with light extractable petroleum hydrocarbons.

Analysis of the groundwater collected from the network of monitoring wells over the last few years has indicated a general decrease in concentrations of hydrocarbons. This positive trend should be monitored, as biodegradation is key to reducing the risk to aquatic biota. Hemmera recommends that the monitoring wells be sampled in the spring or summer. Groundwater samples should be analysed for hydrocarbons and metals.

7.0 RECOMMENDATIONS

Based on the human health and ecological risk assessment conducted for the Subject Area at the Brooks Brook Property, Hemmera recommends the following:

1. With regard to the surficial soil around the perimeter of Foundation AB where concentrations of copper and zinc may pose a potential risk to the ecological health of terrestrial plants and soil invertebrates, it is recommended that INAC consider the following three options:
 - a) The soils could be submitted for bioassay tests to verify whether the predicted impacts reflect reality;
 - b) The soils could be scraped and removed from the area without any additional studies; or,
 - c) Leave "as is" (No effects on vegetation were apparent in a 2002 site visit).
2. Annual monitoring of the groundwater wells should occur until such time that the actual field data confirms hydrocarbon contamination in groundwater has attenuated and poses no potential impact to Brooks Brook.

8.0 RISK MANAGEMENT

The risk management approach for the impacted groundwater would be annual monitoring and sampling of all of the monitoring wells in the Subject Area. Each of the wells should be sampled for LEPH/HEPH and dissolved metals. Ongoing monitoring of the hydrocarbon concentrations in the groundwater will assess the rate and degree of attenuation over time. Monitoring would cease upon confirmation of lowered concentrations of LEPH and naphthalene to levels of minimal concern. If the levels do not decrease and are shown to impact Brooks Brook, then optional management procedures such as excavation will have to be considered.

The risk management options for surficial soils contaminated with metals should be evaluated. The bioavailability of the metals may be minimal and vegetation and terrestrial species may have little potential to be harmed. The selected risk management option should be made on the basis of sound science, common sense and cost benefit.

9.0 REPORT CREDITS

1. This report was commissioned by:

Indian and Northern Affairs Canada
Contact name: Brett Hartshorne
Address: 415A Elijah Smith Building
White Horse, Yukon
Telephone: (867) 667-3268

2. Report authors:

Kelli Bergh, B.Sc.
Dennis Konasewich, PhD.
Address: Suite 350 – 1190 Hornby Street
Vancouver, BC V6Z 2K5
Telephone: (604) 669-0424

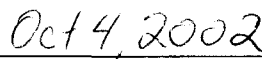
3. Contributors to report:

Dennis Konasewich, PhD., Project Manager

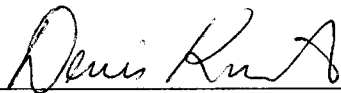
HEMMERA ENVIROCHEM INC.



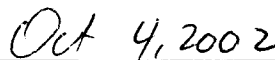
Per: Kelli Bergh B.Sc.



Date



Per: Dennis Konasewich, PhD.
Project Manager



Date

10.0 STATEMENT OF LIMITATIONS

This report ("Report") was prepared by Hemmera Envirochem Inc. ("Hemmera") for the sole benefit and exclusive use of Indian and Northern Affairs Canada ("INAC"). The material in it reflects Hemmera's best judgement in light of the information available to them at the time of preparing the Report. Any use which a third party makes of this Report, or any reliance on or decisions made based on it, are the responsibility of such third parties. Hemmera accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this Report.

Hemmera has performed the work as described in the Scope of Work and made the findings and conclusions set out in this Report in a manner consistent with the level of care and skill normally exercised by members of the environmental science profession practising under similar conditions at the time the work was performed.

This Report was prepared by Hemmera for INAC and represents a reasonable review of the information available to Hemmera within the established Scope of Work, work schedule and budgetary constraints. It is therefore possible that currently unrecognised contamination or potentially hazardous materials may exist at the site(s) and that the levels of contamination or hazardous materials may vary across the site(s). No warranty, expressed or implied, is given concerning the presence or level of contamination on the site. The conclusions and recommendations contained in this Report are based upon applicable legislation existing at the time the Report was drafted and changes in the legislation may alter the conclusions and/or recommendations. Further, any discussion of regulatory implications is based on the applicable legislation existing at time of drafting the Report.

In preparing this Report, Hemmera has relied in good faith on information provided by others as noted in this Report, and has assumed the information provided by those individuals is both factual and accurate. Hemmera accepts no responsibility for any deficiency, misstatement or inaccuracy in this Report resulting from the information provided by those individuals.

The liability of Hemmera to INAC shall be limited to injury or loss caused by the negligent acts of Hemmera. The total aggregate liability of Hemmera related to this agreement shall not exceed the lesser of the actual damages incurred, or the total fee of Hemmera for services rendered on this project.

11.0 BIBLIOGRAPHY

- Abbasi, S.A., and R. Soni. 1983. Stress-induced enhancement of reproduction in earthworm *Ostochaetus pattoni* exposed to chromium (VI) and mercury (II) – implication in environmental management. *Int. J. Environ. Stud.* 22: 43-47.
- Abernethy, S., A.M. Bobra, W.Y. Shiu, P.G. Wells, and D. MacKay. 1986. Acute Lethal Toxicity of Hydrocarbons and Chlorinated Hydrocarbons to Two Planktonic Crustaceans: The Key Role of Organism-Water Partitioning. *Aquat. Toxicol.* 8: 163-174.
- Allred, P.M. and J.P. Giesy. 1985. Solar Radiation-Induced Toxicity of anthracene to *Daphnia pulex*. *Environ. Toxicol. Chem.* 4: 219-226.
- Bastian, M.V. and D.W. Toetz. 1982. Effect of eight polynuclear hydrocarbons on growth of *Anabaena flos-aquae*. *Bull. Environ. Contam. Toxicol.* 29: 531-538.
- Bastian, M.V. and D.W. Toetz. 1985. Effect of Polynuclear Hydrocarbons on Algal Nitrogen Fixation (Acetylene Reduction). *Bull. Environ. Contam. Toxicol.* 35: 258-265.
- BC Environment, 1992. Risk Assessment Guidance.
- BC Environment, 1998. Tier I Ecological Risk Assessment Guidelines.
- BC Ministry of Environment Lands and Parks, 1996. British Columbia Contaminated Sites Review Document/Workshop.
- BCE (British Columbia Ministry of Environment, Lands, and Parks). Ambient Water Quality Criteria for Polycyclic Aromatic Hydrocarbons (PAHs). Prepared pursuant to the Waste Management Act, Section 2(e). August 13, 1993.

- C. Cowerd Jr., et al. Development of Emission Factors for Fugitive Dust Sources, EPA-450/3-74-037, U.S. Environmental Protection Agency, Research Triangle Park NC, June 1974.
- Black, J.A., W.J. Birge, A.G. Westerman, and P.C. Francis. 1983. Comparative aquatic toxicology of aromatic hydrocarbons. *Fundam. Contam. Toxicol.* 29(5):353-538.
- Booth, N.H. and L.E. MacDonald, 1982. *Veterinary Pharmacology and Therapeutics*, 5th Edition. Iowa State University Press, Ames, Iowa.
- Borovsky, D., J.R. Linley, and J. Kagan. 1987. Polycyclic Aromatic Compounds As Phototoxic Mosquito Larvicides. *J. Am. Mosq. Control Assoc.* 3: 246-250.
- Bowling J.W., G.J. Leversee, P.F. Landrum and J.P. Giesy. 1983. Acute Mortality of Anthracene-Contaminated Fish Exposed to Sunlight. *Aqua. Toxicol.* 3: 79-90.
- Bowmer, C.T., R.N. Hooftman, A.O. Hanstveit, P.W.M. Venderbosch, and N. Van der Hoeven. 1998. The Ecotoxicity and the Biodegradability of Lactic Acid, Alkyl Lactate Esters and Lactate Salts. *Chemosphere.* 37(7):1317-1333
- Breeze, V.G. 1973. Land reclamation and river pollution problems in Croal Valley caused by waste from chromate manufacture. *J. Appl. Ecol.* 10: 513-525.
- British Columbia Environment, Lands and Parks. 1990. Waste Management Act, Special Waste Regulation, B. C. Reg. 63/88 (as amended by BC Reg. 10/89, and 106/89), No. 7. April 1992.
- British Columbia Ministry of the Environment Lands and Parks. 1997. Waste Management Act, Contaminated Sites Regulation, BC Reg, 375/96, (as amended by BC Reg 132/99 and 244/99) February 1997.

- Call, D.J., L.T. Brooke, S.L. Harting, S.H.Poirier, and D.J. McCauley. 1986. Toxicity of phenanthrene to several freshwater species, University of Wisconsin-Superior, Center for Lake Superior Environmental Studies, Superior, WI.
- Canada Council of Ministers of the Environment, 1995, 1996, 1997 and 1999 (updates). *Canadian Environmental Guidelines*.
- Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil, 2001.
- Chang, A. C., A. L. Page, J. E. Warneke, M. R. Resketo, and T. E. Jones. 1983. Accumulation of cadmium and zinc in barley grown on sludge-treated soils: a longterm field study. *Journal of Environmental Quality* 12:391-397.
- Clark, M.L., D.G. Harvey and D.J. Humphreys, 1981. *Veterinary Toxicology, 2nd Edition*. Bailliere Tindall, London.
- Clemens, H.P., and K.E. Sneed. 1959. Lethal Doses of Several Commercial Chemicals for Fingerling Channel Catfish. U.S.Fish Wildl.Serv.Sci.Rep.Fish.No.316, U.S.D.I., Washington, D.C.
- Driesbach, R.H., 1983. *Handbook of Poisoning: Prevention Diagnosis and Treatment*. Lang Medical Publications, Los Altos, Ca.
- Eisler, R. 1986. Chromium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Rep. 85(1.6). 60 pp.
- Eisler, R. 1993. Zinc hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildlife Service, Washington, DC. Biological Report No 85(10).
- Elinder, C. G. 1986. Zinc. Pages 664-679 in L. Friberg, G. E Nordberg, and V. B. Vouk, editors.

Handbook on the toxicology of metals, second edition. Volume II: specific metals.
Elsevier, New York.

Environment Canada. 1996. Canadian soil quality guidelines for lead: Environmental. Supporting document – Final draft. December 1996. Science Policy and Environmental Quality Branch, Guidelines Division, Ottawa.

Environmental Science Group. 1996. An Environmental Assessment of Brooks Brook, Yukon Territory. January 1997.

Foster, G.D., and R.E. Tullis. 1984. A Quantitative Structure-Activity Relationship between Partition Coefficients and the Acute Toxicity of Naphthalene Derivatives in *Artemia*. *Aquat.Toxicol.* 5(3):245-254

Foster, G.D., and R.E. Tullis. 1985. Quantitative Structure-Toxicity Relationships with Osmotically Stressed *Artemia salina* Nauplii. *Environ.Pollut.Ser.A Ecol.Biol.* 38:273-281

Friberg, L., Piscator, M. and Nordberg, G.F. and Kjellstrom, T. 1974. Cadmium in the environment II. CRC Press, Cleveland Ohio. 248 pp.

Garrett, C.L., 1988. Chemicals in the Environment – Pacif. and Yukon Region – IV Lead. Environment Canada, Pacific and Yukon region, North Vancouver, B.C.

Gellera, R.J., 1992. Chromium: Hazardous Materials Toxicology. Eds Sullivan, J.B.Jr. and Kreiger, G.R. Williams and Wilkins, Baltimore, Maryland, p.p. 891-895.

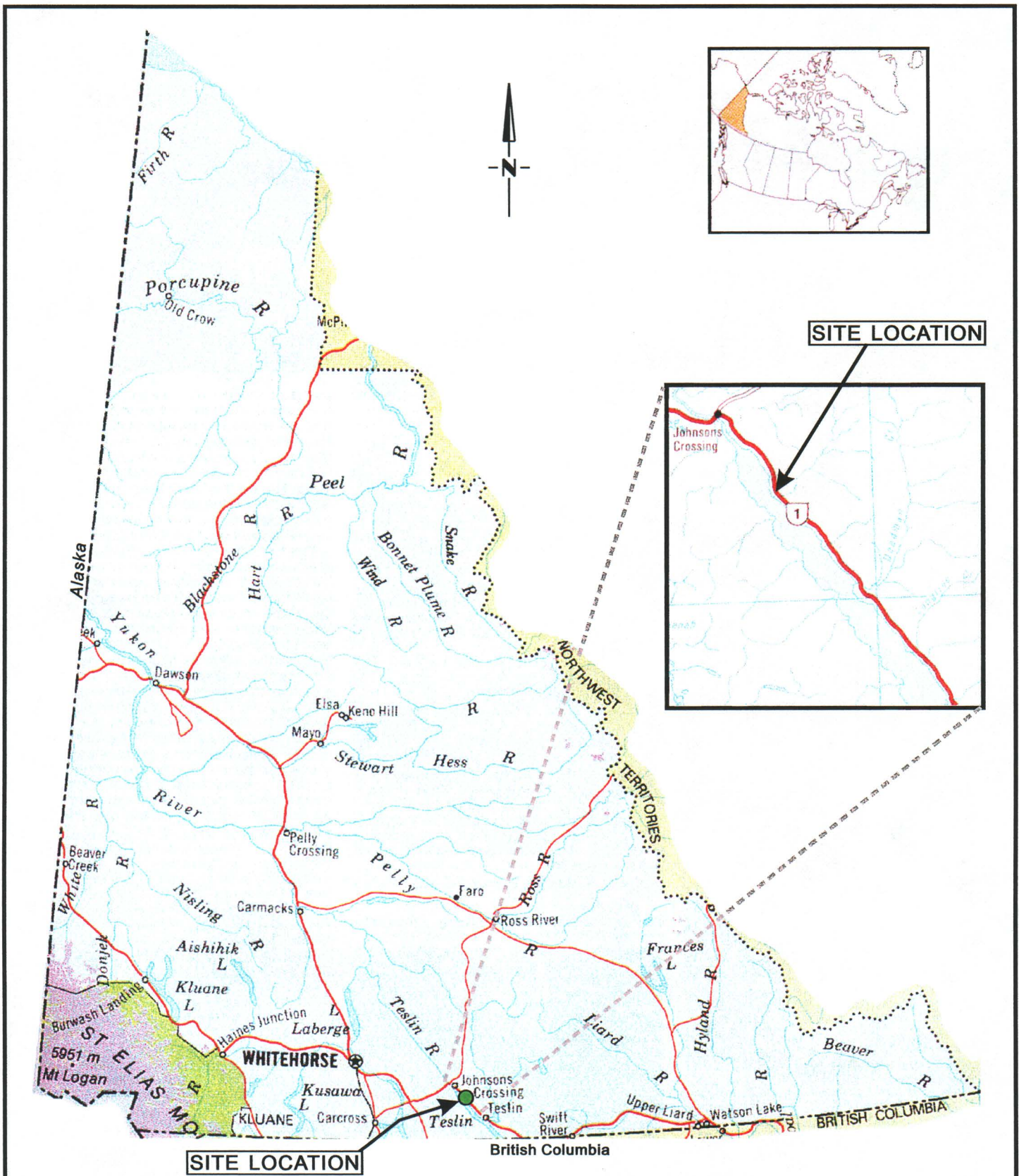
Gerhardt, A.1995. Joint and Single Toxicity of Cd and Fe Related to Metal Uptake in the Mayfly *Leptophlebia marginata* (L.) (Insecta). *Hydrobiologia* 306(3):229-240

Goyer, R.A., 1991. Toxic Effects of Metals: toxicology; the Basic Science of Poisons. 4th Edition,

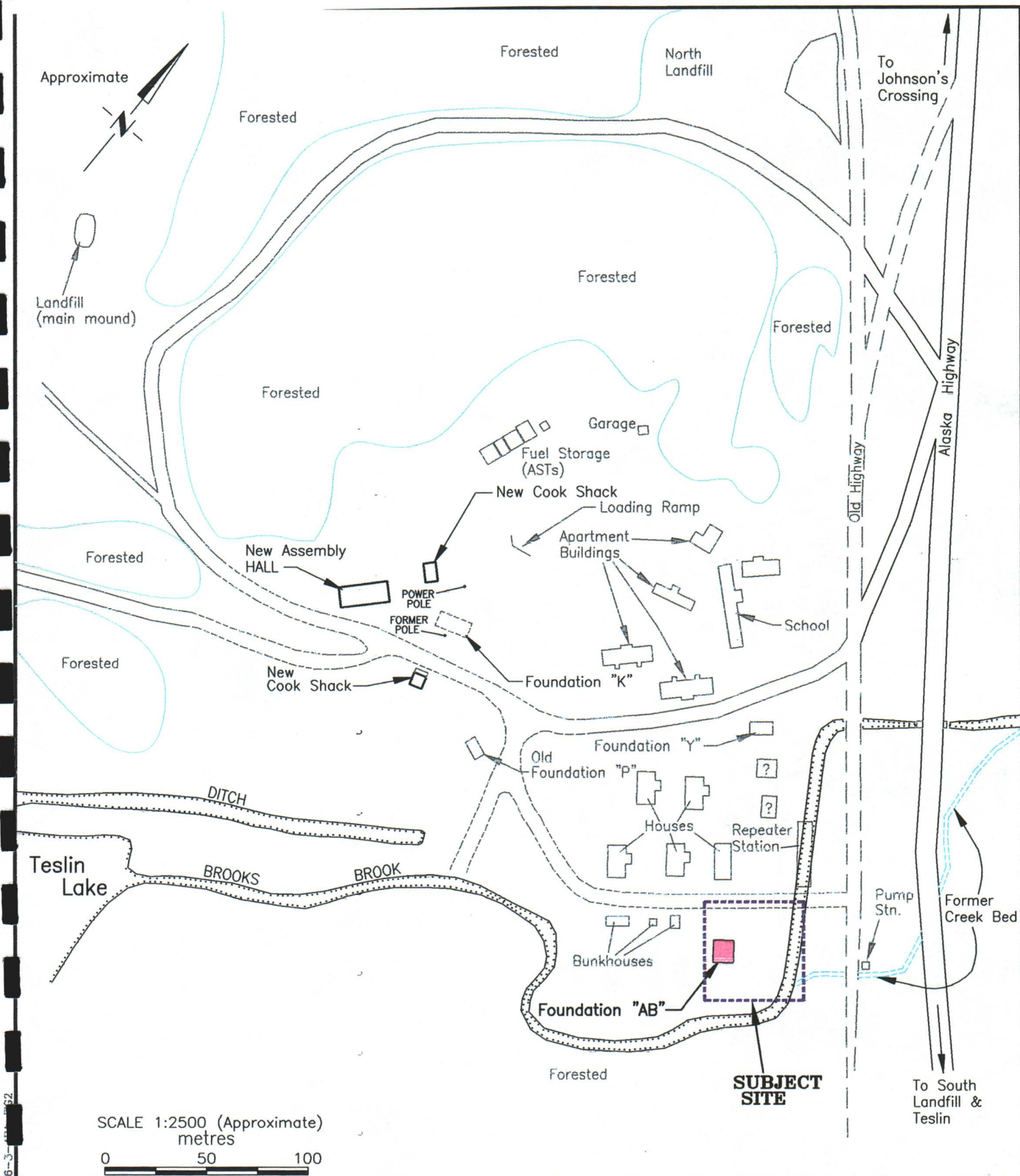
- Eds. M.O. Amdur, J. Doull and C.D. Klaassen. Pergamon Press Canada Ltd. Toronto Ontario, p.p. 623-680.
- Health Canada, 1995. Investigating Human Exposure to Contaminants in The Environment: A Handbook of Calculations. Ministry of National Health and Welfare.
- Hemmera Resource Consultants. 1998. Phase III Assessment of Brooks Brook, Yukon Territory. March, 1999.
- Hemmera Resource Consultants. 1999. OCP Remediation at Brooks Brook, Yukon Territory. March 2000.
- Ivankovic, S; Preussman, R. (1975) Absence of toxic and carcinogenic effects after administration of high doses of chronic oxide pigment in subacute and long-term feeding experiments in rats. Food Cosmet Toxicol 13(3):347-351.
- Kagan, J., E.D. Kagan, I.A. Kagan, P.A. Kagan, and S. Quigley. 1985. The Phototoxicity of Non-Carcinogenic Polycyclic Aromatic Hydrocarbons in Aquatic Organisms. Chemosphere 14: 1829-1834.
- Krishnayya, N.S.R., and S.J. Bedi., 1986. Effect of automobile lead pollution in *Cassia tora* L. and '*Cassia occidentalis* L. Environ. Pollut. 40A:2 1-226
- Lide, D.R. (ed). 1992. CRC handbook of chemistry and physics. 72d ed. CRC Press Cleveland. OH
- Lorimer and Associates Ltd. and Hemmera Resource Consultants Ltd., 1998. *Phase II Assessment for Brooks Brook, Yukon Territory* – DRAFT, June, 1998.
- McKeague, J.A., and M.S. Wolynetz. 1980. Background levels of minor elements in some Canadian soils. Geoderma 24:299-307.

- Moles, A. 1980. Sensitivity of Parasitized Coho Salmon Fry to Crude Oil, Toluene, and Naphthalene. *Trans.Am.Fish.Soc.* 109(3):293-297
- Newsted, J.L. and J.P. Giesy. 1987. Predictive Models for Photoinduced Acute Toxicity of Polycyclic Aromatic Hydrocarbons to *Daphnia magna*, Strauss (Cladocera, Crustacea). *Environ. Toxicol. Chem.* 6: 445-461.
- NRCC (National Research Council of Canada), 1976. *Effects of Chromium in the Canadian Environmnent*. NRCC No. 15017. NRCC, Ottawa, Ontario.
- Oris, J.T. and J.P. Giesy, Jr. 1986. Photoinduced toxicity of anthracene to juvenile bluegill sunfish (*Lepomis macrochirus* Rafinesque): Photoperiod effects and predictive hazard evaluation. *Environ. Toxicol. Chem.* 5: 761-768.
- Oris, J.T. and J.P. Giesy, Jr. 1987. The Photo-Induced Toxicity of Polycyclic Aromatic Hydrocarbons to Larvae of the Fathead Minnow (*Pimephales promelas*). *Chemosphere* 16: 1395-1404.
- Puls, R., 1994. *Mineral Levels in Animal Health* 2nd Ed. Sherpa International, Clearbrook British Columbia.
- Royal Society of Canada, 1986. *Lead in the Canadian Environment: Science and Regulation*. The Commission of Lead in the Environment. Ottawa, Ontario.
- Schweiger, G. 1957. The Toxic Action of Heavy Metals Salts on Fish and Organisms on Which Fish Feed. *Arch.Fischereiwiss.* 8:54-78
- Soni, R., and S.A. Abbasi. 1981. Mortality and reproduction in earthworms *Pheritima posthuma* exposed to chromium (VI). *Int. J. Environ. Stud.* 17: 147-149.
- Sullivan, J.B., and Krieger, G.R., 1992. *Hazardous Materials Toxicology: Clinical Principles of Environmental Health*. Williams and Wilkins, Baltimore, Maryland.

- Tandon, S.K., D.K. Saxena, J.S. Gaur, and S.V. Chandra. 1978. Comparative toxicity of trivalent and hexavalent chromium. Alterations in blood and liver. Environ. Res. 15:90-99.
- U.S. EPA (1996, April 23) Proposed guidelines for carcinogen risk assessment. Federal Register 61(79):17960-18011.
- U.S. EPA 1984. Health Effects Assessment for Lead. Volumes III, IV. Prepared by the Office of Health and Environmental Criteria and Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH, for the Office of Emergency and Remedial Response, Washington DC. EPA/540/1-86/055. NTIS PB85-163996/AS.
- U.S. EPA. (1984) Health effects assessment for trivalent chromium. Prepared by the Environmental Criteria and Assessment Office, Cincinnati, OH OHEA, for the Office of Solid Waste and Emergency Response, Washington, DC.
- U.S. EPA. (1998) Toxicological review of trivalent chromium. Available online at <http://www.epa.gov/iris>.
- Wang, W. 1986. Toxicity Tests of Aquatic Pollutants by Using Common Duckweed. Environ.Pollut.Ser.B Chem.Phys. 11(1):1-14



 HEMMERA ENVIROCHEM INC. Suite 350, 1190 Hornby Street Vancouver, BC V6Z 2K5		RISK ASSESSMENT Brooks Brook, Yukon Territory		
LOCATION MAP				
CLIENT: INDIAN & NORTHERN AFFAIRS CANADA		PROJECT No. 316-003.04		
			March 2002	Figure 1



RISK ASSESSMENT
BROOKS BROOK , ALASKA HIGHWAY, YT

SITE LAYOUT
BROOKS BROOK, YT

HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC V6Z 2K5

CLIENT:

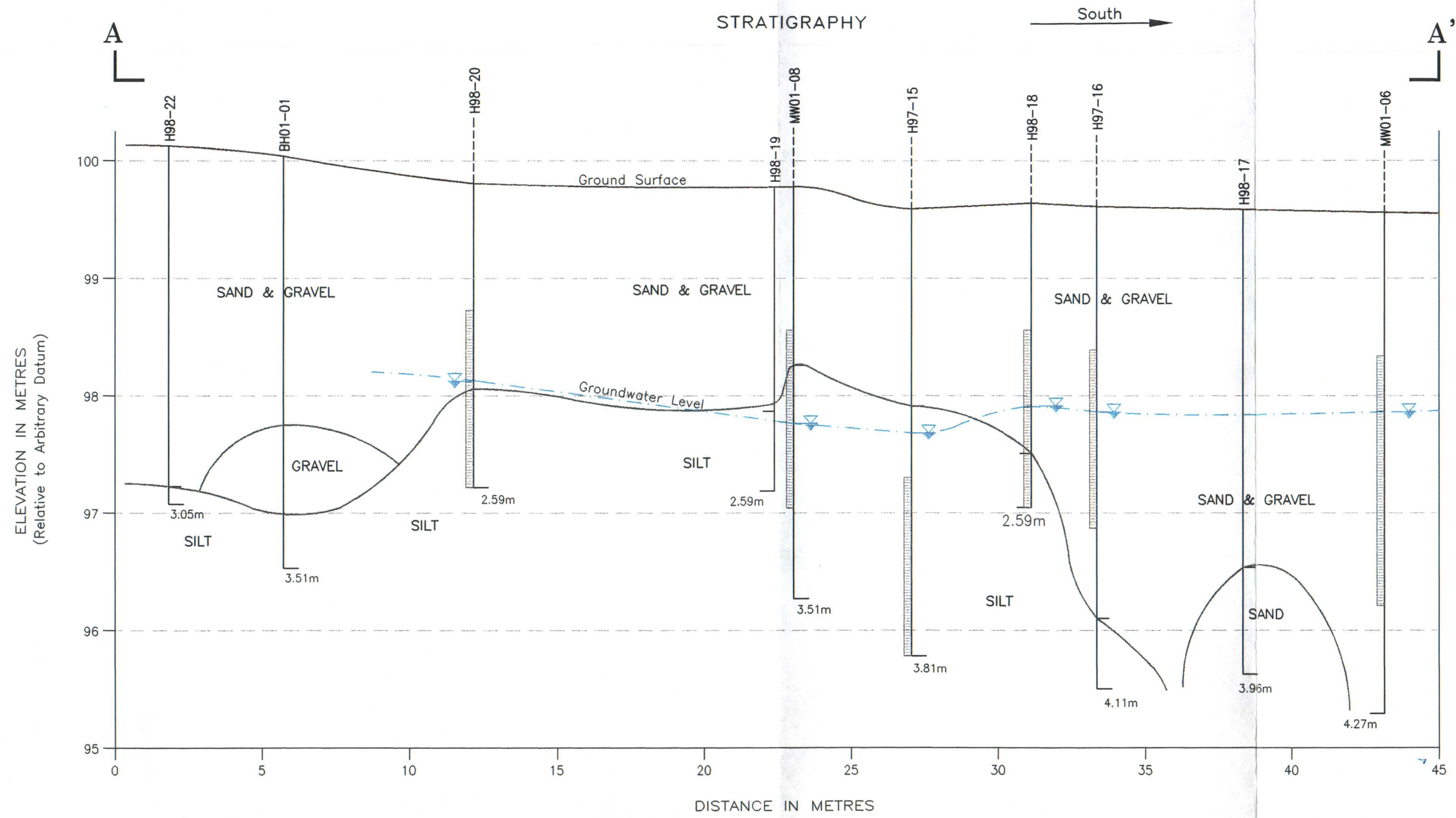
INDIAN & NORTHERN AFFAIRS CANADA

File No.

