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- First Nations Liaison

25 1973-1998

August 31, 1999 GLL 98-800

Ross River Dena Council
Ross River Yukon
Y0B 1S0

Attn: George Smith and Vera Sterriah

Dear Mr. Smith and Ms Sterriah:

Re: 1998 Environmental Site Investigations along the Canol Road and MacMillan Pass, Human Health and Ecological Risk Assessment of Sites along the Canol Road.

Gartner Lee Limited and Cantox Environmental Inc. are pleased to provide the Ross River Dena Council with nine bound copies of our final report on the 1998 Environmental Site Investigations and Risk Assessment completed last fall at sites along the Canol Road, Yukon and MacMillan Pass, NWT. As well, we are enclosing one unbound reproducible copy.

The Environmental Site Investigation report by Gartner Lee outlines the detailed work completed at five sites in the MacMillan Pass area and follow-up work at three sites in the Yukon. The conclusions regarding site conditions and the recommendations made for each site is based on the field and laboratory data compiled. Environmental conditions at each site are discussed separately and in detail.

The Human Health and Ecological Risk Assessment report prepared by Cantox Environmental Inc. details the preliminary quantitative risk assessment conducted for 7 sites in the Yukon and NWT. The objective of the risk assessment project was to determine whether or not the chemicals identified as the sites pose unacceptable risks to humans and/or the environment.

An overview of our findings and recommendations are provided in the Executive Summary following this letter.

We trust this letter and the enclosed report meet your present needs. We continue to enjoy the opportunity to be involved in this project and look forward to working together in the future. Please do not hesitate to call me at our Whitehorse office if you have any questions.

Yours very truly,
GARTNER LEE LIMITED

S.R. Morison

Stephen Morison, Principal
Senior Geoscientist/Manager

Executive Summary

The Canol Road and Pipeline project was built during World War II under the direction of the US Military. The pipeline, road and associated structures passes through the traditional lands of the Ross River Dena and the community of Ross River is located roughly half way along the Yukon portion of the Canol Road.

Since 1996 the Ross River Dena Council has retained Gartner Lee Limited to conduct environmental investigations of abandoned military sites associated with the Canol project. This work has been supported and funded by the Department of Indian and Northern Affairs Contaminants/Waste Program. A summary of the sites investigated from 1996 to 1998 is presented following this summary. The 1998 program consisted of:

1. Detailed site assessment of 5 sites in the MacMillan Pass, NWT area;
2. Follow-up sampling and monitoring at 3 Yukon sites;
3. Human Health and Ecological Risk Assessment at 7 sites.

Detailed Site Assessment in the MacMillan Pass Area, NWT

Five sites were investigated in the MacMillan Pass area in 1998. Scope of work included site mapping, shallow hand test pitting, soil sampling and surface water sampling where available. The site of most concern is Pump Station 6 at MP 208. Partially full and full drums of hydrocarbon products, grease drums, a large storage tank with crude oil tars, and a full Underground Storage Tank were found at this site. Furthermore, several areas of hydrocarbon contaminated soils were found on site. These is a significant amount of debris and collapsing buildings at this site which may present a human health and safety concern. Other sites investigated in the MacMillan Pass area, although characterized by a significant amount of surface debris, did not reveal extensive contamination.

Follow-up Sampling & Monitoring, Canol Road Yukon.

Follow-up soil sampling was conducted at two sites along the Yukon portion of the Canol Road. Groundwater monitoring was conducted at two sites where groundwater monitoring wells have been installed. Free hydrocarbon product was found in a new well installed down slope from the dump at MP 73 – Gravel Creek Pump Station.

Human Health and Ecological Risk Assessment

Early in the Canol Environmental Assessment project, it was recognized that although the Yukon and Federal governments have Contaminated Sites Regulations and CCME guidelines, these standards may not be appropriate for the Ross River Dena since the regulations do not reflect the traditional land use patterns of the Dena people. Therefore, it was decided to conduct preliminary quantitative human health and ecological risk assessment at sites with the highest levels of contamination. This assessment conducted on seven sites by Cantox Environmental integrated traditional land use patterns and Valued

Ecosystem Components (VECs) with the toxicological risk assessment. A complete executive summary of the risk assessment findings are presented in Cantox Environment's following report.

Community Consultation & Participation

Community participation and involvement was a key component of this project to ensure the transfer of technical environmental knowledge to the community. Transfer of traditional knowledge back to the project team was an important feedback into the project methodology. In the 1998 field program a Ross River student and elder accompanied the project team into the field and participated in all aspect of the environmental assessment. A questionnaire used to document traditional land use patterns at the sites assessed was distributed to the entire community. This information was used to develop the appropriate assumptions for the Risk Assessment as well as identify Valued Ecosystem Components. A workshop was conducted in the spring of 1999 to present the findings of the site assessment and risk assessment work to the community.

Acknowledgements

GARTNER LEE LIMITED would like to acknowledge the contributions of the following people:

- Robertson Dick for his guidance, knowledge and for keeping our camp warm in the snow;
- Greg McLeod for all his hard work in the field;
- John Carl Jr. Sterriah and William Atkinson for doing such a thorough job on the VEC questionnaire,
- George Smith and the staff at RRDC Land Claims for all their support and interest in this project;
- Brett Hartshorne and Mark Palmer at DIAND Contaminants/Waste program for all their support, patience and for making this whole project possible and a success.

Summary of Sites Assessed Along the Canol Road/Canol Trail 1996-1998

Mile Post	Site Name	Date of Assessment	Intensity of Assessment
MP 73	Gravel Creek – Pump Station 10	1996 1997 1998	Detailed UST Removal & Monitoring Monitoring
Minfile 105F 011	Upper Sheep Creek Mining Camp	1997	Reconnaissance
MP 99.5	Lapie Lake Miliary Camp	1996	Detailed
-	Boulder Creek	1997	Reconnaissance
MP 124.5	Lapie River – Pump Station 9	1996 1997	Detailed UST Removal
MP 124.5	Ram Creek	1997	Reconnaissance
-	Old Ross Townsite	1996 1997	Detailed Site Clean-up
-	Tenas Creek Sawmill	1997	Reconnaissance
MP 174	Flat Creek – Pump Station 8	1996 1997	Detailed Follow-up
MP 212	Sheldon Lake Military Camp Dump	1996	Detailed
MP 213	Sheldon Lake Military Camp	1996	Detailed
MP 221	Sheldon Lake Sawmill	1997	Reconnaissance
MP 220	Sheldon Lake Pullouts	1997	Reconnaissance/Detailed
MP 233	Moose Creek - Pump Station 7	1996	Detailed
MP 234	Moose Creek Pump Station 7A	1997 1998	Detailed Follow-up
MP 234	Moose Creek Military Camp / Burial Site	1996 1997 1998	Detailed Monitoring & Geophysical Surveys Monitoring
MP 234.5	Moose Creek Burial Site	1997	Detailed & Geophysical surveys
MP 247	Military Site	1997	Detailed
MP 267.5	Mac#2 Military Camp	1997 1998	Detailed Follow-up
MP 268	Mac#2 Laydown Area	1996	Detailed
MP 207.5 NWT	Laydown Area	1998	Detailed
MP 208 NWT	Pump Station 6	1998	Detailed
MP 210 NWT	Old Squaw Barrel Dump	1998	Detailed
MP 215-216 NWT	Boulder Creek Gravel Pit	1998	Detailed
MP 233 NWT	Vehicle Boneyard	1998	Detailed

Gartner Lee

1998 Environmental Site Investigations along the Canol Road, Yukon and MacMillan Pass, NWT

Prepared For:
Ross River Dena Council

Prepared By:
Gartner Lee Limited

GLL 98-800

August, 1999

Distribution

10	*Ross River Dena Council*
2	*DIAND Contaminants/Waste Program*
2	*Gartner Lee Limited*
1	*Cantox Environmental Inc.*

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1. Introduction

The Ross River Dena Council has retained Gartner Lee Limited (GLL) since 1996 to conduct a series of environmental site investigations at former military sites associated with the Canol Road within the Ross River Dena people's traditional territory. The 1997 field season and report (GLL 1998) identified several sites for follow-up work and environmental monitoring, as well as new sites of concern in the MacMillan Pass area of Northwest Territories (NWT). The MacMillan Pass area has been identified as important to the Ross River people's traditional land use, and to many, the "Mac Pass" area is considered the heart of their traditional roots. In conjunction with the investigations, a Ross River trainee and Ross River elder accompanied the GLL environmental professionals to provide an exchange of information and knowledge in the field setting. This project was funded by and undertaken as part of the Department of Indian Affairs and Northern Development's (DIAND) Action on Waste Program for the delineation of waste sites in the Yukon. Technical support was provided to the Ross River Dena and GLL by Mr. Brett Hatshorne, Manager of the Action on Waste Program.

1.1 Objectives

The goal of this on-going project as prepared in the Ross River Dena Council's 1996 request is as follows; "*to gain preliminary environmental information of waste sites in the Ross River Dena people's traditional territory and establish a technical understanding of the environmental issues for the Ross River Dena people.*" This goal was used to guide Gartner Lee Limited (GLL) in the design and implementation of the 1996 through 1998 projects. The following are the objectives which were developed by the Ross River Dena Council and the Department of Indian Affairs and Northern Development's (DIAND) Contaminants/Waste program to ensure that the above goal was achieved:

- to provide the Ross River Dena with additional scientific understanding of identified waste sites in their traditional territory;
- to continue a transfer of knowledge through all stages and aspects of this project for the benefit of the Ross River Dena;
- to prepare work plans for the recommended follow-up investigations sites and environmental monitoring identified in the previous years' work;
- as part of the above work plan, implementation of a training program for an environmental trainee from Ross River Dean community; and
- present a report which outlines the findings and interpretations of the site investigations and follow-up monitoring activity.

The report will also provide recommendations for remediation to assist the Ross River Dena Council and the Department of Indian Affairs and Northern Development (DIAND) to make management decisions with respect to the sites on the North Canol Road, South Canol Road and Canol Trail in the NWT.

2. Background

2.1 Canol Road Construction History

K .Bisset and Associates (1995) provides the following excellent summary of the Canol Project history:

> The Canol No. 1 pipeline was the sole military activity in [the Ross River Dena traditional territory]. Beginning in the winter of 1942/43, the route was surveyed through to MacMillan Pass area. Locals were hired to act as guides to select the best route.(52) At Ross River there was a trading post, located on the north bank of the Pelly River and the mouth of the Ross River. At Sheldon Lake, approximately halfway between Norman Wells and Whitehorse, there was another trading post, and beyond that the MacKenzie River, for 300 miles there was no human habitation(51) (Figure 2.1.1). In June 1943, workers started progressing from Johnson's Crossing towards MacMillan Pass to meet the other crew of road builders, pipe layers and telephone crews from Canol Camp, NWT. The "Golden Weld" when they joined the ends of the pipe was at MP281.5 near the Yukon/NWT border, February 14, 1944. Crude oil flowed to Whitehorse for 331 days until March 13, 1945, when evacuation orders had been given for the Canol workers. Buildings were boarded up, equipment winterized and everything left, in case the pipeline would open again. The pipeline was closed by April 30, 1945.

2.2 Canol Road Clean-up Efforts and Previous Studies

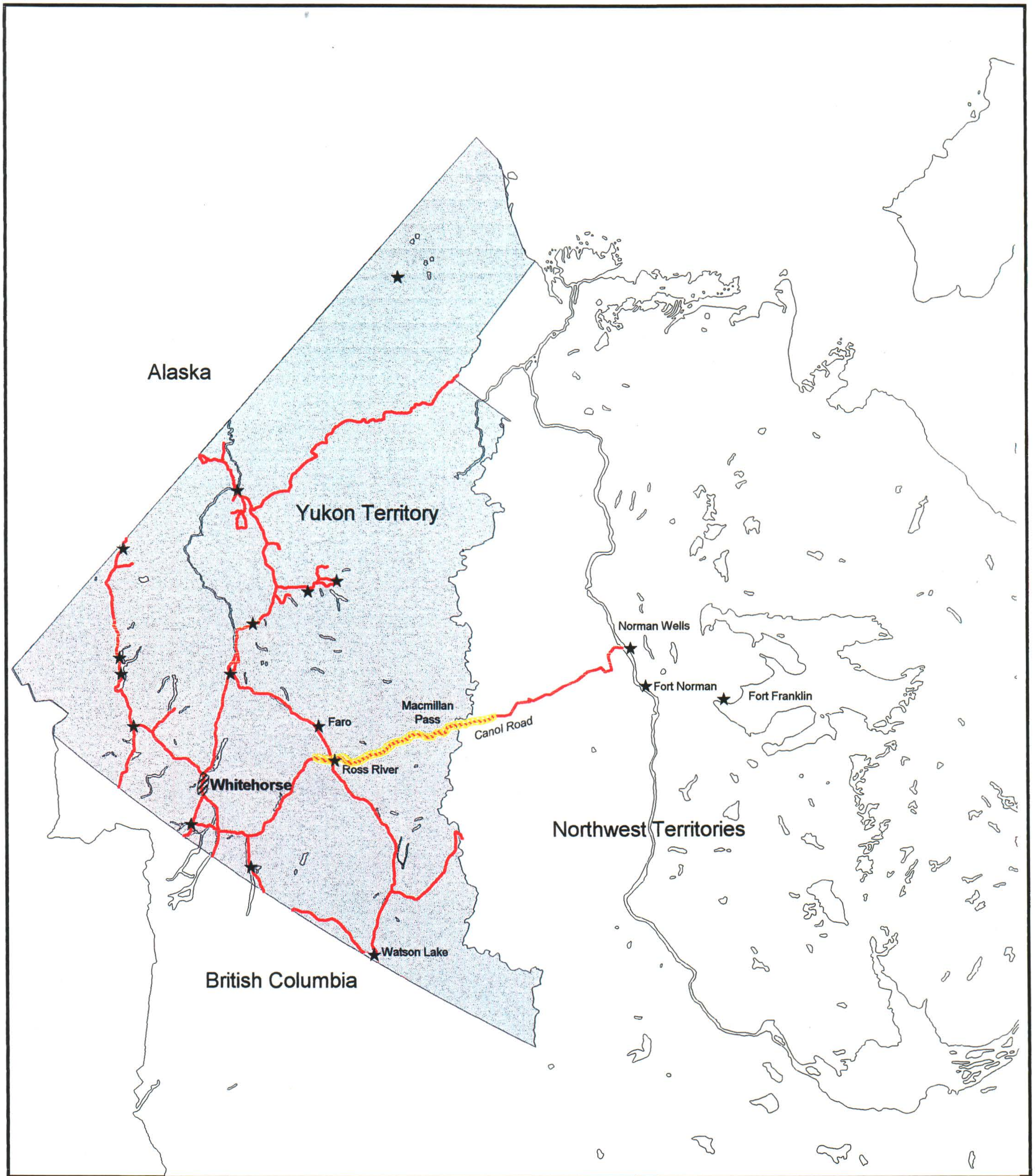
Previous studies and clean-up work conducted on the Canol Road include the following:

- The Canadian Government was given the first option to purchase the salvage rights of the project; however, the government declined and the rights were sold to by (according to anecdotal accounts) Canadian Forces or Dept. of Public Works in Edmonton to private salvage companies (Synergy West Ltd. 1975). There appears to have been some salvaging of such objects as 6" pipeline and large fuel storage tanks (POL tanks) prior to Canadian Forces' 1970 report. There was no ferry in operation after the war, and the bridges deteriorated until travel was not feasible on the North Canol Road.

- The Yukon Government decided to re-activate the road in 1969. In the early 1970's exploration by mining companies in the MacMillan Pass area required that the road and bridges be maintained. Since that time, the Yukon Territorial Government (YTG) has supervised upkeep of the road.

- In 1970, Canadian Forces No. 1 Construction Engineering Unit wrote the report "*Engineering Study O-CEU-43, Pollution Canol Highway*" which inventoried debris and waste along the Canol Road.

- Telegraphy wire winding was conducted in 1974-75. L. Gay produced a pictorial report documenting this work. (Gay 1975a).



Legend

Project Location

Not to Scale

Drawn By: F. Pearson	Project No. 98-800
Site Name: Canol Road	Date: 08.04.99

Canol Road Project Location

Canol Road Site Assessment

Gartner Lee Limited

Figure No. 2.1.1

- In 1975 Synergy West Ltd conducted the "*Canol Road Clean-Up Assessment Study*" which concentrated on compiling an inventory and clean-up plan, including costs, for removal of abandoned materials remaining from military activities. L. Gay also produced a pictorial report at this time entitled *"Canol Road Cleanup Pictorial Report"*.

- There has been clean-up efforts conducted by YTG in the 1970's, acting upon the findings in Synergy West Ltd.'s 1975 report. Two salvage contractors were involved, Yukon Pioneer Transport Ltd. for the South Canol clean-up and Deines Bothers Arctic Services Ltd. for the North Canol clean-up. This work involved removal and crushing of drums, winding of telegraph wire, burial of debris, demolition and burning or burial of woody debris, and some removal of scrap iron. The alignment of vehicle hulks along the Canol Road today may have been completed as part of this work (K. Bissett and Associates 1995).

- In 1994 two reports describing environmental site investigations along the NWT side of the Canol Trail have been released. These reports, *"Environmental Assessment and Cleanup Options for Selected Sites Along the Canol Trail, N.W.T."* (DIAND 1994) and "*An Environmental Study of the Canol Trail, NWT*" (Royal Roads Military College 1994) provide waste inventories and preliminary analytical results from selective sampling of Canol Trail sites in the NWT. There are preliminary clean-up options presented in each report. Many of the drums containing hydrocarbon product in the MacMillan Pass area identified by Royal Roads have since been removed.

- "*Research of Former Military Sites and Activities in Yukon*" was written by K. Bissett and Associates in 1995. This report reviewed activities at sites throughout the Yukon and identified potential contaminants of concern including petroleum hydrocarbons, metals and pesticides from past military operations.

- In 1996 Gartner Lee Ltd prepared *"Environmental Site Investigations Along the Canol Road"* (1997) for the Ross River Dena Council. This project investigated 10 sites for soil and water contamination related to military activities. The report provides recommendations for follow-up work, further investigations and preliminary remediation options.

- In 1997 Gartner Lee Ltd conducted follow-up work on six of the sites investigated in 1996. Work included installation of groundwater monitoring wells, further soil sampling, underground storage tank removal from two pump stations, clean-up of one site, and geophysical surveys. Detailed investigations were conducted at 5 new sites, as well as reconnaissance visits to nine other sites in Yukon and NWT. A draft report entitled *"1997 Environmental Investigations along the Canol Road, Draft for Discussion"* was prepared documenting this work.

3. Scope of Work and Technical Approach

The work program completed by Gartner Lee Limited in 1998 is summarized below:

- review of 1996 and 1997 results and research of previous reports for design of the 1998 field program (July-August);
- identification and hiring a Ross River trainee to accompany the field team (Aug. 24-Sept. 3);
- prepare logistics of mobilization and field work in the remote MacMillan Pass area (Sept. 1-7);
- mobilized to the Ross River, install and sample monitor wells at MP73 (Sept. 8);
- meet with Ross River Dena Council and mobilize to Sheldon Lake (Sept. 9);
- mobilize to MP 208, NWT—establish base camp (Sept. 10)
- conducted detailed investigations of sites MP 208, 207.5, 210, 215-216 and 223 including mapping, soil and water sampling, and hand test pitting. (Sept. 11-14)
- return to Ross River for supplies, survey wells at MP 234 (Sept. 15)
- follow-up hydrocarbon tar samples were collected from MP 174 and MP 124.5 (Sept. 15)
- conduct follow-up sampling at MP 267.2 and MP 234A (Sept 17-19);
- submitted selected samples to an accredited analytical laboratory for testing (Sept. 21-24); and
- produce a report documenting site conditions, work completed and providing recommendations for preliminary remedial measures and follow-up action (Oct. 20-current).

The field portion of the program commenced September 8th, 1998. Work was conducted by:

- Mr. Forest Pearson, Engineering Geologist EIT from Gartner Lee's Whitehorse office;
- Mr. Brent Belzac, Environmental Technician from Gartner Lee's Burnaby office
- Mr. Greg McLeod, Ross River trainee and
- Elder Robertson Dick of Ross River Dena Council.

Project Management and supervision was conducted by:

- Ms. Vera Sterriah, Ross River Dena Council; and
- Mr. Steve Morison, Gartner Lee's Whitehorse office manger.

3.1 MacMillan Pass Site Selection

Potential sites in the MacMillan Pass area NWT were selected for investigation after the following process:

- concern expressed by Ross River community;
- findings from the 1997 reconnaissance visit to MacMillan Pass area; and
- follow-up work based upon finding from Royal Road's 1994 report.

As result of this process, 4 sites on the NWT side of MacMillan Pass were investigated. These sites are:

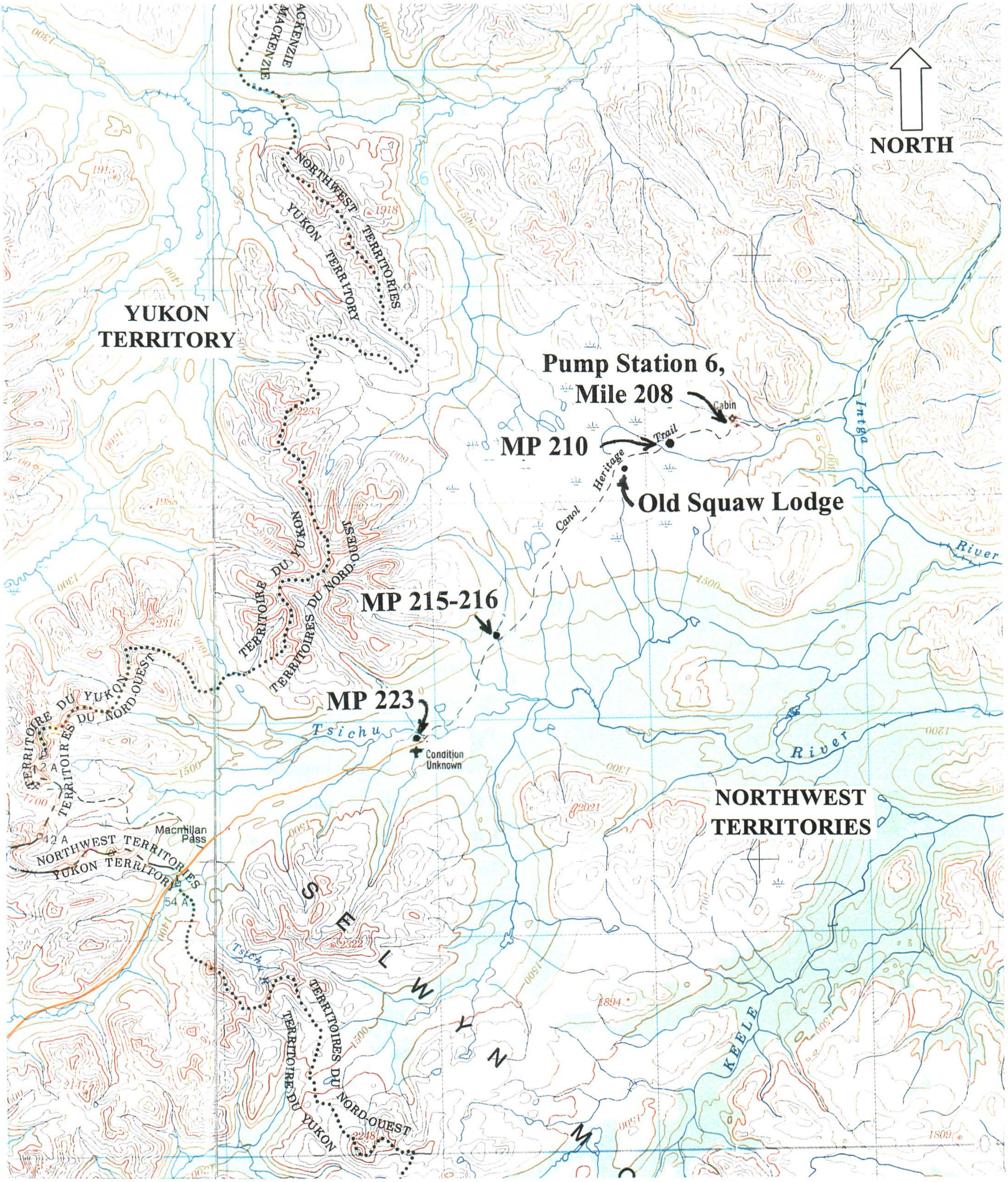
Table 3.1.1: MacMillan Pass, NWT Site for Investigation

Site Name	Mile Post*	Royal Roads Site Name**	Description
Pumps Station 6	MP 208	Site 17 -MP 208	Large, intact pump station site, contains subsidiary site labeled 207.5
Laydown Area	MP 207.5	MP 208	Vehicle boneyard 500m east of Pump Station 6
Old Squaw Barrel Dump	MP 210	Site 18	Three barrel dumps.
Boulder Creek Gravel Pit	MP 215-216	Site 19A & 19B	Quarry with barrel dumps. Subsidiary site (19B) located west of main site.
Vehicle Boneyard	MP 223	Site 20	Vehicle Boneyard & domestic waste dump.

*All mileposts in NWT are measured from Norman Wells.

** Royal Roads 1994.

The location of the four sites are presented in Figure 3.2.1



Legend

Risk Assessment Sites

NOTE:
All Mile Post locations are referenced from Norman Wells

Scale 1:250,000

Drawn By: F. Pearson	Project No. 98-800
Site Name: Canol Road	Date: 12.01.98

MacMillan Pass
Risk Assessment Sites

1998 Environmental Investigation
Canol Road

Gartner Lee Limited

Figure No. **3.2.1**

3.2 Follow-up Work Program

Table 3.1.2 lists the sites that follow-up work was proposed based upon 1997 field program findings:

Table 3.1.2: Yukon Sites Proposed for Follow-up Work

Site Name	Mile Post*	Follow-up Work Program	Status of Work
Pumps Station 10 – Gravel Creek	MP 73	• Install 3rd groundwater monitor and collect groundwater samples.	See section 5.1
Tenas Creek Sawmill	MP 147	• Remove full 45-gallon drums.	Unable to relocate drums – may have been removed by Forestry.
Pump Station 7 – Moose Creek	MP 233	• Remove barrels from pond.	Work not feasible with equipment available.
Moose Creek Military Camp	MP 234	• Survey groundwater wells • Collect groundwater samples • Conduct follow-up soil sampling at POL tank farm.	See section 5.2
MacMillan 2 Military Camp	MP 267.5	• Conduct follow-up soil sampling at site.	See section 5.3
Destruction of Underground Storage Tanks (UST)	Ross River	• Clean & destroy USTs removed in 1997. • Sample product collected from UST for characterization & disposal	See section 5.4
Crude Oil Tar Sampling	MP 174, 124.5, 73	• Sample tars from POL tank spills for disposal/remediation characterization	See section 5.5

*All mile posts in Yukon are measured from Johnson's Crossing.

3.3 Site Investigations

3.3.1 Approach

Once the sites had been selected, the investigative phase of the project commenced. This was completed through the combination of both a preliminary desktop review and visits to each of the sites.

The desktop review was carried out to gather as much information about the sites prior to commencing the field program. This information was considered essential in order to gain an advanced understanding of the expected site conditions. Information was compiled from the review of previous Canol Road reports, topographic maps and a review of aerial photographs of the areas surrounding the sites.

Additional information was provided by members of the Ross River Dena First Nation who were familiar with the sites, and other members of the Ross River community.

Site investigations involved grid mapping of the site, documentation of environmental hazards, and collection of soil, water and vegetation samples where appropriate. Complete mapping and sampling methodologies are presented in the Methodologies section in Appendix A.

Site mapping was critical in order to produce a good quality reference plan of each site. Features identified during the site walkover were located, as were slopes, water courses and discernible boundaries.

Upon completion of mapping, samples were collected from the site. Based upon the site conditions observed, a "hot-spot" (ie. visual staining) sampling strategy was used. Judgmental samples were selected on the basis of visual staining in order to characterize the type and nature of contaminants present. Samples were also collected from areas down gradient of the "hot-spots". Surficial soil samples were collected from the near surface soils using a shovel to expose the mineral soils. Background soil, water and vegetation samples were also collected.

Selected samples were submitted for analytical testing and the results compared to established guidelines and standards, as discussed in the next two sections. The results for each site were also assessed in the context of the site setting (see section 4.1 Regional Geochemistry). As part of that assessment, the project team considered a "source-pathway-receptor" model. This is an integrated approach based on the way in which contaminants disperse from a source and then impact on the natural environment. The focus of this project was to identify the sources of contamination, as well as the presence of pathways for contaminant migration towards potential receptors.

3.3.2 Analytical Program

The analytical program concentrated on the potential contaminants of concern as identified from the results of the 1996 Canol Road program. This program identified hydrocarbons as the primary contaminant of concern. The results of the 1996 program indicated that metals and pesticides were not a concern at the sites investigated along the Canol Road (Gartner Lee Ltd. 1997). Soil and occasionally water and vegetation samples were collected at most sites.

The specific laboratory tests performed and the standard against which the results were compared are outlined in Table 3.3.1.

Soil samples were assessed for petroleum hydrocarbon content (e.g. gasoline, diesel fuel and crude oil) using a gross parameter or investigative scan, namely an extractable petroleum hydrocarbons (EPH) analysis. The total EPH result is quantified into two portions: C10-C18 and C18-C31.

These two portions represent Light Extractable Petroleum Hydrocarbons (LEPH) and Heavy Extractable Petroleum Hydrocarbons (HEPH) including any Polycyclic Aromatic Hydrocarbon (PAH). However, past analytical results from the Canol Road have shown that PAHs are not found in significant concentrations and therefore would not change the EPH results if analyzed separately and subtracted from the total concentration. A description of the methodologies used for each of these analyses is provided with the analytical reports from ASL and reproduced in the Technical Appendix.

Selected soil samples were analyzed for metals using and ICP scan.

Surface water samples were collected at sites were a body of water was identified in close proximity to the site and was considered a potential receptor. Groundwater samples were collected from installed groundwater monitor well. Samples were analyzed for EPH content and selected samples for PAH and dissolved metal content.

Vegetation samples of leaves and twigs were collected from a variety of plants, but mainly from willows with leaf buds and reindeer lichen, which were both common to all the sites and are browsed by local wildlife. Selected samples, as well as background samples were analyzed for metals to determine plant uptake of individual elements.

3.3.3 Analytical Standard

Interpretation on analytical data was based on a comparison against published federal and territorial guidelines and standards, as well as on professional experience and judgement. For the most part, the results were compared to the Yukon Contaminated Sites Regulations (January, 1997). These regulations specify standards based on land use in urban areas. There are different standards for each parameter based on Parkland, Agricultural, Residential, Commercial and Industrial land use. For this assessment, the analytical results were evaluated against the Park Land Use standard.

The issue of which numerical limit is appropriate for First Nations in terms of maintaining the traditional lifestyle of utilizing the land is beyond the scope of this report. The selection of Parkland use standards may be appropriate from a First Nation perspective. Gartner Lee Limited has used the existing standard for contaminated sites as a guide. The final decision on whether the recommendations are appropriate rests with the Ross River Dena Council.

Table 3.3.1: Summary of Regulatory Standard Used for Soil and Water Samples

PARAMETERS	REGULATORY STANDARD FOR SOIL [1]			...FOR WATER [1]
	Parkland (mg/kg = ppm)	Industrial (mg/kg = ppm)	Special Waste [2] (mg/kg = ppm)	Aquatic Life (ug/L = ppb)
PETROLEUM INDICATORS				
Light Extractable Hydrocarbons (LEPH)	1000	2000	30,000	500 [3]
Heavy Extractable Hydrocarbons (HEPH)	1000	5000		No free product [3]
Mineral Oil & Grease	1000 [4]	5000 [4]		-
Polycyclic Aromatic Hydrocarbons (PAHs)				-
Benzo(a)pyrene	1	10		-
Napthalene	5	50		-
Pyrene	10	100		-
METALS				
Antimony (Sb)	20	40	-	300
Arsenic (As)	35	60-150	-	500
Barium (Ba)	500	2000	-	10,000
Cadmium (Cd)	1.5-35*	1.5-700*	-	2-18
Chromium (Cr)	60	60	-	20
Lead (Pb)	150-500*	150-1000*	-	40-160
Molybdenum (Mo)	10	40	-	10,000
Tin (Sn)	50	300	-	-
Zinc (Zn)	150-450*	150-600*	-	300

[1] Yukon Contaminated Sites Regulations, Yukon Environment Act, December 1998

Numerical soil standards are for Environment Protection, Toxicity to soil invertebrates and plants, or groundwater flow to surface water used by aquatic life.

[2] Waste Management Act, Special Waste Regulations, Province of British Columbia, supported by Yukon Environmental Assessment and Protection Brach policy.

[3] Proposal to reconcile regulatory process of contaminated sites regulation and special waste regulations for petroleum hydrocarbon in water, as prepared by the Water Quality Regulatory Task Group of the BCMELP, Nov. 16, 1998.

[4] Standard for Managing Contaminated Sites (CMCS) in British Columbia, B.C. Environment, November 1989 (Draft 5)

* Varies with pH.

4. Findings – MacMillan Pass Site Investigations

This section provides a summary of the field observations for each site as well as analytical results, a discussion of the findings, conclusions and recommendations. All five sites in Northwest Territories are included in this section of the report, with each site represented as a separate subsection from 4.2 to 4.6.