316-003.04

March 2002

FIGURE 2



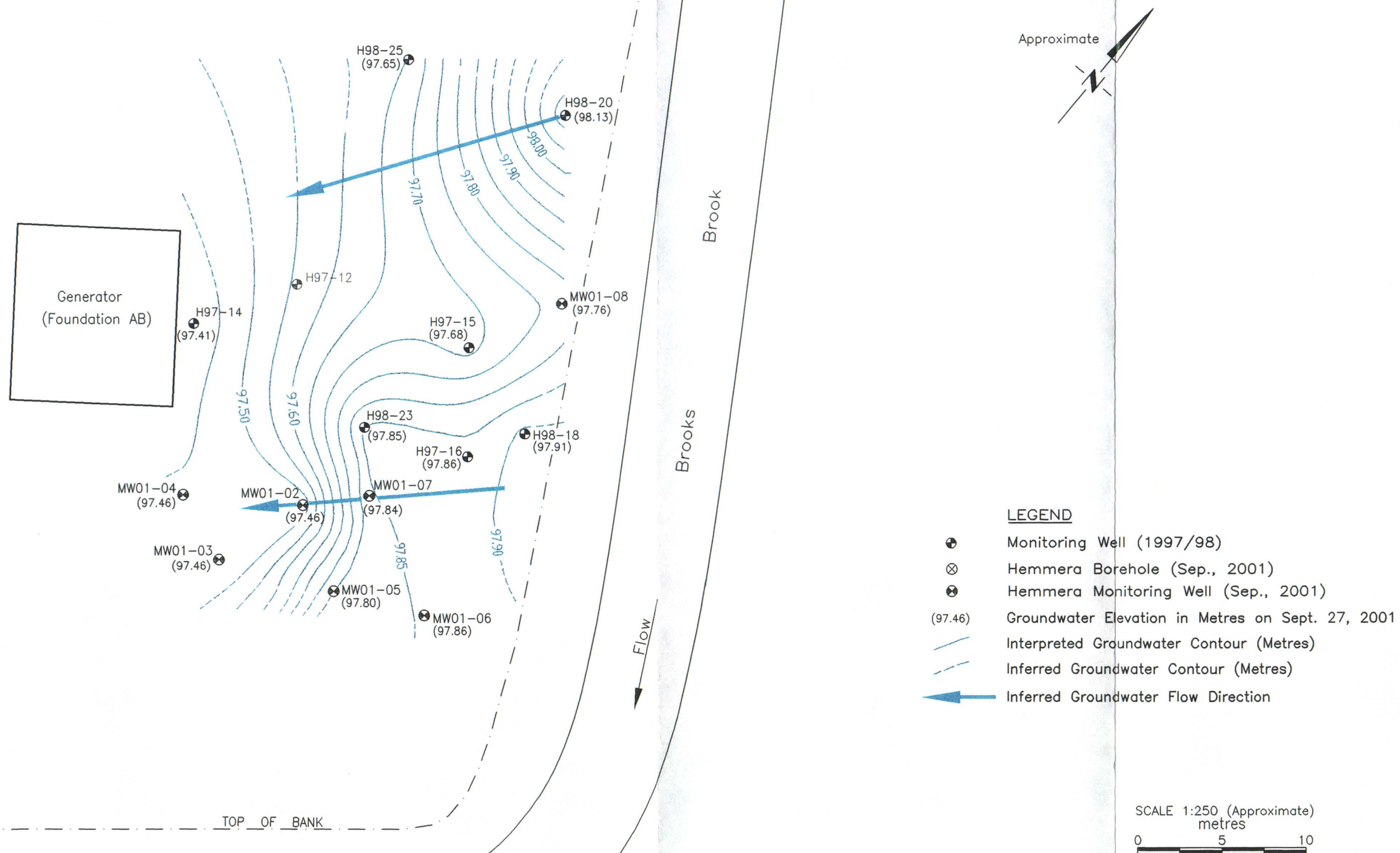
HORIZONTAL SCALE:
1:150 (Approximate)
metres

0 3 6

VERTICAL SCALE EXAGGERATED 4X.

NOTE: See Figure ? for location of section.

HEMMERA ENVIROCHEM CLIENT: INDIAN & NORTHERN AFFAIRS CANADA	RISK ASSESSMENT BROOKS BROOK, ALASKA HIGHWAY, YT		
	FOUNDATION AB AREA CROSS SECTION A-A'		
PROJECT No:	316-003.04	March 2002	FIGURE 3



**HEMMERA
ENVIROCHEM**

HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC V6Z 2K5

CLIENT:

INDIAN & NORTHERN AFFAIRS CANADA

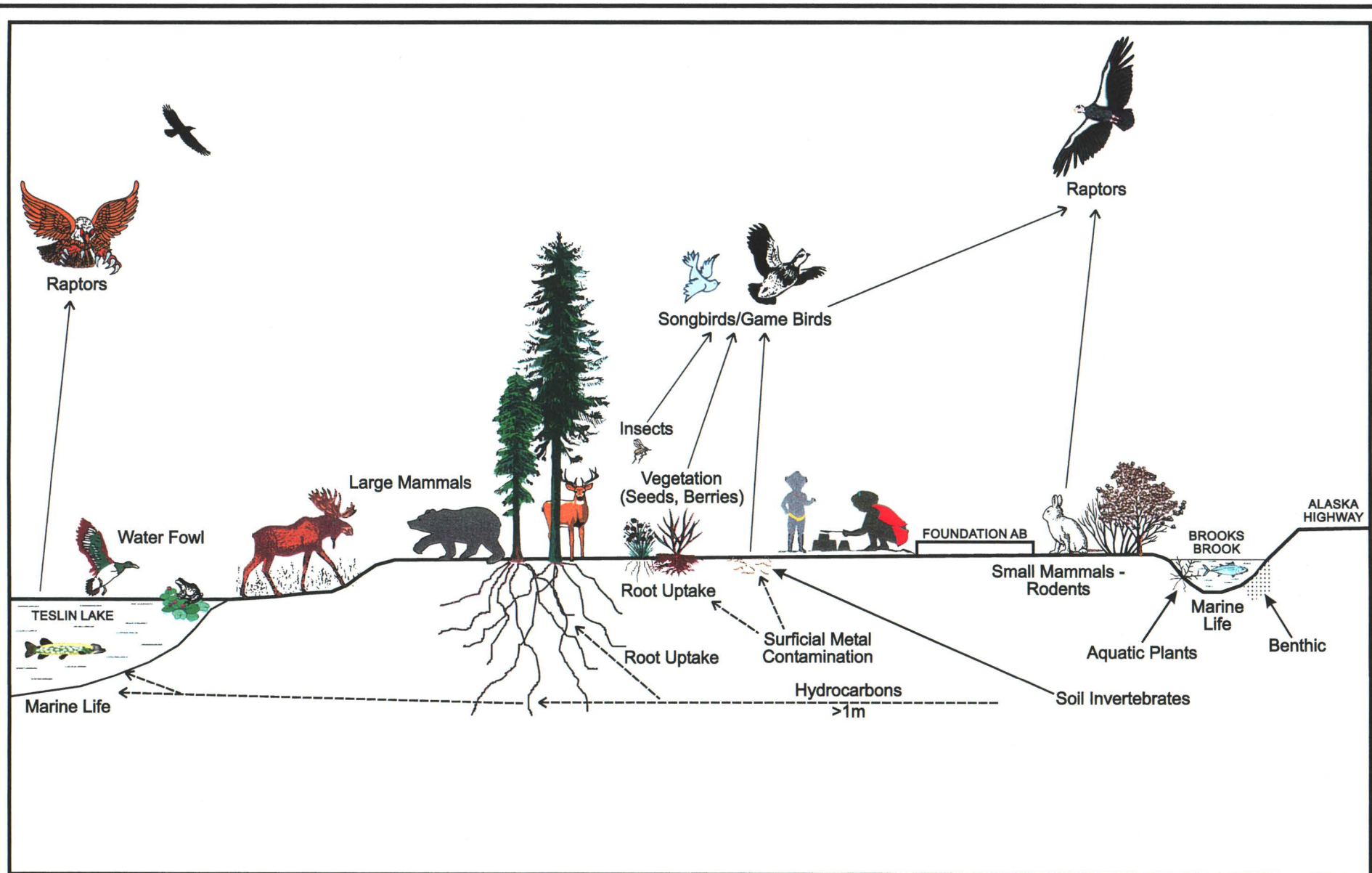
**DETAILED SITE INVESTIGATION
BROOKS BROOK, ALASKA HIGHWAY, YT**

**FOUNDATION AB AREA
INFERRED GROUNDWATER FLOW DIRECTION
(SEPTEMBER 27, 2001)**

PROJECT No:
316-003.04

March 2002

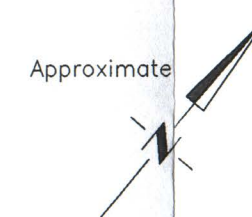
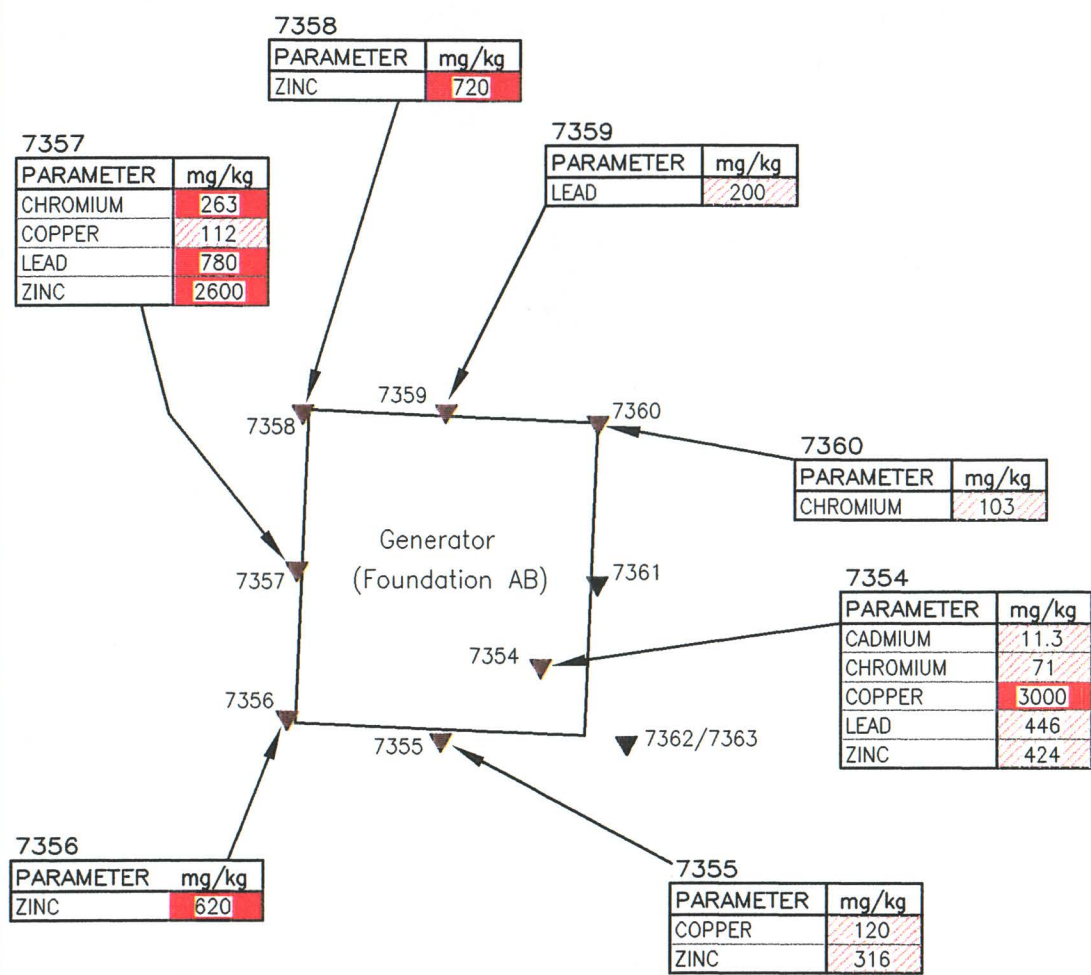
FIGURE 4



Note: The carnivores (eg. bear, fox) and larger birds (eg. Raven, Magpie) will consume vegetation, mammals, marine life, insects, invertebrates, and carrion.

	HEMMERA ENVIROCHEM INC. Suite 350, 1190 Hornby Street Vancouver, BC V6Z 2K5	
	CLIENT: INDIAN & NORTHERN AFFAIRS CANADA	

RISK ASSESSMENT BROOKS BROOK, ALASKA HIGHWAY, YT		
CONCEPTUAL DIAGRAM OF RECEIVING ENVIRONMENT & RECEPTORS		
PROJECT No. 316-003.04	March 2002	Figure 5



LEGEND

▼ ESG Surface Sample (1997)

STANDARDS/GUIDELINES (mg/kg)

PARAMETER	YCSR RL/PL	CCME RL/PL
CADMIUM	35	10
CHROMIUM	150	63
COPPER	150	64
LEAD	500	140
ZINC	450	200

Exceeds CCME RL/PL Guideline

Exceeds CCME RL/PL Guideline and YCSR RL/PL Standard

SCALE 1:250 (Approximate)
metres

0 5 10

HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC V6Z 2K5

CLIENT:

INDIAN & NORTHERN AFFAIRS CANADA

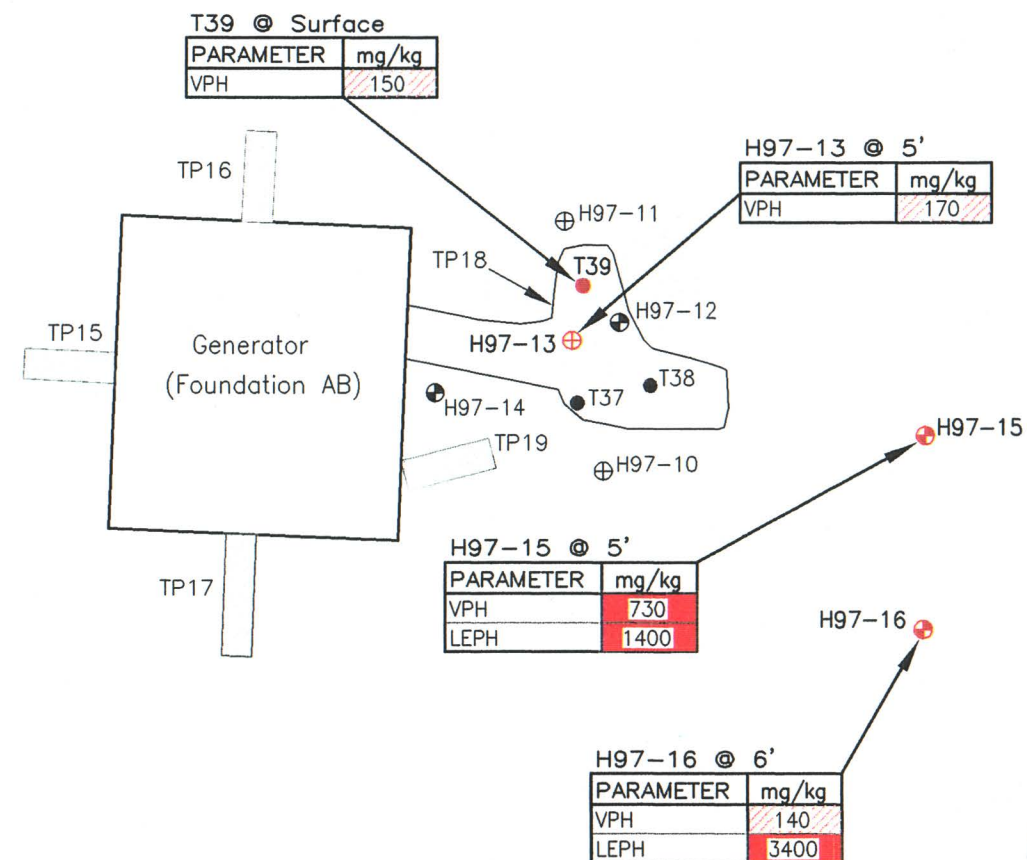
RISK ASSESSMENT
BROOKS BROOK, ALASKA HIGHWAY, YT

EXPERIMENTAL SCIENCES GROUP - 1996 INVESTIGATION
EXCEEDANCES FOR METALS IN SOIL

File No.
316-003.04

March 2002

FIGURE 6



Approximate

LEGEND

- ⊕ Monitoring Well (1997)
- ⊕ Borehole (1997)
- Test Pit (1997)

STANDARDS (mg/kg)

PARAMETER	YCSR RL/PL	CWS TIER 1
VPH (F1)	200	130
LEPH (F2)	1000	450

- Exceeds CWS TIER 1 Standard
- Exceeds CWS TIER 1 and YCSR RL/PL Standard

NOTE: VPH and LEPH concentrations have been compared to the Canada Wide Standards for petroleum hydrocarbons Tier 1 for Residential Eco Soil Contact for coarse grained soils.

SCALE 1:250 (Approximate)
metres

0 5 10

HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC V6Z 2K5

CLIENT:

INDIAN & NORTHERN AFFAIRS CANADA

RISK ASSESSMENT
BROOKS BROOK, ALASKA HIGHWAY, YT

LORIMER & ASSOCIATES/HEMMERA RESOURCE CONSULTANTS
1997 INVESTIGATION

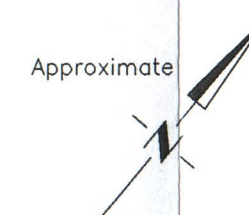
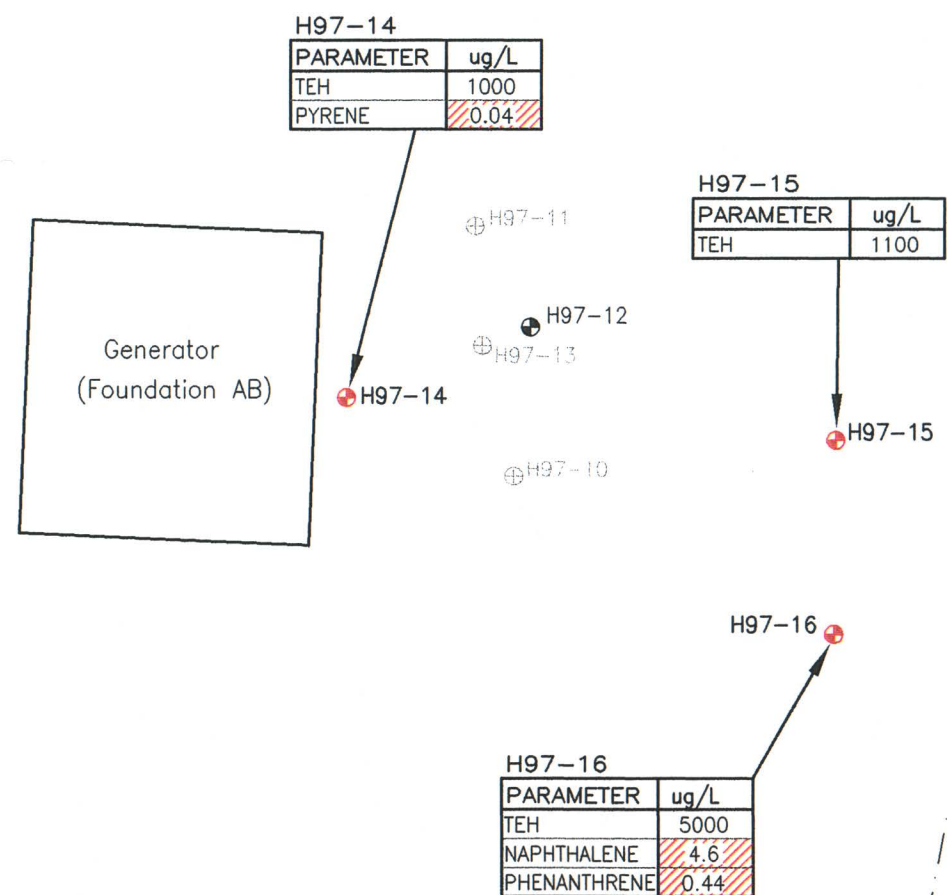
EXCEEDANCES FOR HYDROCARBONS IN SOIL

File No.

316-003.04

March 2002

FIGURE 7



LEGEND

- ⊕ Monitoring Well (1997)
- ⊕ Borehole (1997)

STANDARDS/GUIDELINES (ug/L)		
PARAMETER	YSCR AW	CCME FAL
TEH	No Standard	No Guideline
NAPHTHALENE	10	1.1
PHENANTHRENE	3	0.4
PYRENE	0.2	0.025

- Exceeds CCME FAL Guideline
- Exceeds YSCR AW Standard & CCME FAL Guideline

NOTE: Elevated TEH concentrations have been included for reference purposes only.

SCALE 1:250 (Approximate)
metres

0 5 10

HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC V6Z 2K5

CLIENT:

INDIAN & NORTHERN AFFAIRS CANADA

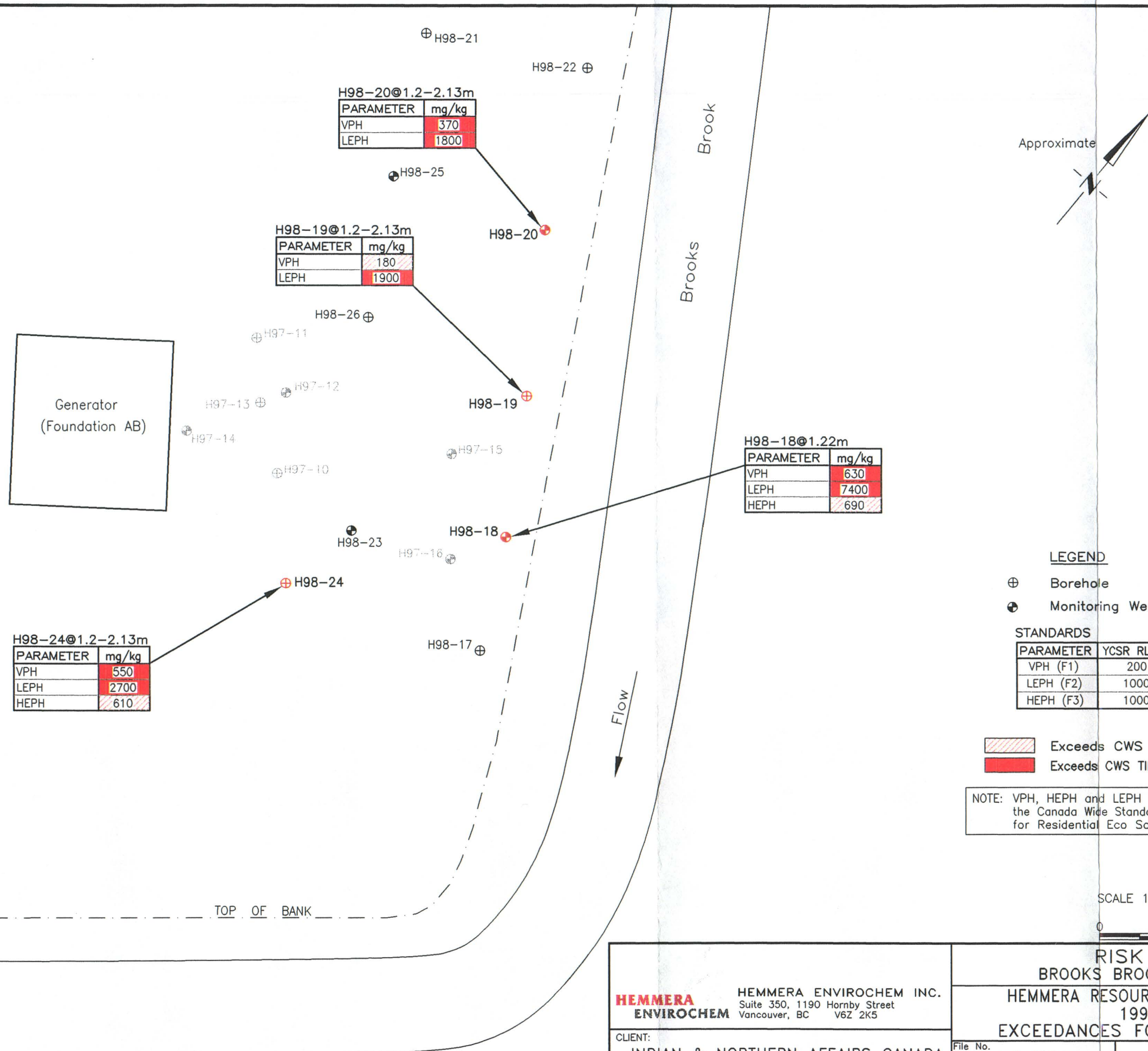
RISK ASSESSMENT
BROOKS BROOK, ALASKA HIGHWAY, YT

LORIMER & ASSOCIATES/HEMMERA RESOURCE CONSULTANTS
1997 INVESTIGATION
EXCEEDANCES FOR HYDROCARBONS IN GROUNDWATER

File No.
316-003.04

March 2002

FIGURE 8



HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC V6Z 2K5

CLIENT:

INDIAN & NORTHERN AFFAIRS CANADA

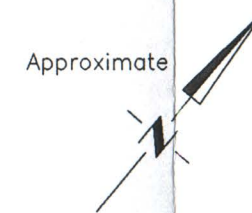
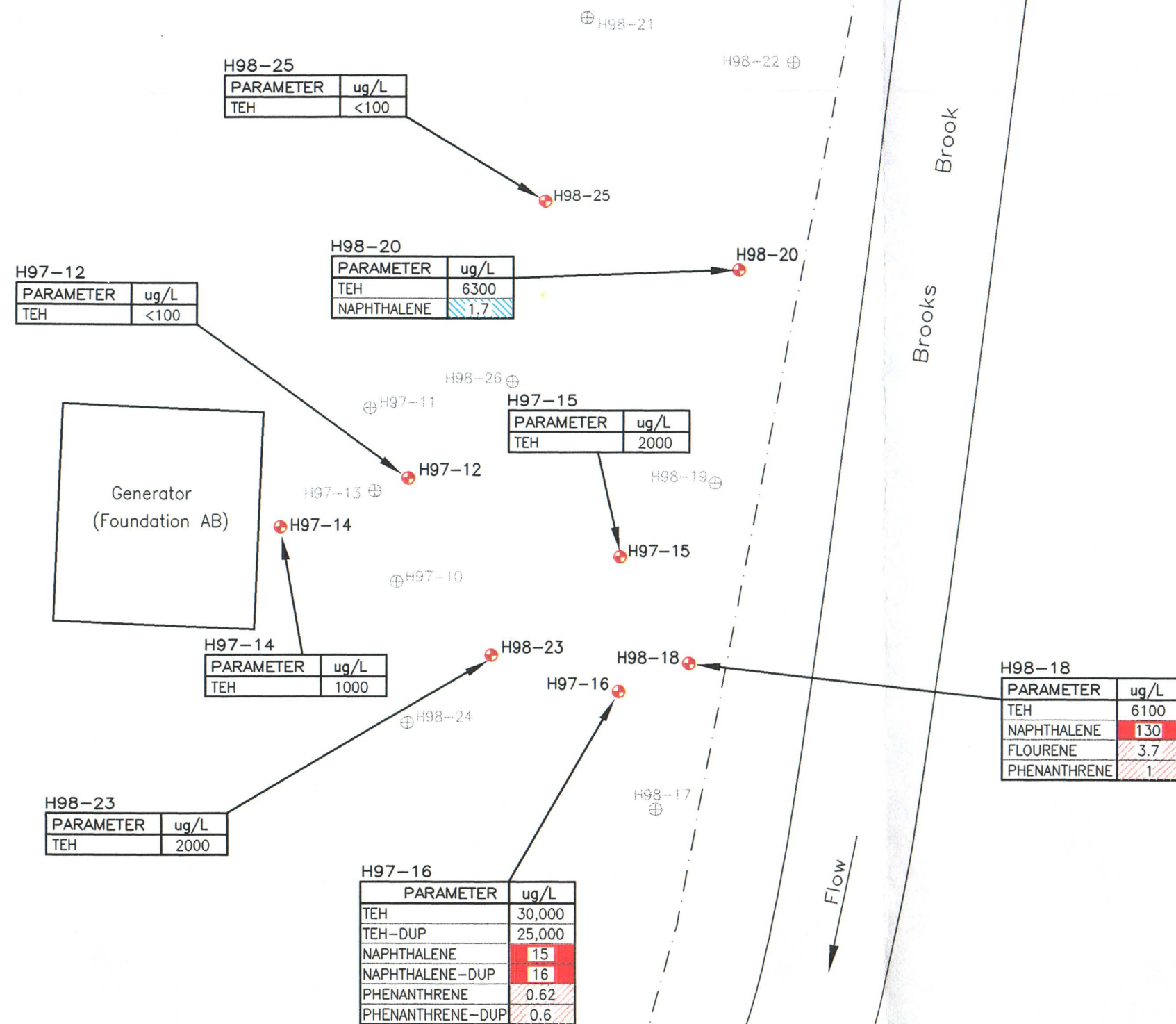
File No.