4.1 Regional Geochemistry

The regulatory standards used in this report to assess the contamination of a site are based on background soil conditions in non-mineralized areas where individual concentrations of elements are naturally low. This must be taken into account when interpreting the analytical data from areas of known mineralization. In mineralized areas, trace metal concentrations can exceed the established standard naturally and may not necessarily be the result of a man-made source of contamination.

The anomalous geochemical results found at many of the sites investigated appear to be related to the background concentrations of naturally occurring trace metals found in soil and stream sediments. This linkage has been established primarily by reviewing the regional geochemistry, which has been done previously for this area (Friske et al. 1991).

The MacMillan Pass is an area well known for its mineral deposits. Base metal deposits dominate the known mineralization and appear to be related to the elevated concentrations of many elements in the soils.

Sediments deposited in the region by glacial processes have resulted in widespread redistribution of metals throughout the region from the MacMillan Pass area. Geochemical maps of selected individual elements from the MacMillan Pass area (105P) are presented in Appendix C to show this widespread distribution and the following table compares the established regulatory standard to naturally occurring concentrations for several elements found in stream sediments.

Table 4.1.1: Summary of Regulatory Standards and Background Regional Geochemistry

Parameter	CSR Parkland Standard (ppm)	Background Concentrations (from Friske et al, 1991)(ppm)
As	35	40-80
Ba	500	2200-3500
Cd	1.5-35[1]	1.2
Ni	100	49-78
Pb	150-500[1]	25-38
Zn	150-450[1]	8-208

[1]Can vary with pH.

4.1.1 Vegetation Background Samples

At the request of the Ross River Dena Council, vegetation samples were collected from selected sites for metal content analysis. These samples were select on the basis of traditional knowledge of human and animal usage. The most common plant sampled was the buds of willows *(salix sp.)* which are commonly browsed by ptarmigan, moose and other animals. Background samples were not collect as part of the sampling effort, so results have been compared with background samples collected by Royal Roads in late August 1994. Royal Roads developed an *Impact Criteria* which was two times the mean background metal concentrations (n=13, mixed species). The 1998 sampling program occurred in early September and the weather was cold with nightly snow fall that melted daily. Most plants had entered a dormant state at the time of sampling that may make comparison of samples tenuous.

Table 4.1.2: Summary of Background Vegetation Samples Collected by Royal Roads, Aug 1994.

Inorganic Element	Royal Roads Impact Criteria	Royal Road Background Concentration for MP 208 (*Salix glauca*)	Royal Road Background Concentration for MP 223 (Site 20) (*Salix glauca)*
Arsenic (As)	0.4	<0.2	<0.2
Cadnium (Cd)	2.4	5.4	3.8
Coblt (Co)	10	<5	<5
Cromium (Cr)	21	<10	<10
Copper (Cu)	10	4.9	6.9
Nickel (Ni)	10	<5	<5
Lead (Pb)	30	<15	<15
Zinc (Zn)	260	85	190

*All units in ppm or mg/kg

4.2 MP 208 – Pump Station #6

4.2.1 Physical Setting

General Description

Pump Station 6 is located approximately 36 km east along the Canol Trail from the Yukon, NWT border and 7 km east past Old Squaw Lodge. (Figure 4.2.1) The subject site is located mostly on the north side of the road, situated in a narrow limestone canyon with a stream flowing eastward through the centre of the site. Steep limestone cliffs that drop down to a terrace above stream level bound the north side of the site. Rounded slopes dropping to the stream's flood plain bound the south side of the canyon.

The site (see Figure 4.2.2) is comprised of two main sections, divided by the creek. The south half between the Canol Trail and the creek is the industrial side of the site, housing the pump station, powerhouse, Petroleum, Oil and Lubricant (POL) tank and other building remains and debris. The north half of the site is the camp site, and consists of the remains of nine Quonset huts, the wash house and miscellaneous debris. There are two overgrown causeways built of angular limestone fill that cross between the two halves of the site. The bridges over the stream are no longer in place. Generally, the site is very heavily littered with metallic debris, woody waste, domestic waste and 45-gallon drums. There are many areas of hydrocarbon staining associated with these drum caches.

Upstream and west of the main site, is a small area with several collapsed cabooses. East from the site along the Canol Trail, debris and 45-gallon barrel dumps are strewn along the roadside for some 250 m. 400 m east of the site, the Canol trail emerges from the site's canyon to a flattened hill that was described by Royal Road (1994) as the "Laydown area". This site is described separately as MP 207.5.

The pump station itself consists of a 30 m x 12 m building that is divided longitudinally by a wall. The northern half housed the pipeline and pumps, while the southern half housed the pump motors, a furnace room and possibly an office. The south half of the building is open and has been converted to a stable and corral by local outfitters. An underground storage tank (UST) was encountered just below the surface 3 m from the northwest corner of the pump station. The UST consists of three 45-gallon drums welded together in a lengthwise direction and is connected to the pump station via two 0.05 m diameter lines. The UST appears to be an overflow tank for oil spilled inside the pump station. The tank was found to be full (approximately 500 L) of what appears to be crude oil.

South of the pump station lies a small building described at the "powerhouse" by Royal Roads (1994). Drums have been aligned around the south edge of the pump station and the powerhouse to create a horse corral. West of the pump station is another standing building that has been described as the "kitchen". This building is divided into two halves and is actively used as shelter for hunters.

Between the pump station and the kitchen is a shallow pit filled with garbage and debris. Six to eight posts surround this pit. It is interpreted that this pit had a ramp over it and was used to conduct oil and grease changes on vehicles. The ramp has subsequently disappeared (or been burnt) and the pit filled with domestic waste.

North east of the pump station is another causeway leading the station's POL tank. This tank is on the south bank of the stream and stands an a small hill three to four metres above the surrounding terrain. The tank is 2.4 m high by 5.5 m in diametre and is constructed of riveted plate steel. The tank appears to be in good shape, but there are numerous holes from missing pipefitting and bullet holes. Approximately five to ten centimeters of sludge remains in the tank. There are 20 45-gallon drums east of the POL tank; this area has been labeled barrel dump 'H'. 17 of the drums contain a thick hydrocarbon product in them (less than 10% full).

Immediately west of the pump station lies an area of extensive area of debris. The debris consists of burnt buildings, drums, collapsed cabooses, vehicles, and other metallic debris. In this area, three full drums of light hydrocarbon product were identified, as well as a small drum of grease which has spilled. There are bear claw prints and hair in the grease indicating that bears are attracted to this grease.

There is debris and barrel dumps scattered for 250 m east of the pump station along the Canol Trail. Moving from west to east, there are empty drums scattered south of the road, and were identified in Royal Road's 1994 report as barrel dump 'A' (see Figure 4.2.2). A field inventory of drums in each of these dumps is provided in the table below—this inventory does not account for another 100 to 150 drums scattered elsewhere on site. Further west, seven truck remains are scattered along the north side of the road. A full pot of grease was found on the bed of one of these trucks. On the south side of the road was a pile of woody debris that is assumed to be a collapsed building.

Barrel Dump Area	Estimated Number of Drums
Dump A	134 empty over 100 m
Dump B	30
Dump C	28*
Dump D	1 full grease barrel (others removed since 1994)
Dump E	100+*
Dump F	18 45-gallon drums*, 20 partially empty 15-gallon drums*, 3 full 15-gallon barrels
Dump H	17 partially full barrels, 6 empty

(* from Royal Roads 1994)

West of the woody debris were 4 areas of drums, identified as dumps B, C, D, and F. The barrels in dumps B and C appeared to be mostly empty. The barrels of dump D were mostly small grease drums, and they appear to have been removed since Royal Road's report was completed. There is still significant amounts of grease and grease stained soils at the dump site. A full, broken open grease drum was found several metres up slope from this dump. Dump F is a collection of partially crushed small and large drums. Many of these examined are still partially full of light hydrocarbon product. West of dump F is an area shallow soils with extensive hydrocarbon staining. On the north side of the road across from dumps B, C, D, and F is a large dump of mostly empty drums called barrel dump 'E'.

The north (camp) side of the creek is located on a small, man made terrace at the base of the canyon cliffs. There are 8 partially standing and collapsed Quonset huts. A large standing building is central to the camp and has been called the 'Bathhouse' by Royal Roads (1994). South of this building is a large timber cribbed pit approximately 3 m x 2 m by 2 m deep. The pit is partially covered, but is collapsing in. It is interpreted that this is a septic pit for the bathhouse/camp complex. On the flats below the camp terrace, a square welded plate steel tank was found. This tank was called a "Surge Tank" by Royal Roads, but closer inspection revealed hot-water coils inside the tank. It is interpreted that the tank was used to pre-heat oil in the pipeline prior to leaving the pump station to reduce oil viscosity and increase flow through the pipeline. An insolated water line was found running between the bathhouse and the oil-heater tank.

Geology

An airphoto interpretation of the site is found on Figure 4.2.3. The main portion of the site lies on thin layer alluvial and organic sediments. These sediments grade into or mixed with the glacial till blanket that mantles the southern slopes. Limestone debris cones and bedrock cliffs form the north side of the canyon. There are areas of boulder fields and morainal mounds on the valley bottom. The pump station lies on a pad of gravel and limestone fill. The camp area lies on a modified bedrock/colluvium terrace at the base of the cliffs.

Surface Water

A small creek flows eastward through the side. The stream substrate is large boulders with occasional pools. The creek is approximately 1.5 m wide by 0.5 m deep, with flows in September estimated at 170 L/s. A recently abandoned beaver dam and pond lies downstream of the site.

A small wetland area lies north of the pump station with areas of shallow standing water. Between the pump station and the POL tank is another, more extensive wetland area with sanding water and ponds as shown on Figure 4.2.2.

A small spring was found to discharge in the ditch of the Canol Trail west of the site as shown on the site map. A dry flood channel was found to parallel the north side of the Canol Trail east of the site.

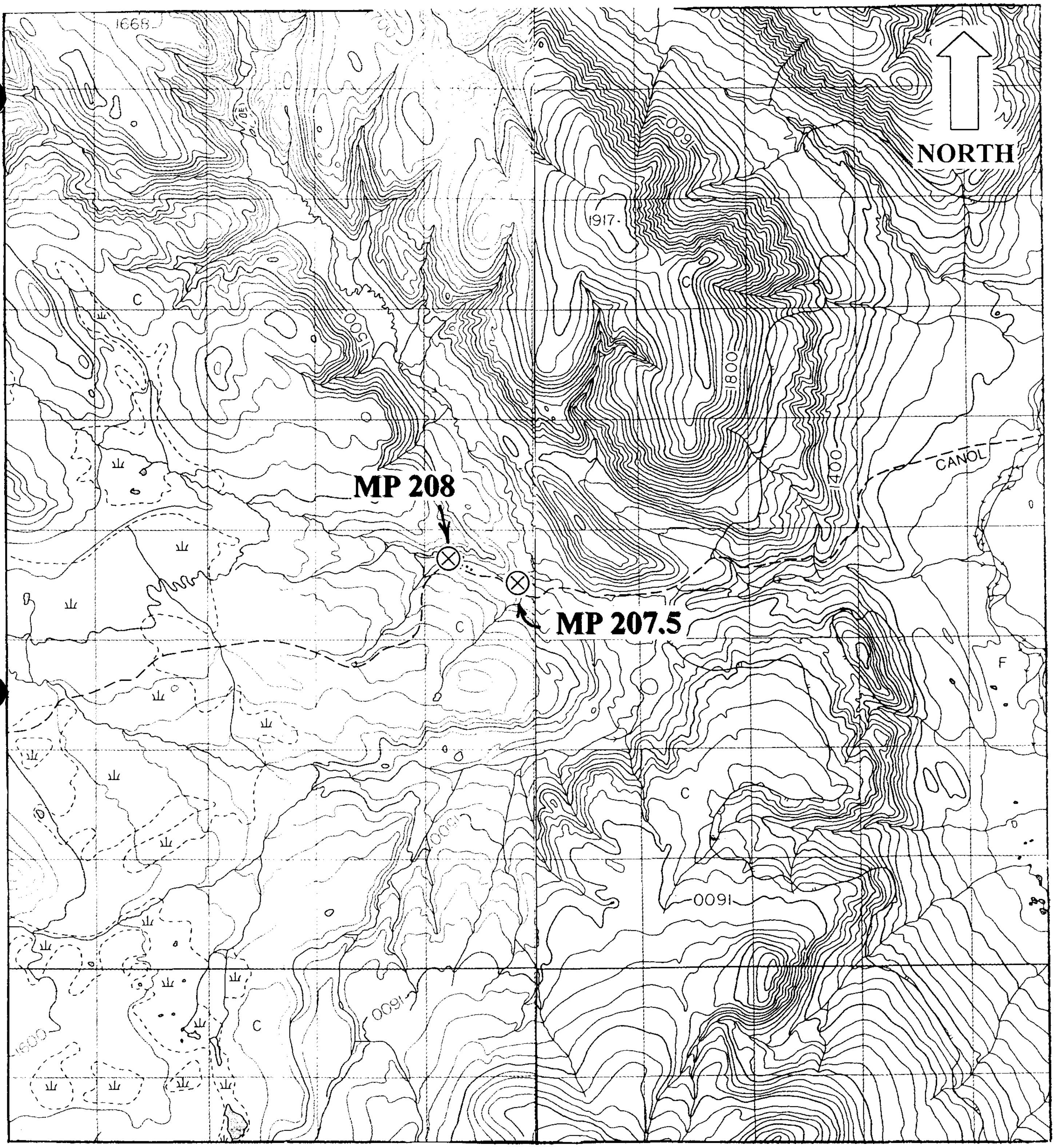


FIGURE 4.2.1: MP 208 SITE LOCATION

LEGEND:

⊗ SITE LOCATION

SOURCE: NTS 105 P/5 P/6

SCALE
1:50,000
1500M 0 1500M
1CM = 500 M

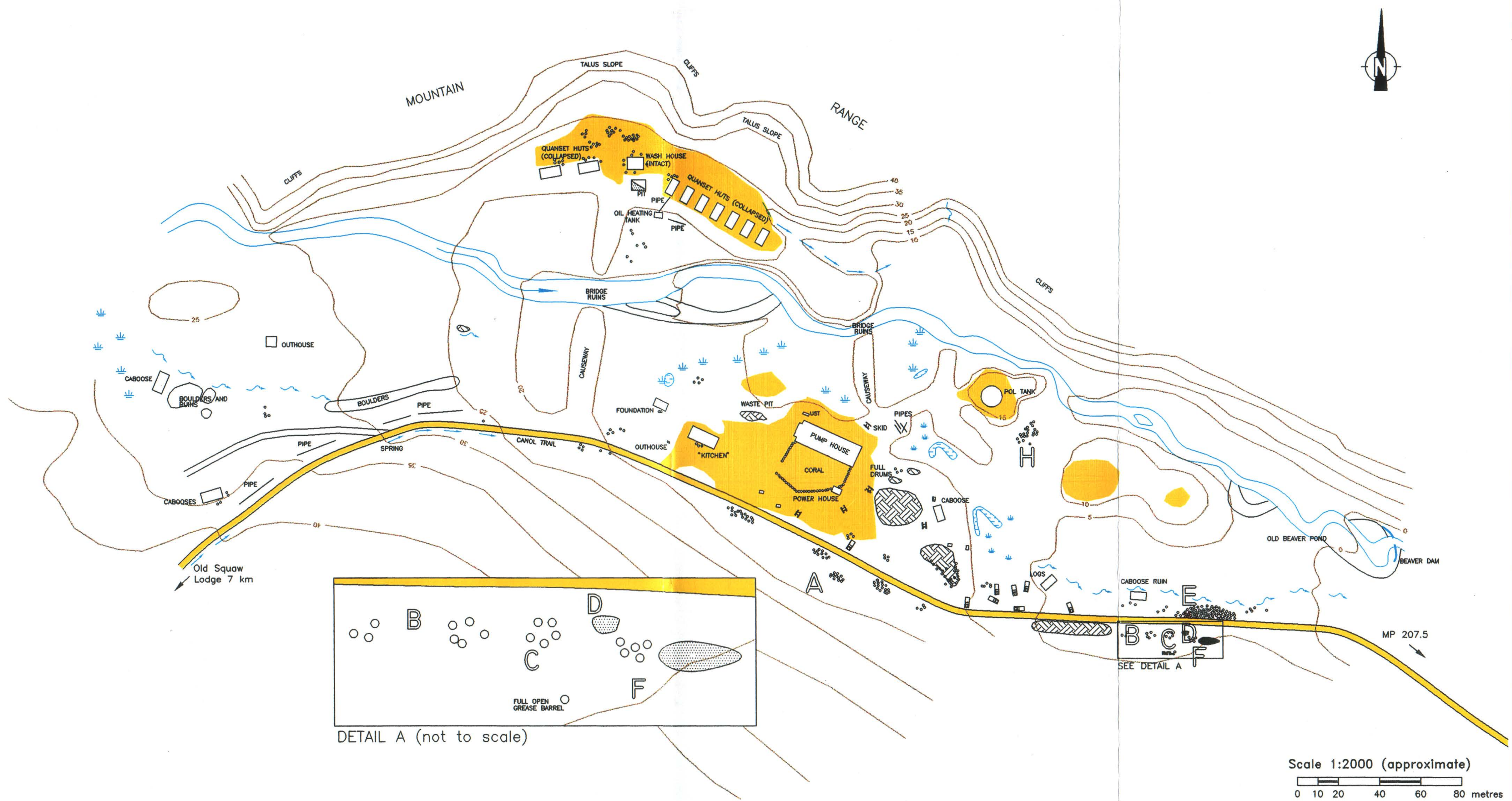
DRAWN BY: F. PEARSON	PROJECT NO.: 98-800
APPROVED BY:	FILE NAME: F4_2_1.DWG
DATE: 01/04/99	

PUMP STATION #6
MILE POST 208

1998 ENVIRONMENTAL INVESTIGATIONS
MACMILLAN PASS, NWT

Gartner Lee

FIGURE NO.: 4.2.1



LEGEND

- Clearing
- Hydrocarbon Staining
- Surface Debris
- Drums (55 gallons)
- Vehicle Hulk
- Skid/Sled Frame
- Surface Drainage
- Drainage Ditch
- Swamp
- Ponded Water
- Contour
- A Drum Dump I.D.

Contour interval approximately 5 metre, determined through visual mapping.

Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800001

Site Map MP 208 NWT
Pump Station 6

Canol Road
Site Assessment

Gartner Lee

Figure No.
4.2.2

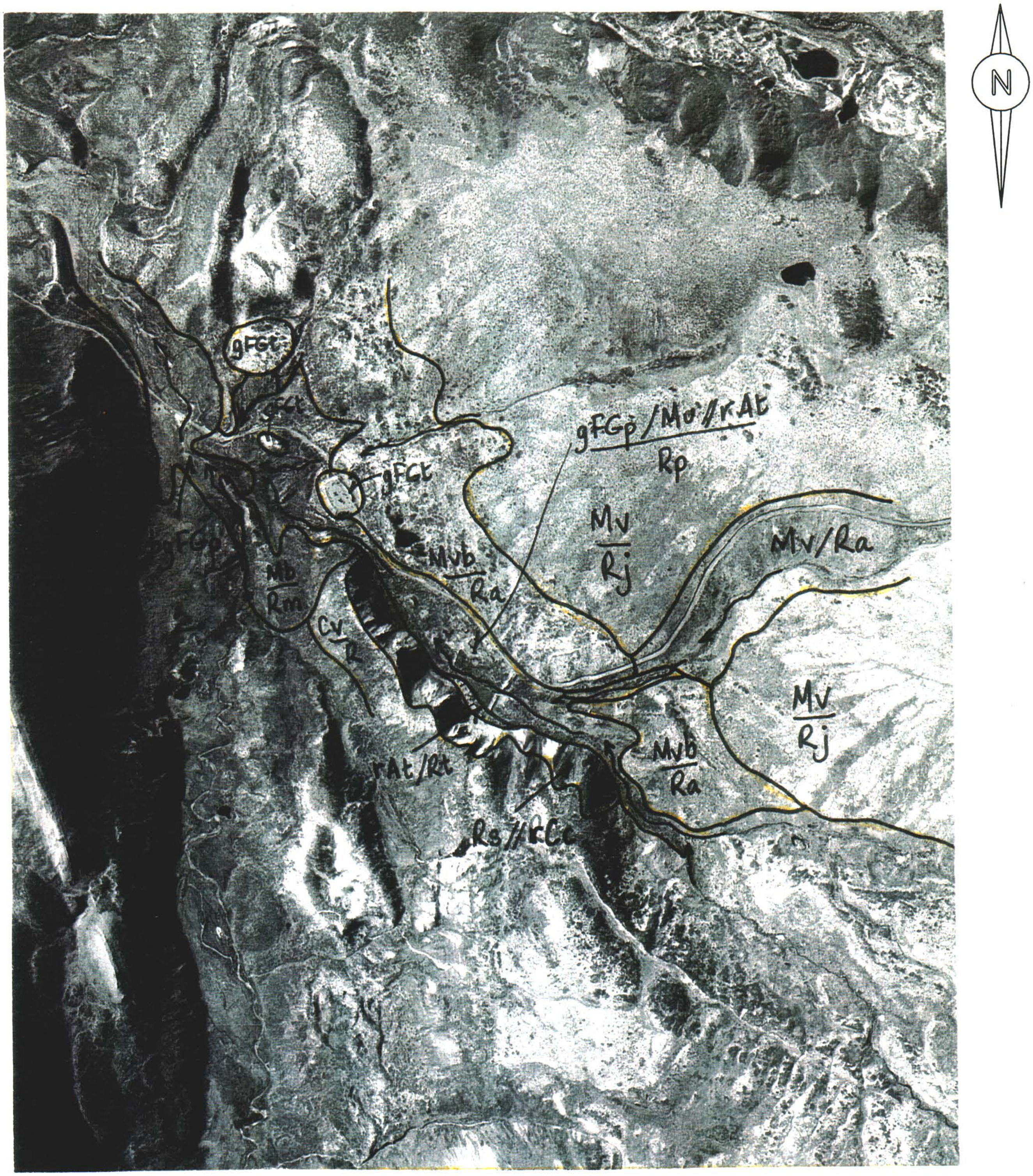


FIGURE 4.2.3: MP 208 TERRAIN INTERPRETATION

LEGEND:

SEE APPENDIX A

SOURCE: NAPL A25766-10

SCALE
1:30,000
750M 0 750M
1CM = 300 M

DRAWN BY: F. PEARSON	PROJECT NO.: 98-800
APPROVED BY:	FILE NAME: F4_2_3.DWG
DATE: 01/04/99	

PUMP STATION #6
MILE POST 208

1998 ENVIRONMENTAL INVESTIGATIONS
MACMILLAN PASS, NWT

Gartner Lee

FIGURE NO.: 4.2.3

Hydrogeology

The groundwater table is inferred to be near surface due to small springs found on the south side of the canyon, and numerous wetlands in the valley bottom. Water tables are interpreted to be near surface due to either near surface bedrock and/or permafrost. Groundwater flow is interpreted to follow the topography of the site—flowing towards the centre of the canyon, and then eastward with the stream, along the canyon floor.

Vegetation

The high plain and hills surrounding the site were mostly vegetated with a low cover of dwarf birch and willow, with ground cover of reindeer lichen and other low shrubs. The canyon floor has a thicker cover of willows and dwarf birch. Numerous wetland areas host sedge, grass and willow cover.

There are areas of grasses and sedges that are slowly reclaiming disturbed areas. Re-growth appears to be slow due in part to the harsh climate of the site, but also due to the rocky nature of the limestone rubble fill used in construction. The camp area on the north side of the site show little to no re-growth. Again, this is due to the camp being constructed on a bedrock and limestone rubble terrace, so there is very little nutrient and moisture holding capacity in the soils.

Wildlife

The area is heavily populated with ptarmigan and arctic ground squirrels. Pika were observed in the talus slopes north of the camp area. Abundant moose dropping were observed at the site, indicating moose heavily browses the valley. Very little indication of caribou was seen, and it is interpreted that the caribou prefer the upland plains above the pump station valley. Extensive bear signs of bear were seen on site, particularly surrounding areas of grease spills. It seems the bears are attracted to the smell of the grease and are clawing at and eating the grease.

4.2.2 Test Results

Soil, surface water, vegetation and hydrocarbon product samples were collected at the site. The location of the samples is shown on Figure 4.2.4. A complete sample list is found in the Technical Appendix.

Soil Chemistry

Selected soil samples were submitted to the analytical laboratory for analysis of potential contaminants of concern as identified in section 3.3.2, Analytical Program. This section provides a summary of the analytical results with the complete results presented in Tables 4.2.1 and 4.2.2 and the Technical Appendix.

A total of 34 samples were analyzed for extractable petroleum hydrocarbon (EPH) content. 15 samples were collected from across the site in general, 3 from the UST excavation (TP1), four from the nearby marshy area, and 12 from the various barrel dumps at the site. EPH content was detected in 27 of the samples collected. Concentrations of Light EPH (C10-C18) were found to exceed Parkland Standard in two samples, and exceed Industrial Standard in six samples. Concentrations of Heavy EPH (C18-C31) in 12 samples exceeded the Parkland Standard, with 8 more samples having concentrations that exceed the Industrial Standard.

Five samples were analyzed for metals, although sample SS-208-15 was a blind replicate of SS-207-7. The analytical results show concentrations of Barium exceeded the standards in all samples. Zinc exceeded Industrial standard for groundwater flow to surface water flow used by aquatic life in sample(s) SS-208-7/SS-208-15. Zinc also exceeded the Industrial standard for groundwater flow to surface water flow used by aquatic life and toxicity to soil invertebrates and plants in sample SS-208-12.

Vegetation Samples

A total of seven vegetation samples were collected from the Pump Station 6 site. These represented a variety of species that were browsed by local fauna. These included willow buds, reindeer lichen, blueberry and grasses. The complete results are presented in Table 4.2.3 and the Technical Appendix.

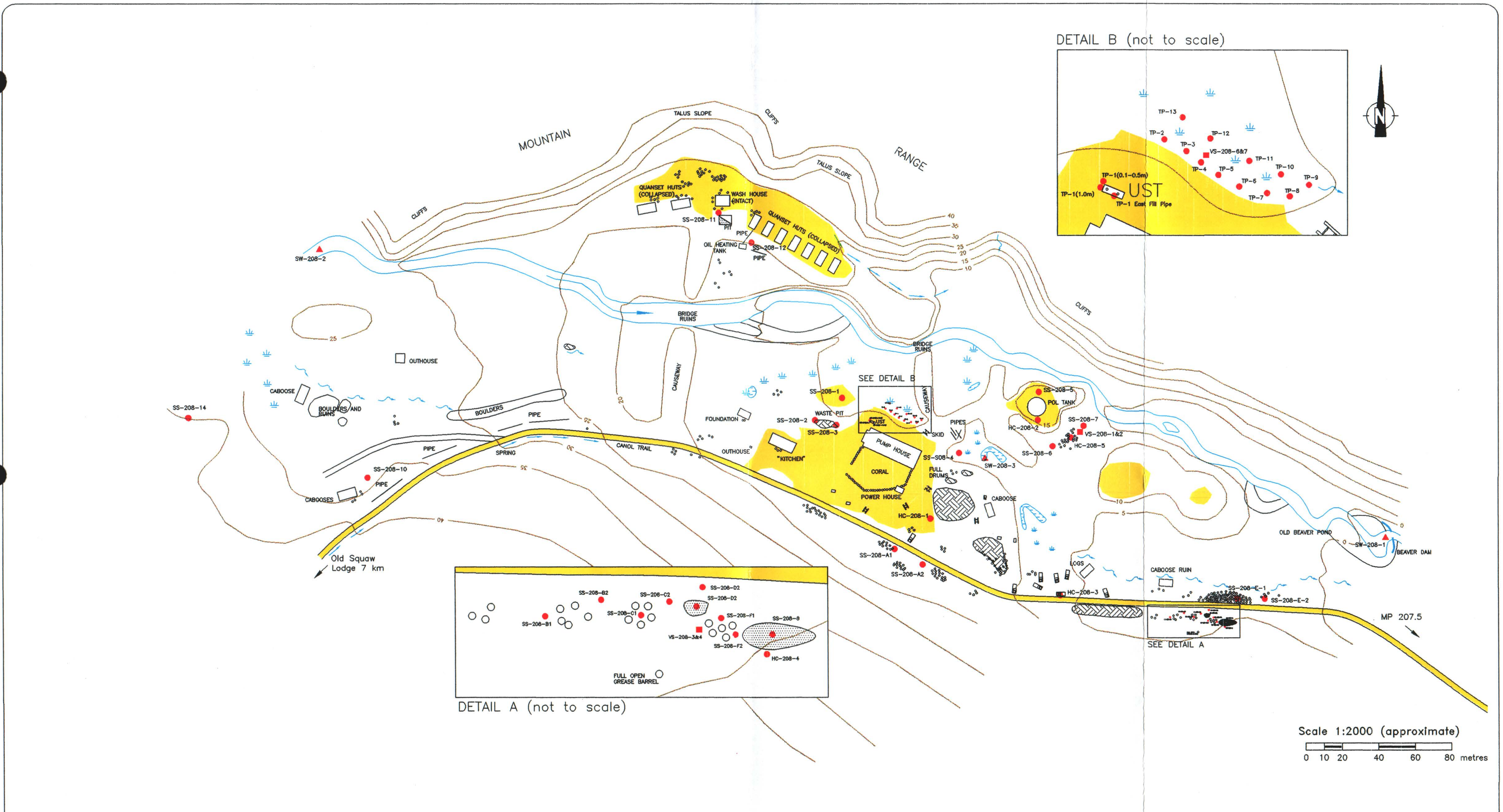
Royal Roads (1994) background cadmium levels were found to exceed their *Impact Criteria* of 2.4 ppm for their willow (*salix*) sample, with levels of 5.4 ppm. Two willow samples taken during this program exceeded the background sample concentration, samples VS-208-1 and VS-208-5. A blueberry bush sample (VS-208-3) exceeded Royal Roads' Impact criteria, but was less than the concentration found in the background willow sample.

Zinc concentrations were found to exceed the background willow sample in three samples, VS-208-1,2 and 5. None of these samples exceeded Royal Roads' Impact criteria.

Surface Water Chemistry.

Four water samples were collected at this site; one at an upstream location (SW-208-2), one at a downstream location (SW-208-1), one from a pond down gradient from the pump station (SW-208-3) and one from a test pit dug in the wetland north of the pump station (TP 5). Metal concentrations in samples SW-208-1 & 2 were within the appropriate standards. The complete results are presented in Table 4.2.4 and the Technical Appendix.

Light extractable hydrocarbon product (EPH) was detected in the sample collected downstream from the site (SW-208-1). High concentrations of both LEPH and HEPH was detected in the water sample collected from TP 5. Both of these samples exceed analytical standard for petroleum hydrocarbon in water for Aquatic Life.



LEGEND

- Clearing
- Hydrocarbon Staining
- Surface Debris
- Drums (55 gallons)
- Vehicle Hulk
- Skid/Sled Frame
- Surface Drainage
- Drainage Ditch
- Swamp
- Ponded Water
- Contour
- SS ● Soil Sample
- TP ● Test Pit
- SW ▲ Water Sample
- VS ■ Vegetation Sample

Contour interval approximately 5 metre, determined through visual mapping.

Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800001

Sample Locations MP 208 NWT
Pump Station 6

Canol Road
Site Assessment

Gartner Lee

Figure No.
4.2.4

TABLE 4.2.1: SOIL CHEMISTRY - HYDROCARBON RESULTS
MP 208 - Pump Station #6

Parameter	Criterion [1]		SS 208-1	SS 208-2	SS 208-3	SS 208-4	SS 208-5	SS 208-6	SS 208-7	SS 208-8	SS 208-9	SS 208-10	SS 208-11
	Parkland	Industrial	Gravel clearing	Grease ramp area	Grease ramp area	Wetland E of	Test pit next to POL tank	SE of POL tank hill	E of barrel dump 'H'	Composite E of dump	Replicate of SS-208-C1	Cabooses W of site	Septic pit area
Physical Tests													
Moisture %	-		5.9	27.8	7.3	63.8	8.6	26.3	40.8	10.7	5.5	25.4	15.9
pH	-		-	-	-	-	-	-	6.04	-	-	-	-
Extractables													
EPH (C10-18) (~LEPH)	1000	2000	393	947	388	9200	3440	<200	<200	1170	256	<200	<200
EPH (C19-31) (~HEPH)	1000	5000	2020	2110	2800	11200	5190	<200	468	21900	6340	<200	<200

2413

Parameter	Criterion [1]		SS 208-12	SS 208-13	SS 208-14	SS 208-15	TP1 East	TP1	TP1	TP3	TP5	TP11	TP13
	Parkland	Industrial	Oil heater tank	Replicate of TP5	Background	Replicate of SS-208-7	End Fill Pipe UST	0-0.1 m UST	0.1-0.5 m UST	0-0.1 m Wetland	0-0.1 m Wetland	0-0.1 m Wetland	0-0.1 m Wetland
Physical Tests													
Moisture %	-		17.6	23.8	16.4	39.4	7.7	9.8	7.8	68.7	23	72.4	47.1
pH	-		7.5	-	-	6.15	-	-	-	6.62	-	-	-
Extractables													
EPH (C10-18) (~LEPH)	1000	2000	<200	468	<200	<200	1430	7050	428	59600	3930	3130	618
EPH (C19-31) (~HEPH)	1000	5000	<200	1520	<200	300	3930	18500	2570	61400	7930	4210	1140

Parameter	Criterion [1]		SS 208-A1	SS 208-A2	SS 208-B1	SS 208-B2	SS 208-C1	SS 208-C2	SS 208-D1	SS 208-D2	SS 208-E1	SS 208-E2	SS 208-F1	SS 208-F2
	Parkland	Industrial	Barrel dump 'A'	Barrel dump 'A'	Barrel dump 'B'	Barrel dump 'B'	Barrel dump 'C'	Barrel dump 'C'	Barrel dump 'D'	Barrel dump 'D'	Barrel dump 'E'	Barrel dump 'E'	Barrel dump 'F'	Barrel dump 'F'
Physical Tests														
Moisture %	-		6.1	6.3	37.1	12.4	6.1	5.9	12.7	8.6	10.8	40.3	20	8.1
pH	-		-	-	-	-	-	-	8.1	-	-	-	-	-
Extractables														
EPH (C10-18) (~LEPH)	1000	2000	<200	<200	<200	<200	329	<200	<200	<200	<200	<200	409	<200
EPH (C19-31) (~HEPH)	1000	5000	<200	<200	399	269	4490	4500	570	8960	1100	1870	7080	790

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).
"-" Denotes no analysis or standard.
"<" Denotes less than detection limit.
Exceeds CSR Standard for Parkland Use
Exceeds CSR Standard for Industrial Land Use.
Exceeds Special Waste Guideline
All concentrations in mg/kg (ppm)

TABLE 4.2.2: SOIL CHEMISTRY - METAL RESULTS
MP 208 - Pump Station #6

Parameter	Criterion[1] Parkland	Industrial	SS 208-7 Barrel dump 'H'	SS 208-12 Oil heater tank	SS 208-15 Replicate of SS-280-7	TP3 0 - 0.1 m Wetland	SS 208-D1 Barrel dump 'D'	SS-208-8 Composite E of dump	VS208-3 Sediment
Physical Tests									
Moisture %		-	40.8	17.6	39.4	68.7	12.7	8.1	24.7
pH		-	6.04	7.5	6.15	6.62	8.1	5.15	
Total Metals									
Antimony T-Sb	20	40	<20	<20	<20	<20	<20	<20	<20
Arsenic T-As	35[3]	150[3]	13	15	18	12	12	10	<100
Barium T-Ba	500	2000	1550	1250	1930	1250	1180	638	807
Beryllium T-Be	4	8	1.5	1.9	2	0.7	1	1	0.9
Cadmium T-Cd	250[3]	700[3]	1.7	1.4	3.8	3.6	0.9	1.1	<2
Chromium T-Cr	60-150[3]	60-500[3]	36	38	53	20	28	32	29
Cobalt T-Co	50	300	22	37	31	5	7	8	7
Copper T-Cu	100-150[3]	100-250[3]	28	14	35	23	22	16	15
Lead T-Pb	250-500[3]	250-1000[3]	<50	<50	<50	68	<50	<50	68
Mercury T-Hg	2	10	0.103	0.04	0.142	0.068	0.042	0.013	
Molybdenum T-Mo	10	40	<4	6	6	<4	<4	<4	<4
Nickel T-Ni	100	500	63	91	75	29	26	22	19
Selenium T-Se	3	10	2.3	1.4	3.4	2.2	0.4	0.3	<50
Silver T-Ag	20	40	<2	<2	<2	<2	<2	<2	<2
Tin T-Sn	50	300	<10	<10	<10	<10	<10	<10	<10
Vanadium T-V	200	-	110	116	167	70	104	72	82
Zinc T-Zn	150-450[3]	150-600[3]	391	633	458	188	99	93	111

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).
[2] Standard varies with soil pH.
[3] Environmental protection, toxicity to invertebrates and plants, or groundwater flow to surface water used by aquatic life
"-" Denotes no analysis or standard.
"<" Denotes less than detection limit.
Exceeds CSR Standard for Parkland Use
Exceeds CSR Standard for Industrial Land Use.
All concentrations in mg/kg (ppm)

TABLE 4.2.3: VEGETATION CHEMISTRY - METAL RESULTS
MP 208 - Pump Station #6

Parameter	VS 208-1 Willow	VS 208-2 Indian Tea	VS 208-3 Blueberry	VS-208-4 Cariboo Lichen	VS 280-5 Willow	VS 208-6 Willow	VS 208-7 Grasses
Physical Tests							
Moisture %	37.4	30.1	45.7	69.5	38.5	40	54.3
Total Metals							
Aluminum T-Al	17	50	77	250	39	126	56
Antimony T-Sb	0.18	0.21	0.41	0.17	0.07	0.15	0.32
Arsenic T-As	<0.05	<0.05	<0.05	0.22	<0.05	0.06	0.08
Barium T-Ba	31.3	221	146	72.6	14.7	60.8	130
Beryllium T-Be	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bismuth T-Bi	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium T-Cd	13.5	1.51	2.53	0.38	8.72	1.4	<0.03
Calcium T-Ca	4870	4650	3110	4080	3150	6070	7180
Chromium T-Cr	<0.5	0.5	0.7	2	1.2	1.2	<0.5
Cobalt T-Co	0.4	<0.1	<0.1	0.1	0.4	0.4	<0.1
Copper T-Cu	4.44	4.49	9.65	1.58	3.94	3.14	0.88
Iron T-Fe	-	-	-	-	-	-	-
Lead T-Pb	<0.1	0.3	0.6	2	0.1	1	0.7
Lithium T-Li	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Magnesium T-Mg	927	730	1100	654	1010	1200	2860
Manganese T-Mn	136	93.2	511	18	56.4	158	294
Molybdenum T-Mo	0.15	0.18	0.31	0.71	0.68	0.17	0.29
Nickel T-Ni	4.2	1.9	1.2	1.4	4.5	0.8	0.3
Phosphorus T-P	-	-	-	-	-	-	-
Potassium T-K	-	-	-	-	-	-	-
Selenium T-Se	<1	<1	<1	<1	1	<1	<1
Silver T-Ag	-	-	-	-	-	-	-
Sodium T-Na	-	-	-	-	-	-	-
Strontium T-Sr	13.6	17.8	6.34	5.49	6.99	11.3	12.7
Thallium T-Tl	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Tin T-Sn	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Titanium T-Ti	-	-	-	-	-	-	-
Uranium T-U	<0.01	<0.01	<0.01	0.02	<0.01	0.01	<0.01
Vanadium T-V	<0.5	<0.5	<0.5	1.2	<0.5	<0.5	<0.5
Zinc T-Zn	212	85	64	23.6	189	73.9	36

All concentrations in mg/kg (ppm)

TABLE 4.2.4: WATER CHEMISTRY RESULTS
MP 208 - Pump Station #6

Parameter	Criterion [1] Aquatic Life	Criterion [1] Drinking Water	SW 208-1 Downstream	SW 208-2 Upstream	SW 208-3 Wetland pond	TP 5 Wetland testpit
Physical Tests						
Hardness $CaCO_3$	-	-	84	75.9	-	-
Total Metals						
Aluminum T-Al	0.050 - 0.5 [2]	0.2	<0.005	0.012	-	-
Antimony T-Sb	0.3	-	<0.2	<0.2	-	-
Arsenic T-As	0.5	0.025	<0.2	<0.2	-	-
Barium T-Ba	10	1	0.23	0.23	-	-
Beryllium T-Be	0.053	-	<0.005	<0.005	-	-
Boron T-B	-	5	<0.1	<0.1	-	-
Cadmium T-Cd	0.002 - 0.018 [3]	0.005	<0.0002	<0.0002	-	-
Calcium T-Ca	-		25.3	23.4	-	-
Chromium T-Cr	0.02	0.05	<0.01	<0.01	-	-
Cobalt T-Co	0.5		<0.01	<0.01	-	-
Copper T-Cu	0.020 - 0.09 [3]	1	<0.01	<0.01	-	-
Iron T-Fe	3	0.3	<0.03	0.1	-	-
Lead T-Pb	0.040 - 0.16 [3]	0.01	<0.001	0.001	-	-
Magnesium T-Mg	-		5	4.2	-	-
Manganese T-Mn	1	0.05	<0.005	<0.005	-	-
Mercury T-Hg	0.001	0.001	<0.00005	<0.00005	-	-
Molybdenum T-Mo	10	0.25	<0.03	<0.03	-	-
Nickel T-Ni	0.250 - 1.5 [3]	-	<0.05	<0.05	-	-
Selenium T-Se	0.01	0.01	0.001	0.001	-	-
Silver T-Ag	0.001	-	<0.0001	<0.0001	-	-
Thallium T-Tl	0.003	-	<0.002	<0.002	-	-
Uranium T-U	-		0.00048	0.00045	-	-
Zinc T-Zn	0.3	5	<0.005	0.006	-	-
Extractables						
EPH (C10-18)	0.5		0.6	<0.5	<0.5	10
EPH (C19-31)	no free product		<1	<1	<1	12

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).

[2] Standard varies with water pH.

[3] Standard varies with water hardness.

" - " Denotes no analysis or standard.

" < " Denotes less than detection limit.

[box] Exceeds CSR Standard for Aquatic Life.

[box] Exceeds CSR Standard for Drinking Water.

TABLE 4.2.5: HYDROCARBON CHARACTERIZATION
MP 208 - Pump Station #6

Parameter	HC 208-1 Grease spill E of powerhouse	HC 208-2 Dried curde oil near POL tank	HC 208-3 Grease pot in truck box	HC 208-4 Motor oil? from dump 'F'	HC 208-5 Black oil from dump 'H'	HC 208-6 Product from UST
Physical Tests						
Flashpoint Degrees C.	>61	>62	>63	-	-	-
Moisture %	<0.1	<0.1	<0.1	-	-	-
Total Metals						
Arsenic T-As	0.3	31	0.12	<4	<4	<4
Cadmium T-Cd	14	<0.3	<0.3	<1	<1	<1
Chromium T-Cr	<2	11	<2	<1	<1	<1
Lead T-Pb	17	114	5	<1	<1	61
Polychlorinated Biphenyls						
Total Polychlorinated Bipheny	-	-	-	<2	<2	<2
Extractables						
EPH (C10-18)	17200	125000	33900	-	-	-
EPH (C19-31)	373000	206000	450000	-	-	-
Organic Parameters						
Total Organic Halide	-	-	-	<300	<300	<300

" - " Denotes no analysis or standard.
" < " Denotes less than detection limit.
Exceeds CSR Standard for Agricultural Land Use
Exceeds CSR Standard for Parkland Use.
Exceeds Special Waste Criteria
All concentrations in mg/L (ppm)

Hydrocarbon Products

Six samples of hydrocarbon products were submitted for characterization. Samples with greater than 3% hydrocarbon content are considered "Special Wastes" and therefore are subject to the Yukon's Special Waste Regulations. The samples were subject to waste oil characterization suite of test to determine acceptable disposal options. All the liquid samples (HC-208-4,5, and 6) are acceptable for use as application to roads as pavement, or as cement kilm fuel as defined in the B.C. Waste Management Act (1995). The samples collected from dried or desiccated hydrocarbon products had elevated metal contents, making them unsuitable for the above disposal options. Crude oil tars, such as sample HC-208-2 are discussed further in section 5.5 of this report. The complete results are presented in Table 4.2.5 and the Technical Appendix.

Asbestos

A single sample for asbestos analysis was collected from hot water line insulation near sample SS-208-12, adjacent to the oil heater tank. This sample indicated that the insulation was fiberglass and not asbestos bearing. The complete results are presented in the Technical Appendix.

4.2.3 Discussion

The field observations at this site show that there is a significant amount of unsightly waste and debris. In addition to 45-gallon drums and vehicle hulks, the site contains collapsed and burnt buildings, cabooses, domestic garbage and 6-inch pipeline.

Barrels Containing Hydrocarbon Products

Preliminary examination of barrels on site identified numerous 15 and 45-gallon drums containing what appears to be hydrocarbon product. These include locations outlined below.

Location	Sample ID (if collected)	Number and Description
Dump 'F'	HC-208-4	**3** 15-gallon drums full of "motor oil" **>10** crushed 15-gallon drums partially (<10%) full of "motor oil"
Dump 'D'		**1** open drum of grease
East of Pump Station	HC-208-1	**3** 45-gallon drums full of "motor oil" **1** partially full (<10%) drum of grease
Dump 'H' (near POL tank)	HC-208-5	**17** 45-gallon drums partially (<10%) full of "crude oil"

The above inventory is not exhaustive. Only a small portion of 45-gallon drums found on site were checked, and the above findings are a summary of that work. Drums checked on site were marked with an 'O' if containing what appeared to be hydrocarbon product, or occasionally an 'X' for empty.

Petroleum, Oil and Lubricants (POL) Tank

The POL tank contains between 1200 L and 2400 L of crude sludge in the tank. There is a small area of desiccated crude oil tar near the inspection port. Sample HC-208-2 was collected from this desiccated material and has 1.2% LEPH content and 2% HEPH content. The gravelly soils under tank appear to be contaminated above Industrial Standard for both LEPH and HEPH (sample SS-208-5). The shallow soils south and east (samples SS-208-6 & 7) of the POL tank hill do not contain concentrations of LEPH/HEPH in excess of parkland standards.

Based upon the field investigations and analytical testing, there are two major areas of contamination concern (AOC A and B). Area of Concern A is the heavily contaminated soil associated with the pump station and UST. The second Area of Concern, (AOC B) is the contaminated soils associated with barrel dumps C, D, E, and F.

Area of Concern A – UST, Pump Station and Wetlands

Samples from the surface immediately around the UST (samples TP1 East end fill pipe and TP1 0-0.1) showed high concentrations of extractable petroleum hydrocarbons. Sample TP1 0-0.1m has heavy EPH concentrations up 1.8% of the total sample. Sample TP1 0.1-0.5 collected from the side and base of the tank only exceeded the Parkland Standard for HEPH. This suggests that contamination attenuates with depth and that the soils under the UST may not be as heavily impacted as the shallow surface soils. As the UST is still full of product, the tank is likely still intact and may not be leaking. Contamination of the surface soil may have come from overflowing of the tank from the fill pipes.

A series of 13 shallow test pits were dug by hand shovel in the wetland area north of the pump station and UST. This area is the immediate receiving environment for spills that have been associated with the pump station since it is a topographic low adjacent to the station. The locations of these pits are shown in detail 208A on Figure 4.2.4. The test pits immediately adjacent to the UST had a strong hydrocarbon odour, and were heavily stained. The observations of contamination decreased further from the UST (i.e. TP9). Shallow samples from TP3, TP5, TP11 and TP13 were submitted for analytical testing, and all contained EPH concentrations in excess of the Parkland Standard. TP3, which was less than 10 m northeast of the UST, showed the highest hydrocarbon concentrations, up to 5.9% LEPH content and 6.1% HEPH. This sample is considered Special Waste. Based on site hydrogeology, it is interpreted that the flow direction from the UST would be east and northeast, parallel with and towards the creek. Concentrations of hydrocarbon in other pits decreased with distance from the UST and support this interpreted flow direction. The lowest hydrocarbon levels detected in the wetland were 1140 ppm HEPH in TP13. TP13 is less than 20 m from the UST, but may lie in a slightly up-gradient direction.

A single shallow test pit sample (SS 208-4) was collected from a wetland lying between the pump house and the POL tank. This wetland is down-gradient of the pump station. The sample, SS-208-4, contains a high hydrocarbon concentrations, up to 1.1% HEPH. The field observations and sample gas chromatograph indicate that this is a similar type of contamination found in the wetland north of the pump house. The water sample collected from the pond in this area (SW-208-3) did not detect petroleum hydrocarbon.

The contamination in the area may have resulted from the salvage of pumps and piping between the POL tank and the pump station. When this equipment was removed, the POL tank may have drained through the piping into the wetland areas and/or overflow from the underground storage tank. The gas chromatographs for all the samples in this area (TP1, TP3, TP11, TP13, HC-208-2, and SS-208-4) show a similar pattern similar to that of crude oil. Sample CH-208-2 is assumed to be an aged sample of the crude which leaked from the POL tank. All the chromatographs for these samples are found in the Technical Appendix.

Area of Concern B – Barrel Dump Area.

The second area of extensive soil contamination is associated with barrel dumps C, D, and F. Samples from the dump C area both exceeded Parkland standard for HEPH. The grease barrels at dump D have mostly been removed since 1994 and there are areas of dried grease that the bears have been eating and scratching. One soil sample from the dump D area exceeded the Industrial standard for HEPH. An open full grease barrel was found between dump D and dump F.

East of the dump F area is an area of extensive hydrocarbon staining. This area is approximately 10 m x 20 m. A composite sample (SS-208-8) from six grid locations across this area yielded LEPH concentrations exceeding the Parkland Standard, and HEPH concentrations exceeding the Industrial Standard (2% heavy extractable hydrocarbon by weight). Many of the barrels in dump F contained what appears to be motor oil (sample HC-208-4), including at least three full 15-gallon drums.

A sample (CAN-124) from this same area collected by Royal Roads (1994) had lead concentrations of 3000ppm, which exceeds the Industrial Standard for lead. Sample SS-208-8 was collected by the field team in 1998 from the same location and using the same methodology as CAN-124. This sample did not duplicate the elevated lead concentrations reported by Royal Roads. The cause of this is unknown, but due to the anomalous nature of the metal content in CAN-124, it is suspected that this could be due to an error in sample collection and/or analysis.

Soil Metal Content

All samples analyzed for metal content exceeded the Parkland standard for barium. When compared to the nearby Regional Geochemical Stream Sediment (RGS) samples, background concentrations of barium are shown to range from 2200 to 3500 mg/kg, which is naturally above the Contaminated Sites Regulation standards for barium. Zinc was also found to exceed Industrial soil standard for groundwater flow to surface water used by aquatic life at two sample localities. These samples ranged from 391 to 633 mg/kg. Royal Road analyzed 14 samples for metal content at this site (1994). They found the mean zinc concentration at this site was 142 mg/kg with a maximum concentration of 320 ppm and minimum concentration of 27 ppm. This mean value almost exceeds the Industrial numeric soil standard for zinc as described above. The source of the elevated zinc encountered near the oil heater tank (sample SS-208-12) and at barrel dump 'H' (samples SS-208-7 and SS-208-15) cannot be explained at this time.

Surface Water

Water sample SW-208-1 was collected from downstream of the MP 208 site. This sample detected LEPH concentrations slightly above the standard for Aquatic Life, which is 0.5 mg/L. 0.5 mg/L is also the detection limit for the test conducted, and therefore there is uncertainty in an analysis this close to the detection limit. The chromatograph for this sample (see the Technical Appendix) does have petroleum hydrocarbon spikes. The up gradient sample (SW-208-2) did not detect hydrocarbon, but the chromatograph does show similar peaks. This indicates that the hydrocarbon detected in the downstream sample may possibly be attributed to natural humic substances.

Vegetation Samples

Elevated levels of cadmium were found in excess of the background and Impact Criteria willow and blueberry samples at this site. Similar elevate results were noted by Royal Roads' in 1994 and they suggest:

> "Species of *Salix* have been shown to naturally accumulate cadmium (Reimer et al., 1993a). In fact, a background sample *Salix glauca* taken 1 km from Mile 208 contained 5.4 ppm cadmium, a concentration comparable with those found on the site. This observation, coupled with the fact that soils taken from the same sample sites showed levels comparable to background, indicates that these high plant cadmium concentrations are authogenic." (Royal Roads. 1994, p. V1-159)

Zinc concentrations in three samples were also at elevated levels above the background sample, but less than the Impact Criteria.

The above metal concentrations were found in mostly in the low lying area adjacent to the site creek. Samples VS-208-1 & 2 were near the POL tank, where sample VS-208-5 was near the oil heater tank. The elevated metal concentration therefore may be due to stream sediment geochemistry, or related to oil handling operation. Note that the willow sample VS-208-6 was collected from the heavily oil contaminated wetland, but did not show elevated metal concentrations. This indicates that oil spills may not result in metal contamination of the vegetation.

Human Health and Safety

Of human health and safety concerns, the pump station and bath house are falling into disrepair and may collapse under winter snow load. The pump station also contains asbestos wall board as identified by Royal Roads (1994). They found that the pump station buildings were the only buildings to contain asbestos. The Quonset huts on site are collapsing and unstable. There is a danger of people and wildlife falling into the "septic pit' adjacent to the bath house and becoming either injured or trapped.

4.2.4 Conclusions

Based on the findings of the site investigation, the following conclusions can be made:

a) soils in the wetland areas north and east of the pump station have (Area of Concern A) been impacted by petroleum hydrocarbons at concentrations which exceed the Special Waste guidelines;
b) soils in the barrel dump C, D and F area (Area of Concern B) have been impacted by petroleum hydrocarbons and lead at concentrations which exceed the Industrial standard;
c) a UST with approximately 500 L of what appears to be crude oil or an oil/water emulsion is located adjacent to the northwest corner of the pump station and surface soils have been impacted by petroleum hydrocarbons at concentrations which exceed Industrial standard;
d) at least 35 barrels of hydrocarbon products were found full or partially full on site and many are open to wildlife;
e) the POL tank contains between 1200 L and 2400 L of crude oil sludge, and the soils below to the tank have been impacted by petroleum hydrocarbons at concentrations which exceed the Industrial standard;
f) barium concentrations found in soils are related to naturally occurring conditions;
g) zinc concentrations have been found to exceed the Industrial standard at two location; the source of this contamination is undetermined;
h) petroleum hydrocarbon concentrations exceed the Aquatic Life standard in the creek have been detected down gradient from the site; and
i) there is a large accumulation of metal and domestic debris at this site.

4.2.5 Recommendations

The following recommendations are made based on the conclusions outlined above:

1. complete a screening level *quantitative* human health risk assessment of petroleum hydrocarbons in soil which provides estimates of human health risks for use of the site (*e.g.*, parkland uses);
2. complete a screening level *quantitative* ecological risk assessment of petroleum hydrocarbons in soil which provide estimates of ecological risks for Valued Ecosystem Components that are identified in the area;
3. clean out, remove and destroy the UST;
4. clean-up the contaminated soils surround the UST;
5. remove barrels containing hydrocarbon products from site;
6. remove the hydrocarbon sludge from and decommission the POL tank; clean-up the associated contaminated soils;
7. conduct further sampling to determine the extent of contamination in Area of Concern A associated with the Pump Station;
8. conduct further sampling to determine the extent of contamination in Area of Concern B associated with the barrel dumps;
9. fill in septic pit to eliminate human and wildlife health and safety risks;
10. follow-up creek water sampling; including sampling after remediation efforts;
11. have a structural engineer assess stability of site buildings & recommend stabilization strategy to protect structure of potential historic value;
12. clean-up soils associated with grease ramp area;
13. general site clean-up of debris; and
14. leave features, structures and materials on site that have identified historic value.

4.3 MP 207.5 – Laydown Area

4.3.1 Physical Setting

General Description

The site consists of a flattened gravel hill top approximately 500 m south east of Pump Station 6 at MP 208 (Figure 4.2.1) and was described by Royal Roads (1994) as a "Laydown area". The site is situated on a rolling north facing slope. The creek from the pump station flows out of the canyon to the west, and along the base of the hill towards a larger creek referred to as "207-Mile Creek". The Canol Trail crosses 207-Mile Creek approximately 500 m east the MP 207.5 site. The site is located on the north side of the Canol Trail, approximately 30 m above a broad creek valley to the north.

The site (Figure 4.3.1) consists of a small gravel hill that has been flattened to create a level surface approximately 60 m x 80 m. There are 11 vehicle hulks parked on the site, as well as bulldozer and vehicles. Debris is scattered over the site, including 45-gallon drums and some broken tractor batteries. Lubricant dispensing equipment lies in the southeast corner of the site. Metallic and woody debris has been pushed over the edge of the hill, and litters the base and sides of the site

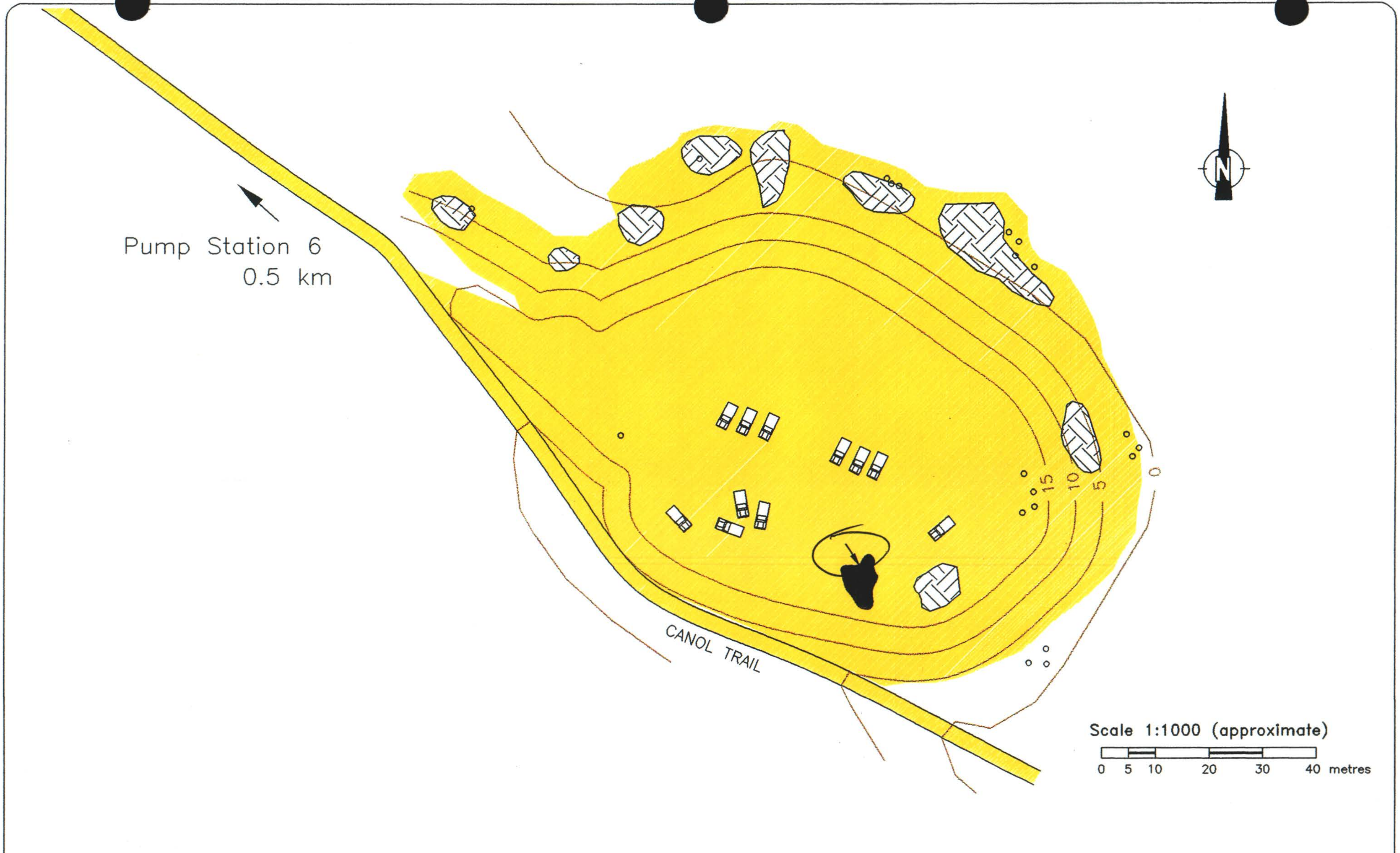
An area of dark hydrocarbon staining was found at the southeast corner of the site and is interpreted to be the former site of Royal Road's (1994) Barrel area 'G'. The drums they identified are no longer on site.

Geology

Airphoto interpretation (Figure 4.2.3) indicates that the hill may be a deposit of glacial fluvial gravel. The feature is interpreted to be a kame terrace. These pea-gravel sized sediments were deposited by streams flowing from, or in direct contact with glacial ice. The site area is interpreted to be a naturally occurring gravel terrace that has been flattened for road construction use. The surrounding hillside is an undulating morainal blanket of silts, gravel and large boulders. There are alluvial/glaciofluvial flats north of the site through which modern steams flow.

Surface Water

No surface water was observed on site. The stream from the Pump Station 6 site flows east from a valley down around the base of the hill on which the site is located. This stream flows northeast from the site to join 207-Mile Creek (see Figure 4.2.1). 207-Mile Creek is said by local people to have Arctic Grayling and Trout. A small run-off channel lies east of the site and drains a broad ravine to the south.



LEGEND

- Clearing
- Hydrocarbon Staining
- Surface Debris
- Drums (45 gallons)
- Vehicle Hulk
- Surface Drainage
- Drainage Ditch
- Swamp
- Ponded Water
- Contour

Contour interval approximately 5 metres, determined through visual mapping.

Drawn by: BB/FP
GLL Project Number: 98–800
File Name: 98800001

Site Map MP 207.5 NWT
Laydown Area

Canol Road
Site Assessment

Gartner Lee

Figure No.
4.3.1

Hydrogeology

No groundwater was encountered on site. This is due in part to the site's high relief relative the alluvial plain to the north. Furthermore, the permeable nature of the gravelly soils result in the site being well drained. The water table is interpreted to be near the base of the hill, some 30 metres down. The direction of groundwater flow is interpreted to follow the valley's topography, flowing northward towards the creeks in the valley.

Vegetation

The site is un-vegetated and consists of a bare gravel surface. This is interpreted to be due to the permeable nature of the exposed gravel and lack of proper mineral soil. Willow and dwarf birch is found growing on the slopes around the hill. Vegetation on undisturbed hill sides near the site consists of the typical alpine community of willow, dwarf birch with undergrowth of lichens and occasional shrubs such as blueberries.

4.3.2 Test Results

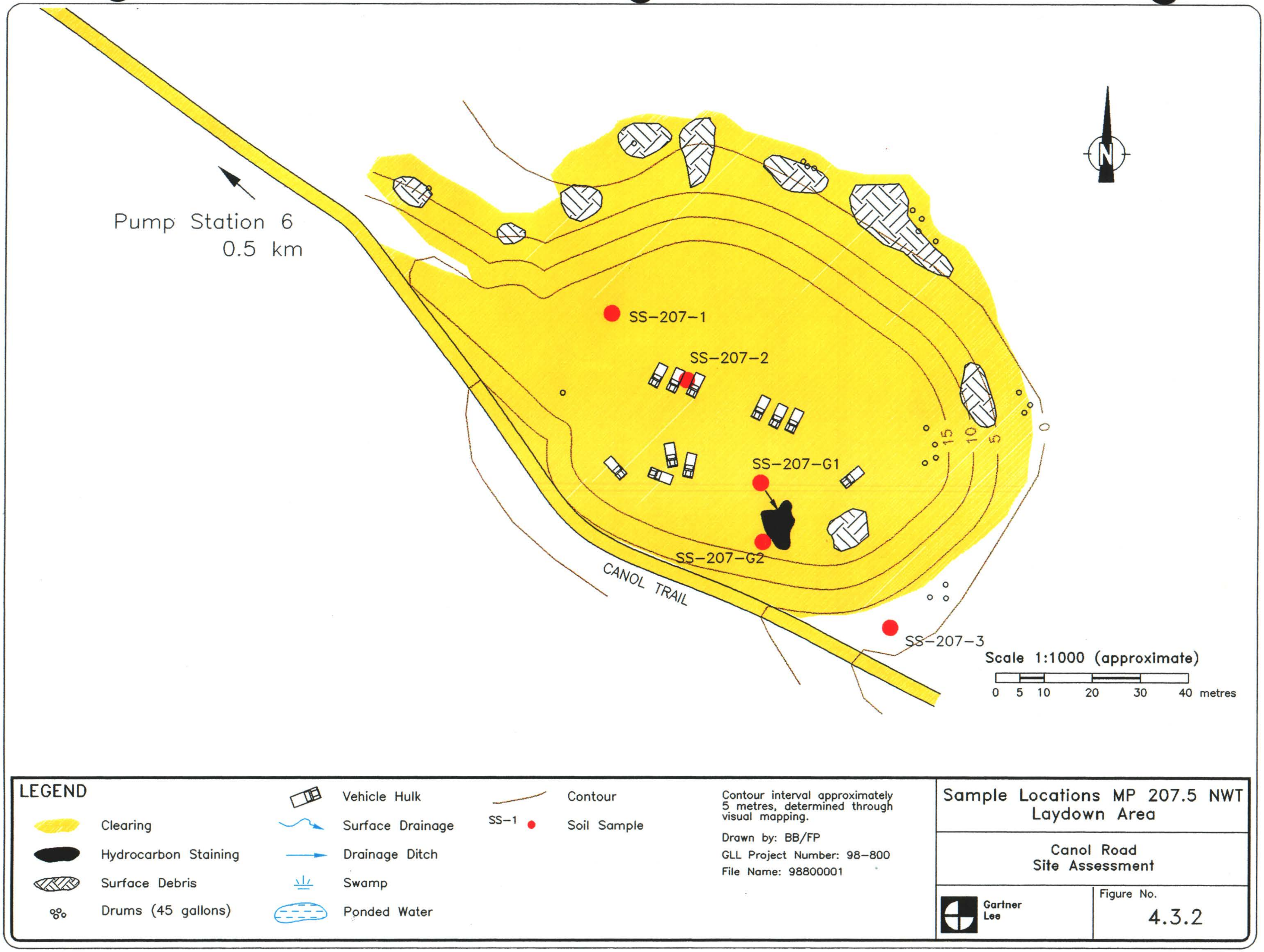
Soil samples were collected at the site and the location of the samples is shown on Figure 4.3.2. A complete sample list is found in the Technical Appendix.

Soil Chemistry

Selected soil samples were submitted to the analytical laboratory for analysis of potential contaminants of concern as identified in section 3.3.2, Analytical Program. This section provides a summary of the analytical results with the complete results presented in Tables 4.3.1 and 4.3.2 and the Technical Appendix.