316-003.04

March 2002

FIGURE 9

RISK ASSESSMENT
BROOKS BROOK, ALASKA HIGHWAY, YT
HEMMERA RESOURCE CONSULTANTS - PHASE III
1998 INVESTIGATION
EXCEEDANCES FOR HYDROCARBONS IN SOIL



LEGEND

⊕ Borehole
⊕ Monitoring Well

GUIDELINES/STANDARDS (ug/L)

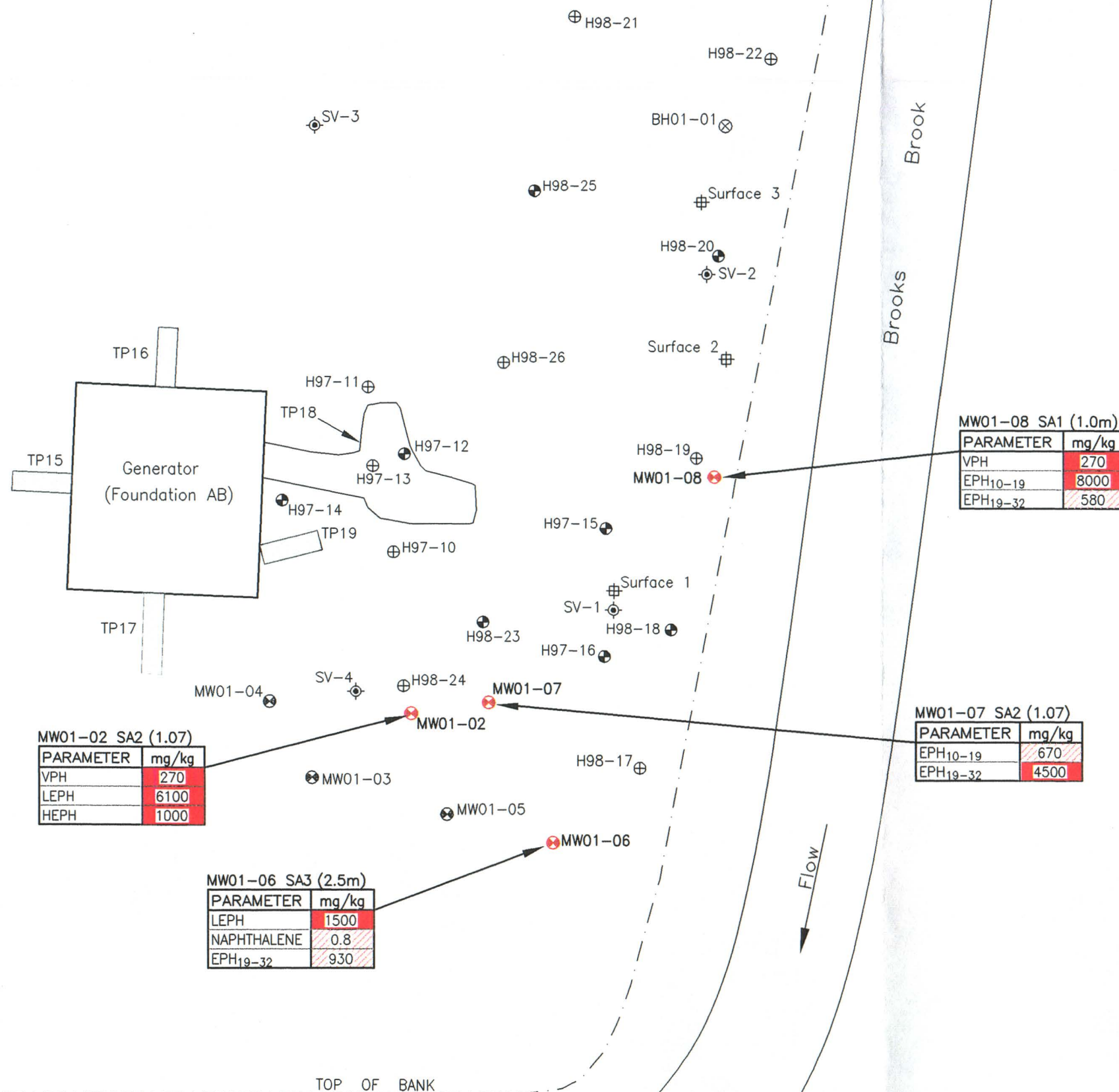
PARAMETER	CCME FAL	YSCR AW
TEH	No Guideline	No Standard
NAPHTHALENE	1.1	10
PHENANTHRENE	0.4	3
FLOURENE	3	120

Exceeds YSCR AW Standard
 Exceeds CCME FAL Guideline
 Exceeds CCME FAL Guideline and YSCR AW Standard

NOTE: Elevated TEH concentrations have been included for reference purposes only.

SCALE 1:250 (Approximate)
metres
0 5 10

HEMMERA ENVIROCHEM	HEMMERA ENVIROCHEM INC. Suite 350, 1190 Hornby Street Vancouver, BC V6Z 2K5	RISK ASSESSMENT BROOKS BROOK, ALASKA HIGHWAY, YT	
	HEMMERA RESOURCE CONSULTANTS - PHASE III 1998 INVESTIGATION		
	EXCEEDANCES FOR HYDROCARBONS IN GROUNDWATER		
CLIENT: INDIAN & NORTHERN AFFAIRS CANADA	File No. 316-003.04	March 2002	FIGURE 10



Approximate

LEGEND

- ⊕ Monitoring Well (1997/98)
- ⊕ Borehole (1997/98)
- ⊗ Hemmera Borehole (Sep., 2001)
- ⊗ Hemmera Monitoring Well (Sep., 2001)
- ⊗ Hemmera Vapour Probe (Sep., 2001)
- ⊕ Hemmera Surface Sample (Sep., 2001)
- (1.2m) Average Depth of Sample

STANDARDS [mg/kg]		
PARAMETER	YCSR RL/PL	CWS TIER 1
VPH (F1)	200	130
LEPH (F2)	1000	450
HEPH (F3)	1000	400

VPH Volatile Petroleum Hydrocarbons
 LEPH Light Extractable Petroleum Hydrocarbons
 HEPH Heavy Extractable Petroleum Hydrocarbons
 NOTE: EPH₁₀₋₁₉ and EPH₁₉₋₃₂ have been compared to LEPH and HEPH Standards and Canada Wide Standards for F2 and F3.

- Exceeds CWS TIER 1 Standard
- Exceeds CWS TIER 1 and YCSR RL/PL Standard

NOTE: VPH, HEPH and LEPH concentrations have been compared to the Canada Wide Standards for petroleum hydrocarbons Tier 1 for Residential Eco Soil Contact for coarse grained soils.

SCALE 1:250 (Approximate)
metres

0 5 10

HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC V6Z 2K5

CLIENT:

INDIAN & NORTHERN AFFAIRS CANADA

RISK ASSESSMENT
BROOKS BROOK, ALASKA HIGHWAY, YT

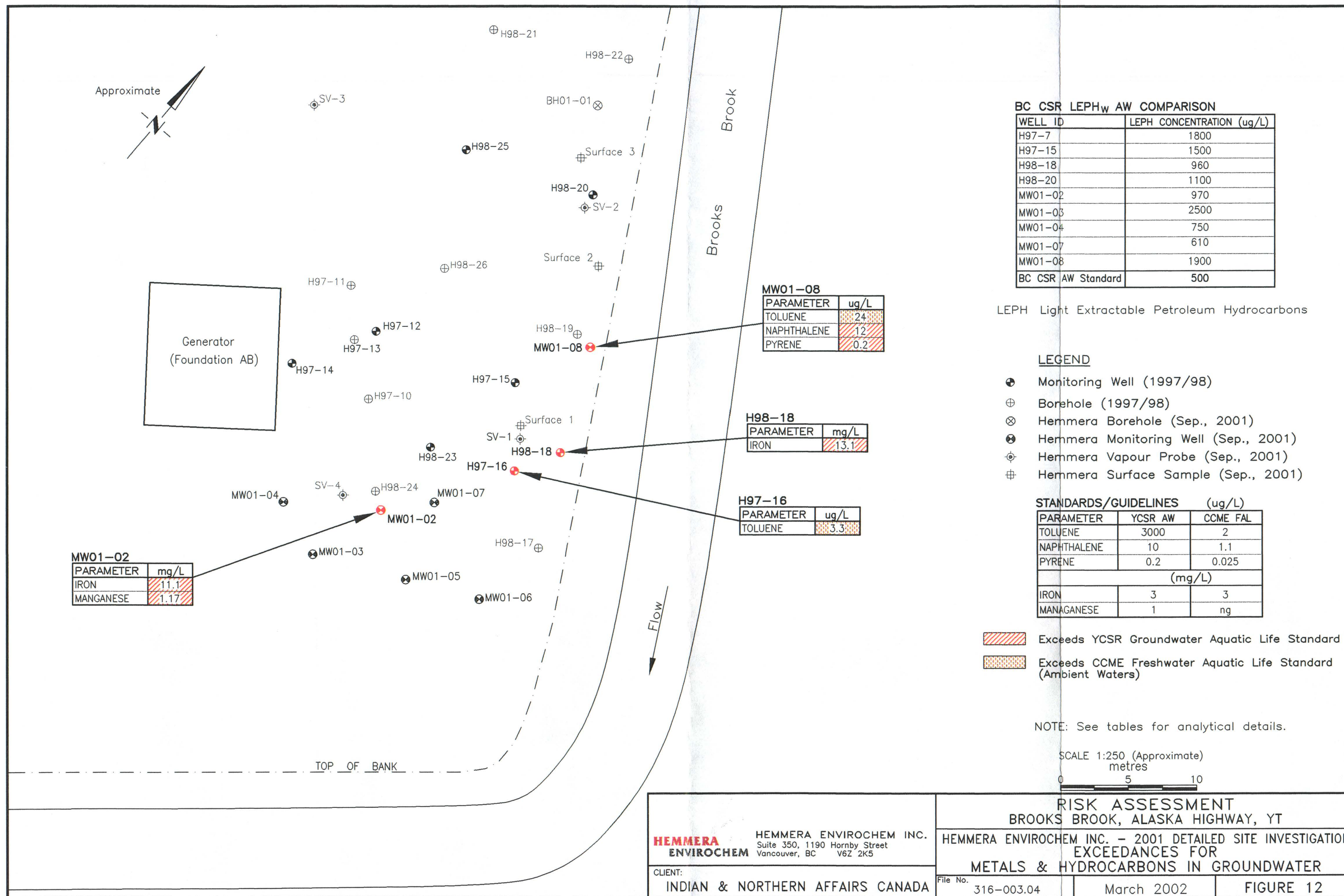
HEMMERA ENVIROCHEM INC.
2001 DETAILED SITE INVESTIGATION
EXCEEDANCES FOR HYDROCARBONS IN SOIL

File No.

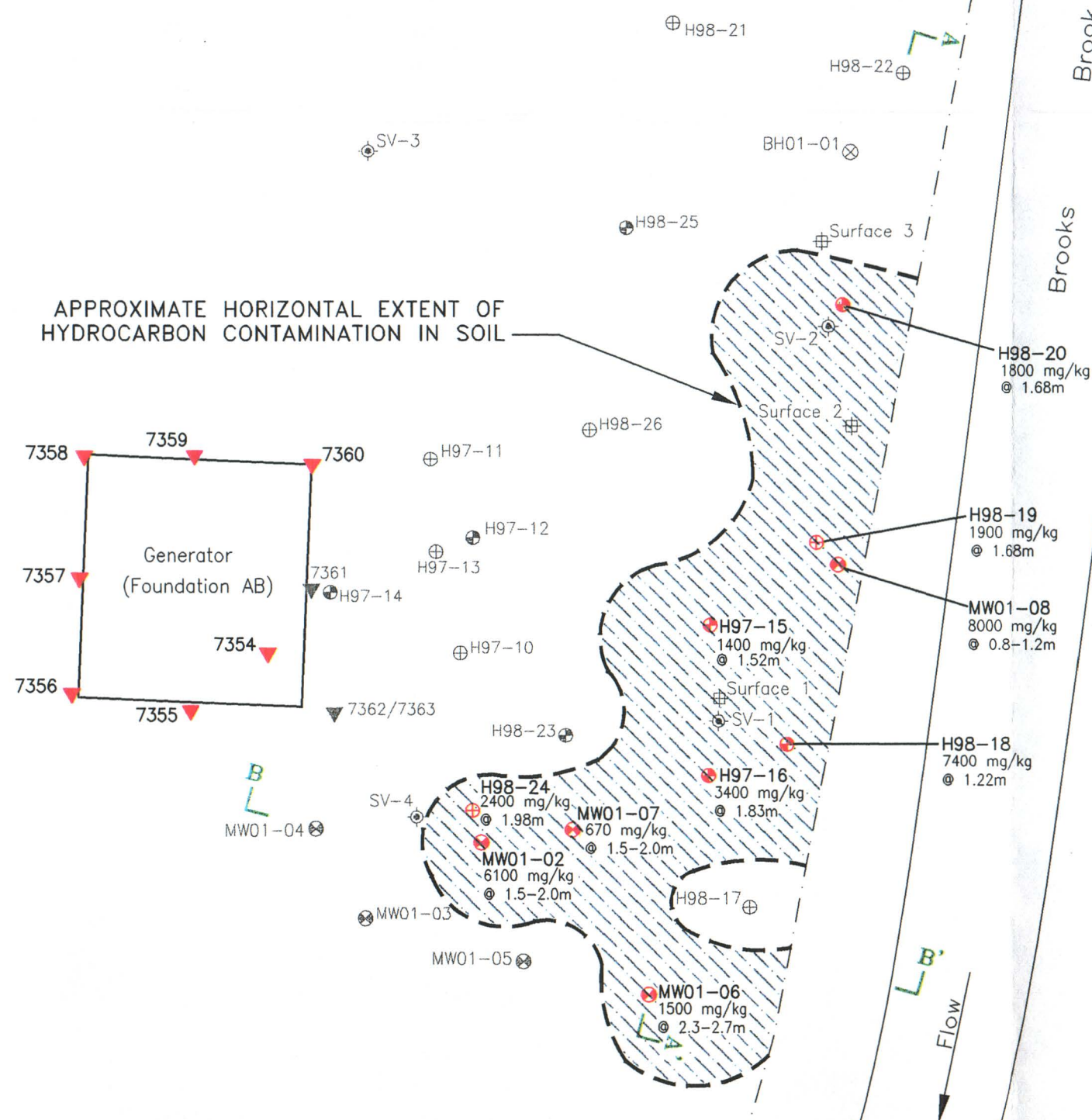
316-003.04

March 2002

FIGURE 11



APPROXIMATE HORIZONTAL EXTENT OF
HYDROCARBON CONTAMINATION IN SOIL



Approximate

LEGEND

- ⊕ Monitoring Well (1997/98)
- ⊕ Borehole (1997/98)
- ⊗ Hemmera Borehole (Sep., 2001)
- ⊗ Hemmera Monitoring Well (Sep., 2001)
- ⊗ Hemmera Vapour Probe (Sep., 2001)
- ⊕ Hemmera Surface Sample (Sep., 2001)
- ▼ Surface Soil Sample (1966)
- ⊗/⊕/⊗/▼ Sample Exceeded Standard and/or Guideline for Light Extractable Petroleum Hydrocarbons in Soil

B B'

Location of Cross Section
- See Figure 2 & 14A for Cross Section A-A'
- See Figure 14B for Cross Section B-B'

NOTE: See tables for analytical details.

SCALE 1:250 (Approximate)
metres

0 5 10

HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC V6Z 2K5

CLIENT:
INDIAN & NORTHERN AFFAIRS CANADA

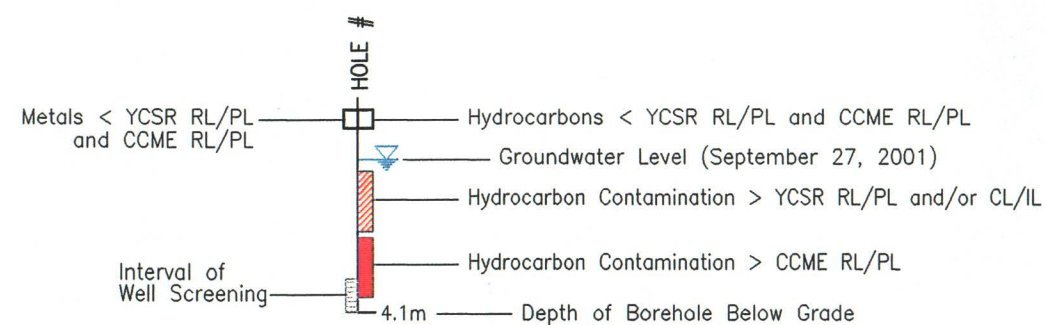
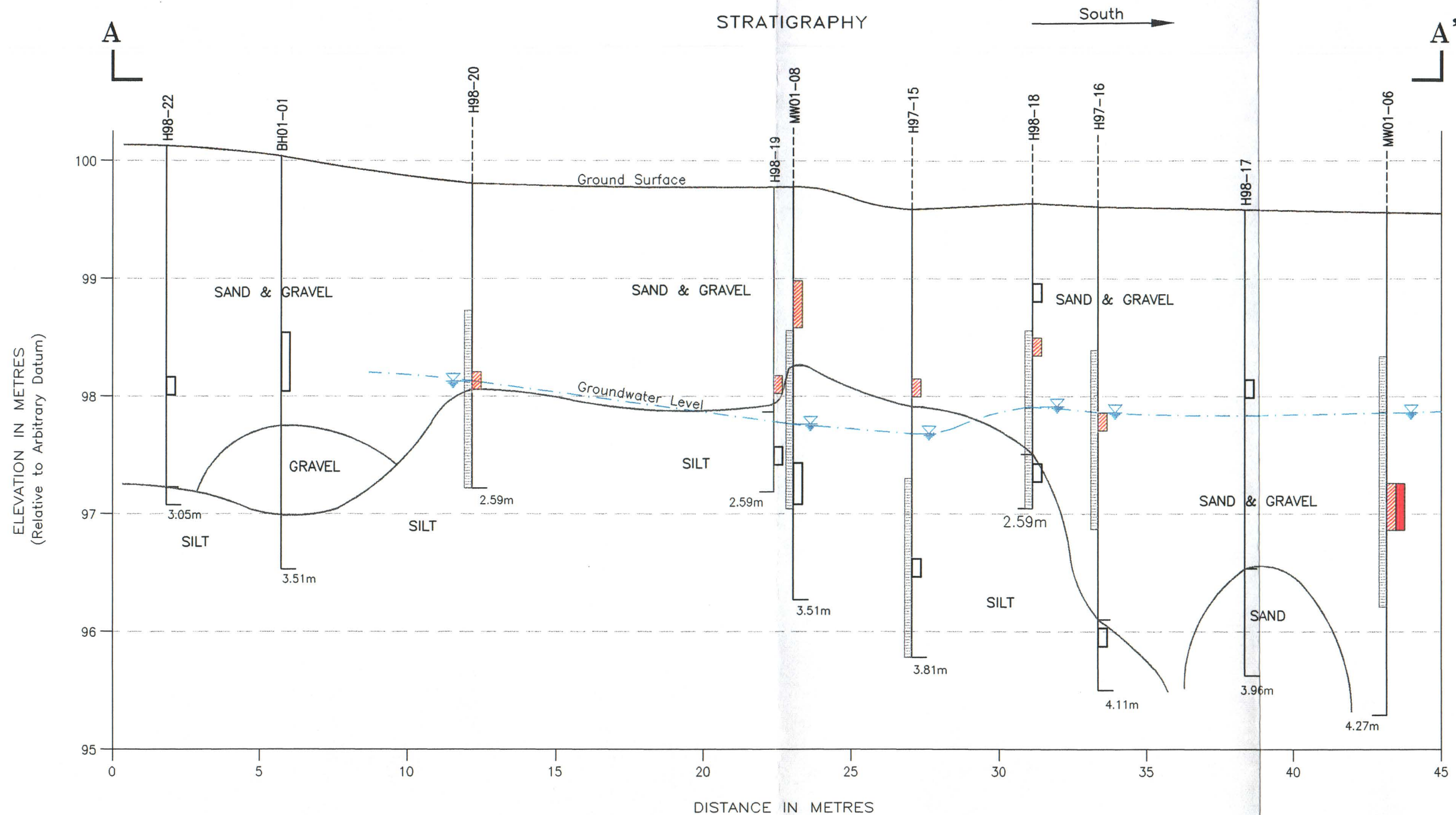
RISK ASSESSMENT
BROOKS BROOK, ALASKA HIGHWAY, YT

HEMMERA ENVIROCHEM INC.
2001 DETAILED SITE INVESTIGATION
HORIZONTAL EXTENT OF IMPACTED SOIL

File No.
316-003.04

March 2002

FIGURE 13



NOTE: SEE TABLES FOR DETAILS OF ANALYSIS.

HORIZONTAL SCALE:
1:150 (Approximate)
metres

0 3 6

VERTICAL SCALE EXAGGERATED 4X.

NOTE: See Figure 13 for location of section.

HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC V6Z 2K5

CLIENT:

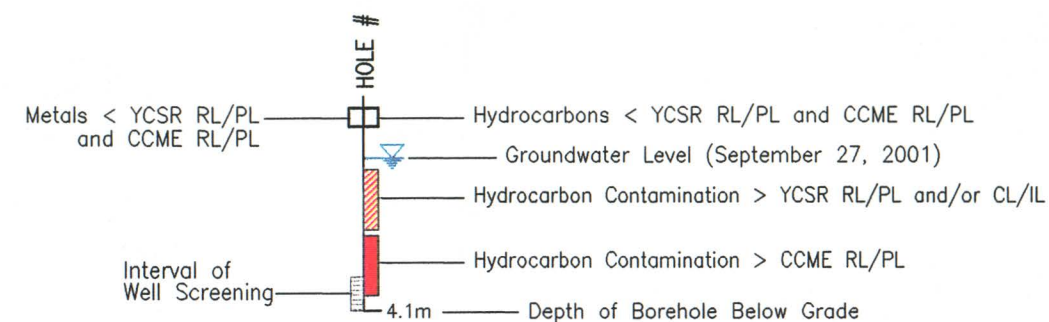
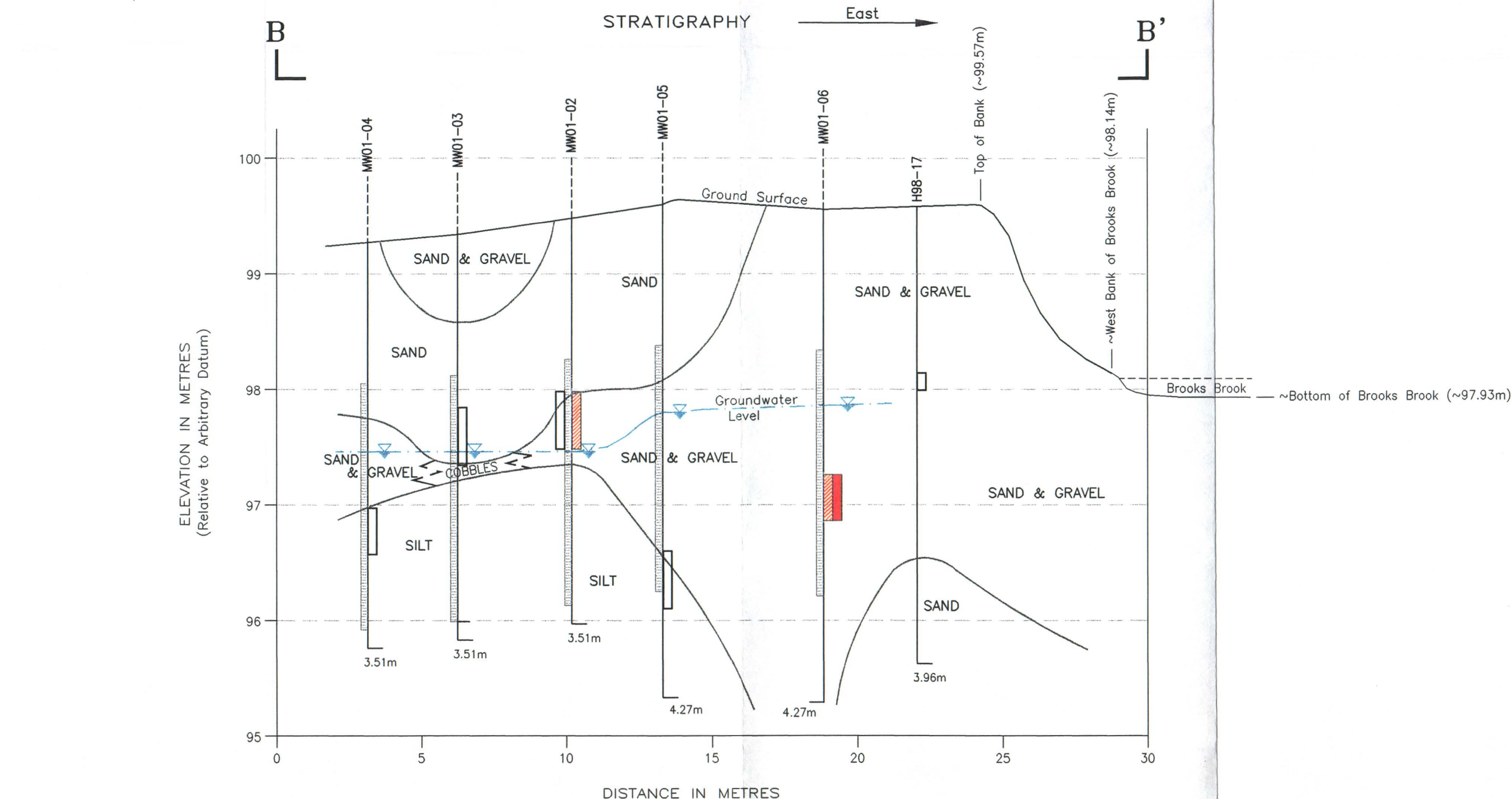
INDIAN & NORTHERN AFFAIRS CANADA

RISK ASSESSMENT
BROOKS BROOK, ALASKA HIGHWAY, YT
EXTENT OF HYDROCARBON IMPACTED SOIL
CROSS SECTION A-A'

PROJECT No:
316-003.04

March 2002

FIGURE 14A



NOTE: SEE TABLES FOR DETAILS OF ANALYSIS.

HORIZONTAL SCALE:
1:150 (Approximate)
metres

0 3 6

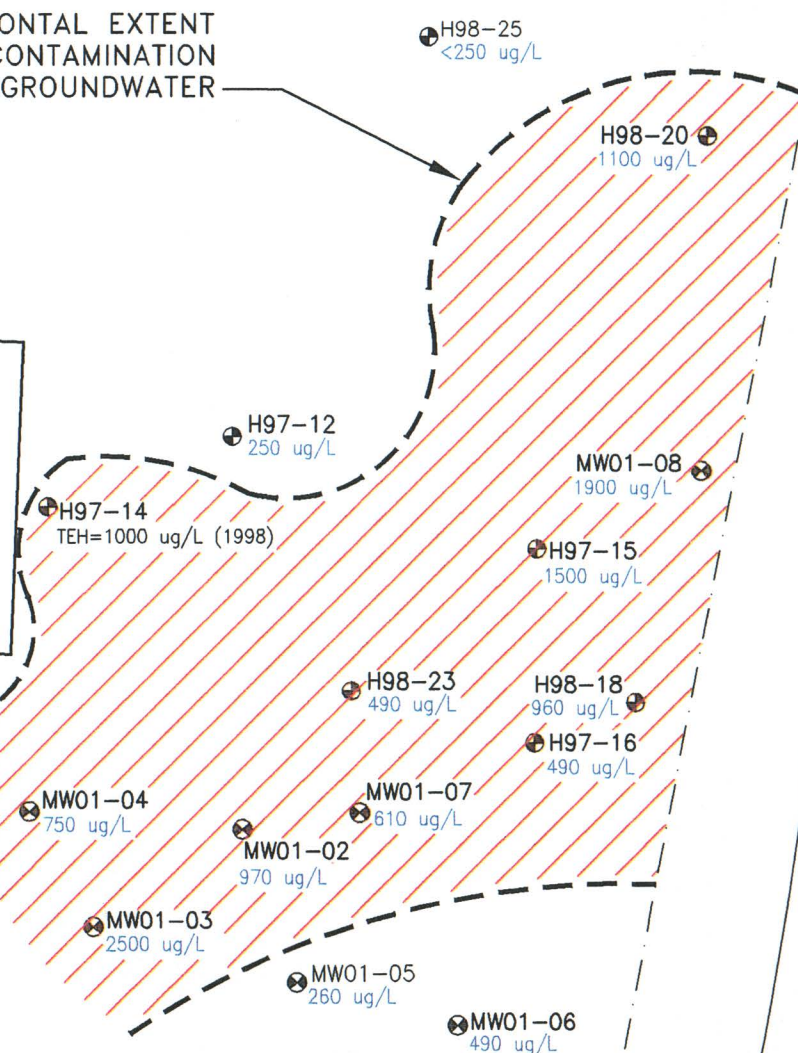
VERTICAL SCALE EXAGGERATED 4X.

NOTE: See Figure 13 for location of section.

HEMMERA ENVIROCHEM CLIENT: INDIAN & NORTHERN AFFAIRS CANADA	RISK ASSESSMENT BROOKS BROOK, ALASKA HIGHWAY, YT		
	EXTENT OF HYDROCARBON IMPACTED SOIL CROSS SECTION B-B'		
PROJECT No: 316-003.04	March 2002	FIGURE 14B	

APPROXIMATE HORIZONTAL EXTENT
OF HYDROCARBON CONTAMINATION
IN GROUNDWATER

Generator
(Foundation AB)



LEGEND

- Monitoring Well (1997/98)
- Hemmera Borehole (Sep., 2001)
- Hemmera Monitoring Well (Sep., 2001)
- 250 ug/L LEPH Concentration in 2001
(Concentration for H97-14 is for TEH in 1998)
- LEPH Light Extractable Petroleum Hydrocarbons
- TEH Total Extractable Hydrocarbons

NOTE: See tables for analytical details.

SCALE 1:250 (Approximate)
metres

0 5 10

HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.
Suite 350, 1190 Hornby Street
Vancouver, BC V6Z 2K5

CLIENT:

INDIAN & NORTHERN AFFAIRS CANADA

File No.

316-003.04

March 2002

FIGURE 15

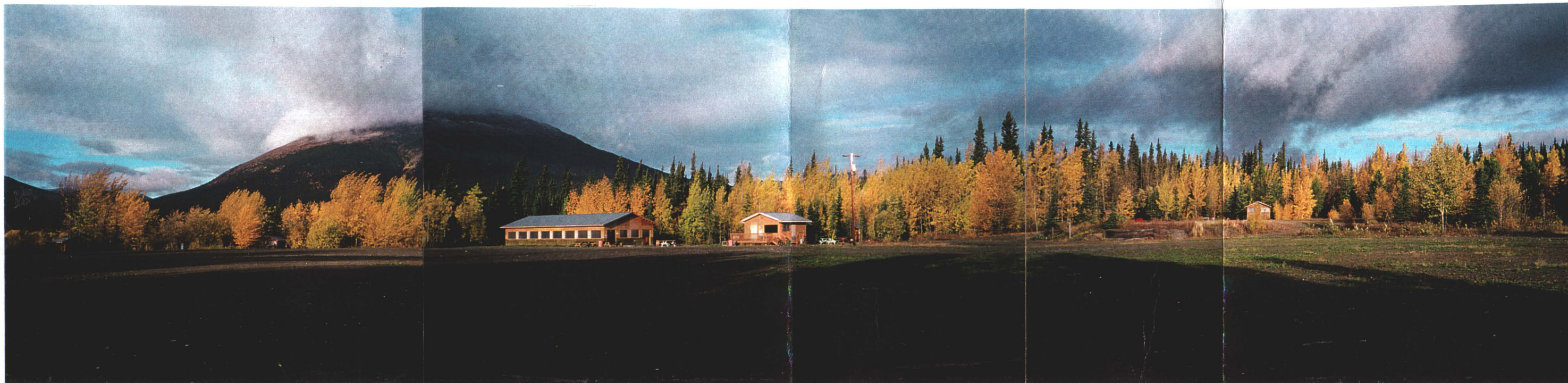


PHOTO 1: View of the Brooks Brook property looking west towards main site area.

File: 316-003.04
CLIENT:
INDIAN & NORTHERN AFFAIRS CANADA
Site: Brooks Brook, Alaska Highway, YT

HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.

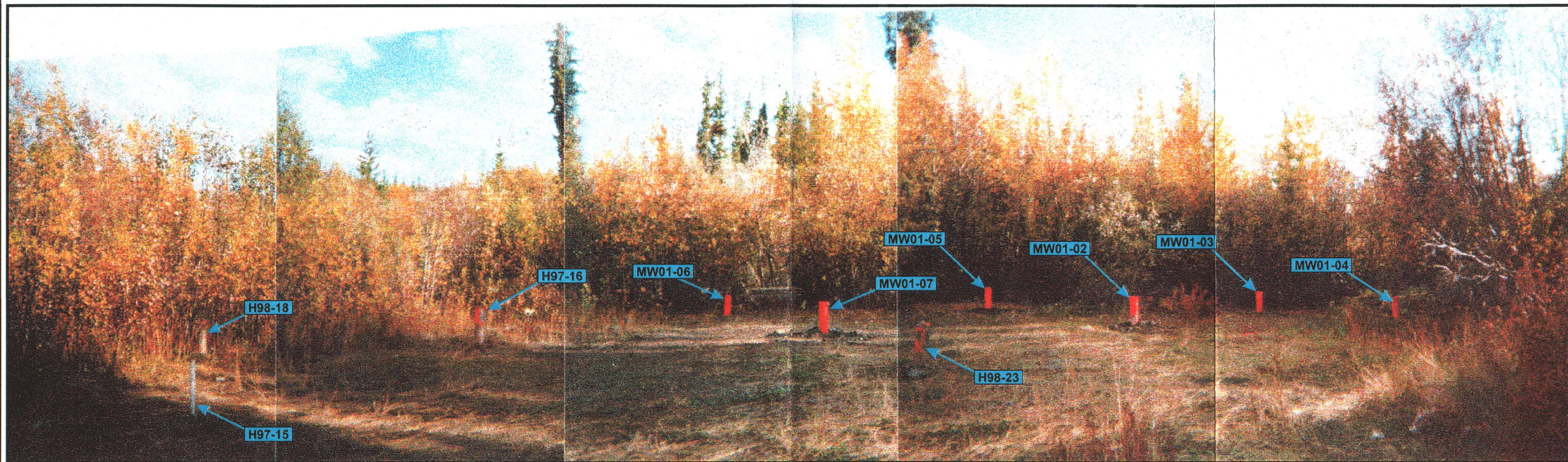


PHOTO 2: View of the subject area looking southeast. Brooks Brook is located just behind the brush located on the perimeter of the clearing.

File: 316-003.04

CLIENT:
INDIAN & NORTHERN AFFAIRS CANADA

Site: Brooks Brook, Alaska Highway, YT



HEMMERA ENVIROCHEM INC.

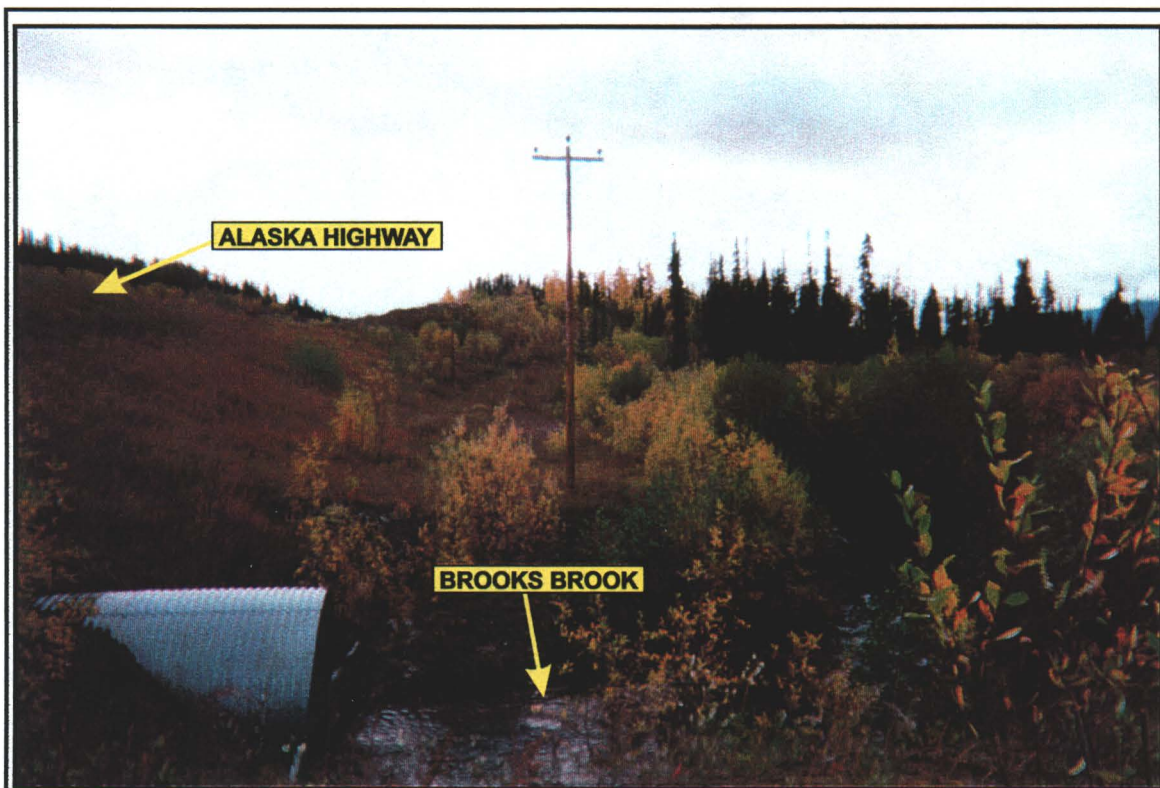


PHOTO 3: View of the topography sloping from the Alaska Highway to Brooks Brook.

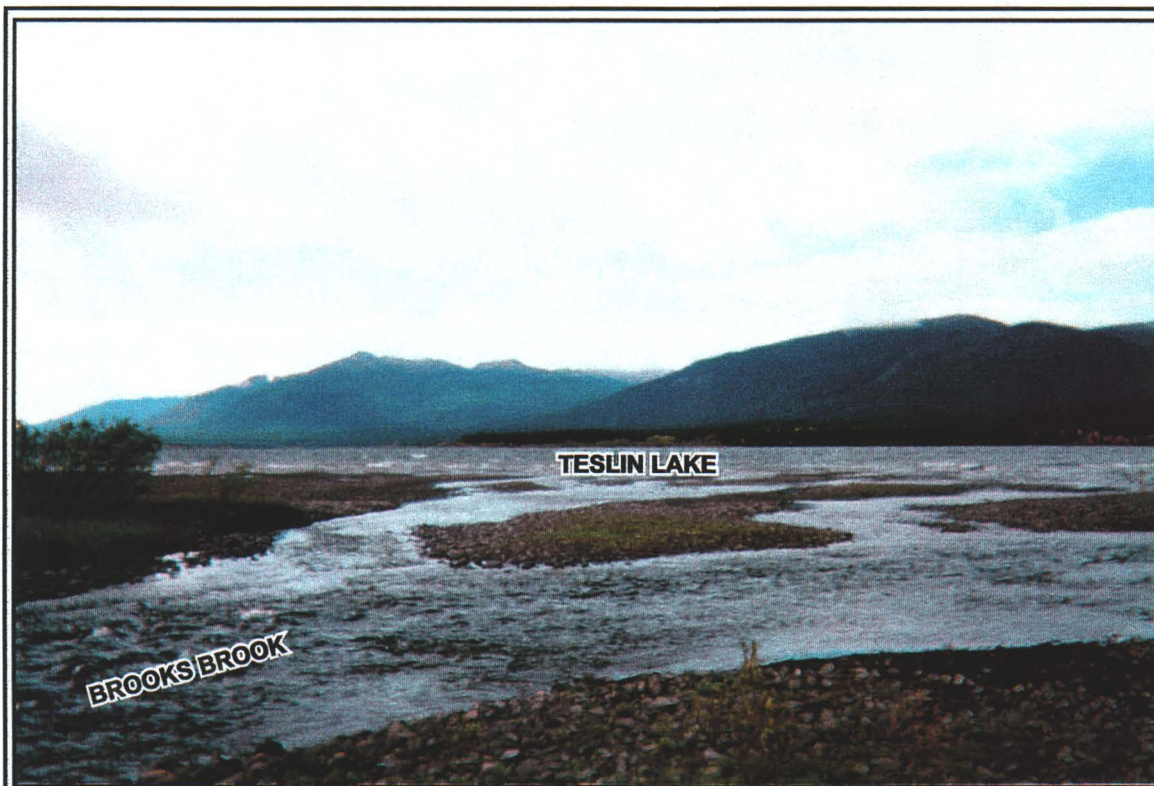


PHOTO 4: View of Brooks Brook flowing into Teslin Lake, approximately 300m west of the subject site.

File: 316-003.04

CLIENT:

INDIAN & NORTHERN AFFAIRS CANADA

Site: Brooks Brook, Alaska Highway, YT

HEMMERA
ENVIROCHEM

HEMMERA ENVIROCHEM INC.



PHOTO 5: Heavy vegetation along the banks of Brooks Brook.

File: 316-003.04

CLIENT:

INDIAN & NORTHERN AFFAIRS CANADA

Site: Brooks Brook, Alaska Highway, YT



HEMMERA ENVIROCHEM INC.

Table I
Statistical Summary of Chemical Parameters in Excess of the YCSR RL/PL Standards and CCME RL/PL Guidelines for Soil

PARAMETER	YCSR RL/PL	CCME RL/PL	CWS Tier 1	No. of Samples	Range (mg/kg)		Mean (mg/kg)	Median (mg/kg)	# > YCSR	# > CCME	# > CWS	95th Percentile mg/kg
					Min	Max						
PAHs												
Naphthalene	5	0.6	ns	7	0.025	0.8	0.33	0.25	0	2	na	0.77
MAHs												
Volatile Pet. Hydrocarbons (F1)	200	ng	130	44	5	730	100.73	72.36	6	na	10	532
LEPH-uncorrected for PAH's (F2)	1000*	ng	450	44	125	8000	895.34	510.17	9	na	10	5830
HEPH-uncorrected for PAH's (F3)	1000*	ng	400	44	125	4500	307.5	216.25	2	na	6	906
Metals												
Cadmium Cd	8 (pH6.5- 7.0)*†	10	ns	15	0.125	11.3	1.59	0.5	0	1	na	8.43
	35 ‡‡											
Chromium Cr	60*	64	ns	15	19	263	61.73	49	3	3	na	151
Copper Cu	150‡	63	ns	15	15	3000	234.87	28	1	3	na	984
Lead Pb	500 ‡‡	140	ns	15	5	780	123.6	18	1	3	na	546
Zinc Zn	450‡	200	ns	15	23	2600	358.27	82	3	5	na	1284

Footnotes:

All values in mg/kg (ppm)

YCSR RL/PL - Yukon Contaminated Sites Regulation Residential/Park Land Standards

CCME RL/PL - Canadian Council of Ministers of the Environment Residential/Park Land Guidelines

CWS Tier 1 - Canada Wide Standards for Petroleum Hydrocarbons, Tier 1 for eco soil contact of surface soils

* YCSR - Groundwater Flow to Surface Water used by Aquatic Life

‡ YCSR - Toxicity to Soil Invertebrates and Plants

† YCSR - Standard varies with pH

‡‡ YCSR - Intake of Contaminated Soil

ns = No Standard

ng = No Guideline

Table II
Statistical Summary of Chemical Parameters in Excess of YCSR AW Standards and CCME FAL Guidelines for Groundwater

Parameter	YCSR AW	CCME FAL	No. of Samples	Range (ug/L)		Mean (ug/L)	Median (ug/L)	# > YSCR	# > CCME	95th Percentile (ug/L)
PAHs										
Naphthalene	10	1.1	24	0.15	130	7.59	0.15	4	6	15.85
Fluorene	120	3	24	0.025	3.7	0.54	0.025	0	1	2.09
Phenanthrene	3	0.4	24	0.025	1	0.17	0.025	0	5	0.69
Pyrene	0.2	0.025	24	0.01	0.2	0.02	0.01	1	2	0.09
MAHs										
Toluene	3000	2	29	0.05	24	1.14	0.05	0	2	2.48
VPHs	ns 1500*	ng	15	50	470	124.67	50	na	na	323
Extractable Hydrocarbons										
TEH	ns	ng	27	50	30,000	4071.40	1000	na	na	19390
LEPH	ns 500*	ng	15	125	2500	923.67	780	na	na	2080
HEPH	ns	ng	15	125	420	155	125	na	na	322
Dissolved Metals										
Dissolved Iron Fe	3	0.3	4	11.1	13.1	12.1	12.1	4	4	13.1
Dissolved Manganese Mn	1	ng	4	0.6	1.17	0.88	0.875	2	2	1.167

Footnotes:

YCSR RL/PL - Yukon Contaminated Sites Regulation Residential/Park Land Standards

CCME RL/PL - Canadian Council of Ministers of the Environment Residential/Park Land Guidelines

ns = no standard

ng = no guideline

* = British Columbia Contaminated Sites Regulation Aquatic life Standards (AW) provided for comparison purposes only

**Table III. Summary of Soil Vapour Survey Conducted During The Hemmera
Envirochem Detailed Site Investigation**

Brooks Brook Risk Assessment

TABLE D1: SOIL VAPOUR SURVEY DETAILS				
Sample Location	Location	Depth of rod below grade (m)	Length of Screened Section (m)	Air pump operating time (min)
SV#1	Vicinity of H98-18 and H97-16	0.4	0.25	348
SV#2	Vicinity of H98-20	0.45	0.25	321
SV#3 (background)	West of H98-25	0.45	0.25	227
SV#4	Vicinity of MW01-02	0.45	0.25	44

TABLE D2: SOIL VAPOUR RESULTS (ug)					
Sample Location	Benzene	Toluene	Ethylbenzene	Xylenes	Total Hydrocarbons
SV#1	<0.5	2.7	1.7	1.8	24.5
SV#2	<0.5	4.1	<0.5	1.8	33.6
SV#3	<0.5	3.0	<0.5	0.6	45.6
SV#4	<0.5	<0.5	<0.5	<0.5	<5

TABLE D3: TOTAL HYDROCARBON CONCENTRATION CALCULATION				
Sample Location	Time Operated (min)	Flow Rate (l/min)	Total Hydrocarbons (ug)	Concentration (ug/L)
SV#1	348	0.2065	24.5	0.341
SV#2	321	0.2065	33.6	0.507
SV#3 (background)	227	0.2065	45.6	0.973
SV#4	44	0.2065	<5	<0.55

TABLE D4: BTEX CONCENTRATIONS IN SOIL VAPOUR (ug/L or mg/m³)				
	Benzene	Toluene	Ethylbenzene	Xylenes
SV#1	<0.007	0.038	0.024	0.025
SV#2	<0.008	0.062	<0.008	0.027
SV#3 (background)	<0.01	0.065	<0.01	0.013
SV#4	<0.055	<0.055	<0.055	<0.055
Yukon WCB 8-hour exposure	32	375	435	435

Table IV
Statistical Summary of Chemical Parameters in Excess of YCSR Soil Standards and CCME Soil Guidelines for the Protection of Human Health

PARAMETER	YCSR	CCME RL/PL	CWS Tier 1	No. of Samples	Range (mg/kg)		Mean (mg/kg)	Median (mg/kg)	# > YCSR	# > CCME	# > CWS	95th Percentile mg/kg
					Min	Max						
PAHs												
Naphthalene	5 ⁽¹⁾	0.6	ns	7	0.025	0.8	0.33	0.25	0	2	na	0.77
MAHs												
Volatile Pet. Hydrocarbons (F1)	200 ⁽¹⁾	ng	15,000 ⁽⁴⁾ > 30,000 ⁽⁵⁾	44	5	730	100.73	72.36	6	na	0	532
LEPH-uncorrected for PAH's (F2)	1000 ⁽²⁾	ng	8000 ⁽⁴⁾	44	125	8000	895.34	510.17	9	na	0	5830
HEPH-uncorrected for PAH's (F3)	1000 ⁽²⁾	ng	18,000 ⁽⁴⁾ > 30,000 ⁽⁵⁾	44	125	4500	307.5	216.25	2	na	0	906
Metals												
Cadmium Cd	35 ⁽²⁾	10	ns	15	0.125	11.3	1.59	0.5	0	1	na	8.43
Chromium Cr	150 ⁽³⁾	64	ns	15	19	263	61.73	49	1	3	na	151
Copper Cu	15,000 ⁽⁴⁾	63	ns	15	15	3000	234.87	28	0	3	na	984
Lead Pb	500 ⁽⁴⁾	140	ns	15	5	780	123.6	18	1	3	na	546
Zinc Zn	10,000 ⁽⁴⁾	200	ns	15	23	2600	358.27	82	0	5	na	1284

Footnotes:

All values in mg/kg (ppm)

YCSR - Yukon Contaminated Sites Regulation Residential/Park Land Standards

CCME RL/PL - Canadian Council of Ministers of the Environment Residential/Park Land Guidelines

CWS Tier 1 - Canada Wide Standards for Petroleum Hydrocarbons, Tier 1 for eco soil contact of surface soils

⁽¹⁾ Residential/Parkland generic standard

⁽²⁾ Groundwater flow to surface water used by aquatic life

⁽³⁾ Protection of human health

⁽⁴⁾ Intake of contaminated soil

⁽⁵⁾ Dermal Contact

ns = No Standard

ng = No Guideline

Table I. Terrestrial Plant Species Identified in the ESG 1997 Report

Common Name	Genus Species Name
High bush cranberry	<i>Viburnum trilobum</i>
Sphagnum moss	<i>Sphagnum spp.</i>
Labrador tea	<i>Ledum latifolium</i>
Leather leaf	<i>Chamaedaphne calyculata</i>
Wild rose	-
Lodge pole pine	<i>Pinus contorta</i>
Strawberry	<i>Fragaria sp.</i>
Perennial herb (Pussytoes)	<i>Antennaria rosea</i>
Fireweed	<i>Epilobium angustifolium</i>
Milk Vetch	<i>Astragalus alpinus</i>
Dandelion	<i>Taraxacum sp.</i>
Slender Wheatgrass	<i>Agropyron trachycailus</i>
Spike Trisetum	<i>Trisetum spicatum</i>
Yarrow	<i>Achillea millefolium</i>
Jacob's Ladder	<i>Polemonium spp.</i>
Bluegrass	<i>Poa spp.</i>
Slender Wheatgrass	<i>Elymus trachycaulus</i>
Common Bearberry	<i>Arctostaphylos uva-ursi</i>
Black Cottonwood	<i>Populus balsamifera</i>
White Spruce	<i>Picea glauca</i>
Common Dandelion	<i>Taraxacum officinale</i>
Common Horsetail	<i>Equisetum arvense</i>
Rosehip	-
Grasses	-
Lingonberry	<i>Vaccinium vitis-idaea</i>
Alaska Willow	<i>Salix alexensis</i>
Prickly Rose	<i>Rosa acicularis</i>
Trembling Aspen	<i>Populus tremuloides</i>
Vetch	<i>Vicia spp.</i>
Soapberry	<i>Shepherdia canadensis</i>
Arctic Lupin	<i>Lupinus arcticus</i>
Field Locoweed	<i>Oxytropis campestris</i>
Sedges	<i>Carex sp.</i>
(grass)	<i>Agropyrum violaceum</i>
Lichen	-
Prostrate juniper	<i>Juniperous communis</i>
Clover	<i>Trifolium epilobium</i> <i>anustifolium</i>
Alaska Plantain	<i>Plantago</i>
Bluejoint	<i>Calamagrotis</i>
Northern Scouring Rush	<i>Equisetum variegatum</i>

Willow	<i>Salix longistylis</i>
Tall Bluebells	<i>Mertensia paniculata</i>
Narrow-leaved Cotton Grass	<i>Eriophorum angustifolium</i>
Mushrooms	-
Hawksbeard	<i>Crepis spp.</i>
Sitka Alder	<i>Alnus crispa</i>
Twinflower	<i>Linnea borealis</i>
Kentucky Bluegrass	<i>Poa pratensis</i>
Raspberry	-
Sandwort	<i>Mohringia fern</i>
Villous Cinquefoil	<i>Potentilla</i>
Knotweed	<i>Polygonum macrophyllum</i>
Gooseberry	<i>Ribes lacustre</i>
Lousewort	Pedicularis Family
Lichen	<i>Fruticose</i>
Bastard toad-flax	<i>Comandra umbellata</i>
Mushroom	<i>Glecaulon lividum</i>
Wintergreen	<i>Pyrola</i>
Horsetail	<i>Equisetum scirpoides</i>
Horsetail	<i>Equisetum saipoides</i>
-	<i>Astragalus Mckenzie</i>

61 mammal species.