Petroleum hydrocarbons were detected in one of the soil samples analyzed. Heavy extractable hydrocarbon products (HEPH) exceeded Parkland standard in samples SS-207-G1

One sample was analyzed for metals. Samples SS-207-1 was collected adjacent to tractor battery fragments. The sample detected lead and barium concentrations in excess of the Parkland Standard and antimony in excess of the Industrial standard although the barium concentration is typical of the background concentrations in the region.



Pump Station 6
0.5 km
SS-207-1
SS-207-2
SS-207-G1
SS-207-G2
SS-207-3
CANOL TRAIL
15
10
5
0
N
Scale 1:1000 (approximate)
0 5 10 20 30 40 metres
LEGEND
Clearing
Hydrocarbon Staining
Surface Debris
Drums (45 gallons)
Vehicle Hulk
Surface Drainage
Drainage Ditch
Swamp
Ponded Water
Contour
SS-1
Soil Sample
Contour interval approximately 5 metres, determined through visual mapping.
Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800001
Sample Locations MP 207.5 NWT
Laydown Area
Canol Road
Site Assessment
Gartner Lee
Figure No.
4.3.2

TABLE 4.3.1: SOIL CHEMISTRY - HYDROCARBON RESULTS

MP 207.5 - Laydown Area

Parameter	Criterion [1]		SS 207-1 Gravel near battery	SS 207-2 Gravel soil near	SS 207-3 Base of hill	SS 207-G1 Composite over dump 'G'	SS 207-G1 0.3 - 0.4 m dump 'G'
	Parkland	Industrial					
Physical Tests							
Moisture %	-		5.7	7.6	12.8	6.6	6
pH	-		7.68	-	-	-	-
Extractables							
EPH (C10-18) (~LEPH)	1000	2000	<200	<200	<200	<200	<200
EPH (C19-31) (~HEPH)	1000	5000	<200	<200	<200	2780	<200

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).

" - " Denotes no analysis or standard.

" < " Denotes less than detection limit.

Exceeds CSR Standard for Parkland Use

Exceeds CSR Standard for Industrial Land Use.

All concentrations in mg/kg (ppm)

TABLE 4.3.2: SOIL CHEMISTRY - METAL RESULTS
MP 207.5 - Laydown Area

Parameter	Criterion [1]		SS 207-1 Gravel near battery
	Parkland	Industrial	
Physical Tests			
Moisture %	-		5.7
pH	-		7.68
Total Metals			
Antimony T-Sb	20	40	142
Arsenic T-As	35 [3]	150 [3]	14
Barium T-Ba	500	2000	536
Beryllium T-Be	4	8	1
Cadmium T-Cd	250 [3]	700 [3]	2.6
Chromium T-Cr	60-150 [3]	60-500 [3]	26
Cobalt T-Co	50	300	7
Copper T-Cu	100-150 [3]	100-250 [3]	33
Lead T-Pb	250-500 [3]	250-1000 [3]	8370
Mercury T-Hg	2	10	0.061
Molybdenum T-Mo	10	40	<4
Nickel T-Ni	100	500	28
Selenium T-Se	3	10	0.5
Silver T-Ag	20	40	<2
Tin T-Sn	50	300	<10
Vanadium T-V	200	-	110
Zinc T-Zn	150-450 [3]	150-600 [3]	113

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; I

[2] Standard varies with soil pH.

[3] Environmental protection, toxicity to invertebrates and plants, or groundwater flow to surface water used by aquatic life.

" - " Denotes no analysis or standard.

" < " Denotes less than detection limit.

[box] Exceeds CSR Standard for Parkland Use

[box] Exceeds CSR Standard for Industrial Land Use.

4.3.3 Discussion

Barrel dump 'G' as identified by Royal Roads has been removed since their 1994 investigation. An area of stained soils indicates the former site of this dump area. Sample SS-207-G1 was a composite surface sample of the stained area and indicates impact by petroleum hydrocarbons. A deeper sample (SS-207-G2) was collected from 0.3 to 0.4 m below the surface and did not contain petroleum hydrocarbons, indicating that the spillage may not have penetrated deep into the soil. Petroleum hydrocarbons were not detected in other samples as measured by EPH analysis.

The high lead and antimony concentrations found in sample SS-208-1 may be related to the broken tractor battery at the site. If this is the case, the level of contamination would be localized to the battery area.

Terrain analysis indicates that this site is a naturally occurring hill. The site was most likely created by flatting the hill either for a source of road aggregate and/or a level area for equipment storage and maintenance. The debris seen on the side of the hill was deposited by pushing it over the side of the bank.

4.3.4 Conclusions

Based on the findings of the site investigation, the following conclusions can be made:

a) the site is a modified or flattened naturally occurring glaciofluvial kame terrace;
b) surface soils at the former barrel dump 'G' area have been impacted by petroleum hydrocarbon at concentrations which exceed the Parkland standard; and
c) lead and antimony contamination in excess of the Industrial standard have been detected at the west end of the site and are likely related to disintegration of batteries.

4.3.5 Recommendations

The following recommendations are made based on the conclusions outlined above:

1. cleanup oil contaminated soils associated with the former barrel dump 'G';
2. cleanup metal contaminated soils associated with broken batteries;
3. general site clean-up of debris associated with site cleanup at Pump Station 6; and
4. leave feature, structures and materials on site that have identified historic value.

4.4 MP 210 – Old Squaw Barrel Dump (Royal Roads Site 18)

4.4.1 Physical Setting

MP 210 is located 34 km east along the Canol Trail from the Yukon, NWT border and 4 km east past Old Squaw Lodge. (Figure 4.4.1). The origin of this site is not related to the modern or historic operations at Old Squaw Lodge, only that it is located near the Lodge. The site has previously been identified in Royal Roads' 1994 report as "Site 18". The site is located on a high rolling alpine plain. Site topography is a gentle south and west sloping hill. The Canol Trail crosses a small creek approximately 400 m west of the site.

This site appears to be in no way associated with the current activities at Old Squaw Lodges. The site has been titled "Old Squaw Barrel Dump" for ease of reference due to its proximity to the Old Squaw Lodge site.

The site (see Figure 4.4.2) is located on both sides of the east-west running Canol Trail. Debris at the site consists of three large piles of barrels called Barrel dumps A, B, and C. Royal Roads (1994) and Bowen (1994) have provided estimates of 427 to 432 drums at this site; 200 at dump A, 210 at dump B, and 22 in dump C. The vehicle hulks and building remains described by Royal Roads (1994) were not found at the site.

There are several campsites at the west end of the site on both sides of the road. These campsites consist of a flattened area for vehicle parking and erecting canvas wall tents. Poles and stakes for erecting the tents were found on site. The campsite appears to be regularly used.

Barrel dump A is the eastern most dump and is located on the south side of the road. A partially full drum of grease was found here, but the majority of the drums appeared to be empty. Barrel dump B is the largest barrel cache and is located 60 west of dump A. Dump B consists of three piles of drums scattered along 50 m of trail. Dump C is a small pile of drums 20 m west of dump B.

Geology

The site consists of a gently rolling blanket of till. This material is directly deposited from glacial ice and consists of silts, sand, gravel and large boulders. Terrain interpretation is shown of Figure 4.3.3. It is interpreted that this material is overlying the native bedrock. To the west of the site in the creek drainage, soils are interpreted to be finer grained and more organic in content. Permafrost is likely to be encountered near surface.

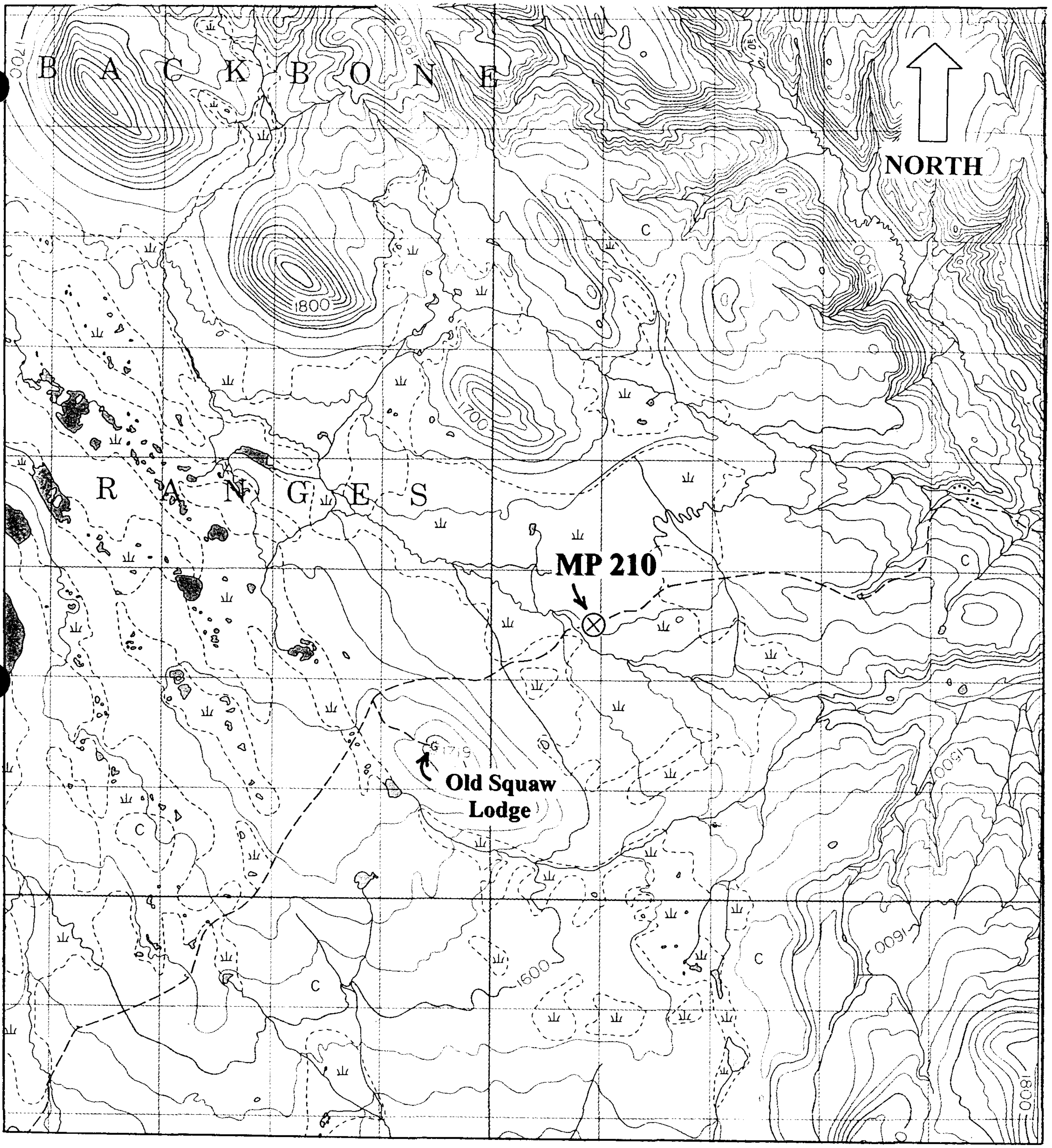
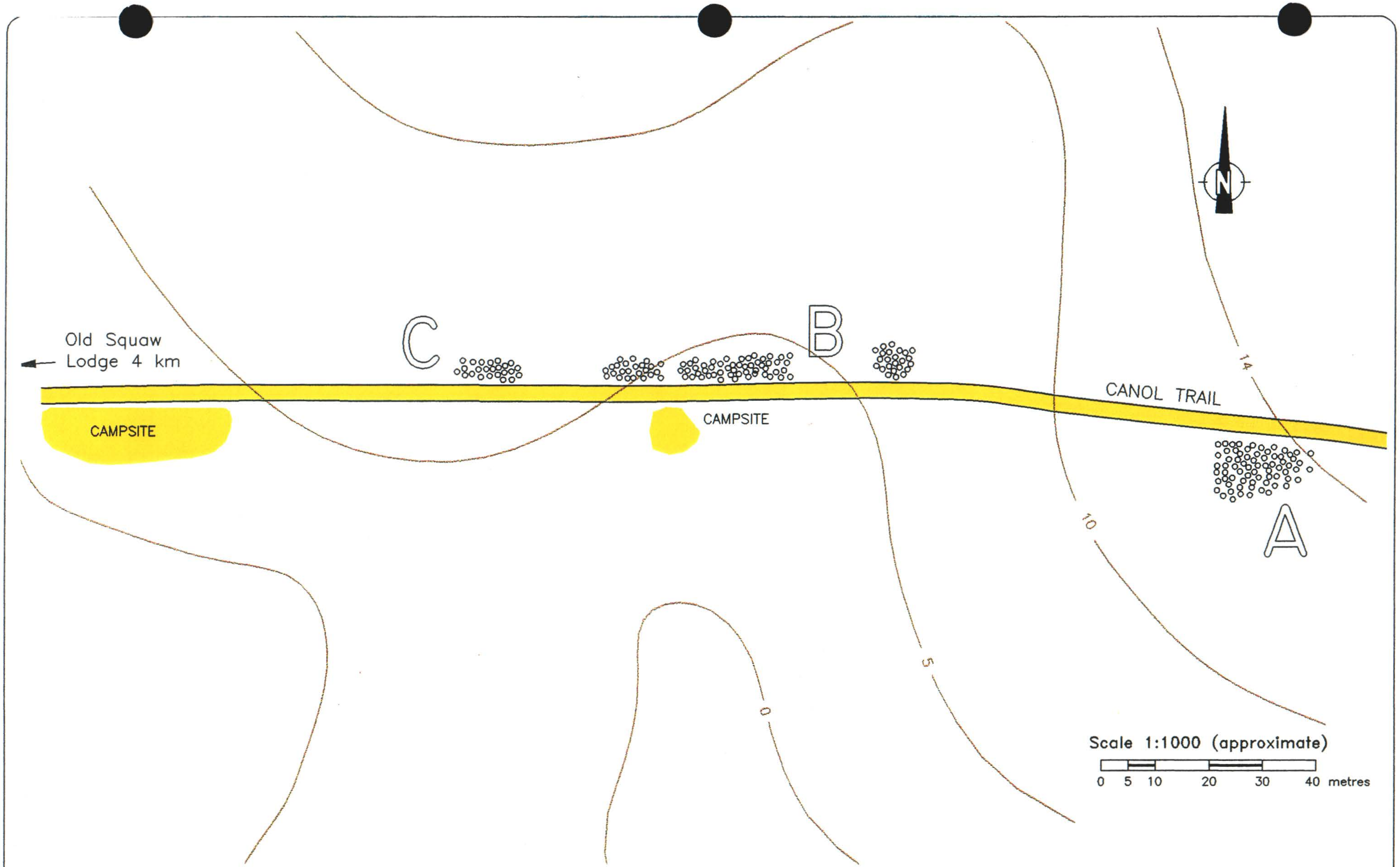


FIGURE 4.4.1: MP 210 SITE LOCATION

LEGEND:	SCALE 1:50,000	OLD SQUAW BARREL DUMP MILE POST 210
⊗ SITE LOCATION	1500M 0 1500M 1CM = 500 M	1998 ENVIRONMENTAL INVESTIGATIONS MACMILLAN PASS, NWT
SOURCE: NTS 105 P/5	DRAWN BY: F. PEARSON PROJECT NO.: 98-800 APPROVED BY: FILE NAME: F4_4_1.DWG DATE: 01/04/99	Gartner Lee FIGURE NO.: 4.4.1



LEGEND

Clearing	Vehicle Hulk	Contour
Hydrocarbon Staining	Surface Drainage	Drum Dump I.D.
Surface Debris	Drainage Ditch	
Drums (45 gallons)	Swamp	
	Ponded Water	

Contour interval approximately 5 metres, determined through visual mapping.

Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800001

Site Map MP 210 NWT
Barrel Dump

Canol Road
Site Assessment

Gartner Lee

Figure No.
4.4.2

FIGURE 4.4.3: MP 210 TERRAIN INTERPRETATION

LEGEND:	SCALE 1:30,000	OLD SQUAW BARREL DUMP MILE POST 210
SITE LOCATION	750M 0 750M 1CM = 300 M	1998 ENVIRONMENTAL INVESTIGATIONS MACMILLAN PASS, NWT
SOURCE: NAPL A25766-12	DRAWN BY: F. PEARSON / PROJECT NO.: 98-800 APPROVED BY: / FILE NAME: F4_4_3.DWG DATE: 01/04/99	Gartner Lee / FIGURE NO.: 4.4.3

Surface Water

No surface water was encountered on site, although a small creek flows south approximately 400 m west of the site. This creek is shown on Figure 4.3.3. A low swale drains the site to the south and east. Spring run-off water may flow down through this topographic low, but was dry during the time of the field investigation.

Hydrogeology

Groundwater water was not encountered in test pits. It is interpreted that groundwater flow follows topography to the south and west towards the creek. Permafrost is anticipated near surface, and therefore perched groundwater may overly the permafrost layer.

Vegetation

Sparse vegetation at this site consisted of the typical alpine community encountered elsewhere in the project and consisted of dwarf birch and willow with ground cover of reindeer lichen, grasses and small shrubs.

4.4.2 Test Results

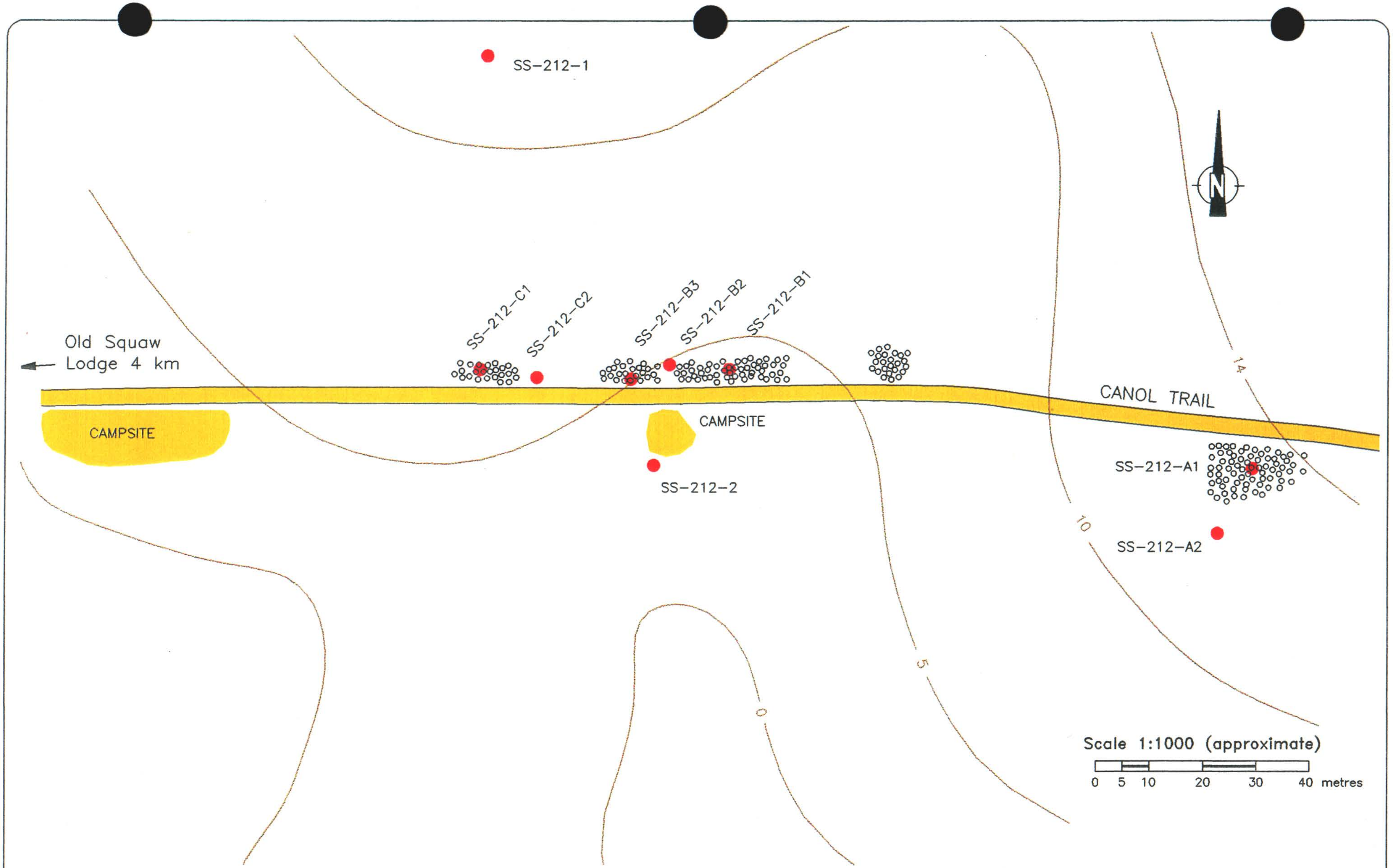
Soil and vegetation samples were collected at the site. The location of the samples is shown on Figure 4.4.4. A complete sample list is found in the Technical Appendix.

Soil Chemistry

Selected soil samples were submitted to the analytical laboratory for analysis of potential contaminants of concern as identified in section 3.3.2, Analytical Program. This section provides a summary of the analytical results with the complete results presented in Tables 4.2.1 and 4.2.2 and the Technical Appendix.

Heavy extractable petroleum hydrocarbons (HEPH) concentrations exceeding the Parkland Standard were detected in two samples. HEPH concentrations were detected in a third sample, but did not exceed the standards.

One sample was analyzed for metals. The analytical results show concentrations of Barium exceeded Parkland Standard in the samples. This concentration may be related to regional geochemistry.



LEGEND

- Clearing
- Hydrocarbon Staining
- Surface Debris
- Drums (45 gallons)
- Vehicle Hulk
- Surface Drainage
- Drainage Ditch
- Swamp
- Ponded Water
- Contour
- SS-1 Soil Sample

Contour interval approximately 5 metres, determined through visual mapping.

Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800001

Sample Locations MP 210 NWT Barrel Dump

Canol Road
Site Assessment

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Figure No. 4.4.4

TABLE 4.4.1: SOIL CHEMISTRY - HYDROCARBON RESULTS

MP 210 - Old Squaw Barrel Dump

Parameter	Criterion [1]		SS 212-1 Background (north)	SS 212-2 Downgradient (south)	SS 212-A1 Barrel dump 'A'	SS 212-A2 Down hill of dump 'A'	SS 212-B1 Barrel dump 'B'	SS 212-B2 Barrel dump 'B'	SS 212-B3 Barrel dump 'B'	SS 212-C1 Barrel dump 'C'	SS 212-C2 Barrel dump 'C'
	Parkland	Industrial									
Physical Tests											
Moisture %	-		34.1	62.3	45.1	13.3	28.2	21.8	28.7	33.3	30
pH	-		5.37	-	5.26	-	-	-	-	-	-
Extractables											
EPH (C10-18) (~LEPH)	1000	2000	<200	<200	<200	<200	<200	<200	<200	<200	<200
EPH (C19-31) (~HEPH)	1000	5000	<200	<200	<200	<200	<200	1130	581	<200	1580

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).

" - " Denotes no analysis or standard.

" < " Denotes less than detection limit.

[ ] Exceeds CSR Standard for Parkland Use

[ ] Exceeds CSR Standard for Industrial Land Use.

TABLE 4.4.2: SOIL CHEMISTRY - METAL RESULTS
MP 210 - Old Squaw Barrel Dump

Parameter	Criterion [1] Parkland	Criterion [1] Industrial	SS 212-A1 Barrel dump 'A'	SS 212-1 Background (north)
Physical Tests				
Moisture %	-		45.1	34.1
pH	-		5.26	5.37
Total Metals				
Antimony T-Sb	20	40	<20	<20
Arsenic T-As	35 [3]	150 [3]	13	16
Barium T-Ba	500	2000	890	956
Beryllium T-Be	4	8	1.2	1.4
Cadmium T-Cd	250 [3]	700 [3]	1.1	0.4
Chromium T-Cr	60-150 [3]	60-500 [3]	45	44
Cobalt T-Co	50	300	6	9
Copper T-Cu	100-150 [3]	100-250 [3]	22	15
Lead T-Pb	250-500 [3]	250-1000 [3]	<50	68
Mercury T-Hg	2	10	0.044	0.031
Molybdenum T-Mo	10	40	4	<4
Nickel T-Ni	100	500	33	24
Selenium T-Se	3	10	1	0.5
Silver T-Ag	20	40	<2	<2
Tin T-Sn	50	300	<10	<10
Vanadium T-V	200	-	181	131
Zinc T-Zn	150-450 [3]	150-600 [3]	143	73

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).
[2] Standard varies with soil pH.
[3] Environmental protection, toxicity to invertebrates and plants.
"-" Denotes no analysis or standard.
"<" Denotes less than detection limit.
[ ] Exceeds CSR Standard for Parkland Use
[ ] Exceeds CSR Standard for Industrial Land Use.
All concentrations in mg/kg (ppm)

TABLE 4.4.3: VEGETATION CHEMISTRY - METAL RESULTS
MP 210 - Old Squaw Barrel Dump

Parameter	VS 212-1 Willow 980913	VS 212-2 Cariboo Lichen 980913
Physical Tests		
Moisture %	53.9	64.9
Total Metals		
Aluminum T-Al	58	442
Antimony T-Sb	0.12	0.25
Arsenic T-As	<0.05	0.28
Barium T-Ba	394	97.8
Beryllium T-Be	<0.1	<0.1
Bismuth T-Bi	<0.1	<0.1
Cadmium T-Cd	8.93	1.2
Calcium T-Ca	16500	2730
Chromium T-Cr	1.3	3
Cobalt T-Co	1.5	0.3
Copper T-Cu	4.06	2.12
Iron T-Fe	-	-
Lead T-Pb	0.3	2.2
Lithium T-Li	<0.2	0.3
Magnesium T-Mg	4060	568
Manganese T-Mn	86.2	23
Molybdenum T-Mo	0.91	0.36
Nickel T-Ni	7.3	2.2
Phosphorus T-P	-	-
Potassium T-K	-	-
Selenium T-Se	<1	<1
Silver T-Ag	-	-
Sodium T-Na	-	-
Strontium T-Sr	49.5	6.92
Thallium T-Tl	<0.03	<0.03
Tin T-Sn	<0.2	<0.2
Titanium T-Ti	-	-
Uranium T-U	<0.01	0.03
Vanadium T-V	<0.5	2.1
Zinc T-Zn	208	36.5

Vegetation Samples

Two vegetation samples were collected from the MP 210 site. One sample was collected from willow buds and the second of reindeer lichen. The complete results are presented in Table 4.4.3 and the Technical Appendix.

Cadmium and zinc concentrations in the willow sample (VS-212-1) were both found to exceed the background sample for willow. This sample was collected from the centre of barrel dump A.

4.4.3 Discussion

All but one of the drums inspected at the site were found to be empty. An open drum in dump 'A' was found lying on its side and partially full of grease.

One sample collected from barrel dump 'B' and a second from dump 'C' showed levels of HEPH contamination slightly above the Parkland Standard. This most likely has occurred from residue hydrocarbon content in the drums leaking into the local soils. Based on the number of samples, it appears that the contamination is very minimal and localized to the immediate barrel dump area. Down-gradient samples showed no impacts.

The cadmium concentration in the willow sample (VS-212-1 – 8.9 ppm) exceeded the Royal Roads' background willow sample concentration of 5.4 ppm. Cadmium in soil at this site was found to be 44 ppm. Therefore, the elevate cadmium concentration in the willow buds may be related to naturally occurring cadmium levels in the soil

4.4.4 Conclusions

Based on the findings of the site investigation, the following conclusions can be made:

a) two shallow soil samples, one sample from dump 'B' and dump 'C', exceeded Parkland Standard for HEPH contamination;
b) one barrel containing grease was found on site, but most drums appear empty;
c) the area is heavily used as a traditional campsite; and
d) impacts from previous site activities appear to be minimal.

4.4.5 Recommendations

The following recommendations are made based on the conclusions outlined above:

1. remove barrels containing hydrocarbon products from site;
2. leave features, structures and materials on site that have identified historic value; and
3. no further action.

4.5 MP 215-216 – Boulder Creek Gravel Pit (Royal Roads Site 19)

Physical Setting

MP 215-216 is located 23 km east along the Canol Trail from the Yukon, NWT border and 6.5 km west of Old Squaw Lodge. (Figure 4.5.1). The site has previously been identified in Royal Roads' 1994 report as "Site 19A and B". The site is located on a high flat alpine plain. Site topography dips gently to the south. There are two parts to the site, the eastern end (site 19A) is a quarry with miscellaneous debris, barrel dumps, and cabooses; and approximately 1 km west is another barrel dump and a single caboose (called site 19B by Royal Roads, 1994)

The eastern part of the site (see Figure 4.5.2) lies mostly on the southeast side of the Canol Trail. A 170 m x 40 m, 2 m deep quarry parallels the road. The southwest end of the quarry is filled with standing water. The northeast end of the pit is swampy and has open shallow water. The quarry appears to have been used to excavate black shales for road construction. Pyritic rocks were found in the pit, indicating elevated suphide content in the rock. A small ravine (2m wide by 1 m deep) drains the southwest corner of the pit. This gully was most likely created by water erosion when the pit overfills with water and spills out at this point.

There are three areas of 45-gallon barrels dumped at this site labeled barrel dumps A, B and C. Barrel dump A consists of 52 (Royal Roads 1994) empty 45-gallon drums dumped into the mouth of the gully and the ponded water in the quarry (see Figure 4.5.2). Dump B is on the mud flats north of the pond, and consists of 45 barrels. Dump C is north of the Canol Trail across from the quarry and consists of 120 barrels (Royal Roads 1994).

Two intact cabooses and a collapsed caboose lie southwest of the quarry. There are several sleigh frames in the area as well as other wooden and metal debris. An intact propane tank was found in this area and may still be carrying a charge. This area is frequently used as a campsite for hunters. At the time of the field investigation, a single wall tent and camp was established at the site.

A small area of dried crude oil was found between the quarry and the Canol Trail (see Figure 4.5.2). This material had hardened to a tar, and is interpreted to be a small pipeline spill.

At MP 216, or Site 19B, the site consists of a single caboose, a truck hulk and barrel dump. Royal Roads (1994) estimates there are 140 drums at this site, most of which appear to be empty. The site plan shown on Figure 4.5.3.

Geology

MP 215-216 is located on a gently sloping plane. Terrain interpretation (Figure 4.5.4) suggests the site represents a morainal veneer overlying bedrock. This is seen in the quarry on site. There are local areas of relative thicker deposits of till that have been used as aggregate sources for road construction.

Surface Water

The only surface water seen on site was the ponded water and marshy areas within the quarry. The gully in the south corner of the pit is probably a runoff channel for spring melt-water that collects in the pit. The gully discharges to a flat grassy area south of the site. Spring run-off water most likely flows through the topographic lows south of the site.

Hydrogeology

Groundwater was not encountered in test pits at the site, but due to the ponded water in the pit, it is estimated that the groundwater table lies 1 to 2 m below the surface in the bedrock. The groundwater flow is inferred to follow topography of the site. Groundwater flow may be hindered by permafrost in the soil and bedrock.

Vegetation

Sparse vegetation at this site consisted mostly of reindeer lichen, low shrubs and grasses. Topographic low areas had a cover of grasses and sedges. Locally, around the site, vegetation consisted of dwarf birch and willow with a ground cover as described above. Marshy areas with in the quarry had a layer of thick mosses.

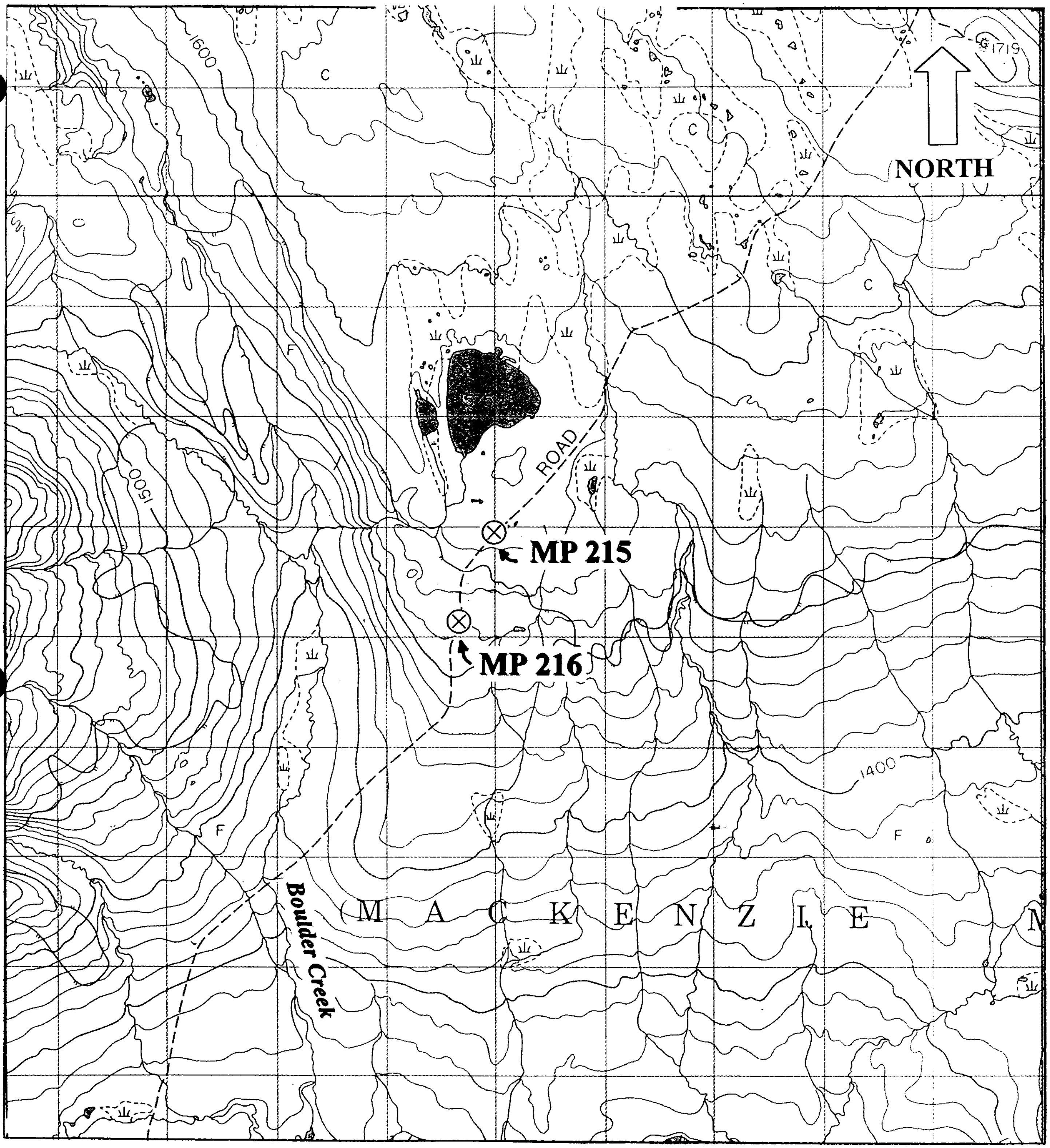


FIGURE 4.5.1: MP 215-216 SITE LOCATION

LEGEND: ⊗ SITE LOCATION SOURCE: NTS 105 P/5	SCALE 1:50,000 1500M 0 1500M 1CM = 500 M	BOULDER CREEK MILE POST 215-216 1998 ENVIRONMENTAL INVESTIGATIONS MACMILLAN PASS, NWT
DRAWN BY: F. PEARSON	PROJECT NO.: 98-800	Gartner Lee
APPROVED BY:	FILE NAME: F4_5_1.DWG	FIGURE NO.: 4.5.1
DATE: 01/04/99		

LEGEND

Clearing	Vehicle Hulk	Contour
Hydrocarbon Staining	Surface Drainage	Drum Dump I.D.
Surface Debris	Drainage Ditch	
Drums (45 gallons)	Swamp	
	Ponded Water	

Contour interval approximately 1 metre, determined through visual mapping.

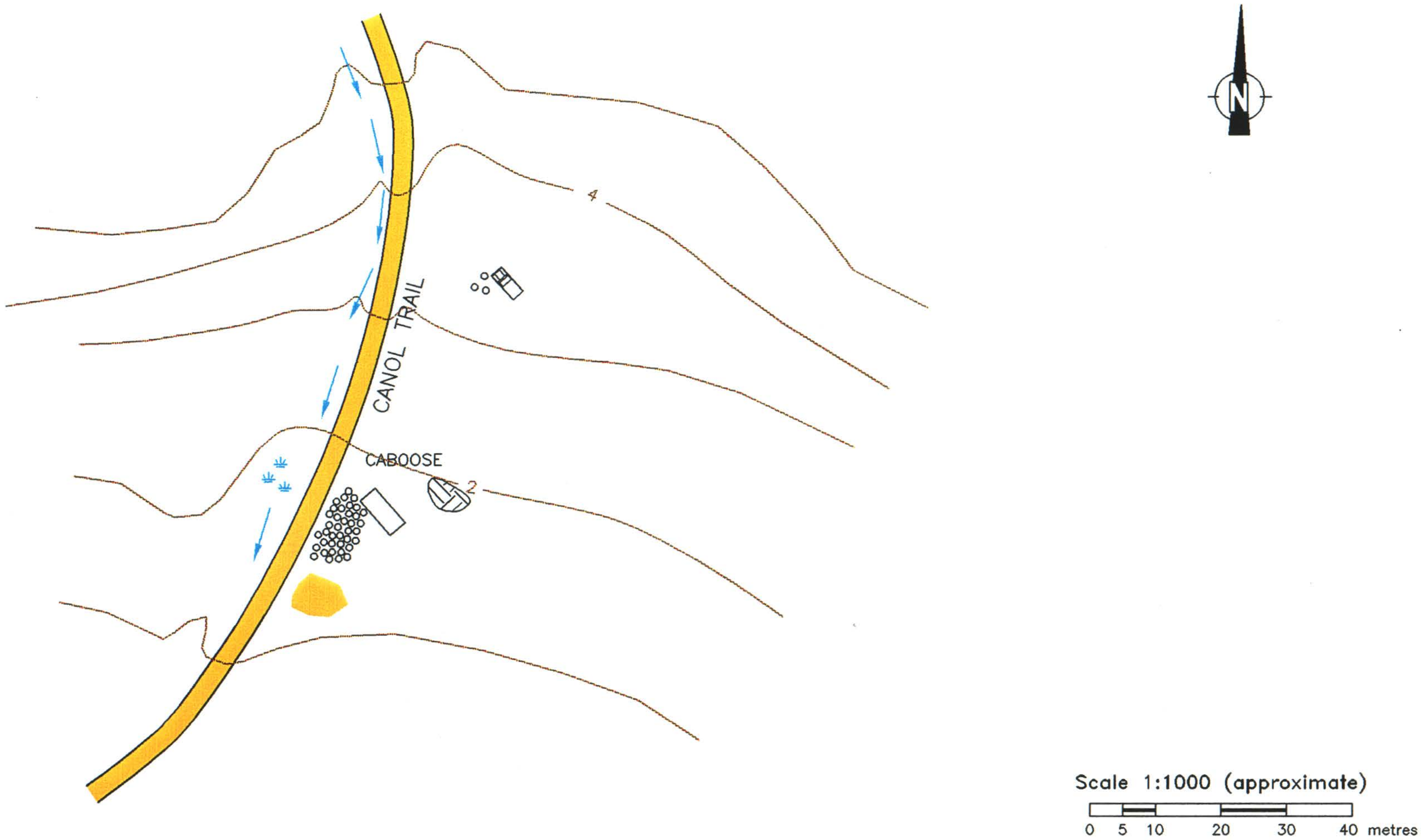
Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800001

Site Map MP 215 NWT
Boulder Creek Quarry/Barrel Dump

Canol Road
Site Assessment

Gartner Lee

Figure No.
4.5.2



LEGEND

Clearing	Vehicle Hulk	Contour
Hydrocarbon Staining	Surface Drainage	
Surface Debris	Drainage Ditch	
Drums (45 gallons)	Swamp	
	Ponded Water	

Contour interval approximately 1 metre, determined through visual mapping.

Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800001

Site Map MP 216 NWT
Boulder Creek Barrel Dump

Canol Road
Site Assessment

Gartner Lee

Figure No.
4.5.3

N

FIGURE 4.5.4: MP 215-216 TERRAIN INTERPRETATION

LEGEND:	SCALE 1:30,000	BOULDER CREEK MILE POST 215-216
SEE APPENDIX A	750M 0 750M 1CM = 300 M	1998 ENVIRONMENTAL INVESTIGATIONS MACMILLAN PASS, NWT
SOURCE: NAPL A25766-51	DRAWN BY: F. PEARSON APPROVED BY: DATE: 01/04/99	PROJECT NO.: 98-800 FILE NAME: F4_5_4.DWG
	Gartner Lee	FIGURE NO.: 4.5.4

4.5.1 Test Results

Soil, surface water, vegetation and hydrocarbon product samples were collected at the site. The location of the samples is shown on Figure 4.5.5 & 4.5.6. A complete sample list is found in the Technical Appendix.

Soil Chemistry

Selected soil samples were submitted to the analytical laboratory for analysis of potential contaminants of concern as identified in section 3.3.2, Analytical Program. This section provides a summary of the analytical results with the complete results presented in Tables 4.5.1 and 4.5.2 and the Technical Appendix.

Petroleum hydrocarbons were detected in the surficial soils in two of the samples collected from the barrel dump 'B' area. Hydrocarbons were detected in a single sample at MP 216. None of these samples exceeded the standards.

One sample was analyzed for metals. The analytical results show concentrations of Barium exceeded Parkland standard which can be attributed to regional geochemistry.

Vegetation Samples

Two vegetation samples were collected from willow buds at the MP 215 site. The complete results are presented in Table 4.5.3 and the Technical Appendix.

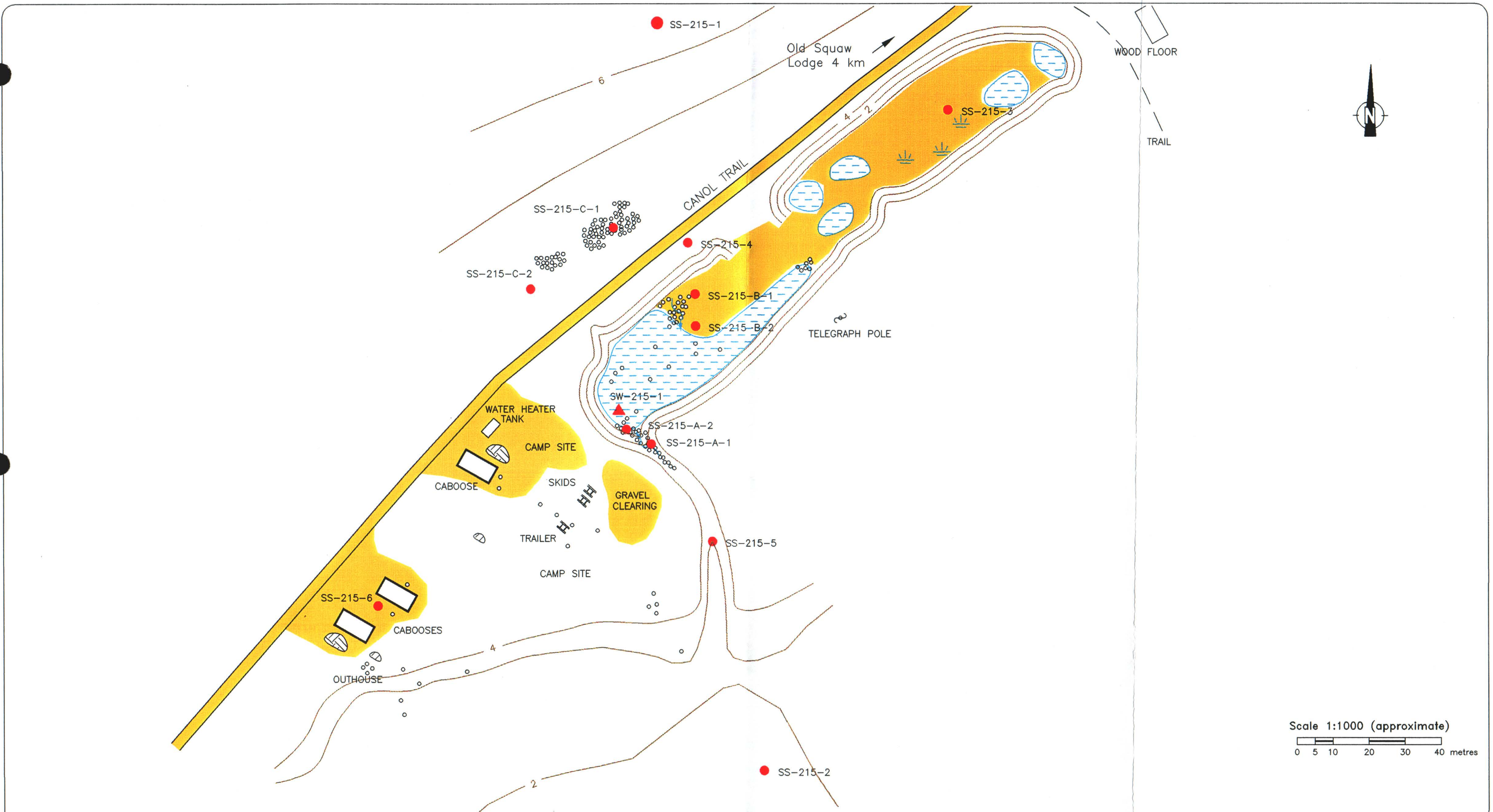
Zinc and cadmium were found to exceed Royal Roads' Impact Criteria. No background willow samples were collected in the area.

Surface Water Chemistry.

A single water sample was collected from the ponded water at MP 215. Petroleum hydrocarbons were not detected in the sample, and metal concentrations were all within drinking water standard. The complete results are presented in Table 4.5.4 and the Technical Appendix.

Hydrocarbons

A sample of dried tar was analyzed for hydrocarbon content. Sample SS-215-4 shows LEPH concentrations of 5840 ppm and HEPH concentrations of 4.7% and therefore this sample is considered Special Waste under the program guidelines. Metal and PAH concentrations were all below the standards. The complete results are presented in Table 4.5.5 and the Technical Appendix.



LEGEND

- Clearing
- Hydrocarbon Staining
- Surface Debris
- Drums (45 gallons)
- Vehicle Hulk
- Surface Drainage
- Drainage Ditch
- Swamp
- Ponded Water
- Contour
- SS-1 Soil Sample
- 73-1 Water Sample

Contour interval approximately 1 metre, determined through visual mapping.

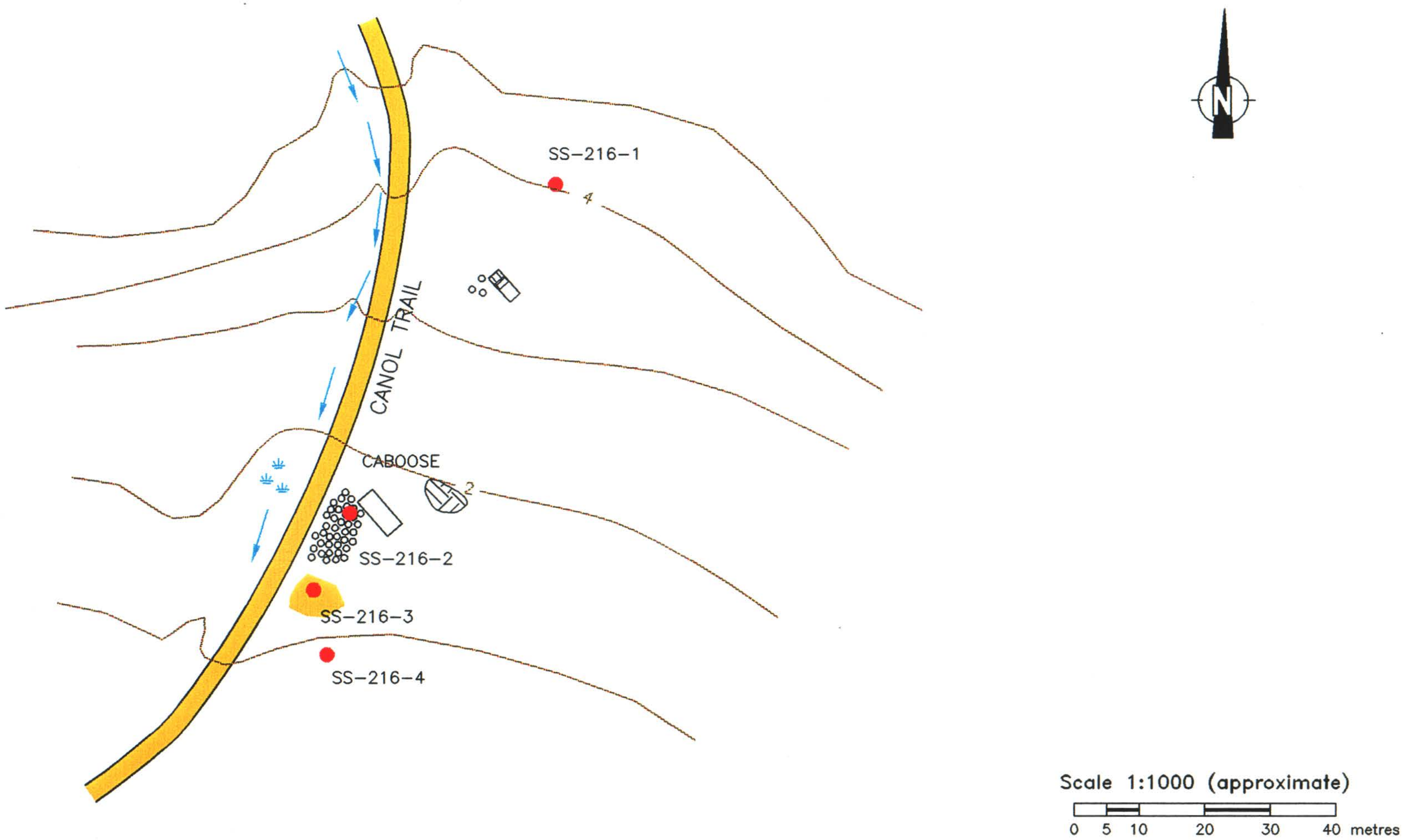
Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800001

Sample Locations MP 215 NWT
Boulder Creek Quarry/Barrel Dump

Canol Road
Site Assessment

Gartner Lee

Figure No. 4.5.5



LEGEND

- Clearing
- Hydrocarbon Staining
- Surface Debris
- Drums (45 gallons)
- Vehicle Hulk
- Surface Drainage
- Drainage Ditch
- Swamp
- Ponded Water
- Contour
- SS–1 Soil Sample

Contour interval approximately 1 metre, determined through visual mapping.

Drawn by: BB/FP

GLL Project Number: 98–800

File Name: 98800001

Sample Locations MP 216 NWT Boulder Creek Barrel Dump

Canol Road
Site Assessment

Gartner Lee

Figure No. 4.5.6

TABLE 4.5.1: SOIL CHEMISTRY - HYDROCARBON RESULTS
MP 215 - Boulder Creek Quarry

Parameter	Criterion [1]		SS 215-1	SS 215-2	SS 215-3	SS 215-5	SS 215-6	SS 215-A1	SS 215-A2	SS 215-B1	SS 215-B2	SS 215-C1	SS 215-C2
	Parkland	Industrial	Background (north)	Downgradient of gully	Pyrite- middle of quary	Mouth of gully	Between cabooses	Centre of gully - dump 'A'	Shore of pond - dump 'A'	North end of dump 'B'	Shore of pond - dump 'B'	Centre of dump 'C'	SW of dump 'C'
Physical Tests													
Moisture %	-		31.8	39.7	22.2	9.7	20	31	55.3	43.4	62.9	44	23.5
pH	-		-	-	-	-	-	5.98	-	-	-	-	-
Extractables													
EPH (C10-18) (~LEPH)	1000	2000	<200	<200	<200	<200	<200	<200	<200	202	<200	<200	<200
EPH (C19-31) (~HEPH)	1000	5000	<200	<200	<200	<200	<200	<200	<200	685	561	<200	<200

Parameter	Criterion [1]		SS 216-1	SS 216-2	SS 216-3	SS 216-4
	Parkland	Industrial	Gravel Clearing North of site	Middle of barrel dump	South of barrel dump	Downgradient of barrel dump
Physical Tests						
Moisture %	-		19.3	47.4	28.2	20.2
pH	-		-	-	-	-
Extractables						
EPH (C10-18) (~LEPH)	1000	2000	<200	<200	<200	<200
EPH (C19-31) (~HEPH)	1000	5000	<200	314	<200	<200

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).

"-" Denotes no analysis or standard.

"<" Denotes less than detection limit.

Exceeds CSR Standard for Parkland Use

Exceeds CSR Standard for Industrial Land Use.

All concentrations in mg/kg (ppm)

TABLE 4.5.2: SOIL CHEMISTRY - METAL RESULTS
MP 215 - Boulder Creek Quarry

Parameter	Criterion[1]		SS 215-A1
	Parkland	Industrial	Centre of gully - dump 'A'
Physical Tests			
Moisture %	-		31
pH	-		5.98
Total Metals			
Antimony T-Sb	20	40	<20
Arsenic T-As	35[3]	150[3]	16
Barium T-Ba	500	2000	735
Beryllium T-Be	4	8	1
Cadmium T-Cd	250[3]	700[3]	0.9
Chromium T-Cr	250[3]	800[3]	28
Cobalt T-Co	50	300	5
Copper T-Cu	150[3]	250[3]	53
Lead T-Pb	1000[3]	2000[3]	<50
Mercury T-Hg	2	10	0.177
Molybdenum T-Mo	10	40	8
Nickel T-Ni	100	500	35
Selenium T-Se	3	10	6
Silver T-Ag	20	40	<2
Tin T-Sn	50	300	<10
Vanadium T-V	200	-	168
Zinc T-Zn	450[3]	600[3]	178

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996)

[2] Standard varies with soil pH.

[3] Environmental protection, toxicity to invertebrates and plants.

"-" Denotes no analysis or standard.

"<" Denotes less than detection limit.

Exceeds CSR Standard for Parkland Use

Exceeds CSR Standard for Industrial Land Use.

All concentrations in mg/kg (ppm)

TABLE 4.5.3: VEGETATION CHEMISTRY - METAL RESULTS
MP 215 - Boulder Creek Quarry

Parameter	VS 215-1 Dump 'A' Willow	VS 215-2 Mouth of gully - Willow
Physical Tests		
Moisture %	34.3	45.8
Total Metals		
Aluminum T-Al	25	13
Antimony T-Sb	0.07	0.04
Arsenic T-As	0.05	<0.05
Barium T-Ba	24.9	26.4
Beryllium T-Be	<0.1	<0.1
Bismuth T-Bi	<0.1	<0.1
Cadmium T-Cd	8.53	18.1
Calcium T-Ca	5310	3440
Chromium T-Cr	<0.5	<0.5
Cobalt T-Co	0.6	0.3
Copper T-Cu	4.07	5.38
Iron T-Fe	-	-
Lead T-Pb	0.2	<0.1
Lithium T-Li	<0.2	<0.2
Magnesium T-Mg	1260	1440
Manganese T-Mn	222	128
Molybdenum T-Mo	1.32	0.21
Nickel T-Ni	6.2	0.8
Phosphorus T-P	-	-
Potassium T-K	-	-
Selenium T-Se	<1	<1
Silver T-Ag	-	-
Sodium T-Na	-	-
Strontium T-Sr	12.6	6.62
Thallium T-Tl	<0.03	<0.03
Tin T-Sn	<0.2	<0.2
Titanium T-Ti	-	-
Uranium T-U	<0.01	<0.01
Vanadium T-V	<0.5	<0.5
Zinc T-Zn	202	340

TABLE 4.5.4: WATER CHEMISTRY RESULTS
MP 215 - Boulder Creek Quarry

Parameter	Criterion [1]		SW 215-1 Pond Water
	Aquatic Life	Drinking Water	
Physical Tests			
Hardness $CaCO_3$	-	-	40.5
Total Metals			
Aluminum T-Al	0.050 - 0.5 [2]	0.2	0.042
Antimony T-Sb	0.3	-	<0.2
Arsenic T-As	0.5	0.025	<0.2
Barium T-Ba	10	1	0.02
Beryllium T-Be	0.053	-	<0.005
Boron T-B	-	5	<0.1
Cadmium T-Cd	0.002 - 0.018 [3]	0.005	<0.0002
Calcium T-Ca	-		10
Chromium T-Cr	0.02	0.05	<0.01
Cobalt T-Co	0.5		<0.01
Copper T-Cu	0.020 - 0.09 [3]	1	<0.01
Iron T-Fe	3	0.3	0.2
Lead T-Pb	0.040 - 0.16 [3]	0.01	<0.001
Magnesium T-Mg	-		3.8
Manganese T-Mn	1	0.05	<0.005
Mercury T-Hg	0.001	0.001	<0.00005
Molybdenum T-Mo	10	0.25	<0.03
Nickel T-Ni	0.250 - 1.5 [3]	-	<0.05
Selenium T-Se	0.01	0.01	0.004
Silver T-Ag	0.001	-	<0.0001
Thallium T-Tl	0.003	-	<0.002
Uranium T-U	-		0.00001
Zinc T-Zn	0.3	5	0.014
Extractables			
EPH (C10-18)	0.5		<0.5
EPH (C19-31)	1		<1

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).
[2] Standard varies with water pH.
[3] Standard varies with water hardness.
"-" Denotes no analysis or standard.
"<" Denotes less than detection limit.
Exceeds CSR Standard for Aquatic Life.
Exceeds CSR Standard for Drinking Water.
All concentrations in mg/L (ppm)

TABLE 4.5.5: HYDROCARBON CHARACTERIZATION
MP 215 - Boulder Creek Quarry

Parameter	Criterion [1]		SS 215-4 Crude Oil Tar
	Parkland	Industrial	
Flashpoint Degrees C.	-		>60
Moisture %	-		<0.1
Total Metals			
Arsenic T-As	35 [3]	150 [3]	4
Cadmium T-Cd	250 [3]	700 [3]	<0.3
Chromium T-Cr	250 [3]	800 [3]	6
Lead T-Pb	1000 [3]	2000 [3]	25
Polycyclic Aromatic Hydrocarbons			
Acenaphthene	-		0.11
Acenaphthylene	-		<0.05
Anthracene	-		<0.05
Benz(a)anthracene	1	10	0.06
Benzo(a)pyrene	-		<0.05
Benzo(b)fluoranthene	1	10	0.24
Benzo(g,h,i)perylene	-		0.1
Benzo(k)fluoranthene	1	10	<0.05
Chrysene	-		0.66
Dibenz(a,h)anthracene	1	10	<0.05
Fluoranthene	-		<0.05
Fluorene	-		<0.05
Indeno(1,2,3-c,d)pyrene	1	10	<0.05
Naphthalene	5	50	0.16
Phenanthrene	5	50	0.09
Pyrene	10	100	0.52
Extractables			
EPH (C10-18)	1000	2000	5840
EPH (C19-31)	1000	5000	46900

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).
[2] Standard varies with soil pH.
[3] Environmental protection, toxicity to invertebrates and plants.
"-" Denotes no analysis or standard.
"<" Denotes less than detection limit.
Exceeds CSR Standard for Agricultural Land Use
Exceeds CSR Standard for Parkland Use.
Exceeds Special Waste Criteria

4.5.2 Discussion

Analytical results indicate that there is limited to no contamination found during soil sampling at this site. Petroleum hydrocarbons were detected in the mud flats around barrel dump 'B', but did not exceed the standards. Water samples collected from the pond did not detect petroleum hydrocarbons, nor did metals exceed drinking water standards. There were no petroleum hydrocarbon contamination found to be associated with barrel dumps 'A' and 'C'. The barrels in the ravine and pond are unsightly and should be removed, but based on the above results, these barrels do not seem to be contaminating the water.

Royal Roads in 1994 detected elevated levels of arsenic (43 ppm) in the vicinity of barrel dump 'B'. This elevated level is still within the background regional geochemistry. Furthermore, pyrite mineralization was found in the quarry, and so elevated arsenic levels in the form of asenopyrite in the rock is a likely source.

Sample SS-208-4 is tar like substance collected from an area along the north rim of the quarry area. This tar is interpreted to be due to a pipeline oil spill, and is most likely to be crude oil. The substance has dried to a hard asphalt like surface. Due to its extremely consolidated state, minimal environmental risk is anticipated to be associated with this tar.

The vegetation samples had elevated zinc and cadmium concentrations. Although no background samples were collected at this site, these concentration are interpreted to be naturally occurring due to the presence of sulphide (pyrite) mineralization found in the shales of the pit. This is compounded by Royal Roads' suggestion that willow vegetation concentrates zinc and cadmium in their tissues.

In addition to the barrels on site, there is some unsightly debris. The cabooses appear to be structurally sound and are regularly used by people in the MacMillan area. There is a rusted propane tank on site, which is quite heavy and still maybe carrying a charge.

The caboose at MP 216 has a large iron water heater tank on its roof. The caboose is appears to be unstable and in danger of collapse. Two 45-gallon drums are placed end-on-end under the tank to support the tank on the roof of the caboose. This situation is a human health and safety issue, and the tank should be removed from its precarious location.

4.5.3 Conclusions

Based on the findings of the site investigation, the following conclusions can be made:

a) there does not appear to be significant hydrocarbon contaminated soils associated with the barrel dumps or elsewhere at this site;
b) barrels from dumps 'A' and 'B' are partially submerged in the ponded area;

c) there is a one area of dried asphalt like crude oil;
d) elevated arsenic levels detected in 1994 is related to bedrock geochmistry;
e) the area is heavily used as a traditional campsite; and
f) impacts from previous site activities appear to be minimal beyond unsightly waste and debris on site.

4.5.4 Recommendations

The following recommendations are made based on the conclusions outlined above:

1. remove barrels from pond;
2. discharge and remove propane tank from the site;
3. remove water heater tank from the caboose roof at MP 216;
4. general site clean-up of debris; and
5. leave and stabilize features, structures and materials on site that have identified historic value.

4.6 MP 223 – Vehicle Boneyard (Royal Roads Site 20)

4.6.1 Physical Setting

MP 223 is located 12 km east along the Canol Trail from the Yukon, NWT border (Figure 4.6.1). The site has previously been identified in Royal Roads' 1994 report as "Site 20". The site is located in the centre of the broad Tsichu River valley. The terrain is hummocky with numerous small pothole lakes.

The site, located on the north side of the Canol Trail (see Figure 4.6.2) consists of a flattened hill top approximately 100 m long by 40 m at its widest point. A ravine or low area lies between the site and another small rounded hill to the north. A small wetland area lies to the west of the site, and a pond to the east.

There are 23 vehicle hulks on the site along with other miscellaneous metallic debris. A garbage pile is found in a ravine north of the site as shown on Figure 4.6.2.

Geology

The site is interpreted to lie on a low glaciofluvial gravel hummock created by melting stagnant glacial ice. This stagnation has created the hummocky terrain and pothole lakes shown on Figure 4.6.3. Sediments consist primarily of gravel, but there are intermixed localized areas of both finer grained (silt) and coarser grained sediments in the glaciofluvial complex. The boneyard area is interpreted to be a naturally occurring sandy pebble gravel hummock that has been flattened for road construction use. There are organic sediments that have formed in the low wetland areas around the site. Permafrost is anticipated in the organic soils.

Surface Water

No flowing surface water was found at the site, but there is a pothole lake northeast of the site. There is a grassy wetland area to the west of the site, and small linear wetland area connecting this to the lake to the east.

Hydrogeology

Groundwater was not encountered in test pits, but based upon the number of lakes and wetland areas, the groundwater table is interpreted to be 3 to 4 metres below the site. Soils are permeable gravel and flow direction through the glaciofluvial complex is interpreted to be eastward and northward towards the Tsichu River to the north, which flows eastward. The boneyard area itself appeared to be well drained due to its locally high relief and permeable sandy pebble gravel soils.