4 amphibian

278 Bird sp.

27 freshwater sp.

1000
pl.

DEPARTMENT OF RENEWABLE RESOURCES



10 Burns Road
Whitehorse,
Yukon
Y1A 4Y9

Ph: 867-667-5652
Fax: 867-393-
6213

[Home Page](#)

[Biodiversity](#)

[Amphibians](#)

[Birds](#)

[Fish](#)

[Mammals](#)

[Plants](#)

[Protecting
Wildlife](#)

[Protecting
Habitat](#)

[Ecoregions](#)

[Urban Wildlife](#)

[Wildlife at Risk](#)

[Bear Safety](#)

[Youth Programs
and Teacher
Resources](#)

[Arctic Fox](#)

[Cougar](#)

[Fisher](#)

[Marten](#)

[Red Fox](#)

[Wolverine](#)

[Caribou](#)

[Mountain Goat](#)

[Thinhorn Sheep](#)

[Arctic Ground Squirrel](#)

[Hoary Marmot](#)

[Lemmings](#)

[Porcupine](#)

[Woodchuck](#)

[Little Brown Bat](#)

Carnivores

[Black Bear](#)

[Coyote](#)

[Grizzly Bear](#)

[Mink](#)

[River Otter](#)

[Wolf](#)

Hoofed Mammals

[Elk](#)

[Mule Deer](#)

[Wood Bison](#)

[Collared Pika](#)

[Ermine and Least Weasel](#)

[Lynx](#)

[Polar Bear](#)

[Snowshoe Hare](#)

[Moose](#)

[Muskox](#)

Rodents

[Beaver](#)

[Jumping Mice](#)

[Muskrat](#)

[Red Squirrel](#)

[Wood Rat](#)

[Deer Mouse](#)

[Least Chipmunk](#)

[Northern Flying Squirrel](#)

[Voles](#)

Others

[Seals](#)

[Whales](#)

[Shrews](#)

[Home](#) | [Wildlife Viewing & Wilderness Travel](#) | [Wildlife, Fish & Ecology](#) | [Hunting, Fishing & Tra](#)
[Protected Areas & Special Places](#) | [Environment](#) | [Agriculture](#) | [Publications, Library & GIS](#)



DEPARTMENT of RENEWABLE RESOURCES

Yukon

10 Burns Road
Whitehorse,
Yukon
Y1A 4Y9

Home	Wildlife Viewing & Wilderness Travel	Wildlife, Fish & Ecology	Hunting, Fishing & Trapping
Protected Areas & Special Places	Environment	Agriculture	Publications, Library & GIS

FISH SPECIES IN THE YUKON TERRITORY

Ph: 867-667-5652
Fax: 867-393-6213

Home Page

Biodiversity

Amphibians

Birds

Fish

Mammals

Plants

Protecting Wildlife

Protecting Habitat

Ecoregions

Urban Wildlife

Wildlife at Risk

Bear Safety

Youth Programs and Teacher Resources

INCONNU
BROAD WHITEFISH
PYGMY WHITEFISH
ARCTIC CISCO
LAKE CHUB
LAKE TROUT
BULL TROUT
RAINBOW TROUT/STEELHEAD
SOCKEYE SALMON
CHINOOK SALMON
PIKE
LONGNOSE SUCKER
SLIMY SCULPIN
TROUT PERCH

LAKE (HUMPBACK) WHITEFISH
ROUND WHITEFISH
LEAST CISCO
ARCTIC GRAYLING
BOREAL SMELT
DOLLY VARDEN
ARCTIC CHAR
KOKANEE
COHO SALMON
CHUM SALMON
BURBOT
WHITE SUCKER
NINESPINE STICKLEBACK
ARCTIC LAMPREY

INCONNU

Stenodus leucichthys (Guldenstadt). Its name in French means "the unknown fish". also called coney or sheefish. Inconnus are light in exterior colouring with the dor fins dusky at the tip, the tail fin shading to dark at the edge. The lower jaw is long than the upper and usually somewhat hooked. The flesh is white, but rather soft a oily. In the Yukon, inconnus are smaller than the 25-30 pound fish of the MacKen delta area. Although they will take the hook and are excellent fighting fish, most a caught by gillnets of domestic fishermen. They are late summer or fall spawners Inconnu are fairly abundant in the Yukon, Pelly, Stewart and Porcupine River syste

LAKE (HUMPBACK) WHITEFISH

Coregonus clupeaformis (Mitchill). This species is important commercially in th Yukon, where it is found in most of the lakes. In colouring the whitefish is olivace on the upper part of the body, with whitish sides and under portions. The tail fin deeply forked. The lower fins may be dusky. The mouth is subterminal. Adults hav fleshy bump at the shoulders; hence their name. Mature fish average 18 inches in le and weigh about 2.5 pounds. They live on minute molluscs, crustaceans and other s aquatic creatures. Its summer habitat is in the deeper, colder parts of the lakes, fro which it moves into more shallow water at spawning time - late October onward Gillnetting is the chief method of catching them, although they have been known strike angler lures in early spring.

BROAD WHITEFISH

Coregonus nasus (Pallas). Flattened sides and a compressed body have resulted in whitefish species being given the name "broad whitefish". The head is short and t snout blunt. Adults have a large adipose fin and a deeply forked tail fin. During f spawning, the large scales become covered with white conical tubercles, especially the males. Adults have a brown or blackish coloured back and yellowish or silver

belly. Commercially caught broad whitefish are 3-5 pounds in weight although much heavier fish do exist. They are found mostly in rivers, but sometimes in lakes. As evidenced by their blunt snouts, broad whitefish are bottom feeders, feeding mainly on molluscs and aquatic insect larvae. In the Yukon, broad whitefish are more important for local consumption than for commercial purposes.

ROUND WHITEFISH

Propomium cylindraceum (Pallas). As their Latin name implies, round whitefish are almost cylindrical in cross-section. They are cigar-shaped with a strongly forked short head, small mouth devoid of teeth, and a laterally "pinched" snout which projects beyond the lower jaw. Large, easily loosened scales cover their dark brown olive-green above and silvery below bodies. They average under 16.5 inches in length and 2 pounds in weight. They are widely distributed throughout the Yukon. Round whitefish are shallow water bottom feeders, feeding mainly on caddis fly larvae and pupae, snails, and fish eggs. Spawning occurs along lake and stream shorelines in autumn. "Rounds" are not important as a commercial species as they are seldom caught in mesh gillnets, but are utilised by First Nations who fish for their own needs.

PYGMY WHITEFISH

Prosopium coulteri (Eigenmann & Eigenmann). Their range in the Yukon Territory is limited to the Alsek River system and the headquarters of the Yukon River. Squan Lake, east of Whitehorse, has a sizeable population of pygmy whitefish. The pygmy whitefish has a cigar-shaped body, round in cross-section, short head, blunt snout, small mouth devoid of teeth. Adult fish are dark brown above, silvery below, and fins are clear of any pigment. Little is known about their behaviour except that they are carnivorous, feeding on organisms such as aquatic insect larvae, crustaceans and molluscs. Spawning occurs in autumn or early winter in lakes or streams with the gravel being scattered over gravel.

LEAST CISCO

Coregonus sardinella (Valenciennes). The least cisco has often been called "lak herring" because of resemblance to the salt water herring. A trout-like body, moderate sized head, large eyes and scales, no teeth and a projecting lower jaw identify the species. Adults are gray to olive-green above and silvery below. The non-migratory form seldom exceeds 9 inches in length and has no spots on the fins or back. It occurs abundantly in almost all lakes and rivers of the upper Yukon system right up to the headwaters, including Lake Laberge, Atlin, Teslin, Tagish and Bennett Lakes. Least cisco are plankton feeders, but smaller insect larvae form a part of their summer diet. In autumn, they are preyed upon by burbot, northern pike, inconnu and lake trout. Least cisco are autumn spawners.

ARCTIC CISCO

Coregonus autumnalis (Pallas). The Arctic cisco has a trout like body, moderate sized head and eyes, and large scales. When its mouth is closed, the upper and lower jaw are equal. Though they may attain a length of 25 inches and a weight of 5.5 pounds, average is much smaller. Anadromous adults are brown to light green on their back and bright silver below. Spawning males develop rows of flat tubercles on their sides. As their name implies, Arctic cisco are found along the Beaufort Sea coast. They are common in the lower reaches of the rivers and are particularly abundant in brackish water. They feed mainly on crustaceans and small fish. In spring they ascend rivers where they spawn in late summer, after which they migrate back to a marine environment.

ARCTIC GRAYLING

Thymallus arcticus (Pallas). Arctic grayling have a slender body, short head, unusually large eyes, small square shaped mouth, and a greatly enlarged dorsal fin. They migrate

grow as large as 24 inches long and attain a weight of 5 pounds, but the average Yu grayling would be less than 20 inches long with a weight under 2 pounds. They are vividly coloured fish, especially during the spawning period. The adult grayling has a dark purplish blue back and purplish grey sides with scattered black spots. The large dorsal fin with its rows of orange or emerald green spots edged with orange give the Arctic grayling male an iridescent peacock coloration. Terrestrial insects form the larger part of their diet, but they also feed on bottom nymphs, snails, small fish and eggs.

LAKE CHUB

Couesius plumbeus (Agassiz). This Yukon species has a slender body, short flat head, broad snout and no adipose fin. The mouth is oblique and of moderate size, the upper jaw extending backward. There is a distinct barbel near the end of the upper jaw. Lake chub are small fish, usually less than 4 inches in length. Adults are blackish dark brown or green above, pale silvery below with an indistinct dark mid-lateral band. Lake chub frequent lakes and streams (both clear and muddy waters) throughout the territory. They remain close to the bottom regardless of depth and may occur in large schools. Terrestrial and aquatic insects (both larval and adults forms), zooplankton, algae, freshwater shrimp and small fish are eaten by the lake chub. In turn they serve part of the diet of larger fish.

BOREAL SMELT

Osmerus eperlanus (Linnaeus). The smelt family is comprised of small, slender silvery fish which tend to occur in schools. The head and eyes of the boreal smelt are of moderate size, but the mouth is large, extends well back and has well developed teeth in both jaws. They are generally less than 10 inches long though they may grow to 18 inches. Adult fish are light olive green on the back and iridescent silver below. Spawning males develop large tubercles on their scales as well as a slight lateral ridge. Boreal smelt are anadromous in the Yukon and have been taken from some of the Arctic coastal rivers as well as in the Beaufort Sea. Adult fish feed partially on crustaceans and on small fish, as suggested by their large canine teeth.

LAKE TROUT

Salvelinus namaycush (Walbaum). In exterior colouring, lake trout vary from almost black to greyish or very light green with light coloured, irregular shaped spots. Similarly, there are variations in the colour of the flesh - from deep red to pale ivory. These differences are probably determined in part by heredity and in part by environment. Their main food is fish although smaller aquatic organisms are also eaten. Spawning occurs in the fall. Lake trout are sport fish as well as important commercially. Growth is quite slow in most water bodies in the Yukon yet twenty pound fish are not uncommon. Those living in large lakes usually grow to a larger size than those in smaller bodies of water. They will take the hook in fly fishing with artificial lures, as well as some baits.

DOLLY VARDEN

Salvelinus malma (Walbaum). A trout like body, slightly oblique mouth, forked tail and small scales typify the dolly varden. They are dark blue to olive-green on the back and sides covered with light coloured yellow spots on the dorsal surface and orange pink spots on the sides fading to white or dusky underparts. The spots are usually smaller in diameter than the pupil of the eye. The non-migratory fish found in the Yukon Territory average 4 to 6 pounds and are smaller than the sea-run form. Adult fish are carnivorous, feeding mainly on other fish, aquatic insect larvae and gastropods. They are autumn spawners. Stella Lake (MP 108, Haines Road) contains landlocked dollys. They are also reported from the Blackstone River (MP 68, Dempster Hwy). These fish are easily confused with Bull trout which are now known to be a separate species.

BULL TROUT

Salvelinus confluentus. Bull trout have long been confused with Dolly Varden, although we now know that they are a distinct species. They are very similar in appearance to the Dolly Varden and can only be distinguished by a few subtle differences. The easiest to distinguish physical characteristics are that Bull trout have no black spots on the dorsal fin and the eye is closer to the top of the head than a Dolly Varden. They also occupy different geographic ranges. Fish fitting this description found in the Liard drainage are likely Bull trout, while those found elsewhere in the Yukon are likely Dolly Varden. Beware of confusing these fish with Arctic char as well.

ARCTIC CHAR

Salvelinus alpinus (Linnaeus). The Arctic char occurs in two principal forms. One migrates into the sea in the summer to feed, but returns to fresh water to pass the winter. The non-anadromous form remains in fresh water throughout its entire life. Arctic char has an elongate body and in the sea run form is silvery with a deep bluish greenish blue on the back and upper sides. The non-anadromous form varies from blue to olive green or brown. Both forms have violet-pink or red spots on the dorsal surface and the sides which are usually larger in diameter than the pupil of the eye. As Arctic char approach spawning condition in the autumn, body colours range from bright red to deep vermilion. Adults are sexually mature at 18 inches and fish of over 20 pounds have been caught in Canada. During the winter, char feed little or not at all, but use large fat reserves stored during the previous summer. Arctic char occur in the north drainages of the Yukon naturally, but are also stocked by the Yukon government in some accessible pothole lakes.

RAINBOW TROUT/STEELHEAD

Oncorhynchus mykiss. A typically trout like body, rounded snout, large mouth and black spots on the back, dorsal, adipose and tail fins identify the rainbow trout. The back is bluish green to brown with white or dusky sides and underparts. Usually a pink to vivid red distinct lateral stripe is visible. In lake populations with good food sources (generally stocked lakes in the Yukon) rainbows can reach 15 pounds in weight, but native stream fish typically weigh less than 3 pounds. Adult trout feed mainly on crustaceans (freshwater shrimp), aquatic insect larvae (caddis and black fly) mollusks and the occasional small fish. Their flesh ranges from bright orange to pink and is very delicious.

The steelhead is a sea-going form of rainbow trout. When in the sea, the body is mainly silvery, with a blue back. At spawning time a band of red colour develops along the side of the body. After spawning, many adult steelhead go back to the sea and so although usually not a high proportion, return to fresh water after recuperation to spawn a second time. Females survive more often than males. The young fish live for one to two full years in freshwater before travelling to the sea as smolts from 4-10" in length. This migration takes place in the spring. Steelheads have been reported from the Alsea-Tatshenshini River system in the southwest corner of the territory. They are often confused with the native trout which also exist in this watershed. However, steelheads are much larger fish, averaging better than 5 pounds.

KOKANEE

Oncorhynchus nerka (Walbaum). Kokanee are landlocked sockeye salmon and are identical to the anadromous sockeye salmon except for their size. In the Yukon they seldom exceed two pounds in weight or 20 inches in length. Kokanee are usually bright silver bluish colour and typically trout like in appearance. At spawning time they take the appearance and coloration of spawning anadromous sockeye. Males become bright red on the back and sides with dirty white underparts. Their head becomes green in colour with a dusky elongated snout, and a light hump forms behind the head.

the head. Spawning females are similarly coloured, but the red is much darker. During most of the year, kokanee are in deep water. In early June they are found in shallow water in Kathleen Lake and are eagerly sought after by anglers for their tasty flesh.

SOCKEYE SALMON

Oncorhynchus nerka (Walbaum). The body of the sockeye is slightly elongated, the head is conical and the teeth are small and weak. They are distinguished from the other salmon by the absence of black spots on the back and tail fins. They average about 12 inches in length and under 5 pounds in weight. When male sockeye reach the Alsek-Tatshenshini waters at spawning time, their bodies turn brilliant red with metallic green heads. The upper jaw develops its characteristic hook and a slight hump forms behind the head. The female fish are a dark red with green and yellow blotches. After the hatch, young fry spend two years in freshwater lakes before migrating to the ocean where they spend the next three years. Sockeye are the most highly prized salmon because of the rich red, firm flesh.

COHO SALMON

Oncorhynchus kisutch (Walbaum). Coho have the typical body shape and fins of Pacific salmon. They are distinguished from the other salmon by the fine black spot on the back and upper lobe of the tail (above the lateral line), and no black pigment at the base of the teeth in the lower jaw. During spawning, the fish have dark backs and light stomachs, with a red stripe on the sides (males are more brilliant). Young coho salmon reach the ocean before the end of their first year and return to spawn after a further year and some months in the ocean. Coho salmon are found in the Alsek-Tatshenshini River system, e.g. Klukshu River where anglers eagerly seek them out in late September or early October. Cohos are also found in the Porcupine River system in the northern part of the territory.

CHINOOK SALMON

Oncorhynchus tshawytscha (Walbaum). Other names for this Pacific salmon include kings, chinooks, or tyee when they are more than 30 pounds. The top half of the body (including the dorsal fin and both lobes of the tail fin) is heavily marked with irregular black spots and gums in the lower jaw are black. At spawning time, their backs are dark, with the sides being pink to dark reddish in colour. The male snout is elongated and strongly hooked. The adult fish average 15-20 pounds, but fish of 65 pounds have been taken in the Yukon River or its tributaries. The young spend their first year in freshwater lakes or quiet backwaters of the mainstem Yukon before migrating downstream as smolts. They arrive back as 4-7 year old fish ready to spawn.

CHUM SALMON

Oncorhynchus keta (Walbaum). Chum salmon are often called dog salmon because of the sharp dog-like teeth of spawning males and because they are often used to feed dogs. They are distinguished by the lack of black spots on the back and fins. Spawning fish have a greenish colour with dusky red mottlings or bars on their sides. The pectoral and anal fins are white-tipped. Adult fish average under 5 pounds in weight. Chum salmon spawn in the major tributaries of the Yukon River - the White, Stewart, Peel and Teslin Rivers. The Porcupine River and its tributary the Fishing Branch River, contain a sizeable spawning population. They first appear in Dawson about the middle of August and are still running after ice covers the river. The fry migrate immediately upon emerging from the gravel and return in their third or fourth year.

PIKE

Esox lucius (Linnaeus). Northern pike are soft-rayed fish with no adipose fin, and a dorsal fin which is positioned well towards the tail. They are quite long in proportion to depth and width, and have a flattened snout. Their mouths bristle with sharp, pointed teeth. They are a dark green colour across the back, mottled down the sides with light

spots going into a whiteish belly. Adult pike spawn in the spring in shallow, weed flooded areas of rivers, marshes and bays of large lakes. Pike are found throughout year in shallow water due to their ability to tolerate higher water temperatures, low concentrations of oxygen and higher concentrations of carbon dioxide than many species of freshwater fish. They generally lie motionless and well camouflaged among the shallow water vegetation, waiting to pounce on anything that swims too close. Although they primarily eat fish, they also take any other creatures which are small enough and within striking distance.

BURBOT

Lota lota (Linnaeus). An eel like, elongate body tapering to a posterior rounded tail flattened short head, large mouth with a single barbel under the chin, and two spine dorsal fins can only describe the burbot. Although the body feels slippery, there are small embedded scales covered with slime. Adults are olive-green to dark brown on their back and sides with irregular pale blotches. Burbot may reach 4 feet in length and a weight of 75 pounds, but the average Yukon fish is under 10 pounds. They are often called lingcod, ling, maria, or loche. They are voracious feeders, feeding mainly at night on fish, though aquatic insects, crustaceans, plankton and fish eggs can make part of their diet. They are easily caught on baited set lines, as they are bottom dwellers.

LONGNOSE SUCKER

Catostomus catostomus (Forster). Any sucker taken from the Yukon River system is probably of this species. Suckers are identified by their ventral mouth and large lips. The back and sides of adult fish are dark grey to black with white underparts. Adult longnose suckers can attain a length of 25 inches and 3.5 - 4.5 pounds is the average weight. Spawning occurs in spring soon after the ice goes out, at which time the males have dark bands along their backs and lateral lines which are separated by a wide brilliant red stripe. They also have well-developed calcified tubercles on their head, anal and caudal fins. Suckers live in nearly all types of water, but thrive in warm shallow turbid rivers and lakes. They feed upon bottom insects, shells and vegetation sucked up from shallow muddy places.

WHITE SUCKER

Catostomus commersonii (Lacepede). This sucker species is found in some of the southern Yukon streams that drain into the Mackenzie River. Adults are brassy brown to black on their backs and silvery white sides and underparts. There is a dark stripe just below the lateral line, but no red stripe is visible in spawning males, as in the longnose sucker. They spawn in late spring or early summer.

SLIMY SCULPIN

Cogonatus cogonatus (Richardson). Sculpins are grotesque looking, small, bottom dwelling fish with broad flat bony heads, and very large pectoral fins. There are two dorsal fins, the anterior fin is spiny and the posterior is soft. One to three spines are found on the preopercle. Sculpins spawn in spring with the egg masses becoming attached under stones and guarded by the males. Sculpins are principally bottom feeders with aquatic insects and their larvae, plankton, crustaceans, and small fish making up their diets. In turn they are often eaten by burbot or lake trout.

NINESPINE STICKLEBACK

Pungitius pungitius (Linnaeus). The ninespine stickleback is a small (3 inch) but aggressive fish that lacks scales, and instead has bony plates along its sides. Seven to 12 sharp spines are located ahead of the soft dorsal fin or the pelvic fins and the body tapers to a very narrow point just before the tail. Adults are olive green to light brown on the back (irregular mottling present) with yellowish white underparts. Breeding males become jet black under the chin and along the belly. The stickleback species is typically found in shallow bays of lakes, slow streams and tundra ponds. Large schools

may be associated with heavy aquatic vegetation. They are carnivorous fish, feeding mainly on insect larvae, small crustaceans, molluscs which they pick up near the bottom. All sticklebacks are territorial fish with the male building a tunnel shape vegetation nest into which the female is lured.

TROUT PERCH

Percopsis omisomaycus (Walbaum). These are small fish, usually less than 4 inch long, with large blunt heads, long snout and large scales. They have a small adipose and large pectoral fins that extend beyond the start of the pelvic fins. Their bodies elongated, tapering posteriorly, and when alive, they are translucent. Two rows of almost ten small dark blotches are found along the top half of the back. They are found in the Porcupine River and some of its tributaries - the Crow, Bell and Eagle River. They are found in quiet backwaters feeding mainly on aquatic insects, small crustaceans and molluscs. Very little is known about their spawning behaviour, except that it occurs mainly at night during spring or early summer.

ARCTIC LAMPREY

Lampetra japonica (Martens). The Arctic lamprey has an eel like body, short head with a mouth surrounded by a circular sucking disc. No paired fins are present, instead two dorsal fin folds and one caudal fin fold are almost continuous in adults. Lampreys differ from bony fishes in that they do not have scales, bones, jaws, ribs, paired fins or gas bladders. In the parasitic form, teeth are sharp and strongly developed, whereas in the non-parasitic form, teeth are blunt and weakly developed. Arctic lamprey may grow to 2 feet in length and reach 8 ounces in weight. A non-migratory, but parasitic lamprey population is reported to exist in Tatlain Lake (drains into Pelly River) where it feeds on whitefish. Anadromous forms along the Arctic-Yukon coast have invaded some of the river systems. After spawning the adults die. The larval stage is called ammocoete.

[Home](#) | [Wildlife Viewing & Wilderness Travel](#) | [Wildlife, Fish & Ecology](#) | [Hunting, Fishing & Trapping](#) | [Protected Areas & Special Places](#) | [Environment](#) | [Agriculture](#) | [Publications, Library & GIS](#)

DISTRIBUTION CODES

S South: south of 63° N (includes Pelly Crossing but not Stewart Crossing).

SE Southeast: southern Yukon east of 131° W (Swift River) with an underline (SE) for species restricted to the La Biche River and Beaver River valleys in the extreme southeast.

FREQUENCY and BREEDING CODES

r Rare: reported annually in very low numbers or extremely localized.

ca Casual: at least two records but not seen every year.
ac Accidental: recorded only once.

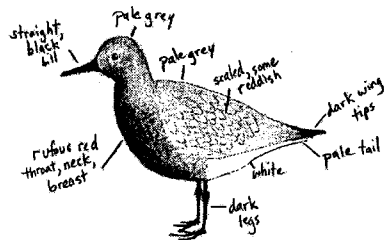
w **Winter:** observed annually in winter (Dec. 1 - Feb. 28).