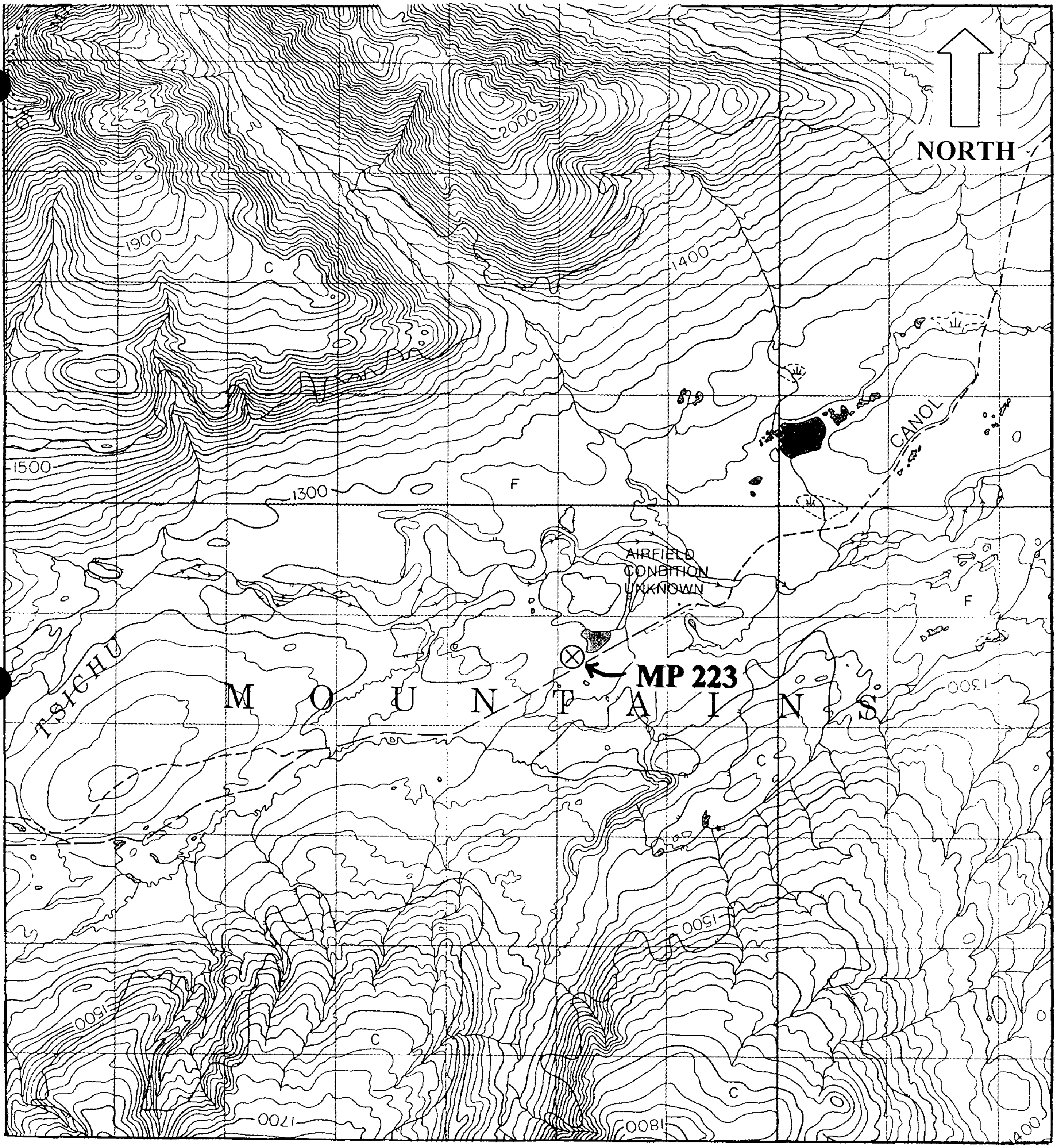
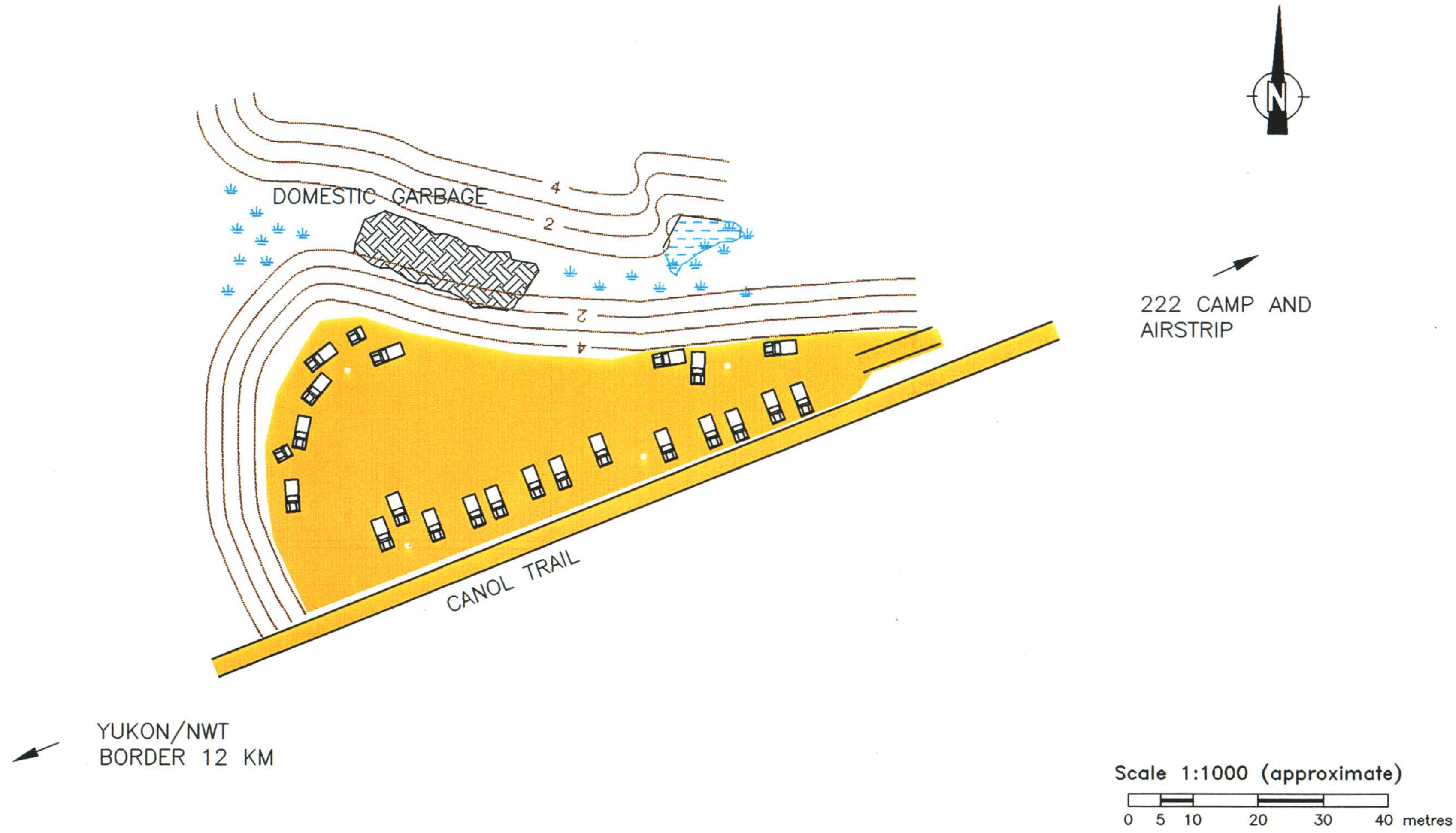


FIGURE 4.6.1: MP 223 SITE LOCATION

LEGEND:	SCALE 1:50,000	VEHICLE BONEYARD MILE POST 223
⊗ SITE LOCATION	1500M 0 1500M 1CM = 500 M	1998 ENVIRONMENTAL INVESTIGATIONS MACMILLAN PASS, NWT
SOURCE: NTS 105 P/5	DRAWN BY: F. PEARSON APPROVED BY: DATE: 01/04/99	PROJECT NO.: 98-800 FILE NAME: F4_6_1.DWG
	Gartner Lee	FIGURE NO.: 4.6.1



LEGEND

- Clearing
- Hydrocarbon Staining
- Surface Debris
- Drums (45 gallons)
- Vehicle Hulk
- Surface Drainage
- Drainage Ditch
- Swamp
- Ponded Water
- A Contour

Contour interval approximately 1 metre, determined through visual mapping.

Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800001

Site Map MP 223 NWT
Vehicle Bonyard

Canol Road
Site Assessment

Gartner Lee

Figure No.
4.6.2

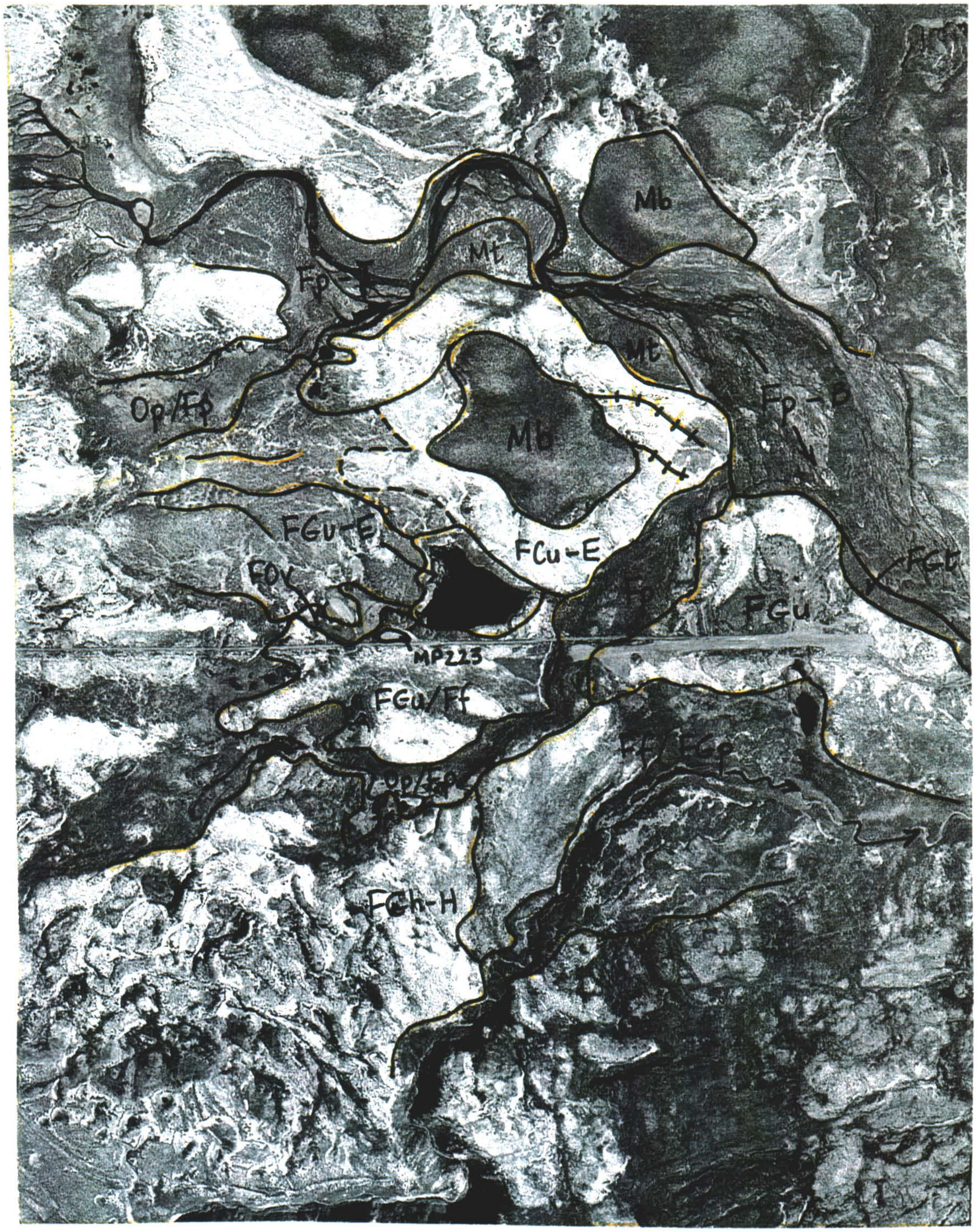


FIGURE 4.6.3: MP 223 TERRAIN INTERPRETATION

LEGEND:

SEE APPENDIX A

SOURCE: NAPL A25766-144

SCALE
1:30,000

750M 0 750M

1CM = 300 M

DRAWN BY: F. PEARSON	PROJECT NO.: 98-800
APPROVED BY:	FILE NAME: F4_6_3.DWG
DATE: 01/04/99	

VEHICLE BONEYARD
MILE POST 223

1998 ENVIRONMENTAL INVESTIGATIONS
MACMILLAN PASS, NWT

Gartner Lee

FIGURE NO.: 4.6.3

Vegetation

The site is un-vegetated, and consists of a bare gravel surface. This is interpreted to be due to the permeable nature of the exposed gravel and lack of proper mineral soil. Willow and dwarf birch is found growing on the slopes around the hill. Vegetation on undisturbed hill sides near the site consists of the typical alpine community of willow, dwarf birch with undergrowth of lichens and occasional shrubs such as blueberries.

4.6.2 Test Results

Soil and surface water samples were collected at the site. The location of the samples is shown on Figure 4.6.4. A complete sample list is found in the Technical Appendix.

Soil Chemistry

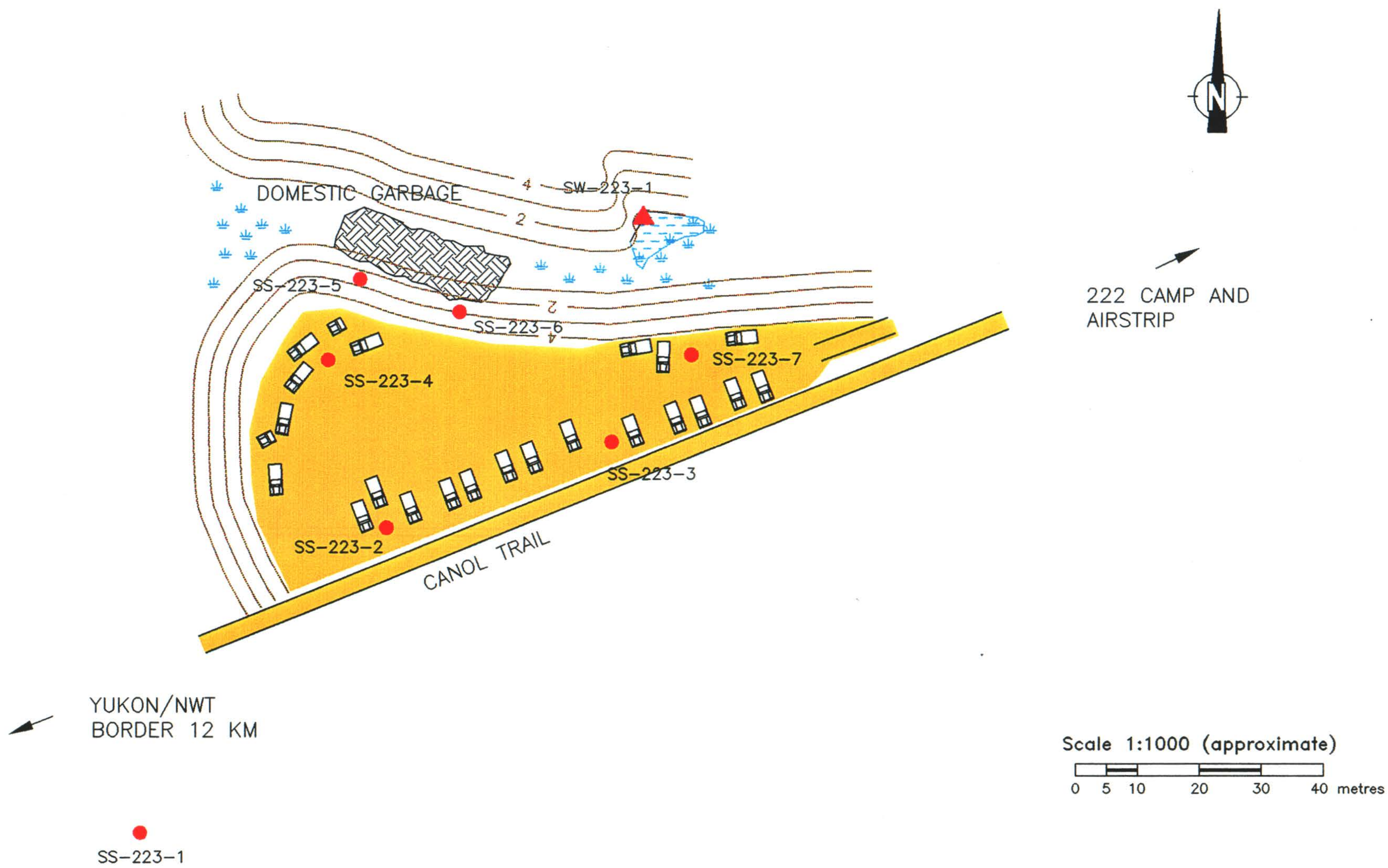
Soil samples were submitted to the analytical laboratory for analysis of potential contaminants of concern as identified in section 3.3.2, Analytical Program. This section provides a summary of the analytical results with the complete results presented in Table 4.6.1 and the Technical Appendix.

Petroleum hydrocarbons were not detected in any of the soil samples collected. No samples were analyzed for metal content.

Surface Water Chemistry.

A single water sample was collected from a small pond or wetland area at the northeast part of the site. This sample was analyzed for hydrocarbon content. The complete results are presented in Table 4.6.2 and the Technical Appendix.

LEPH of 0.6 mg/L and HEPH of 1 mg/L were detected in this water sample. These levels are just above the analytical test detection limits, but exceed the Standard for Aquatic Life.



LEGEND

	Clearing		Vehicle Hulk		Contour
	Hydrocarbon Staining		Surface Drainage	SS-1	Soil Sample
	Surface Debris		Drainage Ditch		
	Drums (45 gallons)		Swamp		
			Ponded Water		

Contour interval approximately 1 metre, determined through visual mapping.

Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800001

Sample Locations MP 223 NWT
Vehicle Bonyard

Canol Road
Site Assessment

Gartner Lee

Figure No. 4.6.4

TABLE 4.6.1: SOIL CHEMISTRY - HYDROCARBON RESULTS
MP 223 - Vehicle Boneyard

Parameter	Criterion [1]		SS-223-1	SS-223-2	SS-223-3	SS-223-4	SS-223-5	SS-223-6	SS-223-7
	Parkland	Industrial	Background - SW of site	West end of site	Middle of site	North end of site	Northest end of site	Southwest corner of	Southeast corner of
Physical Tests			-	-	-	-	-	-	-
Moisture %	-		10.5	21.5	11.7	8.8	8.5	8	7
Extractables									
EPH (C10-18) (~LEPH)	1000	2000	<200	<200	<200	<200	<200	<200	<200
EPH (C19-31) (~HEPH)	1000	5000	<200	<200	<200	<200	<200	<200	<200

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).
" - " Denotes no analysis or standard.
" < " Denotes less than detection limit.
[ ] Exceeds CSR Standard for Parkland Use
[ ] Exceeds CSR Standard for Industrial Land Use.
All concentrations in mg/kg (ppm)

TABLE 4.6.2 WATER CHEMISTRY RESUL
MP 223 - Vehicle Boneyard

Parameter	Criterion [1]		SW-223-1
	Aquatic Life	Drinking Water	Pond east of site
Extractables			
EPH (C10-18)	0.5		0.6
EPH (C19-31)	1		1

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).
" - " Denotes no analysis or standard.
" < " Denotes less than detection limit.
[ ] Exceeds CSR Standard for Aquatic Life.
[ ] Exceeds CSR Standard for Drinking Water.
All concentrations in mg/L (ppm)

4.6.3 Discussion

In addition to the vehicle hulks at the site, there is garbage disposal area. The waste in this area appears to be mostly metallic debris.

Due to frozen ground at the time of sample collection, soil samples could not be collected in the low area east and west of the dump area. Instead, samples were collected from the gravelly soils immediately up-gradient (south) of the dump area. No hydrocarbons were detected in these soil samples. Since hydrocarbon was detected in the wetland east of the dump site, follow-up soil sampling down-gradient of the dump should be conducted to determine the source of the water contamination. The water from which the sample was collected was quite stagnant, and possibly the apparent elevated hydrocarbon levels could be a result of analytical interference from materials created by decomposition of the organic sediments surrounding the pond.

4.6.4 Conclusions

Based on the findings of the site investigation, the following conclusions can be made:

a) soils associated the vehicle boneyard do not appear to have been impacted by petroleum hydrocarbons;
b) a dump of mostly metallic debris exists on site; and
c) petroleum hydrocarbons from unknown source were detected in a nearby pond which exceed the Aquatic Life standard.

4.6.5 Recommendations

The following recommendations are made based on the conclusions outlined above:

1. follow-up water sampling should be conducted from the pond on site (SW-223-1) and from the lake to the east and wetland to the west to determine the extent of surface water contamination;
2. follow-up soil sampling should be conducted down-gradient both east and west of the dump area to further determine is contamination is associated with the dump area;
3. the dump site should be clean-up as part of other clean-up efforts in the MacMillan Pass area; and
4. leave features and materials on site that have identified historic value.

5. Findings – Follow-up Site Investigations & Monitoring

Based on the results of the 1997 field program (GLL 97-751, 1998), it was recommended that several sites have follow-up work conducted. The scope and results of this work is presented below.

5.1 MP73 – Pump Station 10, Gravel Creek

5.1.1 Follow-up Work Program

Based on an analysis of the groundwater monitor wells installed in 1997, it was recommended that a third, central well be installed at the site. Follow-up water quality monitoring was conducted at the time of the site visits.

A third groundwater monitor was installed as shown on Figure 5.1.1. The location of this well was to attempt to intersect a potential contaminant plume leaching from the up-gradient dump site. The well was installed by hand excavating a pit, installing a Waterra environmental grade 2" PVC monitoring well, and backfilling the pit.

5.1.2 Test Results

Soil and groundwater samples were collected at the site. A complete sample list is found in the Technical Appendix.

Soil Chemistry

Selected soil samples were submitted to the analytical laboratory for analysis of potential contaminants of concern as identified in section 3.3.2, Analytical Program. This section provides a summary of the analytical results with the complete results presented in Tables 5.1.1 and the Technical Appendix.

One sample was collected from the MW-3 test pit during the monitor installation. This sample was analyzed for Polycyclic Aromatic Hydrocarbons (PAH) and extractable petroleum hydrocarbons (LEPH/HEPH). LEPH concentrations were detected in excess of the Industrial Standard in this sample. Other parameters analyzed did not exceed standard levels.

Groundwater Chemistry.

Groundwater samples were collected from three groundwater monitors on site. All three samples were analyzed for LEPH/HEPH content, and additionally sample MW-3 was analyzed for PAH concentrations. The complete results are presented in Table 5.1.2 and the Technical Appendix.

LEPH was found in very elevated concentrations in MW-3 in excess of the Aquatic Life guidelines. Concentrations of HEPH were also found, which exceeds the guidelines. PAHs were not detected and LEPH/HEPH was not detected in MW-1 or MW-2.

5.1.3 Conclusions

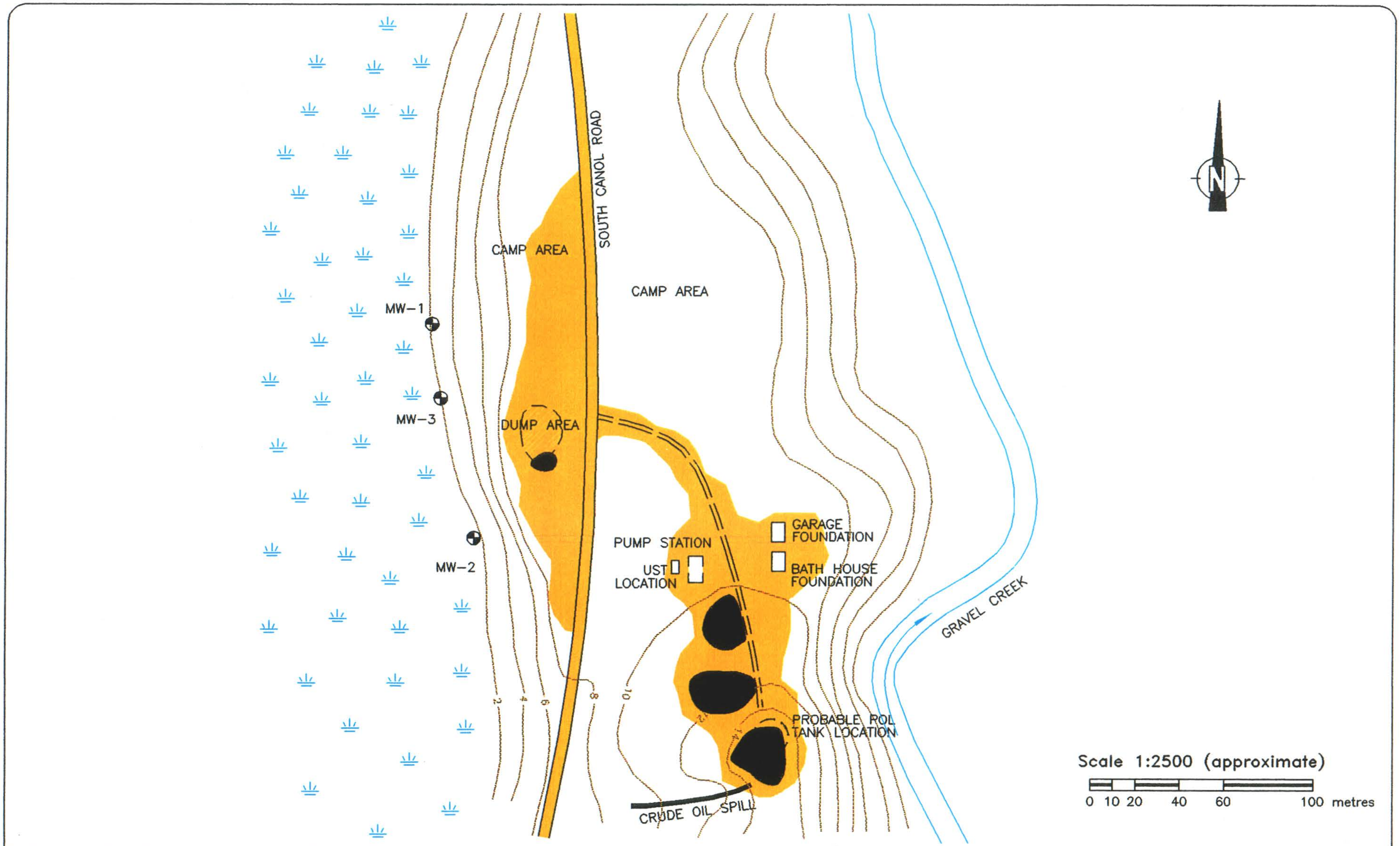
Based on the findings of this year's site investigation, the following conclusions can be made:

a) Hydrocarbon contamination has been confirmed to be leaking from the dumpsite and contaminating groundwater and soil down-gradient of the site. Contamination of surface water is unknown, and the extent of groundwater contamination is uncertain.

5.1.4 Recommendations

The following recommendations are made based on the conclusions outlined above:

1. due to the contaminated soil and groundwater delineated in this year's and previous years' work the following risk assessments should be done:
    - a screening level *quantitative* human health risk assessment of petroleum hydrocarbons in soil to provide estimates of human health risks for use of the site (*e.g.*, parkland uses); and
    - a screening level *quantitative* ecological risk assessment of petroleum hydrocarbons in soil should to provide estimates of ecological risks for Valued Ecosystem Components that are identified in the area;
2. continue monitoring groundwater quality;
3. sample surface water in adjacent wetland to determine if contaminants are migrating into the surface water; and
4. excavate and clean-up dump site and contaminated soils to remove the source of contamination.



LEGEND

- Clearing
- Hydrocarbon Staining
- Surface Debris
- Surface Drainage
- Drainage Ditch
- Swamp
- Ponded Water
- Contour

Contour interval approximately 2 metres, determined through visual mapping.

Drawn by: BB/FP
GLL Project Number: 98–800
File Name: 98800002

Site Map MP 73
Pump Station 10

Canol Road
Site Assessment

Gartner Lee

Figure No.
5.1.1

TABLE 5.1.1: SOIL CHEMISTRY RESULTS
MP 73 - Pump Station #10

Parameter	Criterion [1]		MP73 MW3-E (soil)
	Parkland	Industrial	
Physical Tests			
Moisture %	-		12.5
Polycyclic Aromatic Hydrocarbons			
Acenaphthene	-		0.04
Acenaphthylene	-		0.02
Acridine	-		<0.01
Anthracene	-		<0.01
Benz(a)anthracene		10	<0.01
Benzo(a)pyrene	1 [3]	10 [3]	<0.01
Benzo(b)fluoranthene	1	10	<0.01
Benzo(g,h,i)perylene	-		<0.01
Benzo(k)fluoranthene	1	10	<0.01
Chrysene	-		<0.01
Dibenz(a,h)anthracene	1	10	<0.01
Fluoranthene	-		<0.01
Fluorene	-		<0.01
Indeno(1,2,3-c,d)pyrene	1	10	<0.01
Naphthalene	5	50	<0.01
Phenanthrene	5	50	0.01
Pyrene	5	100	0.01
Extractables			
EPH (C10-18)	1000	2000	3770
EPH (C19-31)	1000	5000	<200

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).

[2] Standard varies with soil pH.

[3] Environmental protection, toxicity to invertebrates and plants.

"-" Denotes no analysis or standard.

"<" Denotes less than detection limit.

[box] Exceeds CSR Standard for Agricultural Land Use

[box] Exceeds CSR Standard for Parkland Use.

TABLE 5.1.2: GROUNDWATER CHEMISTRY RESULTS
MP 73 - Pump Station #10

Parameter	Criterion [1]		MP73 MW1 (groundwater)	MP73 MW2 (groundwater)	MP73 MW3 (groundwater)
	Aquatic Life	Drinking Water			
Physical Tests					
Hardness $CaCO_3$	-	-	-	-	-
Polycyclic Aromatic Hydrocarbons					
Acenaphthene	0.06	-	-	-	<0.0005
Acenaphthylene	-		-	-	<0.0005
Acridine	0.0005	-	-	-	<0.00005
Anthracene	0.001	-	-	-	<0.0001
Benz(a)anthracene	0.0001	0.00001	-	-	<0.00001
Benzo(a)pyrene	0.0001	0.00001	-	-	<0.00001
Benzo(b)fluoranthene	-		-	-	<0.00001
Benzo(g,h,i)perylene	-		-	-	<0.0001
Benzo(k)fluoranthene	-		-	-	<0.00001
Chrysene	-		-	-	<0.0001
Dibenz(a,h)anthracene	-		-	-	<0.00001
Fluoranthene	0.002	-	-	-	<0.0001
Fluorene	0.12	-	-	-	<0.0001
Indeno(1,2,3-c,d)pyrene	-		-	-	<0.00001
Naphthalene	0.01	-	-	-	<0.0002
	-				
Phenanthrene	0.003	-	-	-	<0.0002
Pyrene	0.0002	-	-	-	<0.00002
Extractables					
EPH (C10-18)	0.5		<0.5	<0.5	12.8
EPH (C19-31)	1		<1	<1	2

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).

[2] Standard varies with water pH.

[3] Standard varies with water hardness.

"-" Denotes no analysis or standard.

"<" Denotes less than detection limit.

[box] Exceeds CSR Standard for Aquatic Life.

[box] Exceeds CSR Standard for Drinking Water.

5.2 MP234 – Military Camp and Pump Station 7A, Moose Creek

5.2.1 Follow-up Work Program

Follow-up work at MP 234 consisted of three programs:

- Groundwater sampling and well surveying
- Follow-up step out sampling at POL tank berms (area MP 234A)
- Test pit geophysical anomaly at MP 234.5 Burial Site

Groundwater Monitoring

Groundwater wells installed in 1997 around the dumpsite were surveyed to determine groundwater elevations and gradient. A relative benchmark of +100m was established on the bumper of a van hulk on site. Survey data was as follows:

Relative Elevation	MW-1	MW-2	MW-3
Top of Pipe	96.42	100.23	99.12
Ground Level	95.78	98.83	98.17
Water Level (Aug. 20 1997)	94.83	98.53	97.22
Water Level (Sept. 19 1998)	94.77	dry	dry
Bottom of Hole	94.31	97.94	96.86

Wells MW-2 and MW-3 were dry at the time of sampling (September 19, 1998). Based on the survey results, the groundwater flow is in a north-northeasterly direction as shown on Figure 5.2.1.

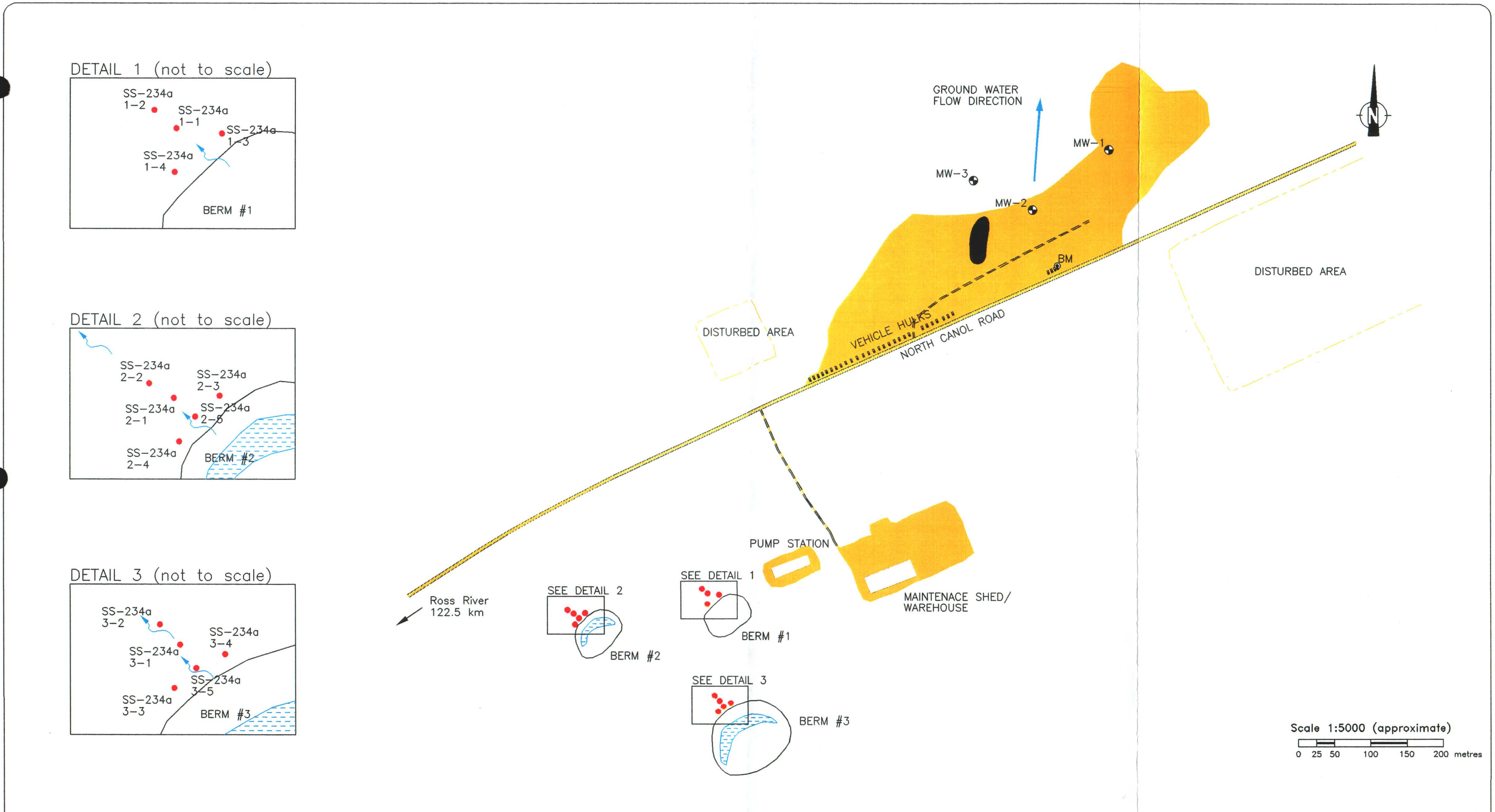
POL Tank Berm Follow-up Sampling

Step-out sampling was conducted around the POL tank berms that were identified in 1997. Samples from around these berms collected in 1997 indicated soil hydrocarbon content in excess of Parkland and Industrial Standards (Gartner Lee Ltd. 1998). Figure 5.2.1 shows the sample locations at this site.