- **Confirmed Breeding:** observations of an active nest or dependent, flightless young.

DOCUMENTING BIRD SIGHTINGS

Contribute to our knowledge of the Territory's bird life by sending written or photo documentation of rare, casual, or accidental species or those not on the checklist, and details of breeding observations to:

The Yukon Bird Club
Box 31054, Whitehorse, Yukon, Canada, Y1A 5P7



A joint publication of the Yukon Bird Club, Canadian Wildlife Service (Whitehorse), and Yukon Renewable Resources, March 2001. Compiled by Cameron Eckert, Helmut Grunberg, Greg Kubica, Lee Kubica and Pam Sinclair with data provided by the Birds of the Yukon Database (Canadian Wildlife Service). Illustrations of American Golden-Plover and Red Knot by Pam Sinclair.

✓ SPECIES

☐ Red-throated Loon *
☐ Pacific Loon *
☐ Common Loon *
☐ Yellow-billed Loon

☐ Pied-billed Grebe * S r
☐ Horned Grebe *
☐ Red-necked Grebe *
☐ Eared Grebe ac
☐ Western Grebe ca

Double-crested Cormorant * S r

___ Great Blue Heron S r
___ Black Vulture ac
___ Turkey Vulture ac

- **Bean Goose** ac
- **Greater White-fronted Goose** *
- **Snow Goose** *
- **Canada Goose** *
- **Brant** *

____ Trumpeter Swan *

___ Wood Duck ac
 ___ Gadwall *
 ___ Eurasian Wigeon S
 ___ American Wigeon *
 ___ Mallard * w
 ___ Blue-winged Teal *
 ___ Cinnamon Teal S r
 ___ Northern Shoveler
 ___ Northern Pintail *

- Green-winged Teal *
- Canvasback *
- Redhead *
- Ring-necked Duck *
- Greater Scaup *
- Lesser Scaup *
- King Eider * N
- Common Eider * N
- Harlequin Duck *
- Surf Scoter *
- White-winged Scoter *
- Black Scoter ca
- Long-tailed Duck *
- Bufflehead *
- Common Goldeneye *
- Barrow's Goldeneye *
- Hooded Merganser S
- Common Merganser *
- Red-breasted Merganser
- Ruddy Duck * S

— Osprey *
Bald Eagle * w

[illegible]

✓ SPECIES

- Northern Harrier *
- Sharp-shinned Hawk *
- Northern Goshawk * w
- Broad-winged Hawk ac
- Swainson's Hawk r
- Red-tailed Hawk *
- Rough-legged Hawk *
- Golden Eagle *
- American Kestrel *
- Merlin *
- Gyrfalcon * w
- Peregrine Falcon *

- ☐ Ruffed Grouse * w
- ☐ Spruce Grouse * w
- ☐ Willow Ptarmigan * w
- ☐ Rock Ptarmigan * w
- ☐ White-tailed Ptarmigan * w
- ☐ Blue Grouse * w
- ☐ Sharp-tailed Grouse * w

— Sora * S
American Coot * S

— Sandhill Crane *
Common Crane ac

Black-bellied Plover
 American Golden-Plover *
 Pacific Golden-Plover ca
 Snowy Plover ac
 Semipalmated Plover *
 Killdeer *
 American Avocet ac
 Greater Yellowlegs S
 Lesser Yellowlegs *
 Wood Sandpiper ac
 Solitary Sandpiper *
 Willet ac

- ☐ Wandering Tattler *
- ☐ Spotted Sandpiper *
- ☐ Upland Sandpiper *
- ☐ Whimbrel *
- ☐ Hudsonian Godwit
- ☐ Bar-tailed Godwit ca
- ☐ Marbled Godwit ac
- ☐ Ruddy Turnstone * N
- ☐ Black Turnstone ca
- ☐ Surfbird * r
- ☐ Red Knot ca
- ☐ Sanderling
- ☐ Semipalmated Sandpiper *
- ☐ Western Sandpiper S
- ☐ Little Stint ac
- ☐ Least Sandpiper *
- ☐ White-rumped Sandpiper n
- ☐ Baird's Sandpiper *

[illegible]

✓ SPECIES

___ Pectoral Sandpiper *
 ___ Sharp-tailed Sandpiper S r
 ___ Dunlin r
 ___ Stilt Sandpiper *
 ___ Buff-breasted Sandpiper * N r
 ___ Short-billed Dowitcher * S
 ___ Long-billed Dowitcher *
 ___ Common Snipe *
 ___ Wilson's Phalarope * S r
 ___ Red-necked Phalarope *
 ___ Red Phalarope * N

- ___ Pomarine Jaeger N
- ___ Parasitic Jaeger * N
- ___ Long-tailed Jaeger *
- ___ Franklin's Gull ca
- ___ Little Gull ac
- ___ Bonaparte's Gull *
- ___ Mew Gull *
- ___ Ring-billed Gull S r
- ___ California Gull S r
- ___ Herring Gull *
- ___ Thayer's Gull S
- ___ Iceland Gull ca
- ___ Lesser Black-backed Gull ac
- ___ Slaty-backed Gull ca
- ___ Glaucous-winged Gull S r
- ___ Glaucous Gull *
- ___ Sabine's Gull ca
- ___ Black-legged Kittiwake ac
- ___ Red-legged Kittiwake ac
- ___ Ross's Gull ac
- ___ Ivory Gull ac
- ___ Caspian Tern S r
- ___ Arctic Tern *
- ___ Black Tern * SE r

- ___ Thick-billed Murre ac
- ___ Black Guillemot * N r
- ___ Ancient Murrelet ac

_____ Rock Dove * S r w
Mourning Dove r

___ Great Horned Owl * w
 ___ Snowy Owl * N r
 ___ Northern Hawk Owl * w
 ___ Great Gray Owl * w
 ___ Long-eared Owl ac
 ___ Short-eared Owl *
 ___ Boreal Owl * w
 ___ Northern Saw-whet Owl ac

___ Common Nighthawk *

___ Rufous Hummingbird S r

Belted Kingfisher *

___ Yellow-bellied Sapsucker *
 ___ Red-breasted Sapsucker ca
 ___ Downy Woodpecker * S w
 ___ Hairy Woodpecker * w
 ___ Three-toed Woodpecker * w
 ___ Black-backed Woodpecker * S w
 ___ Northern Flicker *
 ___ Pileated Woodpecker * SE r
 ___ Olive-sided Flycatcher *
 ___ Western Wood-Pewee *
 ___ Yellow-bellied Flycatcher S r
 ___ Alder Flycatcher *
 ___ Least Flycatcher * S
 ___ Hammond's Flycatcher *
 ___ Dusky Flycatcher S
 ___ Eastern Phoebe * SE r
 ___ Say's Phoebe *
 ___ Western Kingbird ac
 ___ Eastern Kingbird SE r
 ___ Northern Shrike * w
 ___ Blue-headed Vireo SE
 ___ Warbling Vireo * S
 ___ Philadelphia Vireo SE r
 ___ Red-eyed Vireo SE
 ___ Gray Jay * w
 ___ Steller's Jay ca
 ___ Clark's Nutcracker ca
 ___ Black-billed Magpie * S w
 ___ American Crow S r
 ___ Common Raven * w
 ___ Horned Lark *
 ___ Purple Martin ac
 ___ Tree Swallow *
 ___ Violet-green Swallow *
 ___ N. Rough-winged Swallow S r
 ___ Bank Swallow *
 ___ Cliff Swallow *
 ___ Barn Swallow *
 ___ Black-capped Chickadee * w
 ___ Mountain Chickadee * S r w
 ___ Chestnut-backed Chickadee ac
 ___ Boreal Chickadee * w
 ___ Gray-headed Chickadee ca
 ___ Red-breasted Nuthatch * S w
 ___ Brown Creeper ca
 ___ Winter Wren SE r
 ___ Marsh Wren ca
 ___ American Dipper * w
 ___ Golden-crowned Kinglet S

[illegible]

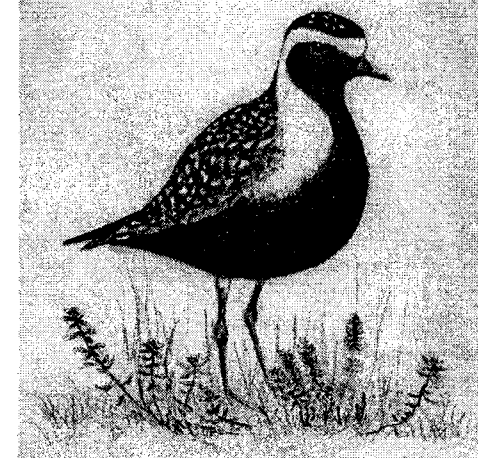
- ☐ Ruby-crowned Kinglet *
- ☐ Bluethroat N r
- ☐ Northern Wheatear *
- ☐ Mountain Bluebird *
- ☐ Townsend's Solitaire *
- ☐ Gray-cheeked Thrush *
- ☐ Swainson's Thrush *
- ☐ Hermit Thrush *
- ☐ Dusky Thrush ac
- ☐ American Robin * w
- ☐ Varied Thrush *
- ☐ European Starling * S r
- ☐ Yellow Wagtail * N r
- ☐ Red-throated Pipit ca
- ☐ American Pipit *
- ☐ Bohemian Waxwing * w
- ☐ Cedar Waxwing * SE r
- ☐ Tennessee Warbler *
- ☐ Orange-crowned Warbler *
- ☐ Nashville Warbler ac
- ☐ Yellow Warbler *
- ☐ Magnolia Warbler * SE
- ☐ Cape May Warbler SE
- ☐ Yellow-rumped Warbler *
- ☐ Townsend's Warbler *
- ☐ Palm Warbler ca
- ☐ Bay-breasted Warbler * SE
- ☐ Blackpoll Warbler *
- ☐ Black-and-white Warbler * SE r
- ☐ American Redstart * S
- ☐ Ovenbird * SE
- ☐ Northern Waterthrush *
- ☐ Mourning Warbler SE r
- ☐ MacGillivray's Warbler * S r
- ☐ Common Yellowthroat *
- ☐ Wilson's Warbler *
- ☐ Canada Warbler SE r
- ☐ Western Tanager * SE
- ☐ American Tree Sparrow *
- ☐ Chipping Sparrow *
- ☐ Clay-colored Sparrow ca
- ☐ Brewer's Sparrow * S r
- ☐ Lark Sparrow ca
- ☐ Savannah Sparrow *
- ☐ Le Conte's Sparrow SE r
- ☐ Fox Sparrow *
- ☐ Song Sparrow * ca
- ☐ Lincoln's Sparrow *
- ☐ Swamp Sparrow * SE
- ☐ White-throated Sparrow * SE
- ☐ White-crowned Sparrow *
- ☐ Golden-crowned Sparrow *

[illegible]

- ☐ Dark-eyed Junco * w
- ☐ Lapland Longspur *
- ☐ Smith's Longspur *
- ☐ Snow Bunting * w
- ☐ Rose-breasted Grosbeak SE
- ☐ Black-headed Grosbeak ac
- ☐ Lazuli Bunting ac
- ☐ Red-winged Blackbird *
- ☐ meadowlark sp. * ca
- ☐ Yellow-headed Blackbird ac
- ☐ Rusty Blackbird *
- ☐ Brewer's Blackbird ca
- ☐ Common Grackle ac
- ☐ Brown-headed Cowbird * S
- ☐ Baltimore Oriole ac
- ☐ Brambling ca
- ☐ Gray-crowned Rosy-Finch * v
- ☐ Pine Grosbeak * w
- ☐ Purple Finch *
- ☐ House Finch ca
- ☐ Red Crossbill * S w
- ☐ White-winged Crossbill * w
- ☐ Common Redpoll * w
- ☐ Hoary Redpoll * w
- ☐ Pine Siskin *
- ☐ American Goldfinch ac
- ☐ Evening Grosbeak SE r w
- ☐ House Sparrow ac

[illegible][illegible]

YUKON BIRDS



D _____

Updated March 2001

Canadian Council of Ministers of the Environment

CANADA-WIDE STANDARDS
for
PETROLEUM HYDROCARBONS (PHCs) IN SOIL
Technical Supplement

January 2001

TABLE OF CONTENTS

Overview of this Technical Supplement	3
Section 1: Development of Tier 1 Generic Soil Quality Levels	4
<i>Approach for PHCs</i>	4
<i>Human Health Levels</i>	5
<i>Protocol Summary</i>	5
<i>Toxicological Basis</i>	5
<i>Derivation of Tier 1 Levels</i>	6
<i>Ecological Levels</i>	7
<i>Protocol Summary</i>	7
<i>Toxicological Basis</i>	7
<i>Derivation of Tier 1 Levels</i>	7
<i>Integration of Ecological and Human Health Levels</i>	8
Section 2: Tiered Framework for Assessment and Management of PHCs at Contaminated Sites.	13
<i>Site Characterization</i>	13
<i>Tier 1 Assessment and Management</i>	14
<i>Tier 2 Assessment and Management</i>	14
<i>Tier 3: Site-specific Risk Assessment</i>	17
<i>Confirmation testing</i>	18
Section 3: Socio-economic Analysis	19
Section 4: Analysis of Petroleum Hydrocarbons in Soils, CCME Tier I Method	22
References	23

Overview of this Technical Supplement

The PHC CWS is a 3-tiered, risk-based remedial standard developed for four generic land uses – agriculture, residential/parkland, commercial and industrial. This technical supplement has been prepared to describe the scientific and socio-economic basis of the standard and guide its appropriate application to PHC contaminated sites in Canada.

The risk-based nature of the PHC CWS means that, for each land use, all values to be protected (life forms or *receptors*, ecosystem properties) are explicitly documented as well as the contaminants considered within PHCs and the pathways by which PHCs can affect these values. This approach provides great flexibility, it allows assessment and management of different variations within a land use and even extension of the standard to other land use categories (e.g., wildlands). The vision, or *exposure scenario*, attached to each land use is the heart of the PHC CWS.

Agricultural lands: where the primary land use is growing crops or tending livestock. This also includes agricultural lands that provide habitat for resident and transitory wildlife and native flora. The portion of a farm that houses people is considered a residential land use.

Residential/Parkland: where the primary activity is residential or recreational activity. The ecologically-based approach assumes parkland is used as a buffer between areas of residency, but this does not include wild lands such as national or provincial parks, other than campground areas.

Commercial: where the primary activity is commercial (e.g., shopping mall) and there is free access to all members of the public, including children. The use may include, for example, commercial day-care centres. It does not include operations where food is grown.

Industrial: where the primary activity involves the production, manufacture or construction of goods. Public access is restricted and children are not permitted continuous access or occupancy.

Section 1 describes the scientific approach, data sources, and specific assumptions made regarding receptors and their interactions with a site under the exposure scenario applicable to each land use. Section 2 describes how the environmental management objectives underpinning the Tier 1 levels can be achieved cost-effectively through the phased acquisition and application of site-specific information in Tiers 2 and 3. Section 3 describes the principal benefits and costs of the PHC CWS as applied at Tier 1. Section 4 provides a summary of the analytical method supporting the PHC CWS.

Section 1: Development of Tier 1 Generic Soil Quality Levels

Approach for PHCs

Tier 1 levels for each land use are derived through a systematic evaluation of all pathways of exposure that apply to the receptors of concern identified under that land use. A detailed account of this process as applied to development of soil quality guidelines is presented in CCME (1996a). Below is a condensed description of the process as applied to development of the Tier 1 PHC CWS. Emphasis is used in areas where changes were made to processes and/or decisions presented in CCME (1996a). A summary of the receptor/pathway combinations considered under each land use in the PHC CWS is presented in Table 1. Each combination is discussed further in the appropriate section of this Technical Supplement. Gaps in the environmental fate and effects literature meant that not all receptor/pathway combinations could be explicitly addressed.

Table 1: Land-uses, key receptors and exposure pathways.

Exposure Pathway	Agriculture	Residential/ Parkland	Commercial	Industrial
Soil Contact	Nutrient cycling Soil invertebrates Crops (plants) Human (child)	Nutrient cycling Invertebrates Plants Human (child)	Nutrient cycling Invertebrates Plants Human (child)	Nutrient cycling Invertebrates Plants Human (adult)
Soil Ingestion	Herbivores Human (child)	(wildlife)* Human (child)	(wildlife)* Human (child)	(wildlife)* Human (adult)
Groundwater/ Surface Water	Aquatic Life/ Livestock Watering Human (child)	Aquatic Life Human (child)	Aquatic Life Human (child)	Aquatic Life Human (adult)
Vapour Inhalation (humans only)	Child, indoor**	Child, indoor	Child, indoor	Adult, indoor
Produce, meat and milk produced on site (humans only)	Child	Child (produce only)		
Off-site migration of Soil/Dust				Human/Eco

* wildlife dermal contact and ingestion data may be particularly important for PHCs (e.g., oiling of feathers, etc., although this should be addressed with an initial assessment of the presence of non-aqueous phase liquids - NAPL), but there are unlikely to be sufficient data to develop guidelines that address this exposure pathway

** a 30m horizontal offset is assumed between the farm residence and the PHC contamination, consistent with oil and gas development practices. Contamination nearer a farm residence triggers a residential assessment.

Tier 1 levels in the CWS are presented as an integration of the above pathway/receptor combinations – only the governing pathway is presented. In application, users will gather information on relevant pathways and will frequently require information on secondary pathways. Tier 1 information on secondary pathways is presented in the technical guidance accompanying this standard (CCME 2000, 2001a).

In addition to the toxic risks addressed by the receptor/pathway analyses, certain other management considerations apply. Chief among these are:

- ignition hazard
- odour and appearance
- effects on buried infrastructure
- formation of non-aqueous phase liquids (NAPL)

Whereas the primary focus in PHC CWS standard development is prevention of toxic effects to the receptors in Table 1, in certain situations these pathways may be of little immediate concern and PHC management is driven by consideration of aesthetic and policy factors.

Human Health Levels

Protocol Summary

Petroleum hydrocarbons are grouped by physico-chemical properties into 4 carbon chain length fractions. Group toxicological and physico-chemical properties are used to estimate concentrations of PHCs in soil that would not lead to an exposure exceeding a hazard index of 1 along the 4 pathways – inhalation of vapours, dermal contact, incidental ingestion of soil and ingestion of cross-contaminated groundwater. The same pathways and same exposure equations are used for all land uses, however, exposure duration and frequency vary between land uses and only an adult's exposure is considered for the industrial land use. Average values for most parameters and characteristics are used which, when combined, gives a protective and practical result. There are insufficient data to evaluate PHC exposure through the food chain. The few data available indicate that plant uptake of PHCs and subsequent exposure at higher trophic levels is not a concern.

Toxicological Basis

Exposure to PHCs leads to a variety of results depending upon the particular compounds or mixtures involved, intensity, frequency and duration of exposure, and exposure pathway. While certain PHCs are confirmed human carcinogens (e.g., benzene, benzo(a)pyrene), these are exceptional and, where present at a site, they are dealt with as separate issues using compound-specific guidelines or risk assessments. Most PHCs are understood to act as threshold toxins, eliciting general narcosis symptoms.

The toxicology of PHCs was extensively reviewed by the US Total Petroleum Hydrocarbons Working Group (US TPHCWG), which was formed by the US Department of Defense in the mid-1990s. The TPHCWG defined 14 aromatic and aliphatic sub-fractions of PHCs based on similar physico-chemical properties. Different oral reference doses (RfDs) and inhalation reference concentrations (RfCs) are presented for each aliphatic or aromatic subfraction in the TPHCWG system. The PHC CWS uses these TPHCWG sub-fractions and further groups them into the four practical fractions -- F1: nC6-C10, F2: >nC10-C16, F3: >nC16-C34, F4: >nC34. Within a TPHCWG sub-fraction the balance between aromatic and aliphatic constituents is assumed to be 20/80 based on an analysis of some representative hydrocarbon products. These analyses were also used to determine appropriate proportions of different carbon ranges within a PHC CWS fraction. Toxicological information for each TPHCWG subfraction is combined with the information on the expected mass of each subfraction to produce a toxicological benchmark for each PHC CWS fraction.

Documented background exposure that Canadians experience is considered in the development of the Tier 1 levels. A review of literature indicated no general information on the occurrence of PHC fractions F2, F3 or F4 in air, water or food. This is likely due to their low volatility and water solubility. Data were available on F1 components indicating that only inhalation exposures are routinely significant. Inclusion of these data reduced the effective RfC for volatile aliphatics by 0.5 to 2% and for volatile aromatics by 20%.

Derivation of Tier 1 Levels

Exposure equations for each pathway are re-arranged to solve for the soil concentration delivering an exposure equivalent to the appropriate allocation of the RfC or RfD (fractions 2, 3 and 4) or "residual" RfC/RfD adjusted for background exposure unrelated to PHC contamination of soil. After all pathways have been assessed the governing value is brought forward for the Tier 1 look-up table.

Soil ingestion and dermal contact values are calculated using the general equation on page 97 of CCME (1996a) and further refined for dermal contact in CCME (2000). These are defined independent of soil texture.

Inhalation exposure Tier 1 levels are based on an implementation of the Johnson and Ettinger (1991) description for intrusion of vapours into an enclosed space (building). Default buildings are, for residential land use, a single family dwelling with basement or slab-on-grade construction and, for commercial and industrial land uses, a slab-on-grade construction. Coarse and fine textured soils, defined as having a median grain size of $>75 \mu\text{m}$ or $<75 \mu\text{m}$ respectively, are presented as separate cases because vapour transport for the former is dominated by advection as opposed to diffusion for fine soils. Equation 21 of the Johnson and Ettinger paper is used to calculate an attenuation factor for the coarse-textured case and this is coupled to the relevant RfC to back-calculate an acceptable soil concentration. For fine soil, equation 23 of the Johnson and Ettinger paper is used. This is a simplification of equation 21 that assumes vapour intrusion is limited by diffusion within the soil. Critical soil variables include depth to contamination, set to 30 cm to reflect common backfilling practice, and soil organic carbon content, set to 0.5% to reflect average sub-soil conditions in Canada. Both of these are adjustable in Tier 2. Where contamination exists within 30 cm of a building, the proponent must carry out a Tier 2 or 3 assessment. Details regarding transport, building characteristics and exposure are provided in CCME (2000).

Potential human exposure to PHCs from ingestion of water is addressed by defining the downgradient boundary of a PHC contaminated site as the point of compliance for groundwater potability. The simple recharge/leaching and dilution model based on water balance used by both CCME (1996) and Atlantic Partners In RBCA Implementation (1999) is used for the Tier 1 levels. Again, soil textures are separated because of differing transport characteristics. Details regarding site characteristics, hydrological regimes and compliance benchmarks are provided in CCME (2000). Dynamic advective-dispersive models may be used at higher Tiers to address offsite management of PHC-contaminated groundwater.

Ecological Levels

Protocol Summary

Tier 1 levels are derived to protect key ecological receptors that sustain normal activities on the four previously defined land use categories: agricultural, residential/parkland, commercial and industrial. The derivation of Tier I levels for ecological receptors focuses on the effects of PHCs on the biotic component of a terrestrial ecosystem. Specifically, it evaluates the potential for adverse effects to occur from exposures to soil-based PHCs at point-of-contact or by indirect means (e.g., soil to groundwater pathways, food chain transfer).

Toxicological Basis

The derivation of Tier 1 levels for ecological receptors for soil contact is based on toxicological data for vascular plants and soil invertebrates. Toxicological data from recent research generated by the PHC CWS and from an in-depth review of the literature to date was collected and screened. Data includes ecotoxicological effects through exposure to F1 (approximated by response to motor gasoline or Mogas), F2 (crude oil derived), F3 (crude oil derived), whole products (e.g., crude oil, diesel, fuel oil, jet fuel), and surrogates (e.g., naphthalene).

Endpoints examined included chronic and sub-chronic responses (e.g., root elongation, shoot growth, reproduction) as well as acute and lethal responses (e.g., invertebrate survival, seed germination) in both field and artificial soils. Plant and invertebrate responses were analyzed separately.

Derivation of Tier 1 Levels

The approach adopted for the derivation of Tier 1 levels of PHC in soils for the protection of ecological receptors is based on a 'weight of evidence' method as outlined in the CCME 1996 Protocol with some modifications. This approach facilitates the incorporation of disparate types of high quality information on the risks of PHCs to ecological receptors by calculating a percentile of the effects data set to estimate a concentration in soil expected to cause no adverse biological effects.

The following discussion outlines the derivation procedures adopted for soil contact (invertebrates, plants) and ground/surface water protection (aquatic life, livestock watering). Limited information was available to evaluate the soil ingestion (livestock, wildlife) pathway and is therefore not discussed in any detail in the technical supplement.

Soil contact exposure values have been derived for specific PHC fractions based on ecotoxicological data for vascular plants and invertebrates and on a modified Effects Concentration Low (ECL) method as outlined in the CCME 1996 Protocol. Motor gasoline (Mogas) gas toxicity data were used as a reasonable approximation of the ecotoxicity of the PHC CWS F1 fraction since Mogas is a very common, light-end distillate which is predominantly F1 hydrocarbons when fresh. Fractions 2 and 3 data were generated for the PHC CWS and are based on the toxicity of the fraction 2 and 3 of Federated crude oil. Results from specific studies to determine the ecotoxicity through soil contact of fraction 4 to soil organisms are not yet available. All values presented for F4 are based on toxicological response to a whole Federated crude oil and professional

judgment. Experiences with management of heavy PHC over a broad range of soil types was used to support the professional judgment recommendations (CCME 2000).

Different percentiles of the distribution of EC_{50} ranked soil contact data were used to estimate an acceptable soil concentration of PHCs in relation to land use. For agricultural and residential uses where expectations for ecological function are high, the 25th percentile of the ranked EC_{50} data for both plants and invertebrates was chosen. For commercial and industrial land uses where there is less dependence on ecological functions for sustaining land use, the 50th percentile of the ranked EC_{50} data for plants only was chosen.

Recent scientific literature indicates that toxicity of PHCs in soils is strongly affected by texture. This toxicity reduction in fine textured soils (e.g., clays, clay loams) is related to many factors that act to reduce bioavailability. Because primary ecotoxicological data were derived using fresh product in coarse textured soils, they represent essentially worst case conditions. In Tables 2 through 5 below, professional judgment has been applied to these data to incorporate knowledge from field studies and laboratory experiments demonstrating reduced PHC toxicity in fine-textured soils.

Concentrations of PHCs in soil that would not be expected to pose a threat to ecological receptors via ground water exposure pathways were estimated by modeling transport from soil through groundwater to a default discharge point 10 m downgradient from the PHC contaminated site. The lateral distance may be varied in Tier 2 up to a maximum of 500 m. The receptors considered were aquatic life in nearby streams, rivers and lakes where PHC contaminated groundwater may be an issue, and livestock (cattle) ingesting drinking water from a surface source located near groundwater receiving inputs from PHC contaminated soils.

Integration of Ecological and Human Health Levels

Tabular Tier 1 levels in the PHC CWS present the lower of the values generated for human health and ecological protection such that both are protected when Tier 1 levels are applied. Detailed results for all potential receptor/pathway combinations are presented for fine and coarse textured soils in Tables 2 and 3 below. Tier 2 and 3 approaches are expected to focus on the governing condition for a particular fraction.