Test pit at MP 234.5

A shallow test pit was hand excavated to investigate a geophysical anomaly detected in the 1997 EM31 survey of the MP 234.5 debris burial site (Gartner Lee Ltd. 1998). There was surface staining in the area around the anomaly.

The test pit was dug to a depth of 1.0 m and encountered medium to dark brown silty cobble and boulder gravel. Some angular oxidized rock fragments were encountered in the test pit. No metallic debris was found in the pit.



LEGEND

Clearing		Surface Drainage		SS-1	Soil Sample
Hydrocarbon Staining		Drainage Ditch			
Surface Debris		Swamp			
Vehicle Hulk		Ponded Water			

Drawn by: BB/FP
GLL Project Number: 98-800
File Name: 98800002

Site Map and Sample Location
MP 234 Moose Creek Camp

Canol Road
Site Assessment

Gartner Lee

Figure No.
5.2.1

5.2.2 Test Results

Soil and groundwater samples were collected at the site. The location of the samples is shown on Figure 5.2.1. A complete sample list is found in the Technical Appendix.

Soil Chemistry

Selected soil samples were submitted to the analytical laboratory for analysis of potential contaminants of concern as identified in section 3.3.2, Analytical Program. This section provides a summary of the analytical results with the complete results presented in Tables 5.2.1 and the Technical Appendix.

Four to five samples were collected down gradient of each tank berm. Petroleum hydrocarbons were detected down gradient of all three tank berms. Sample SS234A-1-2 from the eastern most berm shows very high LEPH concentrations that exceed the Industrial standard. HEPH concentrations also exceed the Parkland standard in this sample. HEPH concentrations that exceeded the Parkland standard were detected in one sample collected from the southern most tank berm (Berm #3).

Groundwater Chemistry

One groundwater sample was collected from MW-1 at this site. MW-2 and MW-3 were dry at the time of sample collection, and therefore no groundwater samples were collected from these wells. Sample MW-1 was analyzed for PAH and LEPH/HEPH concentrations. PAHs were found to exceed both the Aquatic Life standard and the Drinking Water standard for three parameters. LEPH and HEPH were found to exceed Aquatic Life standards. The complete results are presented in Table 5.2.2 and the Technical Appendix

TABLE 5.2.1: SOIL CHEMISTRY - HYDROCARBON RESULTS

Parameter	Criterion [1]		SS-234 (A)-1-1	SS-234 (A)-1-2	SS-234 (A)-1-3	SS-234 (A)-1-4	SS-234 (A)-2-1	SS-234 (A)-2-2	SS-234 (A)-2-3	SS-234 (A)-2-4	SS-234 (A)-3-1	SS-234 (A)-3-2	SS-234 (A)-3-3	SS-234 (A)-3-4	SS-234 (A)-3-5
	Parkland	Industrial													
Physical Tests			-	-	-	-	-	-	-	-	-	-	-	-	-
Moisture %	-		57.1	30.6	14	16.5	39.9	27	44.3	18.9	42.9	39.9	29.7	21.9	6.2
Extractables															
EPH (C10-18) (~LEPH)	1000	2000	<200	14700	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	458
EPH (C19-31) (~HEPH)	1000	5000	233	1940	<200	<200	212	<200	<200	<200	284	<200	<200	<200	2850

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).

" - " Denotes no analysis or standard.

" < " Denotes less than detection limit.

[box] Exceeds CSR Standard for Parkland Use

[box] Exceeds CSR Standard for Industrial Land Use.

All concentrations in mg/kg (ppm)

TABLE 5.2.2: GROUNDWATER CHEMISTRY RESULTS
MP 234A - Moose Creek Camp Dump

Parameter	Criterion [1] Aquatic Life	Criterion [1] Drinking Water	MW-234- MW-1
Polycyclic Aromatic Hydrocarbons			
Acenaphthene	0.06	-	<0.0005
Acenaphthylene	-		<0.0005
Acridine	0.0005	-	0.00009
Anthracene	0.001	-	0.0003
Benz(a)anthracene	0.0001	0.00001	0.00084
Benzo(a)pyrene	0.0001	0.00001	0.00065
Benzo(b)fluoranthene	-		0.00094
Benzo(g,h,i)perylene	-		0.0004
Benzo(k)fluoranthene	-		0.00038
Chrysene	-		0.001
Dibenz(a,h)anthracene	-		0.0001
Fluoranthene	0.002	-	0.0019
Fluorene	0.12	-	<0.0001
Indeno(1,2,3-c,d)pyrene	-		0.00044
Naphthalene	0.01	-	0.0003
	-		
Phenanthrene	0.003	-	0.0009
Pyrene	0.0002	-	0.00163
Extractables			
EPH (C10-18)	0.5		1.8
EPH (C19-31)	1		8

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).

[2] Standard varies with water pH.

[3] Standard varies with water hardness.

" - " Denotes no analysis or standard.

" < " Denotes less than detection limit.

[box] Exceeds CSR Standard for Aquatic Life.

[box] Exceeds CSR Standard for Drinking Water.

5.2.3 Discussion

Dump Site Area

Groundwater monitor surveying at the MP234 dump site indicates a north-northeast groundwater flow direction. Contamination of the groundwater was detected in the sample collected from MW-1. This groundwater monitor was installed directly in the eastern dump area, and therefore does not provide indication if the contaminant is moving out of the dump site. A down-gradient monitor needs to be installed to determine if contamination is leaving the eastern dump area. The down-gradient monitor of the western dump area (MW-3) did not contain detectable contamination during 1997 sampling, although this could not be confirmed in 1998 sampling events.

POL Tank Berm Area

Preliminary sampling of the POL tank berms south of the Canol Road in 1997 identified hydrocarbon contamination. Specifically elevated levels of oil & grease were collected from the spillway of the eastern berm (Berm #1), the centers of the western and southern (Berm #2 and Berm #3 respectively). Follow-up sampling down-gradient of the tank berms in 1998 area identified hydrocarbon contamination associated with berm #1 and berm #3. The contaminated sample collected from berm #1 (SS-234A-1-2) had light hydrocarbon levels of 1.4%. The chromatograph from this sample suggests this material is diesel. Although re-vegetation in this area is approaching a natural undisturbed state, deeper grid sampling should be conducted in the berm #1 area to better delineate the nature of this contamination. The chromatograph for sample SS-234A-3-5, collected from tank berm #3 indicates the contamination may be due to heavy oils.

It is uncertain as to why such containment berms would have been constructed around POL tanks in the 1940's. An article in Environmental Science & Engineering (1998) suggests that "the [containment berm] was always associated with large tanks located above ground; its primary purpose had nothing to do with tank leakage, it was just thought to be a good way to contain product for a short period of time in the advent of catastrophic failure during a fire."

5.2.4 Conclusions

Based on the findings of this year's site investigation, the following conclusions can be made:

a) groundwater flow direction in the MP234 dump site has been determined to be in a north-northeasterly direction;
b) groundwater in the eastern dump area is contaminated above the standards; and
c) hydrocarbon contamination above Industrial standard has been detected down-gradient of tank berms # 1 and # 3.

5.2.5 Recommendations

The following recommendations are made based on the conclusions outlined above:

1. due to the contaminated soil and groundwater delineated in this year's and pervious years' work the following risk assessments should be done:
   - a screening level *quantitative* human health risk assessment of petroleum hydrocarbons in soil to provide estimates of human health risks for use of the site (*e.g.*, parkland uses);
   - a screening level *quantitative* ecological risk assessment of petroleum hydrocarbons in soil to provide estimates of ecological risks for Valued Ecosystem Components that are identified in the area;
2. install MW-4 down-gradient of eastern dump site;
3. continue monitoring MW-3 & proposed MW-4;
4. excavate & clean-up dump site;
5. conduct backhoe test pitting and grid sampling down-gradient of berm #1 and berm #3; and
6. conduct backhoe test pitting and sampling down-gradient of a pump station to locate potential contamination associated with the pump station.

5.3 MP 267.5 – Military Camp, MacMillan #2

5.3.1 Follow-up Work Program

Preliminary sampling from this site in 1997 found elevated levels of hydrocarbon content in soils (Gartner Lee Ltd. 1998). Work in 1998 followed on recommendations to conduct further sampling to determine hydrocarbon contamination associated with the site. Literature review identified a barrel dump on the west side of the road that had not previously been sampled (Gay 1975) which was removed by clean-up crews in the 1970's. Sample locations are shown on Figure 5.3.1

5.3.2 Test Results

Soil samples were collected at the site. The location of the samples is shown on Figure 5.3.1. A complete sample list is found in the Technical Appendix.

Soil Chemistry

Selected soil samples were submitted to the analytical laboratory for analysis of potential contaminants of concern as identified in section 3.3.2, Analytical Program. This section provides a summary of the analytical results with the complete results presented in Tables 5.3.1 and the Technical Appendix.

Ten samples were collected at this site, seven from the west side of the road, and three from the east side. Petroleum hydrocarbon was detected in two samples. Only sample SS-267.5-7 had concentrations of HEPH in excess of the Parkland standard.

LEGEND

Clearing
Hydrocarbon Staining
Surface Debris
Former Structure
Surface Drainage
Drainage Ditch
Swamp
Ponded Water
SS−1 ● Soil Sample

Drawn by: BB/FP
GLL Project Number: 98−800
File Name: 98800002

Site Map and Sample Location
MP 267.5 MacMillan Camp

Canol Road
Site Assessment

Gartner Lee

Figure No.
5.3.1

TABLE 5.3.1: SOIL CHEMISTRY - HYDROCARBON RESULTS

MP 267.5 - MacMillan #2 Camp

Parameter	Criterion [1]		SS-267.5 -1	SS-267.5 -2	SS-267.5 -3	SS-267.5 -4	SS-267.5 -5	SS-267.5 -6	SS-267.5 -7	SS-267.5 -8	SS-267.5 -9	SS-267.5 -10
	Parkland	Industrial										
Physical Tests												
Moisture %	-		14.7	27.7	28.4	13	28.6	12.8	9.2	18.6	11.4	10.8
pH	-		-	-	-	-	-	-	-	-	-	-
Extractables												
EPH (C10-18) (~LEPH)	1000	2000	<200	<200	<200	<200	<200	<200	660	<200	<200	<200
EPH (C19-31) (~HEPH)	1000	5000	<200	<200	<200	<200	<200	<200	4650	<200	<200	844

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).

" - " Denotes no analysis or standard.

" < " Denotes less than detection limit.

Exceeds CSR Standard for Parkland Use

Exceeds CSR Standard for Industrial Land Use.

All concentrations in mg/kg (ppm)

5.3.3 Discussion

Based on 1997 sampling results, there is an area of oil & grease contaminated soil associated with a building remnant as shown on Figure 5.3.1. Sampling on the east the Canol Road did not find any soils exceeding the standards. These samples were collected to investigate the possibility of contamination associated with a barrel dump on the east side of the road. Unfortunately, thorough study of historic photos (Gay 1975) indicates that the dump site may have been further north (as shown on the site map) than the location where the samples were collected in 1998.

5.3.4 Conclusions

Based on the findings of the site investigation, the following conclusions can be made:

a) there is an area of oil & grease contamination as characterized in 1997;
b) a single sample collected in 1998 exceeded Parkland standard of HEPH;
c) sampling east of the Canol Road did not detect significant concentrations of hydrocarbon; and
d) soils at the former barrel dump area east of the Canol Road were not sampled during the 1998 sampling program.

5.3.5 Recommendations

The following recommendations are made based on the conclusions outlined above:

1. follow-up sampling around sample SS-267.5-7;
2. collect shallow Sample barrel dump area to north; and
3. no further action due to natural re-vegetation of site.

5.4 Underground Storage Tank Destruction

5.4.1 Follow-up Work Program

Arrangements were made for the steam-cleaning and destruction of the two underground storage tanks (USTs) removed in 1997. The tanks were steam cleaned by Ross River Enterprises, and subsequently flattened and taken to the Ross River dump. Photographs of the UST destruction are found in the Appendices. Three 45-gallon drums of hydrocarbon product collected from the UST are currently being stored in the Ross River Enterprises compound. Samples were collected from these drums to characterize the product for disposal.

5.4.2 Test Results

Samples were collected from the three barrels of hydrocarbon product in storage in Ross River. These samples were analyzed with a waste characterization package for disposal. The analytical results with the complete results are presented in Tables 5.4.1 and the Technical Appendix.

This analysis indicates that the hydrocarbon product is suitable for normal waste oil disposal options.

5.4.3 Conclusions

Based on the findings of the site investigation, the following conclusions can be made:

a) the USTs from Pump Stations 9 & 10 have been cleaned, destroyed and disposed of as scrap metal at the Ross River dump; and
b) the product collected from the USTs is acceptable for waste oil disposal, although the oil in barrel B73 contains sediment.

5.4.4 Recommendations

The following recommendation is made based on the conclusions outlined above:

1. The three barrels of waste oil in Ross River should be collected and transported to an appropriate waste disposal facility.

TABLE 5.4.1: WASTE OIL CHARACTERIZATION

Parameter	Disposal Options[1]			B73-1	B124-1	B124-2
	Application to Roads	Fuel for Cement Kilm	Fuel other than Cement Kilm	980919	980919	980919
Physical Tests						
Flashpoint Degrees C.	>60	-	-	-	-	-
Total Metals				-	-	-
Arsenic T-As	20	20	5	<4	<4	<4
Cadmium T-Cd	3	3	2	<1	<1	<1
Chromium T-Cr	10	10	10	<1	<1	<1
Lead T-Pb	1000	1000	50	72	16	11
Zinc T-Zn	1000	-	-	-	-	-
Polychlorinated Biphenyls (PCB)						
Total Polychlorinated Biphenyls	5	500	3	<2	<2	<2
Organic Parameters						
Total Organic Halide	2000	3000	1500	<300	<300	<300

[1] Waste Management Act, Special Waste Regulations, Province of British Columbia

" - " Denotes no analysis or standard.

" < " Denotes less than detection limit.

All concentrations in mg/kg (ppm)

5.5 Crude Oil Tar Characterization

5.5.1 Follow-up Work Program

Desiccated crude oil tars have been identified at Pump Stations #8 (Flat Creek), #9 (Lapie River) and #10 (Gravel Creek). At Flat Creek there is sign that the bears are attracted to, and are eating the oil tars. Samples of the tar were collected from the Flat Creek pump station, the Lapie River pump station, a dried oil spill at MP215 NWT, and Pump Station #6 and characterized for disposal options.

5.5.2 Test Results

The analytical results with the complete results are presented in Tables 5.5.1 and the Technical Appendix. Chromatographs from these samples indicate that these are all similar material. The tars have LEPH concentrations ranging from 0.5% to 6.7% and HEPH concentrations ranging from 4.7% to 21.4%. The tar from Pump Station #9 (MP124.5 Crude Tar) had the highest hydrocarbon concentrations, and exceeded Parkland standard for one PAH parameter. Sample SS-215-4 from MP215 NWT had the lowest hydrocarbon content. In samples MP124.5 and MP 174-1, arsenic levels exceeded Parkland and Industrial standards respectively. All of these tars are considered Special Waste due to their elevated hydrocarbon and metal content.

5.5.3 Conclusions

Based on the findings of the site investigation, the following conclusions can be made:

a) all dried oil tars found along the Canol Road are Special Waste;
b) common waste disposal options (application to roads or use as fuel) cannot be used due to metal concentrations above standard; and
c) wildlife (especially bears) is attracted to the odour of the oil tars and appear to be ingesting the tar material.

5.5.4 Recommendations

The following recommendations are made based on the conclusions outlined above:

1. All oil tars should be clean-up and removed or isolated from the environment

TABLE 5.5.1: CRUDE OIL TAR CHARACTERIZATION

Parameter	Criterion [1]		Disposal Options [4]			MP 124.5	MP174-	MP174-	SS 215-4	HC 208-2
	Parkland	Industrial	Application to Roads	Fuel for Cement Kilm	Fuel other than Cement Kilm	Crude Tar 980912	TAR-1 980919	TAR-2 980919	Hydrocarbon 980914	980912
Physical Tests										
Flashpoint Degrees C.	-		>60	-	-	>61	>61	>61	>61	>62
Moisture %	-		-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
Total Metals									-	
Arsenic T-As	35 [3]	150 [3]	20	20	5	39	166	28	4	31
Cadmium T-Cd	250 [3]	700 [3]	3	3	2	<0.3	<0.3	<0.3	<0.3	<0.3
Chromium T-Cr	250 [3]	800 [3]	10	10	10	7	32	6	6	11
Lead T-Pb	1000 [3]	2000 [3]	1000	1000	50	41	227	36	25	114
Polycyclic Aromatic Hydrocarbons										
Acenaphthene	-		-	-	-	2	-	-	0.11	-
Acenaphthylene	-		-	-	-	0.6	-	-	<0.05	-
Anthracene	-		-	-	-	<0.2	-	-	<0.05	-
Benz(a)anthracene	1	10	-	-	-	0.3			0.06	
Benzo(a)pyrene	-		-	-	-	<0.2	-	-	<0.05	-
							-	-		-
Benzo(b)fluoranthene	1	10	-	-	-	1	-	-	0.24	-
Benzo(g,h,i)perylene	-		-	-	-	0.5	-	-	0.1	-
Benzo(k)fluoranthene	1	10	-	-	-	<0.2	-	-	<0.05	-
Chrysene	-		-	-	-	2.3			0.66	
Dibenz(a,h)anthracene	1	10	-	-	-	<0.1	-	-	<0.05	-
							-	-		-
Fluoranthene	-		-	-	-	1.1	-	-	<0.05	-
Fluorene	-		-	-	-	<0.1	-	-	<0.05	-
Indeno(1,2,3-c,d)pyrene	1	10	-	-	-	<0.1	-	-	<0.05	-
Naphthalene	5	50	-	-	-	0.1			0.16	
Phenanthrene	5	50	-	-	-	<0.7	-	-	0.09	-
							-	-		-
Pyrene	10	100	-	-	-	4.8	-	-	0.52	-
Extractables										
EPH (C10-18)	1000	2000	-	-	-	67800	18100	46400	5840	125000
EPH (C19-31)	1000	5000	-	-	-	214000	141000	220000	46900	206000

[1] Yukon Territory of Canada, Contaminated Sites Regulation (CSR; Dec 16, 1996).

[2] Standard varies with soil pH.

[3] Environmental protection, toxicity to invertebrates and plants.

[4] Waste Management Act, Special Waste Regulations, Province of British Columbia

"-" Denotes no analysis or standard.

"<" Denotes less than detection limit.

Exceeds CSR Standard for Agricultural Land Use

Exceeds CSR Standard for Parkland Use.

Exceeds Special Waste Criteria

6. Summary of Recommendations

Complete recommendations on a site by site basis have been included in the subsection for each individual site in the main body of this report. The following table provides a summary of findings and recommendations for individual sites listed in order or priority for future action.

SITE	FINDINGS	RECOMMENDED ACTION
	MacMillan Pass Sites	
MP 208 – Pump Station 6	• Underground Storage Tank with approx. 500 L of hydrocarbon product. • Barrels on site containing hydrocarbon products. • Soils in Area A (wetland) contaminated above Special Waste guidelines. • Soils in Area B (Barrel dump) contaminated above Industrial standard. • POL tank contains oil tar. • Site heavily used by hunters.	• Conduct human and ecological risk assessment of site. • Remove UST & drums of hydrocarbon product. • Define extent of and clean-up soil contamination in Area A (wetland), Area B (barrel dump) & POL tank area • Decommission POL tank • Clean-up site & address human health & safety concerns.
MP 223 – Vehicle Boneyard	• Domestic garbage pit & vehicle hulks. • Hydrocarbon product detected in adjacent pond. • No significant soil contamination found.	• Conduct follow-up water sampling & soil sampling adjacent to pond area.. • Clean-up domestic garbage.
MP 215-216 Boulder Creek Quarry	• Empty drums in pond area & general site debris. • Human health & safety concerns. • Small area of dried crude oil. • Heavily used traditional camp site.	• Remove drums from pond area • Remove human health & safety concerns • Clean-up site. • No further action
MP 207.5 – Laydown Area	• One area of shallow hydrocarbon contamination • One potentially small area of metal contamination • Site is natural feature with misc. debris.	• Clean-up areas of contaminated soil • No further action
MP 210 – Qld Squaw Barrel Dump	• Empty drums scattered along road • Very small areas of elevated hydrocarbon concentrations. • One open drum of grease • Heavily used traditional camp site	• Remove grease drum • No further action

SITE	FINDINGS	RECOMMENDED ACTION
Yukon 1998 Follow-up Sites		
Ross River – UST Waste Oil	• Three drums of hydrocarbon product from UST destruction – suitable for normal waste oil disposal.	• Remove and dispose of waste oil.
MP 73 – Pump Station 10	• Hydrocarbon concentration found in groundwater down-gradient of dump site.	• Conduct human and ecological risk assessment of site. • Define extent of subsurface contamination.
MP 234 – Moose Creek Camp/Pump Station	• Hydrocarbon contamination above Industrial standard found down-gradient of tank berms #1 & # 3. • Hydrocarbon contamination of groundwater in the eastern half of the waste burial site.	• Conduct human and ecological risk assessment of site. • Conduct backhoe test pitting of tank berm area. • Install down-gradient groundwater well
MP 267.5 MacMillan #2 Camp	• Area of Oil & Grease contamination found in 1997 • One 1998 sample exceeded Parkland standard for HEPH	• Conduct follow-up sampling at site & barrel dump • No further action

In addition to the site-specific findings in the Northwest Territories, there is telegraph wire along the length of the NWT side of the Canol Trail. This wire is a hazard to wildlife that can get the caught in the wire. Examples of animals that have died due to wire entanglement can be seen at Old Squaw Lodge. Telegraph wire was clean-up in Yukon during the 1970's. Wire should be clean-up and removed to reduce the risk to wildlife.

Report Prepared by:

Forest Pearson, B.Sc., EIT
Geological Engineer

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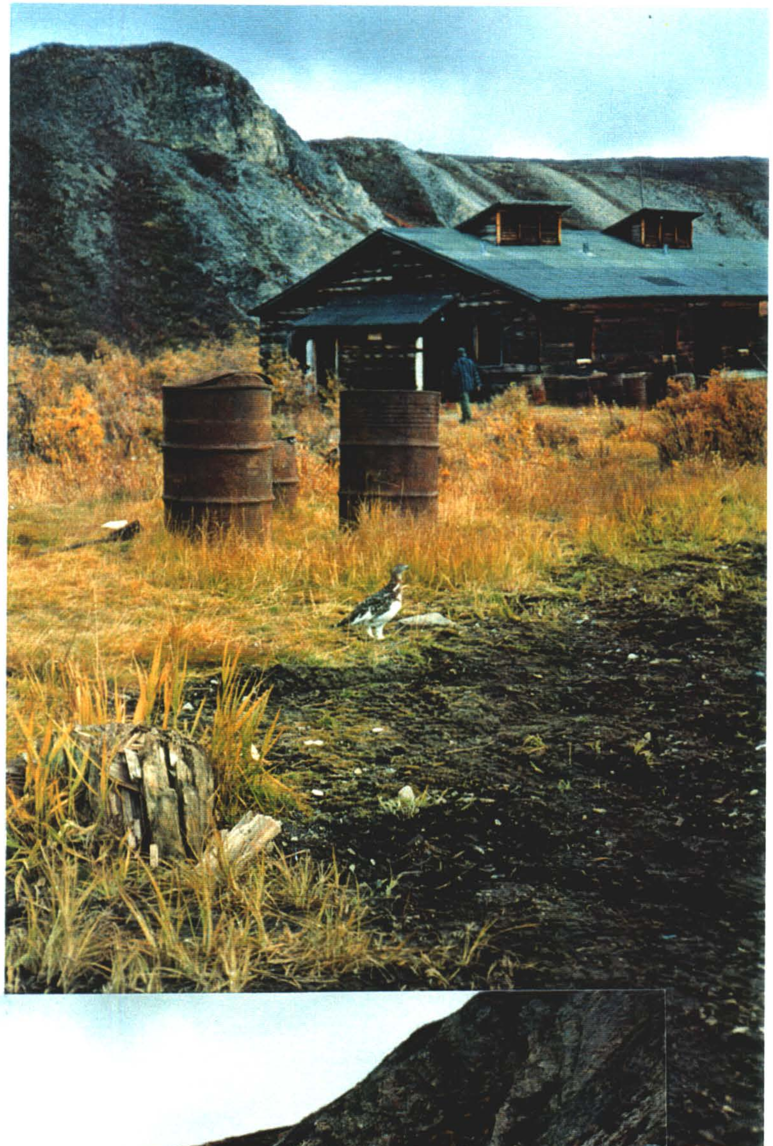
Appendix A

Project Photographs

PHOTOGRAPH 1:
Pump Station 6

PHOTOGRAPH 2:
Morning snow on field camp at MP 209



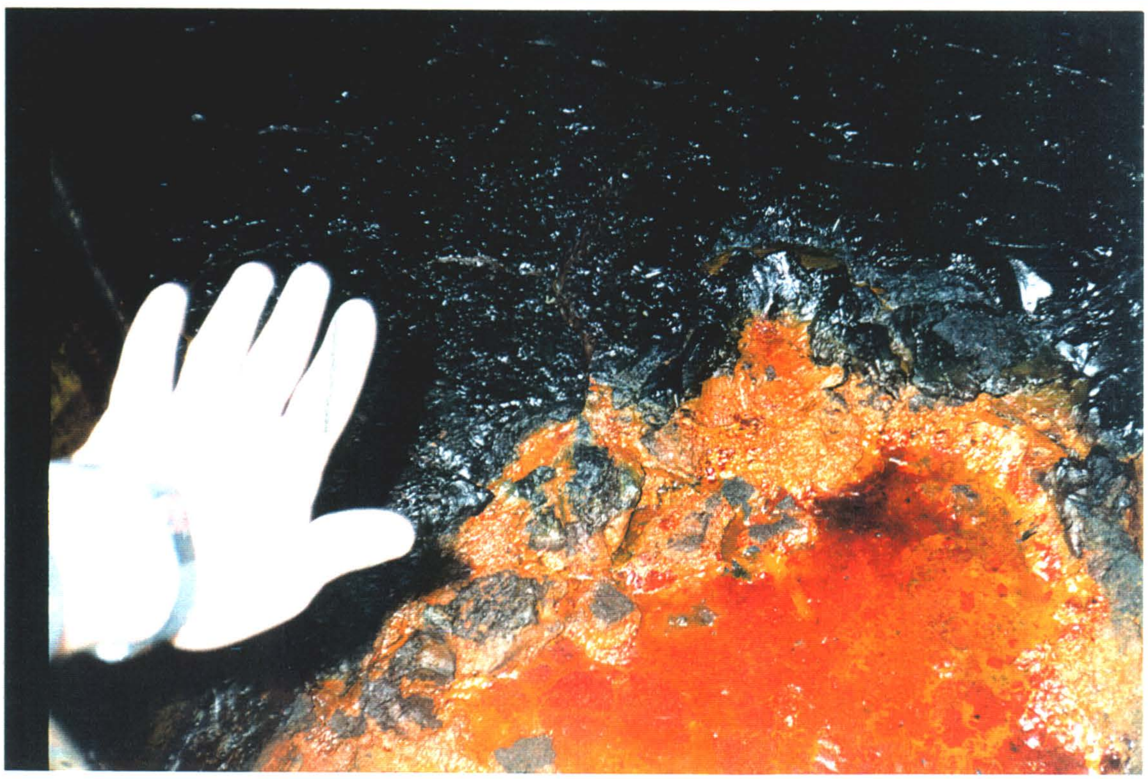
PHOTOGRAPH 3:
Pump Station 6

PHOTOGRAPH 4:
Pump Station 6 camp – north side of creek

PHOTOGRAPH 5:
Wetland adjacent to pump house building

PHOTOGRAPH 6:
Oil saturated soils in wetland area.

PHOTOGRAPH 7:
Sample location SS-208-5, north side of POL tank



PHOTOGRAPH 8:
Crude oil tars inside POL tank

PHOTOGRAPH 9:
Underground Storage Tank – Greg McLeod dips to check oil level – not oil on stick.

PHOTOGRAPH 10:
Exposed west end of underground storage tank.

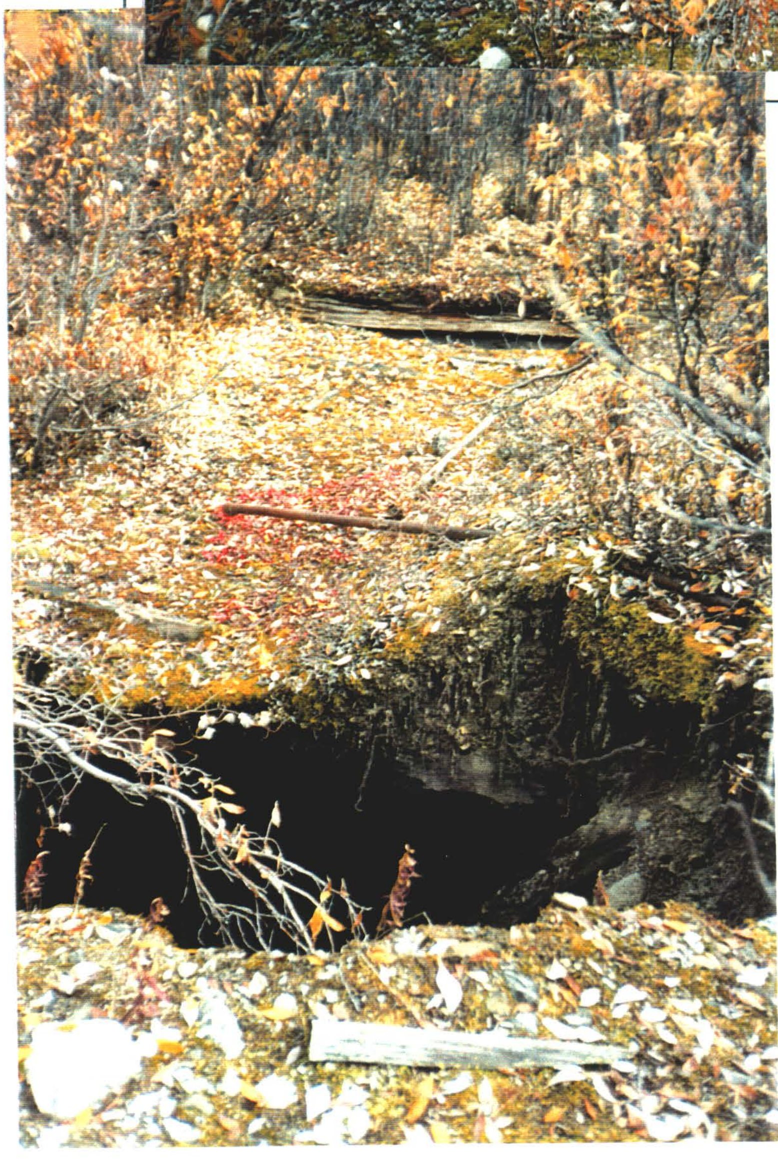
PHOTOGRAPH 11:
Barrel dump 'H' east of POL tank.
Many barrels are up to 10% full of hydrocarbon products

PHOTOGRAPH 12:
Heavily hydrocarbon stained ground east of barrel dump 'F'
Sample SS-208-8 collected from this area.

PHOTOGRAPH 13:
Leaking grease barrel
Note bear claw marks in spilled oil on ground.

PHOTOGRAPH 14:
Open grease barrel west of barrel dump 'F'.

PHOTOGRAPH 15:
Debris and domestic waste at former greasing ramp area
Sample SS-208-2 & 3 collected from this area.



PHOTOGRAPH 16:
Partially collapsed "septic pit" adjacent to bath house.

PHOTOGRAPH 17:
Laydown Area overview looking east.

PHOTOGRAPH 18:
Stained surficial soils at former barrel dump 'G'

PHOTOGRAPH 19:
Barrel dump 'A' area.

PHOTOGRAPH 20:
Barrel dump 'B' area.

PHOTOGRAPH 21:
Cabooses at MP 215

PHOTOGRAPH 22:
Caboose and barrel dump at MP 216

PHOTOGRAPH 23:
Ponded water in gravel pit.
Barrel dump 'B' area, samples SS-215-B1 & B2 collected from this area.

PHOTOGRAPH 24:
Ravine draining gravel pit. Barrel dump 'A', samples SS-215-A1 & A2 collected from this area.

PHOTOGRAPH 25:
Crude oil dried to asphalt like surface.

PHOTOGRAPH 26:
Caribou antlers entangled in telegraph wire – collected at Old Squaw Lodge.

PHOTOGRAPH 27:
Overview of vehicle boneyard looking west.

PHOTOGRAPH 28:
Debris and domestic waste dumped over bank.