Information is also presented in Tables 4 and 5 on generic levels applicable to subsoils, defined as earthy materials below 1.5 m depth. Generic subsoil levels for PHCs are judged to be protective of human health and environment so long as subsoil remains at depth. In addition, allowance has been made for certain exposures that could occur as a consequence of excavation. It is recognized, however, that jurisdictions have discretion in the application of generic subsoil PHC levels with regard to any relevant conditions for on-going management.

Table 2

Tier 1 levels (mg/kg soil) for PHCs for fine-grained surface soils.

Land Use	Exposure Pathways	F1	F2	F3	F4
		(C6-C10)	(>C10-C16)	(>C16-C34)	(>C34)
Agricultural	Soil Ingestion	15,000	8000	18,000	25,000
	Dermal Contact	RES	RES	RES	RES
	Vapour Inhalation (indoor, 30 m offset)	2100	11,400	NA	NA
	Protection of Potable GW ¹	180	250	NA	NA
	Protection of GW for Aquatic Life ²	TBD	TBD	NA	NA
	Protection of GW for Livestock Watering ³	TBD	TBD	NA	NA
	Nutrient Cycling	TBD	TBD	TBD	TBD
	Eco Soil Contact ⁴	260	900	800	5600
	Eco Soil Ingestion	TBD	TBD	TBD	TBD
	Produce, Meat and Milk	NC	NC	NC	NC
Residential	Soil Ingestion	15,000	8000	18,000	25,000
	Dermal Contact	RES	RES	RES	RES
	Vapour Inhalation (indoor)	940	5200	NA	NA
	Protection of Potable GW ¹	180	250	NA	NA
	Protection of GW for Aquatic Life ²	TBD	TBD	NA	NA
	Nutrient Cycling	TBD	TBD	TBD	TBD
	Eco Soil Contact ⁴	260	900	800	5600
	Produce	NC	NC	NC	NC
Commercial	Soil Ingestion	RES	29,000	RES	RES
	Dermal Contact	RES	RES	RES	RES
	Vapour Inhalation (indoor)	4600	25,000	NA	NA
	Protection of Potable GW ¹	180	250	NA	NA
	Protection of GW for Aquatic Life ²	TBD	TBD	NA	NA
	Nutrient Cycling	TBD	TBD	TBD	TBD
	Eco Soil Contact ⁴	660	1500	2500	6600
Industrial	Soil Ingestion	RES	RES	NA	NA
	Dermal Contact	RES	RES	RES	NA
	Vapour Inhalation (indoor)	4600	25,000	NA	NA
	Protection of Potable GW ¹	180	250	NA	NA
	Protection of GW for Aquatic Life ²	TBD	TBD	NA	NA
	Nutrient Cycling	TBD	TBD	TBD	TBD
	Eco Soil Contact ⁴	660	1500	2500	6600
	Offsite Migration	NA	NA	12,000	RES

NA = Not applicable. Calculated value exceeds 1,000,000 mg/kg or pathway excluded.

RES = Residual PHC formation. Calculated value exceeds 30,000 mg/kg and solubility limit for PHC fraction.

NC = Not calculated. Insufficient data to allow derivation.

TBD = To be determined

1 = Assumes site is underlain by groundwater of potable quality in sufficient yield (K of 10^{-4} cm/sec or greater).

2 = Assumes surface water body at 10 m from site.

3 = Generally applicable for this land use as related to use of dugouts and wells for supply of livestock water.

4 = Tier 1 values based primarily on laboratory bioassay response to fractions derived from fresh Federated Crude Oil and adjusted for textural factors.

Table 3
Tier 1 levels (mg/kg soil) for PHCs for coarse-grained surface soils.

Land Use	Exposure Pathways	F1	F2	F3	F4
		(C6-C10)	(>C10-C16)	(>C16-C34)	(>C34)
Agricultural	Soil Ingestion	15,000	8000	18,000	25,000
	Dermal Contact	RES	RES	RES	RES
	Vapour Inhalation (indoor, 30 m offset)	200	1100	NA	NA
	Protection of Potable GW	860	1200	NA	NA
	Protection of GW for Aquatic Life ¹	230	150	NA	NA
	Protection of GW for Livestock Watering ²	9000	4000	NA	NA
	Nutrient Cycling	TBD	TBD	TBD	TBD
	Eco Soil Contact ³	130	450	400	2800
	Eco Soil Ingestion	TBD	TBD	TBD	TBD
	Produce, Meat and Milk	NC	NC	NC	NC
Residential	Soil Ingestion	15,000	8000	18,000	25,000
	Dermal Contact	RES	RES	RES	RES
	Vapour Inhalation (indoor, basement)	50	240	NA	NA
	Vapour Inhalation (indoor, slab-on-grade)	30	150	NA	NA
	Protection of Potable GW	860	1200	NA	NA
	Protection of GW for Aquatic Life ¹	230	150	NA	NA
	Nutrient Cycling	TBD	TBD	TBD	TBD
	Eco Soil Contact ³	130	450	400	2800
	Produce	NC	NC	NC	NC
Commercial	Soil Ingestion	RES	29,000	RES	RES
	Dermal Contact	RES	RES	RES	RES
	Vapour Inhalation (indoor)	310	1700	NA	NA
	Protection of Potable GW	860	1200	NA	NA
	Protection of GW for Aquatic Life ¹	230	150	NA	NA
	Nutrient Cycling	TBD	TBD	TBD	TBD
	Eco Soil Contact ³	330	760	1700	3300
Industrial	Soil Ingestion	RES	RES	NA	NA
	Dermal Contact	RES	RES	RES	NA
	Vapour Inhalation (indoor)	310	1700	NA	NA
	Protection of Potable GW	860	1200	NA	NA
	Protection of GW for Aquatic Life ¹	230	150	NA	NA
	Nutrient Cycling	TBD	TBD	TBD	TBD
	Eco Soil Contact ³	330	760	1700	3300
	Offsite Migration	NA	NA	RES	RES

NA = Not applicable

RES = Residual PHC formation. Calculated value exceeds 30,000 mg/kg and solubility limit for PHC fraction.

NC = Not calculated. Insufficient data to allow derivation.

TBD = To be determined

1 = Assumes surface water body at 10 m from site.

2 = Includes use of dugouts and wells for supply of livestock water.

3 = Tier 1 values based mainly on laboratory bioassay response to fractions derived from fresh Federated Crude Oil.

Table 4
Generic levels for PHCs in fine-grained subsoil (> 1.5 m depth).

Land Use	Exposure Pathways	F1	F2	F3	F4
		(C6-C10)	(>C10-C16)	(>C16-C34)	(>C34)
Agricultural	Soil Ingestion	RES	RES	RES	RES
	Dermal Contact	RES	RES	RES	RES
	Vapour Inhalation (indoor, 30 m offset)	2100	11,400	NA	NA
	Protection of Potable GW ¹	180	250	NA	NA
	Protection of GW for Aquatic Life ²	TBD	TBD	NA	NA
	Protection of GW for Livestock Watering ³	TBD	TBD	NA	NA
	Nutrient Cycling	NA	NA	NA	NA
	Eco Soil Contact ⁴	750	2200	3500	10,000
	Eco Soil Ingestion	TBD	TBD	TBD	TBD
	Produce, Meat and Milk	NA	NA	NA	NA
Residential	Soil Ingestion	RES	RES	RES	RES
	Dermal Contact	RES	RES	RES	RES
	Vapour Inhalation (indoor: basement, slab)	(940, 990)	(5200, 5500)	NA	NA
	Protection of Potable GW ¹	180	250	NA	NA
	Protection of GW for Aquatic Life ²	TBD	TBD	NA	NA
	Nutrient Cycling	NA	NA	NA	NA
	Eco Soil Contact ⁴	750	2200	3500	10,000
	Produce	NA	NA	NA	NA
Commercial	Soil Ingestion	RES	RES	RES	RES
	Dermal Contact	NA	RES	NA	NA
	Vapour Inhalation (indoor)	4800	26,000	NA	NA
	Protection of Potable GW ¹	180	250	NA	NA
	Protection of GW for Aquatic Life ²	TBD	TBD	NA	NA
	Nutrient Cycling	NA	NA	NA	NA
	Eco Soil Contact ⁴	1000	3000	5000	10,000
Industrial	Soil Ingestion	NA	NA	NA	NA
	Dermal Contact	NA	NA	NA	NA
	Vapour Inhalation (Indoor)	4800	26,000	NA	NA
	Protection of Potable GW ¹	180	250	NA	NA
	Protection of GW for Aquatic Life ²	TBD	TBD	NA	NA
	Nutrient Cycling	NA	NA	NA	NA
	Eco Soil Contact ⁴	1000	3000	5000	10,000
	Offsite Migration	NA	NA	NA	NA

NA = Not applicable

RES = Residual PHC formation. Calculated value exceeds 30,000 mg/kg and solubility limit for PHC fraction.

NC = Not calculated. Insufficient data to allow derivation.

TBD = To be determined

1 = Assumes site is underlain by groundwater of potable quality in sufficient yield (K of 10⁻⁴ cm/sec or greater).

2 = Assumes surface water body at 10 m from site.

3 = Generally applicable for this land use as related to use of dugouts and wells for supply of livestock water.

4 = Tier 1 values based primarily on laboratory bioassay response to fractions derived from fresh Federated Crude Oil and adjusted for texture, depth factors and other physical hazard considerations.

Table 5

Generic levels for PHC in coarse-grained subsoil (> 1.5 m depth).

Land Use	Exposure Pathways	F1	F2	F3	F4
		(C6-C10)	(>C10-C16)	(>C16-C34)	(>C34)
Agricultural	Soil Ingestion	RES	RES	RES	RES
	Dermal Contact	RES	RES	RES	RES
	Vapour Inhalation (indoor, 30 m offset)	200	1100	NA	NA
	Protection of Potable GW	860	1200	NA	NA
	Protection of GW for Aquatic Life ¹	230	150	NA	NA
	Protection of GW for Livestock Watering ²	9000	4000	NA	NA
	Nutrient Cycling	NA	NA	NA	NA
	Eco Soil Contact ³	350	1500	2500	10,000
	Produce, Meat and Milk	NA	NA	NA	NA
Residential	Soil Ingestion	RES	RES	RES	RES
	Dermal Contact	RES	RES	RES	RES
	Vapour Inhalation (indoor, basement)	50	240	NA	NA
	Vapour Inhalation (indoor, slab-on-grade)	40	190	NA	NA
	Protection of Potable GW	860	1200	NA	NA
	Protection of GW for Aquatic Life ¹	230	150	NA	NA
	Nutrient Cycling	NA	NA	NA	NA
	Eco Soil Contact ³	350	1500	2500	10,000
	Produce	NA	NA	NA	NA
Commercial	Soil Ingestion	RES	RES	RES	RES
	Dermal Contact	NA	RES	NA	NA
	Vapour Inhalation (indoor)	340	1800	NA	NA
	Protection of Potable GW	860	1200	NA	NA
	Protection of GW for Aquatic Life ¹	230	150	NA	NA
	Nutrient Cycling	NA	NA	NA	NA
	Eco Soil Contact ³	700	2000	3500	10,000
Industrial	Soil Ingestion	NA	NA	NA	NA
	Dermal Contact	NA	NA	NA	NA
	Vapour Inhalation (indoor)	340	1800	NA	NA
	Protection of Potable GW	860	1200	NA	NA
	Protection of GW for Aquatic Life ¹	230	150	NA	NA
	Nutrient Cycling	NA	NA	NA	NA
	Eco Soil Contact ³	700	2000	3500	10,000
	Offsite Migration	NA	NA	NA	NA

NA = Not applicable

RES = Residual PHC formation. Calculated value exceeds 30,000 mg/kg and solubility limit for PHC fraction.

NC = Not calculated. Insufficient data to allow derivation.

TBD = To be determined

1 = Assumes surface water body at 10 m from site.

2 = Includes use of dugouts and wells for supply of livestock water.

3 = Tier 1 values based primarily on laboratory bioassay response to fractions derived from fresh Federated Crude Oil and adjusted for depth factors and other physical hazard considerations.

Section 2: Tiered Framework for Assessment and Management of PHCs at Contaminated Sites.

The framework is based on a synthesis of the ASTM (1995) and CCME (1996a) frameworks for the assessment and management of contaminated sites, and incorporates at successive tiers: (1) the application of generic (national) Tier 1 levels that are protective of human health and the environment, (2) site-specific adjustments to the Tier 1 levels to calculate Tier 2 levels that accommodate unique site characteristics, and (3) Tier 3 levels that are developed from a site-specific ecological or human health risk assessment, when assumptions inherent in the Tier 1 values are not appropriate for a site. The level of protection afforded, and the associated underlying guiding principles, are preserved throughout this tiered process. The tiered approach essentially represents increasing levels of precision in a site assessment through consideration of more specific site characteristics. Equally important to application of the PHC CWS is the recommendation of an approach for the analysis of PHC contamination in soil that is consistent with, and supports application of the ambient soil quality levels.

Though the intent of the CWS is to promote a consistent, high level of protection for human health and the environment as a result of site remediation, in both Tiers 2 and 3, decisions may be taken in calculating a site-specific level that are so specific to a site (e.g. distance to a building), that even minor changes to the specified land use (i.e., a re-located, expanded or additional home on a residentially zoned site) may alter the protection afforded by the recommended ambient soil quality level. Only for stable characteristics of a site (such as depth to groundwater) that will not change with changes to land use, or when the Tier 1 levels are used, should the recommended ambient soil quality level be considered as protective for that site *unconditionally*. Otherwise, *conditions* may be attached to site management (e.g., monitoring, limits to site use, use of groundwater). In situations where engineered or institutional controls are used to manage risks to acceptable levels, closure may also be conditional (i.e., monitoring may be required).

Site Characterization

The goal of site characterization is to adequately describe site conditions in order to address assessment and management options.

The minimum data requirements for a PHC CWS assessment include:

- site description (location, size, etc.)
- land use - historical, existing, intended, and potential land uses at the site and surrounding the site, including presence/absence of critical wildlife habitat
- proximity of the site to surface water and drinking water supplies (presence and nature of any nearby aquatic or marine habitat)
- depth to groundwater (measured or inferred from records)
- human receptors
- ecological receptors
- primary exposure pathways

- stratigraphy and properties of surficial materials (especially soil texture)
- depth to contamination and distances to points of exposure/compliance
- built environment – presence and types of buildings, utility corridors and conduits
- contamination characterization and delineation (including presence or suspected presence of NAPL) as needed for comparison with Tier 1 PHC ambient soil quality levels and soil quality guidelines for other contaminants of concern. Guidance on analytical methods appropriate for the application of the PHC standard is provided in CCME (2001b).

Tier 1 Assessment and Management

Information collected as described above is evaluated to decide whether the site broadly fits any of the four land use categories. If it does not adequately match any of the land uses nor any hybrid thereof, it should be addressed at Tier 3.

Assuming the site is suitable for generic assessment, concentrations of the relevant PHC fractions are determined and compared to the appropriate look-up Tier 1 levels to identify any exceedances. It is critical that the core site characterization data have been collected or the site investigator may enter the lookup tables in a way that leads to management error. For example, Tier 1 levels are available for coarse and fine textured materials. In the absence of soil texture information, it is possible to under-manage contamination by applying Tier 1 values for fine textured sites to a coarse textured site, or over-manage contamination by applying Tier 1 values for coarse textured sites to a fine textured site. In this instance, it is to the proponent's advantage to have textural information because, in its absence, the regulator may insist on the use of the more sensitive default (i.e., Tier 1 values for coarse textured sites).

If no exceedances are found in Tier 1 assessment, investigation ceases and the site can be declared compliant with the PHC CWS. Conversely, if exceedances are found two options exist. First, the site may be remediated to eliminate exceedances. Alternatively, additional site information may be collected to refine the estimate of exposure and risk in a Tier 2 assessment. This may lead to a conclusion that less aggressive management – including, possibly, “no further action” -- is required on the site. Which option is selected will depend on a number of factors including the concentrations and extent of PHC contamination, limiting pathways applicable, availability and cost of technology, and needs for liability reduction.

In general, it is the proponent's responsibility to identify and respond to any site or receptor factors that could unduly accentuate exposure or risk beyond that envisioned in the Tier 1 exposure scenario.

Tier 2 Assessment and Management

Reasonably conservative assumptions are made in Tier 1 regarding site, receptor and contaminant factors to ensure that remediation to these levels will meet environmental management objectives. At individual sites, it is often advantageous to replace default assumptions with actual data concerning certain influential parameters. Tier 2 assessment describes such procedures. In addition, there are opportunities to reduce reliance on

models by replacing model predictions by point-of-exposure or near-point-of-exposure measurements.

Technical options at Tier 2 are not unlimited. Approved procedures meet several criteria:

1. Based on factors influencing exposure that can be measured and verified.
 - Assessments must not be encumbered by technical information regarding factors that have little influence on management outcome
 - Alterations to parameters and assumptions must be made using data that can be relatively easily measured and confirmed as necessary
2. Supports clear land and water use decision making
 - It must be clear what any adjustments mean in terms of the future management of the site
 - The objective is retention or recovery of the maximum range of land and water use options – where options are constrained, this must be made clear to stakeholders
3. Maintains clarity and simplicity in the assessment
 - Stakeholders, including regulators, require that Tier 2 assessments can be reviewed and approved without heavy resource investments. For non-regulatory stakeholders this means faster turnaround on reviews and more efficient land transactions

Taken together, these criteria mean that Tier 2 procedures applicable to *human health protection* will focus on relatively stable aspects of the site and contaminants and how these influence exposure along “secondary pathways” where transport of PHC is involved (primarily inhalation exposures and ingestion of contaminated groundwater). *Characteristics of receptors such as body weight, breathing rate, time spent on site etc. are not candidates for Tier 2 modification because they can be neither predicted nor controlled in a generic way.*

Application of the above criteria to ecological protection indicate that secondary exposure pathways (e.g., transport of PHC to an adjacent surface water body) can be addressed as well as factors that influence the bioavailability of PHC to soil dwelling organisms. *As is the case in human health protection, modifications to exposure scenarios that require changes to the behaviour, distribution or abundance of ecological receptors are not supported in Tier 2. Such proposals generally result in land use limitations and on-going risk management responsibilities. Where necessary, these are best accommodated at Tier 3.*

The following section describes the major data sources relevant to Tier 2 and outlines their application in practical site remediation work. Note that no continuous adjustment procedures are available for pathway/receptor combinations where professional judgement has been used to incorporate qualitative or semi-quantitative factors or information. For example, no calibration adjustments are available for direct contact by ecological receptors. The alternative here is the replication of the bioassay suite used in developing the Tier 1 standards with site soils and relevant representatives of the organismal groups.

DATA-BASED TECHNICAL PROCEDURES

The following procedures may be applied without creation of conditions on land and water use. Details of these procedures are provided in CCME (2001a).

- a) Off-site movement of dust (Industrial Land Use only)
Tier 1 levels for surface soils at industrial sites are supported by an erosion/deposition check to protect any adjacent, sensitive lands. If no such surrounding land exists, the check may be removed.
- b) Fraction of organic carbon in soils
The fraction of organic C in soil is determined by chemical analysis and this result is inserted in the partitioning model used by the vapour and solute transport models.
- c) Depth to contamination from building foundation
This distance is important in determining soil concentrations of F1 and F2 that will be protective against intrusion of vapours into enclosed spaces. The information is gathered through depth sampling and analysis in routine site assessments.
- d) Hydraulic conductivity and gradient
These parameters influence lateral movement of PHC in groundwater. The default parameters in the mixing/dilution model can be replaced by measures or estimates from the site.
- e) Hydrological recharge
This parameter affects degree of dilution of leachate in groundwater and has been calculated to be protective in the general Canadian environment. Low precipitation, high evapotranspiration regions will have more favourable dilutions. The recharge rate may be calculated based on local data on precipitation, evapotranspiration and runoff.
- f) Horizontal distance from contamination source to downgradient property line
This distance is specified as a default in the groundwater model and may be replaced by site data.
- g) Exposure point observations on soil air and groundwater
In Tier 1, potential indoor exposure is based on modeled attenuation of vapours from a proximal soil source area. If information is available on actual vapour concentrations in the envelope surrounding the building, a simpler dilution relationship can be used to calculate potential indoor exposure. Such measurements must be supported by evidence that the vapour concentrations measured will not increase in future. Similarly, screening calculations using a simple dilution model are performed in Tier 1 to estimate groundwater-protective soil concentrations. Observations on groundwater at the site are a better form of information provided that there is evidence that concentrations measured will not increase with time.
- h) Actual proportion of TPHCWG sub-fractions by mass as per site specific analytical results (%)
The 80/20 assumption for aliphatics/aromatics can be replaced by specific information. Also, the balance among C chain-length sub-fractions can be altered.

- i) Depth to groundwater and source dimensions – aquatic life and livestock watering pathways

The model describing PHC movement from soil to groundwater to a point of exposure for aquatic life or livestock watering includes the depth separation between a contaminated soil source and groundwater. The default assumption is that contaminated soil extends to an unconfined aquifer. Distance separation and dimensions of the source can be modified by site-specific measurements.

Other procedures may be acceptable at Tier 2 depending on jurisdiction. Additional candidate procedures may be constrained in application by any combination of:

- Too technically complex to be considered at Tier 2 (appropriate for Tier 3)
- Adjustment alters risk management objectives and requires off-site risk management
- Adjustment mechanism not yet fully proven or demonstrated

Some procedures that may be supported at Tier 2 but are potentially affected by the above practical constraints include:

- a) Volatiles in soil gas via application of Raoult's Law
Information on PHC concentrations in all fractions present may be used to estimate more realistic partitioning of volatile PHC among soil solids, soil moisture, soil air and PHC residuals. The analytical characterization must be conducted in the zone of maximum contamination. Recalculated vapour phase concentrations are inserted into the vapour transport model.
- b) Contaminated soil volume in relation to vapour intrusion pathway
Complete delineation of all source areas allows calculation of the total contaminant mass. This mass is depleted by redistribution of PHC along transport pathways. A screening level estimate of vapour phase exposure resulting from complete redistribution to an enclosed space has been described by Atlantic PIRI.
- c) Point of compliance for groundwater protection outside property boundary
Dynamic advective-dispersive groundwater transport models and monitoring are used to support management of a PHC plume originating on one site and extending to another. The downgradient property owner must agree to forego relevant uses of the groundwater while this condition persists.

In general, site-specific information is useful in creating "headroom" for a PHC proponent when it bears on the governing pathway. Site specific data on non-limiting pathways can promote understanding but does not alter the management outcome.

Tier 2 management may or may not carry on-going risk management considerations that place responsibilities on parties for monitoring, care and control and may require engineered and/or institutional controls. Whether such measures are necessary depends on a number of factors as discussed below.

Tier 3: Site-specific Risk Assessment

In some cases, an Ecological Risk Assessment (ERA) and/or human health risk assessment (HHRA) may be warranted. Risk assessment is an important process for

evaluating and predicting the existing and potential impact of toxic substances and other perturbations on the ecosystem and its components (i.e., species, populations, communities), including human health.

When compared to applying environmental quality guidelines, risk assessment is a more complex and involved method for establishing site-specific remediation objectives. Different descriptions of contaminant fate, behaviour and exposure may be involved. All models must be calibrated and validated for the particular site. Site-specific risk assessment may be appropriate when, for example, guidelines-based objectives (i.e., Tier 1 and 2 levels that have been modified to account for site-specific factors) are not relevant for the specified uses of the site, where guidelines-based objectives do not seem appropriate given the site-specific conditions, where significant or sensitive receptors of concern have been identified, or where there is significant public concern.

Several risk assessment frameworks have been developed in Canada (CCME 1996b; BC MELP 1993; Atlantic PIRI 1999) that are relevant for the assessment and management of petroleum contaminated sites. These frameworks share several common elements, including problem formulation/receptor characterization, exposure and hazard/toxicity assessment, and risk characterization.

The Canadian framework for ecological risk assessment (CCME 1996b) provides a consistent basis for approaching this potentially complex process. The framework provides guidance on deciding when an ERA should be conducted through a series of questions and triggers. Further, it describes key steps and considerations in planning and implementing an ERA, from defining initial goals and objectives and choosing appropriate measurement and assessment endpoints, to reporting the results of an ERA.

The vast majority of site-specific risk assessments are conducted as a consequence of technical or socio-economic barriers to complete remediation. This means that the risk management proposed usually involves exposure management through engineered controls, institutional controls or both. Such controls are necessary when contaminated site stakeholders (owners, operators, adjacent landowners) must alter their actions or refuse to undertake certain future actions in order to prevent exposure (e.g., installation and maintenance of vapour barriers, non-use of groundwater).

Confirmation testing

Once a Tier 1, Tier 2 or Tier 3 approach has been selected and soil PHC contamination levels have been agreed to, analytical information must be supplied to show that these concentrations have been achieved.

Section 3: Socio-economic Analysis

The *Socio-economic Analysis of Canada-wide Standards for Petroleum Hydrocarbons in Soil* was undertaken with the understanding that Tier 1 standards will be implemented and that they will be protective of human and environmental health. The socio-economic analysis is a cost analysis for implementing the standards that assumes all PHC contaminated sites, irrespective of scale and severity of contamination are remediated to Tier 1 levels. In practice, larger and more severely contaminated sites are addressed at Tiers 2 and 3.

The socio-economic analysis was undertaken concurrently with other scientific work done for the PHC Development Committee (DC) and made direct use of the DC's work on human health and ecotoxicity in its consideration of socio-economic impacts. The DC developed recommendations for standards based on that concurrent work and understandings achieved in the socio-economic analysis. Because of this timing the DC provided a set of "seed values" for four categories of land use (agricultural, residential, commercial and industrial), two soil textures (coarse and fine) and conditions that did and did not include protection of groundwater. These were "ball park" estimates of standards that would likely be protective of human and environmental health based on preliminary analyses. Costs of remediating volumes of soil to meet the seed values were estimated assuming common, effective technologies. The socio-economic analysis addressed the matter of how costs and benefits would vary with different levels of protection by considering values that were five times the seed value (i.e. less stringent) and one-fifth the seed value (more stringent). The Development Committee was very clear that the seed values did not have regulatory significance and should not be construed as the most likely set of standards to be recommended to environment Ministers.

The socio-economic analysis considered 11 scenarios of soil contamination to cover most situations pertaining to the upstream, downstream and post-consumer sectors. It examined typical volumes of contamination associated with each scenario. It estimated the costs to remediate those volumes assuming common, effective technologies. The clean up volumes for each scenario were based on the most appropriate combination of land use, soil texture and likely need for groundwater protection for that scenario.

The socio-economic analysis also addressed the potential benefits of implementing a CWS. It did not attempt to economically value health benefits, although it did estimate monetary values for some categories such as reduced agricultural damage and improved land values. Other ecological impacts, such as potential reduction in ability to grow non-agricultural plants or effects on soil fauna that had been scientifically assessed by the DC or Ecological Technical Advisory Group, could not be monetized.

Basic Findings

The analysis confirmed that there is an appreciable difference between costs of remediation to the seed values and to standards more stringent and less stringent than the seed values. The range of costs would be in the order of several billion to a few tens of billions of dollars. Estimated costs to remediate all sites to each of the three levels of protection, for different hypothetical remediation schedules are presented below. The first schedule (clean up all PHC contaminated sites immediately) is unrealistic but sets the context for the other schedules.

	<u>less stringent</u>	<u>seed value</u>	<u>more stringent</u>
All at the present time (\$billion)	7.8	15.6	22.8
10% of sites/yr. for 10 yr. (\$b)	6.0	12.1	17.6
10%/yr for 5 yr., rest deferred (\$b)	4.9	9.7	14.2

Incremental costs of moving from the less stringent case to the seed values and from the seed values to the more stringent case are also shown.

	From less stringent to seed value	From seed value to more stringent
All at present time (\$billion)	7.8	7.2
10% of sites/yr. for 10 yr. (\$b)	6.1	5.5
10%/yr for 5 yr., rest deferred (\$b)	4.8	4.5

The costs were discounted by a public discount rate (5%). The rate at which remediation activity takes place has a large influence on costs.

It was possible to estimate monetary values for some categories of benefits. These included benefits in the areas of: agricultural damage that could be avoided (crop value), increased property value resulting from remediation, blight avoided for some residential sites (effects of PHC contamination on values of adjacent residential sites), and option value of green-field sites (societal preference to clean up a contaminated site rather than developing a previously undeveloped site).

The estimated monetizable benefits are:

	<u>less stringent</u>	<u>seed value</u>	<u>more stringent</u>
All at present time (\$billion)	3.4	5.7	9.5
10% of sites/yr. for 10 yr. (\$b)	2.7	4.5	7.4
10%/yr for 5 yr., rest deferred (\$b)	2.2	3.6	6.0

These monteized benefits do not include health benefits or benefits of ecological protection.

The ratio of monetizable benefits to monetizable costs was approximately 40%, although there was some variation (from 0.37:1 to 0.45:1) depending on the rate of remediation and the stringency of the standard.

It is possible to present monetized costs and benefits according to geographic distribution within Canada.

	<u>% costs</u>	<u>% monetized benefits</u>
West (BC, AB, SK)	70	27
East	23	69
North	5	4

This geographic breakdown does not include human health benefits, which, if included, would be distributed by region in approximately the same proportion as total population.

For most scenarios of contamination that were examined, remediation to any of the three values (seed, less stringent and more stringent) was assumed to be protective of human health. In some instances, however, the margin of safety (based on the work done in the human health component of DC's work) associated with the less stringent values might be considered small. These margins of safety are conservative, and therefore highly likely to be protective of human health, even if small.

These analyses were conducted assuming the Tier 1 values apply to the full depth of contamination. The PHC CWS now includes generic levels for subsoils, which are less stringent than for surface soils. Depending on land use, soil texture, PHC fraction, and depth, the final Tier 1 values recommended by Development Committee vary more or less from the seed values. Generally, Tier 1 levels for surface soils tend to fall between the seed values and the more stringent case, whereas subsoil levels tend to fall between the seed values and the less stringent case.

It is very important to note that the socio-economic analysis addresses only implementation of Tier 1 levels. Tiers 2 and 3 are normally used for many of the more complex PHC release sites because use of site-specific information at those Tiers can contribute to more informed decision making. Often, application of the site-specific information can result in remediation costs that are reduced from those expected if Tier 1 standards were applied. While the reduction in costs of implementing remediation to Tier 2 or Tier 3 is not quantified at this time (principally because the proportion of sites going to the three levels will depend on stakeholder input and regulatory acceptance), it could be appreciable.

Section 4: Analysis of Petroleum Hydrocarbons in Soils, CCME Tier 1 Method

An analytical method was developed in conjunction with the Canada-Wide Standard (CWS) for petroleum hydrocarbons in soil (PHCs) for two reasons. The methods currently in use quantify different fractions of PHCs normally found in soil and secondly, an analytical method must be used in a consistent manner to give consistent results. An interlaboratory study conducted at the beginning of the CWS process confirmed this with results varying by factors of 40.

To develop the method an Analytical Methods Technical Advisory Group (AMTAG) was struck consisting of representatives of provincial and federal governments, the petroleum industry and the private laboratory industry. After considerable effort a consensus was reached on a draft method which was pilot tested and then subjected to an interlaboratory study during the summer of 1999. Based on comments from participants in the study and the PHC CWS Development Committee, the method was finalized (CCME 2001b).

The method is a mixture of performance based elements and prescribed procedures. Effort has been expended to ensure that, if applied properly, the method provides results useful for application of the CWS to PHC contaminated sites. Substitution of alternative methods for use in applying the CWS should only occur if a comprehensive statistical comparison has been conducted. No sampling protocol was developed but reference is made to existing CCME, US EPA and ASTM resources.

The method covers hydrocarbon ranges for nC6 to above nC50 as well as percentage moisture. The analytical fractions were chosen to meet the requirements of the CWS. These are nC6 to nC10 (F1), >nC10 to nC16 (F2), >nC16 to nC34 (F3) and >nC34 to nC50(F4). nC50 is probably the highest molecular weight hydrocarbon that can be routinely chromatographed on normal laboratory equipment. In addition a Gravimetric Heavy Hydrocarbon sub method was developed to account for the fraction occurring above nC50. It is recommended that this result be used if it is greater than the nC34 to nC50 fraction.

It was recognized during the interlaboratory study that laboratories performed better if they had had experience with the method. Thus the continuation of ongoing interlaboratory studies is recommended. Initially these would improve user laboratories' knowledge and handling of this complex method. They would help characterize method performance characteristics such as method detection limit, which is presently being assessed in a single laboratory validation study. After the CWS is incorporated into regulations or guidelines, then these studies would become a means of assessing laboratory performance.

References

- ASTM. 1995. Standard Guide for Risk-based Corrective Action Applied at Petroleum Release Sites. ASTM E1739-95.
- Atlantic PIRI. 1999. Atlantic RBCA (Risk-Based Corrective Action) Reference Documentation For Petroleum Impacted Sites Version 1.0, April 1999
- B.C. Ministry of Environment, Lands and Parks. 1993. Quantitative Human Health Risk Assessment. Phase I – Review of Methods and Framework Recommendation.
- CCME. 1996a. A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines. CCME-EPC-101E.
- CCME. 1996b. A Framework for Ecological Risk Assessment: General Guidance.
- CCME. 2000. Canada-wide Standard for Petroleum Hydrocarbons in Soil: Scientific Rationale.
- CCME. 2001a. Canada-wide Standard for Petroleum Hydrocarbons in Soil: User Guidance.
- CCME. 2001b. Reference Method for the Determination of Petroleum Hydrocarbons in Soil.
- Johnson, P.C. and R.A. Ettinger. 1991. Heuristic model for predicting intrusion rate of contaminant vapors into buildings. Environ. Sci. Technol. 25:1445-1452.

Groundwater Contaminant Transport Calculation: Step Injection

Chemical injected during a finite time period.
Compute concentration as a function of time and
distance or back-calculate injected concentration.
Advection, dispersion, and retardation.

To: [LMNO Engineering home page](#) [Trouble printing?](#)
[Compute gradient from well head measurements](#)
[3-D Slug injection with advection and dispersion](#) [Unit Conversions](#) [Registration](#)



[Register](#) to enable "Calculate" button.

Not registered user	Concentration, C (mg/l):	Will be computed
Click to Calculate	Time, t (day), to compute C:	1000.0
	Distance, x (m), to compute C:	30.0
☒ Check box to include retardation	Injected Concentration, Co (mg/l):	10000.0
Solve for C	Duration of Injection, T (day):	100.0
Sandy Soil (sets K, n, ne, d)	Dispersivity, a (m):	10.0
Trichloroethylene (TCE) (sets Koc)	Diffusion Coeff, D* (m ² /s):	1.0E-9 ✓
Select Units:	Hydraulic Cond, K (cm/s):	0.0010
Concentrations in mg/l or ppm	Hydraulic Grad, -dh/dx (m/m):	0.0070
Times in days	Total Porosity, n (%):	35.0
Distance in m	Effective Porosity, ne (%):	25.0
Dispersivity in m	Soil Bulk Density, d (g/cm ³):	1.6
Diff. and Disp. Coeff. in m ² /s	Soil Organic Carbon, foc (%):	0.1
Hydraulic Conductivity in cm/s	Org. Carbon Coeff, Koc (cm ² /g):	100.0
Hydraulic Gradient in m/m (ft/ft)	Distribution Coeff, Kd (cm ³ /g):	Will be computed
Soil Bulk Density in g/cm ³	Retardation Coeff, Rf:	Will be computed
Koc and Kd in cm ² /g	Pore Water Velocity, Vw (m/s):	Will be computed
Velocities in m/s	Chemical Velocity, Vc (m/s):	Will be computed
http://www.LMNOeng.com	Dispersion Coeff, D (m ² /s):	Will be computed
© 2000 LMNO Engineering,	Peclet Number, Pe=Vc(x/D):	Will be computed
Research, and Software, Ltd.	Plume leading edge, Vc*t (m):	Will be computed
	Plume trailing edge, Vc*(t-T) (m):	Will be computed

Topics on this page: [Introduction](#) [Equations](#) [Applications](#) [Variable Definitions](#)
[Property Data](#) [Error Messages](#) [References](#)

Introduction

[Top of Page](#)

This calculation simulates one-dimensional (x-direction) transport of a chemical in a confined

groundwater aquifer. It is also valid for transport in an unconfined aquifer if the head gradient (dh/dx) is nearly constant. There are two common boundary conditions for chemical transport: One is a step (i.e. continuous) injection of chemical - the chemical is added at $x=0$ from time $t=0$ to $t=T$. The other common boundary condition is a pulse input where a mass of chemical is added instantaneously at $x=0$. This web page uses the first boundary condition though a pulse input can be simulated by using a short injection time T . The calculation solves for concentration at whatever time and distance is desired by the user.

The calculation includes advection, dispersion, and retardation. Advection is chemical movement via groundwater flow due to the groundwater hydraulic (i.e. head) gradient. Dispersion is the longitudinal (forward and backward) spreading of the contaminant. If there were no dispersion, all of the contaminant would travel at the mean chemical velocity. With dispersion, some chemical travels faster and some slower than the mean velocity; the chemical "spreads out." Retardation causes the mean chemical velocity to be slower than the groundwater velocity. If your chemical exhibits no dispersion, set both the dispersivity (α) and diffusion coefficient (D^*) to zero. If the chemical is not retarded, then uncheck the retardation check box or use the chemical drop-down menu to select "User enters K_{oc} " and set $K_{oc}=0.0$.

Equations

[Top of Page](#)

Governing Equation and Boundary Conditions

The governing equation for one-dimensional chemical transport in groundwater with advection, dispersion, and retardation is (Van Genuchten and Alves, 1982):

$$R_f \frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2} - V_w \frac{\partial C}{\partial x}$$

Boundary and Initial Conditions:

$$C(x, t=0)=0 \quad \frac{\partial C}{\partial x}(x=\infty, t)=0$$

$$C(x=0, 0 < t \leq T)=C_0 \quad C(x=0, t > T)=0$$

Solution

The solution to the governing equation and boundary conditions shown above is (Van Genuchten and Alves, 1982):

$$C(x, t) = \frac{C_0}{2} A(x, t) \quad \text{for } 0 < t \leq T$$

$$C(x, t) = \frac{C_0}{2} [A(x, t) - A(x, t-T)] \quad \text{for } t > T$$

where:

$$A(x, t) = \operatorname{erfc}\left(\frac{x - V_c t}{2\sqrt{Dt}}\right) + \exp\left(\frac{V_c x}{D}\right) \operatorname{erfc}\left(\frac{x + V_c t}{2\sqrt{Dt}}\right)$$

$$A(x, t-T) = \operatorname{erfc}\left(\frac{x - V_c (t-T)}{2\sqrt{D(t-T)}}\right) + \exp\left(\frac{V_c x}{D}\right) \operatorname{erfc}\left(\frac{x + V_c (t-T)}{2\sqrt{D(t-T)}}\right)$$

$$V_c = \frac{V_x}{R_f}$$

$$V_x = -\frac{K}{n_e} \frac{dh}{dx}$$

$$R_f = 1 + \frac{d K_d}{n}$$

*

$$K_d = K_{oc} f_{oc} \quad D = a V_c + \frac{L}{n_e}$$

$\text{erfc}()$ is called the "complementary error function." Our calculation uses the most accurate numerical representation of $\text{erfc}()$ given in Abramowitz and Stegun (1972, eqn 7.1.26).

Applications

[Top of Page](#)

The following graphs were developed to demonstrate effects of dispersion for trichloroethylene (TCE) in a sandy aquifer as predicted by the calculation. The following data were used:

$C_o = 10,000 \text{ mg/l}$, $d = 1.6 \text{ g/cm}^3$, $dh/dx = -0.007 \text{ m/m}$, $D^* = 0$, $f_{oc} = 0.1\%$,

$K = 0.001 \text{ cm/s}$, $K_{oc} = 100 \text{ cm}^3/\text{g}$, $n = 35\%$, $n_e = 25\%$. [Click for variable definitions](#)

Therefore, $K_d = 0.1 \text{ cm}^3/\text{g}$, $R_f = 1.46$, $V_w = 2.8 \times 10^{-7} \text{ m/s}$, and $V_c = 1.92 \times 10^{-7} \text{ m/s}$.

Two injection durations were used: $T = 1,000,000 \text{ days}$ in Figure 1 and $T = 100 \text{ days}$ in Figure 2. For Figure 1, T was selected large enough to simulate an infinite duration injection. In both figures, the concentration front occurs at $x = V_c t = 16.6 \text{ m}$ when $a = 0$. In Figure 2, the trailing edge of the concentration front occurs at $x = V_c(t - T) = 14.9 \text{ m}$ when $a = 0$. a is dispersivity.

Figure 1. TCE concentration profile at 1000 days for an injection of duration 1,000,000 days

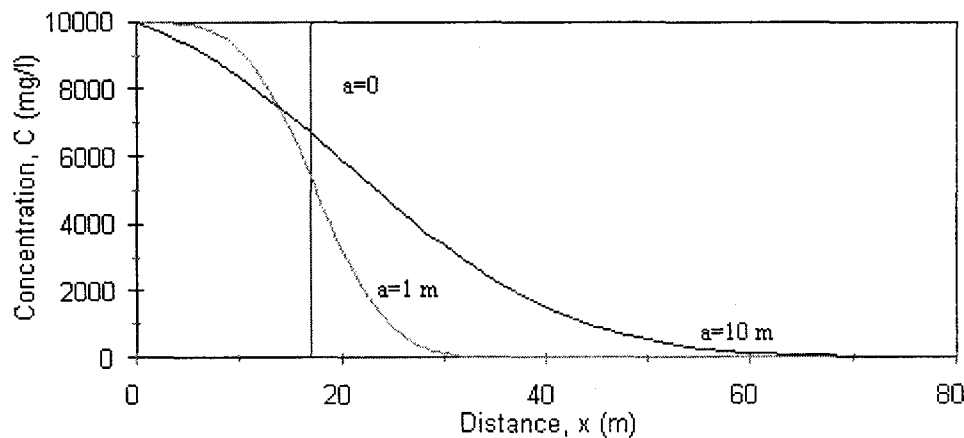
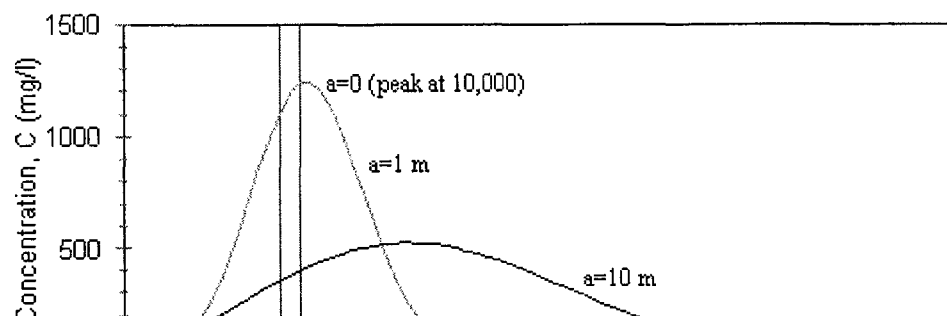
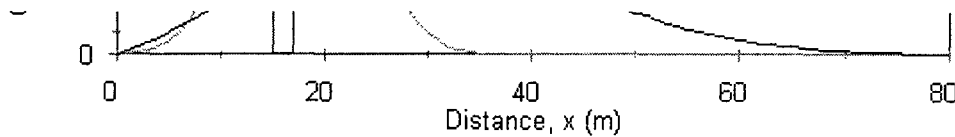


Figure 2. TCE concentration profile at 1000 days for an injection of duration 100 days.





Variable Definitions

[Top of Page](#)

The variables used on this web page are:

a = dispersivity [L]. Varies from 0.1 to 100 m. Field and laboratory tests have indicated that a varies with the scale of the test. Large scale tests have higher a than small lab column tests. An approximate value for a is 0.1 times the scale of your system (Fetter, 1993). If you are simulating contaminant transport in a 1 m long laboratory column, then $a \sim 0.1$ m. However, if you are simulating transport in a large aquifer greater than 1 km in extent, then use $a \sim 100$ m.

C = Chemical concentration [M/L^3].

C_o = Injected concentration at $x=0$ [M/L^3].

d = Dry bulk density of the aquifer [M/L^3].

dh/dx = Hydraulic (or head) gradient [L/L]. Since dh/dx is negative, we ask you to enter $-dh/dx$ so that you can enter a positive number for convenience. You determine dh/dx from two head measurements using the equation, $dh/dx = (h_2 - h_1)/(x_2 - x_1)$.

D = Dispersion coefficient [L^2/T]. The equation $D = a V_c + D^*/n_e$ is adapted from Ingebritsen and Sanford (1998).

D^* = Molecular diffusion coefficient [L^2/T]. Varies somewhat for different chemicals but a typical value to use is $1.0 \times 10^{-9} \text{ m}^2/\text{s}$ (Fetter, 1993).

f_{oc} = Organic carbon fraction in soil [%]. (Mass organic carbon per mass soil) $\times 100\%$.

K = Hydraulic conductivity of aquifer [L/T].

K_d = Distribution coefficient [L^3/M]. Represents chemical partitioning between groundwater and soil.

K_{oc} = Organic carbon partition coefficient [L^3/M]. Represents chemical partitioning between organic carbon and water in soil. Good discussion in Lyman et al. (1982).

n = Total porosity of soil [%]. (Void volume/total volume) $\times 100\%$.

n_e = Effective porosity [%]. Porosity through which flow can occur. A thin film of water bound to soil particles by capillary forces does not move through the aquifer. n_e is always $\leq n$.

Pe = Peclet number. $Pe = (V_c x) / D$. It is a commonly used dimensionless parameter indicating the relative impact of inertial effects to dispersive effects.

R_f = Retardation factor. $R_f = 1$ if there is no retardation which implies that $V_c = V_x$. $R_f = 1$ would occur for a conservative tracer; that is, a tracer that does not sorb to the aquifer soil.

t = Time [T]. Time at which C is to be computed.

T = Duration of injection [T]. C_o is injected from $t=0$ to $t=T$.

V_c = Mean chemical velocity [L/T].

V_w = Pore water velocity [L/T]. Also known as groundwater velocity.

x = Distance [L]. Distance at which to compute C .

Property Data

[Top of Page](#)

The following are tables of hydraulic conductivity, total porosity, effective porosity, bulk density, and organic carbon partition coefficient. Parameter values have been compiled from a variety of sources such as Coduto (1994), Fetter (1993), Freeze and Cherry (1979), Hillel (1982), and Sanders (1998). The values used in the calculation above are typical numbers within the ranges given below.

Table of Soil Properties

Soil Type	Hydraulic Conductivity K (cm/s)	Total Porosity n (%)	Effective Porosity n_e (%)	Bulk Density d (g/cm ³)
Clayey	$10^{-9} - 10^{-6}$	40-60	0-5	1.2-1.8
Silty	$10^{-7} - 10^{-3}$	35-50	3-20	1.1-1.8
Sandy	$10^{-5} - 10^{-1}$	20-50	10-35	1.3-1.9
Gravelly	$10^{-1} - 10^2$	25-40	12-30	1.6-2.1

Table of Organic Carbon Partition Coefficient, K_{oc}

Chemical	K_{oc} (cm ³ /g)	Chemical	K_{oc} (cm ³ /g)
Benzene	20-400	Pyrene	2000-200,000
Ethyl Benzene	90-1500	Tetrachloroethylene	100-3000
Dichloroethane	10-250	Trichloroethylene	20-500
Naphthalene	100-2500		

Error Messages given by calculationTop of Page

"Certain inputs must be > 0 ." No computations. C_o , C , d , $-dh/dx$, K , n , n_e , and T must all be > 0 if entered.

"Certain inputs must be ≥ 0 ." No computations. a , D^* , f_{oc} , K_{oc} , t , and x must all be ≥ 0 if entered.

" n , n_e , and f_{oc} must be $\leq 100\%$." No computations. Total porosity, effective porosity, and soil organic carbon cannot exceed 100%.

" n_e must be $\leq n$." No computations. Effective porosity cannot exceed total porosity.

" C_o cannot be determined" or " $C_o = \text{infinity}$." C_o not computed. Certain input combinations result in computing $\text{erfc}(\text{infinity})$, and $\text{erfc}(\text{infinity}) = 0.0$. Therefore, the equation $C_o = C/0.0$ results, in which C_o cannot be evaluated or is evaluated as infinity.

ReferencesTop of Page

Abramowitz, M. and I. A. Stegun. 1972. Handbook of Mathematical Functions. Dover Publications, Inc.

Coduto, D. P. 1994. Foundation Design Principles and Practices. Prentice Hall, Inc.

Fetter, C. W. 1993. Contaminant Hydrogeology. Macmillan Pub. Co.

Freeze, R. A. and J. A. Cherry. 1979. Groundwater. Prentice Hall, Inc.

Hillel, D. H. 1982. Introduction to Soil Physics. Academic Press, Inc.

Ingebritsen, S. E. and W. E. Sanford. 1998. Groundwater in Geologic Processes. Cambridge University Press.

Lyman, W. J. Adsorption coefficient for soils and sediments. In Handbook of Chemical Property Estimation Methods. Lyman, W. J., W. F. Reehl, and D. H. Rosenblatt, eds. McGraw-Hill Book Co. 1982. pp. 4-1 thru 4-33.

Sanders, L. L. 1998. A Manual of Field Hydrogeology. Prentice Hall, Inc..

Van Genuchten, M. Th. and W. J. Alves. 1982. Analytical Solutions of the One-Dimensional Convective-Dispersive Solute Transport Equation. United States Department of Agriculture, Agricultural Research Service, Technical Bulletin 1661.

© 2000 LMNO Engineering, Research, and Software, Ltd. (All Rights Reserved)

All features enabled

Click to Calculate

☒ Check box to include retardation

Solve for C

Sandy Soil (sets K_r , n , n_e , d)

Trichloroethylene (TCE) (sets K_{oc})

Select Units:

Concentrations in mg/l or ppm

Times in years

Distance in m

Dispersivity in m

Diff. and Disp. Coeff. in m^2/s

Hydraulic Conductivity in m/s

Hydraulic Gradient in m/m (ft/ft)

Soil Bulk Density in g/cm^3

K_{oc} and K_d in cm^2/g

Velocities in m/day

<http://www.LMNOeng.com>

© 2000 LMNO Engineering,
Research, and Software, Ltd.

Concentration, C (mg/l):	0.0010845440692619501
Time, t (yr), to compute C:	5
Distance, x (m), to compute C:	20
Injected Concentration, C_0 (mg/l):	2.5
Duration of Injection, T (yr):	0.03
Dispersivity, a (m):	10.0
Diffusion Coeff, D^* (m^2/s):	1.0E-9
Hydraulic Cond, K (m/s):	1.0E-5
Hydraulic Grad, $-dh/dx$ (m/m):	0.034
Total Porosity, n (%):	40
Effective Porosity, n_e (%):	35
Soil Bulk Density, d (g/cm^3):	1.6
Soil Organic Carbon, f_{oc} (%):	0.1
Org. Carbon Coeff, K_{oc} (cm^2/g):	250
Distribution Coeff, K_d (cm^2/g):	0.25
Retardation Coeff, R_f :	2.0
Pore Water Velocity, V_w (m/day):	0.08393142857142857
Chemical Velocity, V_c (m/day):	0.04196571428571429
Dispersion Coeff, D (m^2/s):	4.86E-6
Peclet Number, $Pe = V_c(x/D)$:	1.9988242210464435
Plume leading edge, $V_c * t$ (m):	76.63988571428571
Plume trailing edge, $V_c * (t - T)$ (m):	76.18004640000001

File Edit View Favorites Tools Help

All features enabled

[Click to Calculate](#)☒ Check box to include retardationSolute type: ☐
Solute type: ☐Solute type: ☐
Solute type: ☐Solute type: ☐
Solute type: ☐**Select Units:**Concentration in mg/L or ppm: ☐Time in years: ☐Distance in m: ☐Dispersion in m: ☐Diffusion Coeff. in m²/s: ☐Hydraulic Conductivity in m/s: ☐Hydraulic Gradient in m/m (ft/ft): ☐Soil Bulk Density in g/cm³: ☐Koc and Kd in cm³/g: ☐Velocities in m/s: ☐<http://www.LMNOeng.com>

© 2000 LMNO Engineering,

Research, and Software, Ltd.

Concentration, C (mg/L):

Time, t (yr), to compute C:

Distance, x (m), to compute C:

Injected Concentration, Co (mg/L):

Duration of Injection, T (yr):

Dispersivity, a (m):

Diffusion Coeff, D* (m²/s):

Hydraulic Cond, K (m/s):

Hydraulic Grad, -dh/dx (m/m):

Total Porosity, n (%):

Effective Porosity, ne (%):

Soil Bulk Density, d (g/cm³):

Soil Organic Carbon, foc (%):

Org. Carbon Coeff, Koc (cm³/g):Distribution Coeff, Kd (cm³/g):

Retardation Coeff, Rf:

Pore Water Velocity, Vw (m/s):

Chemical Velocity, Vc (m/s):

Dispersion Coeff, D (m²/s):

Peclet Number, Pe=Vc(x/D):

Plume leading edge, Vc*t (m):

Plume trailing edge, Vc*(t-T) (m):

0.0010529987576527245

.5

20

.130

0.03

10.0

1.0E-9

1.0E-5

0.034

40

35

1.6

0.1

831.7637711026708

0.8317637711026709

4.3270550844106825

9.714285714285715E-7

2.2450108733960661E-7

2.247868016253209E-6

1.9974579087059523

3.5423577569141846

3.3298162914993337

All files loaded

Internet

Start Groundwater contam. Inbox Microsoft Outlook Microsoft Photo Editor

4:05 PM