Appendix B

Community Consultation

Community Workshop
Military Sites Along the Canol Road
1998 Program Findings
Risk Assessment Results

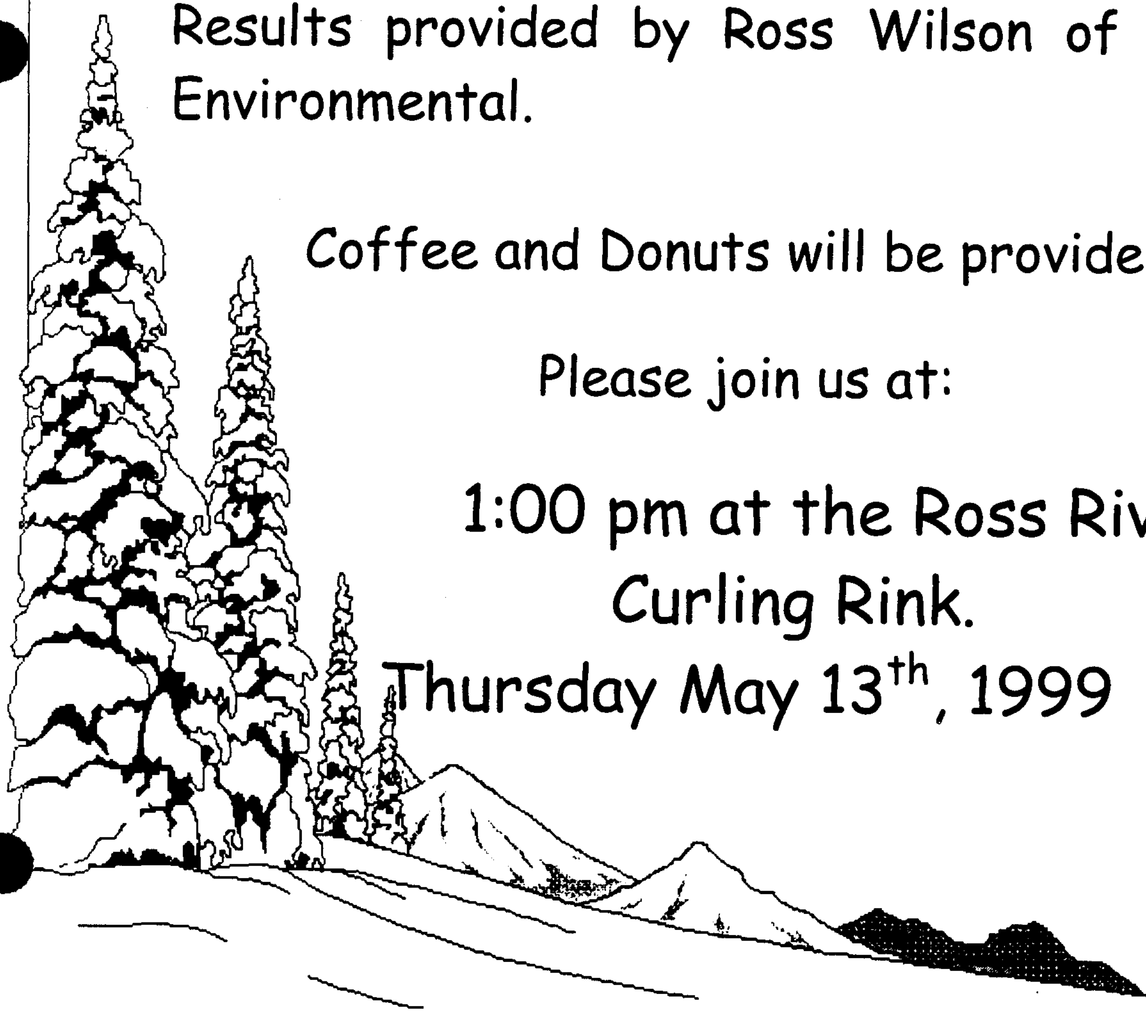
You are invited to a Workshop on the Canol Road hosted by the Ross River Dena Council. The findings of the 1998 environmental program will be presented by Forest Pearson of Gartner Lee Limited with Risk Assessment Results provided by Ross Wilson of Cantox Environmental.

Coffee and Donuts will be provided.

Please join us at:

1:00 pm at the Ross River Curling Rink.

Thursday May 13th, 1999



Ross River Dena Council

ROSS RIVER, YUKON
Y08 1S0

PHONE 969-2278

VALUED ECOSYSTEM COMPONENT CHARACTERIZATION
CANOL ROAD CONTAMINANTS PROJECT
COMMUNITY QUESTIONNAIRE

Gartner Lee Limited and the ***Ross River Dena Council*** is conducting a risk assessment for abandoned military sites along the Canol Road. This assessment will consider the ***risk to human health*** and to ***the environment,*** specifically in relation to oil, grease and gasoline contamination (also known as *hyrdorcarbon contamination)*. To ensure that the traditional land use and concerns of Ross River people are being incorporated into this risk assessment, a ***Valued Ecosystem Component (VEC) Characterization*** is being conducted through interviews with individuals from community of Ross River. This will ensure that your concerns and issues about the environment are brought directly into this risk assessment process.

Gartner Lee and the Ross River Dena Council would like to hear your views on the abandoned military sites along the Canol Road by answering this questionnaire. Please note that this interview is a very important way of voicing your concerns, but there will be future opportunities at contaminants workshops held in Ross River.

Name:	Date:

There are 7 sites of concern, their locations are shown of the attached map.

1. **Do you use the land at any of the following these sites for hunting, fishing or other traditional land use activities ?**

South Canol

- ☐ Gravel Creek Pump Station, Mile Post 73
- ☐ Lapie River Pump Station, Mile Post 124

North Canol

- ☐ Flat Creek Pump Station, Mile Post 174
- ☐ Moose Creek Pump Station (1st set of army trucks), Mile Post 233/234

MacMillan Pass

- ☐ MP 214, Gravel Pit & Cabooses
- ☐ 208 Pump Station (just past Old Squaw Lodge)

2. **If so, can you tell us how often each year and the length of time each year ?**

Number of Days:

OR

Number of Months:

3. What type of fish do you harvest and/or which species of animal do you hunt in these areas?

____
____
____
____
____
____
____
____

4. Do you use the plants in these areas?

Yes :

OR

No:

If yes, for what purposes ?

Food:

Medicines:

Other:

5. What is your source of drinking water in these areas ?

Lakes:

Rivers:

Ice:

Bring your own, or from another creek:

6. Have you noticed a change in the wildlife, plants or the water at the abandoned military sites ?

Yes :

OR

No:

7. Can you explain some of these changes to us. I can record your comments while you are speaking.

8. What do you think should be done about the abandoned military sites along the Canol Road? I can record your comments while you are speaking.

9. Do you think there has been enough consultation on the study and clean up of these abandoned military sites ?

Yes :

OR

No:

10. Do you have any suggestions about the type and level of consultation which should occur ? I can record your comments while you are speaking.

____
____
____
____
____
____
____
____

11. Do you have any other suggestions or ideas you would like to pass on about these abandoned military sites ? I can record your comments while you are speaking.

____
____
____
____
____
____
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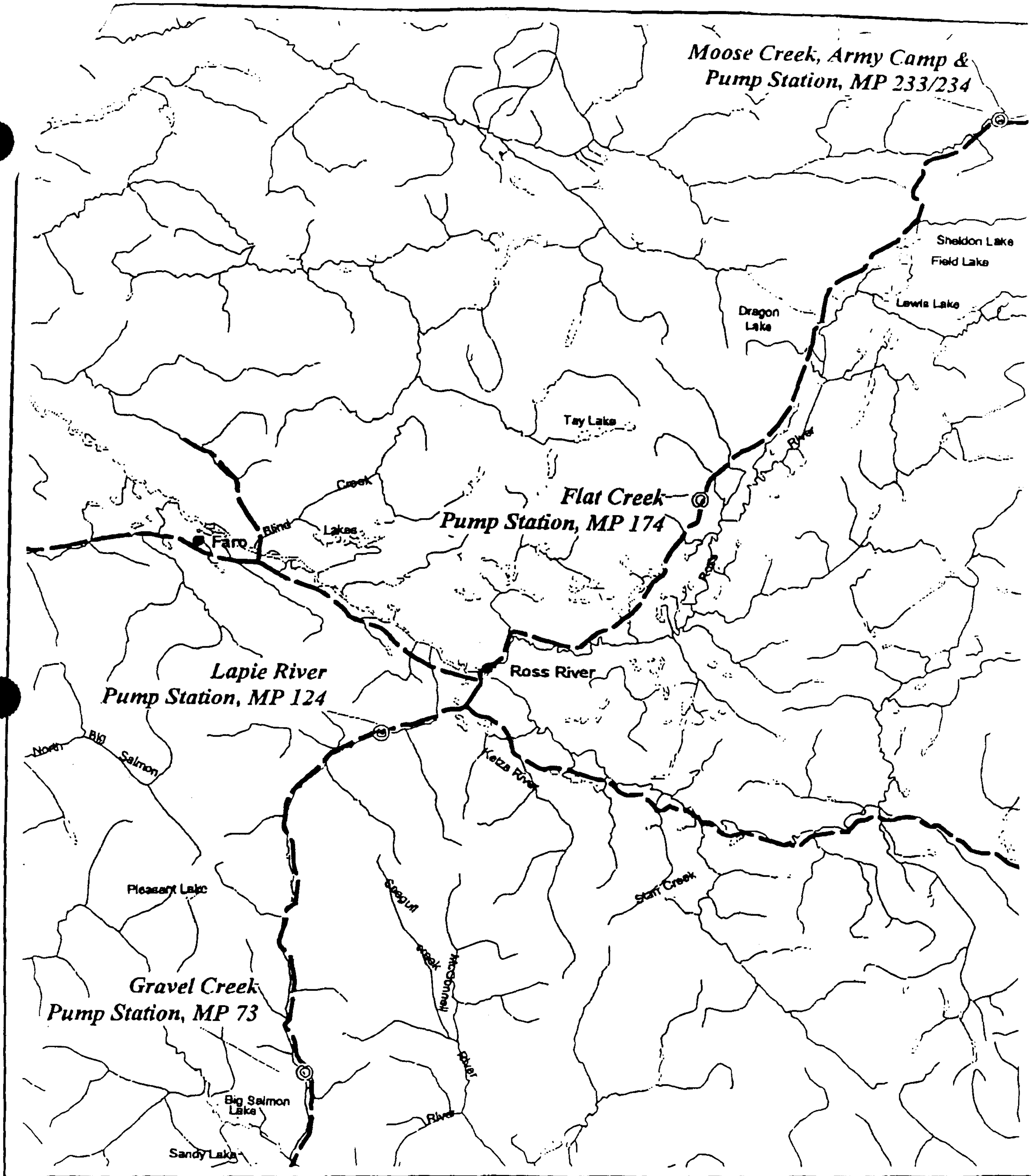
____

Thank you for your time. We would like to use this information for a report which is being done by Gartner Lee for the Ross River Dena Council. Can we use the information which you have provided ?

Yes :

OR

No:



Legend

Risk Assessment Sites

NOTE:
All Mile Post locations are referenced from Johnson's Crossing.

Not to Scale

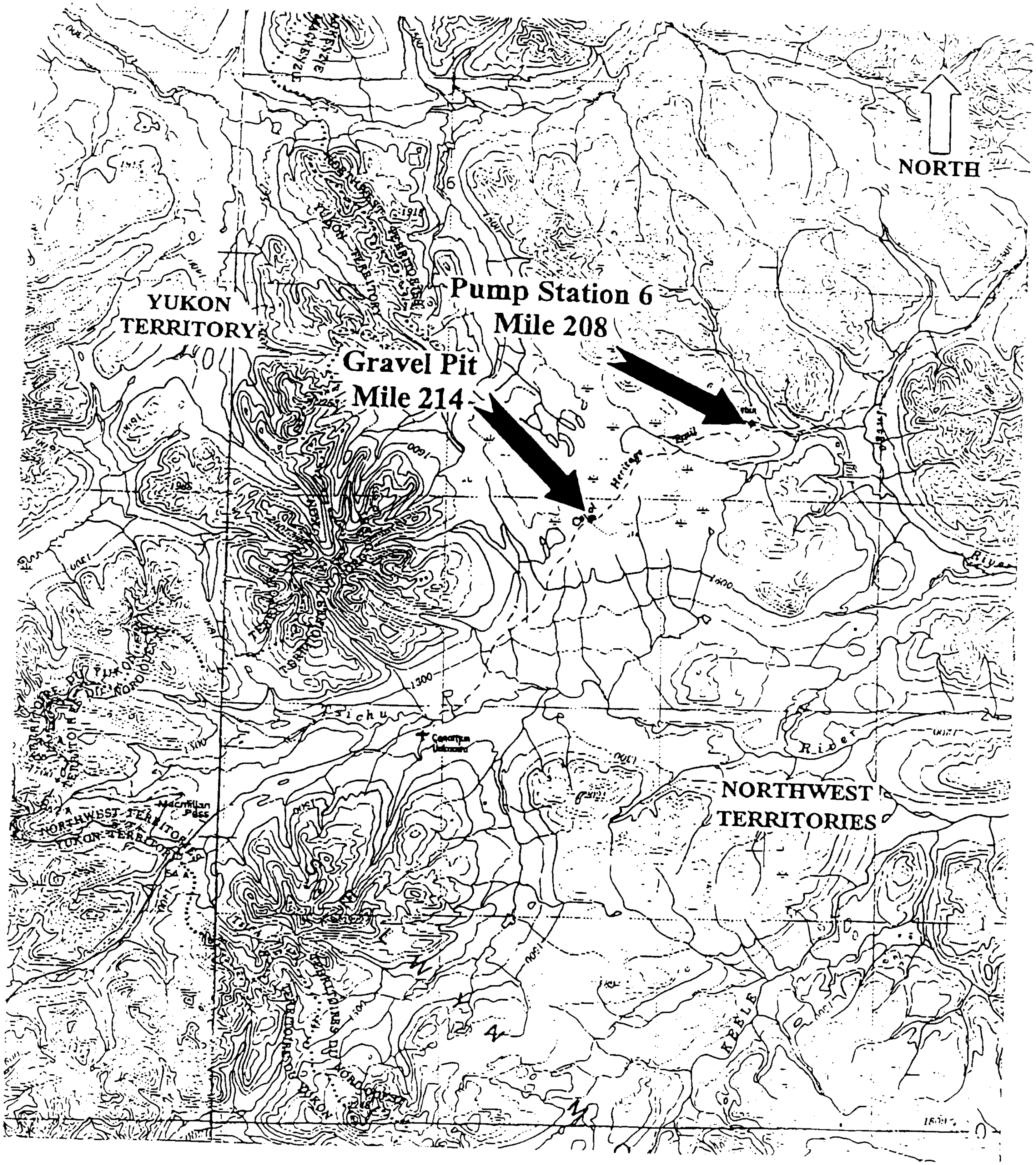
Drawn By: F. Pearson | Project No. 97-751
Site Name: Canol Road | Date: 04.02.98

Canol Road & Priority Sites

1998 Environmental Investigations
Canol Road

Gartner Lee Limited

Figure No. 1



Legend

◎ Risk Assessment Sites

NOTE:
All Mile Post locations are referenced from Norman Wells

1:50,000

Drawn By: F. Pearson	Project No. 94-400
Site Name: Canol Road	Date: 12.01.98

MacMillan Pass
Risk Assessment Sites

1998 Environmental Investigations
Canol Road

Gartner
Lee
Limited

Figure No.
2

CANTOX ENVIRONMENTAL

FINAL REPORT

HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT OF SITES ALONG THE CANOL ROAD AND MACMILLAN PASS AREA

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EXECUTIVE SUMMARY

The Ross River Dena Council, in partnership with the Department of Indian Affairs and Northern Development (DIAND) has requested that Gartner Lee Limited and CANTOX ENVIRONMENTAL INC. complete a preliminary quantitative human health and ecological risk assessment of chemicals identified at 7 sites along the Canol Road and MacMillan Pass area. The risk assessment included an assessment of 6 sites in Yukon Territory (*i.e.,* MP 73, MP 124.5, MP 174, MP 213, MP 233, MP 234) and 1 site in the Northwest Territories (*i.e.,* MP 208). The objective of the project was to determine whether or not the chemicals identified at the sites pose unacceptable risks to humans and/or the environment.

METHODS

The methods used for the risk assessment were based on the fundamental dose-response principle of toxicology, (*i.e.*, the response of a receptor to chemical exposure increases in proportion to the chemical concentration in critical target tissues where adverse effects may occur). The concentrations of chemicals in the target tissues depend upon the degree of exposure, which is proportional to the receptor characteristics, physical/chemical properties of the chemicals and the chemical concentrations in the environment where a receptor lives. The expression of adverse effects from specific concentrations of a chemical depend on the hazard or toxic potency of that chemical.

The steps followed for both the human health and ecological risk assessments included:

(i) Problem Formulation: identification of land use scenarios, human and ecological receptors, exposure pathways and chemicals of concern;

(ii) Exposure Assessment: quantification of the estimated rate of exposure for chemicals, exposure pathways and receptors of concern;

(iii) Toxicity Assessment: the identification and assessment of potential hazards and the recommendation of upper limits of exposure (*i.e.,* maximum exposure without measurable risks to health) for the chemicals of concern; and,

(iv) Risk Characterization: assessment of potential health and ecological risks based on (i) the comparison between the estimated exposures and the recommended exposure limits for the chemicals of concern (modelling approach), and (ii) site-specific toxicity tests and biological field studies to assess potential effects on ecological receptors.

To the extent possible, the risk assessment followed guidance and recommendations provided by regulatory agencies such as Health Canada, Environment Canada, CCME and the US EPA.

RESULTS

Human Health Risk Assessment

The potential for human health risks were found to be dependent on the site, as well as on the intended use of each site, and the time spent on site. The overall conclusions for the assessment are provided in the table below. It should be noted that deterministic, worst-case analyses were used to assess potential health risks and, therefore, considered to be preliminary quantitative estimates. Since a worst-case approach was used, chemicals were identified as posing an acceptable level of risk if the risk estimate was below the critical values of concern. For chemicals posing potentially unacceptable risks, further evaluation would be required before final conclusions can be made.

Summary of Conclusions for the Human Health Risk Assessment

Area	Time Spent on Site (days)	Conclusions [a]
MP 73	14	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	120	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	180	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
MP 124.5	14	Potential unacceptable health risks associated with direct exposure to soil from average and maximum lead concentrations.
	120	Potential unacceptable health risks associated with direct exposure to soil from average and maximum concentrations of LEPH and lead.
	180	Potential unacceptable health risks associated with direct exposure to soil from average and maximum concentrations of LEPH and lead, and maximum concentrations of HEPH.
MP 174	14	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	120	Potential unacceptable health risks associated with direct exposure to soil from average and maximum concentrations of LEPH, and maximum concentrations of HEPH.
	180	Potential unacceptable health risks associated with direct exposure to soil from average and maximum concentrations of LEPH, and maximum concentrations of HEPH.
MP 213	14	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	120	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	180	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
MP 233	14	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	120	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.

Summary of Conclusions for the Human Health Risk Assessment

Area	Time Spent on Site (days)	Conclusions [a]
	180	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
MP 234	14	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	120	Potential unacceptable health risks associated with direct exposure to soil from maximum concentrations of LEPH.
	180	Potential unacceptable health risks associated with direct exposure to soil from maximum concentrations of LEPH.
MP 208 (NWT Site)	14	Potential unacceptable health risks associated with direct exposure to soil from maximum concentrations of LEPH.
	120	Potential unacceptable health risks associated with direct exposure to soil from maximum concentrations of LEPH and HEPH.
	180	Potential unacceptable health risks associated with direct exposure to soil from maximum concentrations of LEPH and HEPH.

[a] shading indicates area/land use of possible concern

Ecological Risk Assessment

Ecological risk assessment of the 7 sites indicated that none of the sites would likely cause a population level effect on any ecological receptors. Some of the sites were found to have small areas of hydrocarbon contamination that influenced the assessments and may have effects on individual animals; however, the size of these areas and degree of contamination was unlikely to have a population effect. Often, site clean-up by removal of these areas would be sufficient to remove ecological health risks to individual animals. A summary of these conclusions is presented below.

Summary of Conclusions for the Ecological Risk Assessment

Site	Conclusions
MP 73	No unacceptable risks would be expected from a population level perspective. Potential unacceptable risks to individual grouse from exposure to LEPH. Risks are for NOAEL end-point, but not for the LOAEL end-point. Weight-of-evidence suggests that ecological risk is minimal for this site.
MP 124.5	No unacceptable risks would be expected from a population level perspective. Potential unacceptable risks calculated for individual grouse, wolf, and bear based on exposure to lead and LEPH. Risk estimates are influenced by small areas on-site with elevated concentrations of lead and hydrocarbons. Removal of these areas would likely be sufficient to remove apparent risk to individual wildlife receptors.
MP 174	No unacceptable risks would be expected from a population level perspective. Potential unacceptable risks calculated for individual grouse based on exposure to LEPH (but no risk for other receptors). Risk estimates are influenced by small areas on-site with elevated concentrations of hydrocarbons. Removal of these areas would likely be sufficient to remove apparent risk to individual wildlife receptors.

Summary of Conclusions for the Ecological Risk Assessment

Site	Conclusions
MP 208	No unacceptable risks would be expected from a population level perspective. Potential unacceptable risks calculated for individual grouse based on exposure to LEPH (but no risk for other receptors). The risk estimates are influenced by small areas on-site with elevated concentrations of hydrocarbons. Removal of these areas would likely be sufficient to remove apparent risk to individual wildlife receptors.
MP 213	No unacceptable risks would be expected from a population level perspective. No unacceptable risks to individual ecological receptors.
MP 233	No unacceptable risks would be expected from a population level perspective. No unacceptable risks to individual ecological receptors.
MP 234	No unacceptable risks would be expected from a population level perspective. Potential unacceptable risks calculated for individual grouse based on exposure to LEPH (but no risk for other receptors). The risk estimates are influenced by small areas on-site with elevated concentrations of hydrocarbons. Removal of these areas would likely be sufficient to remove apparent risk to individual wildlife receptors.

CONCLUSIONS

The risk assessment has indicated that human health risks from these sites is the more sensitive determinant of whether these sites require remediation. Human health risk was directly dependent upon usage patterns and time spent on-site. For scenarios where no unacceptable risks have been predicted, no further evaluation is considered to be necessary. For scenarios determined to exceed the critical values of concern, 4 general options are available:

1) collection of additional site-specific data and revision of the preliminary quantitative human health risk assessment;
2) completion of a more comprehensive risk assessment in order to evaluate the potential for human health effects using more realistic methodology (*i.e.,* stochastic risk assessment);
3) institute restricted land use of the site; or,
4) remediation of the site.

Although the risk assessment represents the best estimate of human health and ecological risks that can be provided within the context of the required scope of work, it is noted that a series of conservative assumptions and methods have been used to estimate risks. If more detailed site-specific data were collected, it is possible that the risk assessment could be revised. However, at this time, it is still possible to view the risk assessment as protective of human health and the environment. Thus, incorporation of the results of the risk assessment into the risk management plan for the sites will ensure protection of humans and the environment from unacceptable health risks related to these chemicals.

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1.0 INTRODUCTION

The Ross River Dena Council, in partnership with the Department of Indian Affairs and Northern Development (DIAND) has requested that Gartner Lee Limited and CANTOX ENVIRONMENTAL INC. complete a preliminary quantitative human health and ecological risk assessment of chemicals identified at 7 sites along the Canol Road and MacMillan Pass area. The risk assessment included an assessment of 6 sites in Yukon Territory (*i.e.,* MP 73, MP 124.5, MP 174, MP 213, MP 233, MP 234) and 1 site in the Northwest Territories (*i.e.,* MP 208). The objective of the project was to determine whether or not the chemicals identified at the sites pose unacceptable risks to humans and/or the environment. Details of the preliminary human health risk assessment are presented in Section 2, and the Section 3 outlines the ecological risk assessment component of the project. Section 4 presents the overall conclusions of the risk assessment.

2.0 HUMAN HEALTH RISK ASSESSMENT

This section of the report outlines the objectives, methods, and results of the preliminary quantitative human health assessment of the 7 sites along the Canol Road/MacMillan Pass area:

1) MP 73 - Pump Station 10
2) MP 124.5 - Pump Station 9
3) MP 174 - Pump Station 8
4) MP 213 - Military Camp/Dump
5) MP 233 - Pump Station 7
6) MP 234 - Military Camp/Pump Station
7) MP 208 - NWT - Pump Station 6

2.1 Objectives of the Human Health Risk Assessment

The current assessment has been completed as a preliminary quantitative human health risk assessment, which is also sometimes referred to as a "screening-level" assessment. The main objectives of the current assessment were to identify potential chemicals of concern, relevant pathways of exposure to these chemicals, human receptors potentially at risk, and potential health risks associated with the use of the sites. Specifically, the major objectives of the human health risk assessment were identified as follows:

- to determine quantitatively the potential human health risks to chemicals of concern, associated with Traditional Land Use of the sites; and

- to determine additional data required for a detailed risk assessment which may or may not be necessary in the future.

2.2 Methodology

For the preliminary quantitative human health risk assessment, potential risks to human receptors were estimated based on existing chemical information available for the site. The methods used to predict the possible adverse effects to humans from exposure to chemicals originating from the site were based on the fundamental dose-response principle of toxicology. That is, the response of a receptor to chemicals is determined by the toxic potency of the chemical and the rate or degree of chemical exposure that is received by the receptor. In addition, the potential response to the chemical increases in proportion to the rate of exposure to the chemical beyond the chemical-specific exposure threshold. Below this exposure threshold, no measurable adverse effects from the chemical would occur to the receptor. The rate of chemical exposure to the receptor is proportional to the receptor characteristics, physical/chemical properties of the chemicals and the chemical concentrations in the environment.

Wherever possible, the approach used to complete the risk assessment was in accordance with formal and informal procedures recommended by Health Canada, Environment Canada and the US EPA. Briefly, the 4 basic steps of the risk assessment procedure were:

(i) Problem Formulation: identification of the land use scenarios, human receptors, exposure pathways and chemicals of concern;

(ii) Exposure Assessment: quantification of the estimated rate of exposure to chemicals, exposure pathways, integration of environmental assessment and VECs, and human receptors of concern;

(iii) Toxicity Assessment: the identification and assessment of potential hazards and the recommendation of upper limits of allowable exposure (*i.e.,* maximum exposure without measurable risks to health) for the chemicals of concern; and,

(iv) Risk Characterization: assessment of potential human health risks based on the comparison between the estimated exposures through lifestyle characteristics (*i.e.,* Traditional Land Use) and the recommended toxicity endpoints for the chemicals of concern.

The methodology to be employed in the preliminary quantitative human health risk assessments is discussed briefly in the sections below.

2.2.1 *Problem Formulation*

The first phase of the preliminary quantitative human health risk assessment involved problem formulation. Problem formulation consisted of identification of the land use scenarios, receptors, exposure pathways and chemicals of concern to be evaluated in the risk assessment.

2.2.1.1 Land Use and Receptor Characterization

In most human health risk assessments completed in Canada, there are 5 general categories of land uses which the various areas of the site could ultimately be used for:

- residential;
- parkland;
- agricultural;
- commercial; and,
- industrial.

However, the site visits and discussion with residents of the Ross River Dena Council and DIAND have indicated that a sixth land use is also possible for the sites of concern. For the purposes of this report, the sixth land use has been termed "Traditional Land Use" and consists of families residing on the land in tents for periods of up to 6 months during the summer. During these periods, it is assumed that people engage in hunting, fishing and gathering activities by living on the land. Since Traditional Land Use appears to be the crucial issue of concern and has the potential to present the greatest amount of exposure to chemicals in the soil, the preliminary quantitative human health risk assessment was completed for this land use scenario only.

2.2.1.2 Exposure Pathway Screening

Traditional Land Use assumes that a family would live on the site in tents during the summer (*i.e.,*when the ground is not snow covered). For this land use, exposures from chemicals in surface soil would occur for a variety of direct pathways of exposure from the soil (*i.e.,* dermal exposure to soil, incidental ingestion of soil, and inhalation of dusts derived from soil). In addition, indirect exposures from the soil involving the consumption of animals hunted in the vicinity of the site would also occur. Under the Traditional Land Use scenario, it was assumed that the receptor that would be most at risk to chemicals from the site would be a female child. However, exposures to other age groups would also occur and need to be evaluated. These assumptions were developed largely with the assistance of the Ross River Dena Council who distributed a Valued Ecosystem Component questionnaire to members of various communities to determine use patterns for the individual sites.

When a family is assumed to camp at any of the 7 sites, the main sources of exposure to chemicals will be from surface soil (and associated pathways), consumption of terrestrial animals caught near the site (*i.e.,* caribou, rabbit and/or grouse), berry consumption, and possibly, through the consumption of water. It is recognized that chemical exposure could result from the consumption of certain fish species and ducks but at the time of the assessment, there was insufficient data to estimate these exposures. The inability to consider this exposure pathway in the preliminary quantitative risk assessment must be considered when interpreting the results obtained (*i.e.,* since exposures to chemicals from fish and ducks were not considered, the results of the preliminary quantitative risk assessment may not be overly conservative). Based on the Traditional Land Use of the site and receptor characteristics for this land use scenario, the following exposure pathways were included:

- inhalation of chemicals which volatilize or are re-suspended as dusts from the soil air surrounding the site;
- ingestion of chemicals in soil, airborne dusts, wild game berries and water; and,
- dermal contact with chemicals in soil and airborne dusts.

Furthermore, discussions with various persons familiar with the traditional lifestyle suggested that tents (that are only partially floored) would typically be used by persons camping at these sites. These assumptions are described in greater detail later in this report.

The drinking water pathway was assessed as a hypothetical scenario at sites where water data was available. This scenario was considered to be hypothetical since: i) the groundwater is not accessible (*i.e.*, no groundwater wells on site); and, ii) surface water may not be used as a source of drinking water at certain sites (e.g., if it is not aesthetically pleasing or of suitable quality).

2.2.1.3 Chemical Selection

Extensive soil sampling has been conducted as part of the environmental study of the Canol Road/MacMillan Pass area sites. The existing data was compiled to aid in chemical selection for the preliminary quantitative human health risk assessment using the methodology described below.

Chemicals advanced to the quantitative phase of the assessment if: (i) maximum soil concentrations of chemicals exceeded Yukon Contaminated Sites Regulation (Yukon Territory, 1996) soil criteria. for parkland use; and (ii) it was determined that the exceedances were due to anthropogenic activities (*i.e.*, not due to background conditions). Using this methodology, the following chemicals were included for evaluation in the risk assessment for each of the sites:

- LEPH (C10-C18);
- HEPH (C19-C32); and
- lead (only for MP 124.5)

It should be noted that lead was in exceedance of criteria values at several sites, but in most cases, the exceedances were due to the background geology based on the expert opinion of Gartner Lee staff. However, at MP 124.5 the lead exceedance was suspected to be related to former site activities, and thus, the potential health risks to lead were examined for this site only.

2.2.2 *Methodology for the Human Health Risk Assessment*

To the extent applicable, the risk assessment was completed in accordance with the methods consistent with those recommended by Environment Canada, Health Canada and the US EPA. It is noted, however, that wherever possible special consideration was given to the uniqueness of Northern conditions. The preliminary quantitative human health risk assessment was completed separately for each of the 7 sites:

- MP 73 - Pump Station 10
- MP 124.5 - Pump Station 9
- MP 174 - Pump Station 8
- MP 213 - Military Camp/Dump
- MP 233 - Pump Station 7
- MP 234 - Military Camp/Pump Station
- MP 208 - NWT - Pump Station 6

The exposure assessment methodology is discussed below.

2.2.2.1 Exposure Assessment

Exposure assessment involves the estimation of the amount of chemical received by human receptors per unit time (*i.e.*, the quantity of chemical and the rate at which that quantity is received). Exposure assessment was conducted for the chemicals, human receptors and exposure pathways identified to be of greatest concern during the problem formulation phase of the risk assessment. The rate of exposure to chemicals from the various environmental media is usually expressed in units of amount of chemical intake per body mass per time (*e.g.*, μg of chemical/kg body weight/day).

For this preliminary quantitative human health risk assessment (also referred to as a screening level risk assessment), the exposure assessment was completed using deterministic or point estimate risk analysis techniques. Briefly, deterministic analysis techniques utilize input parameters which are expressed as point estimates (*i.e.*, a single value is used for each parameter considered in the risk assessment). An alternative to deterministic analysis techniques are stochastic (or probabilistic) analysis techniques which utilize distributions to characterize input parameters (*i.e.*, each parameter is represented by a distribution of values, such as the distribution of body weight observed in a population of people). The main advantage of stochastic analysis is that it produces results that are believed to be more realistic representations of the characteristics that actually exist for the various risk determination parameters, than the use of single, worst-case or upper bound characteristics used in deterministic analysis techniques. However, the deterministic approach requires much less data or information about the receptors, the site and chemical concentrations at the site, and the results of the deterministic approach can serve as an efficient "first-cut" evaluation to determine whether or not further assessment of risks is warranted. Thus, for the purposes of this human health risk assessment, chemicals were first evaluated using deterministic risk analysis techniques. Chemicals which were identified to be of potential concern using deterministic procedures can be subsequently evaluated using stochastic risk analysis techniques in a more comprehensive risk assessment (if deemed to be necessary).

Since the objective of the assessment was to predict potential health risks to people that may occur in the future from conditions that exist at the various sites at the present time, it is not possible to directly measure adverse health outcomes in the people that might use the specific sites. In addition, in order to obtain meaningful results, direct assessment of the people using the sites would require a larger number of people than are available from those that use the sites of concern (*i.e.,* without a sufficiently large population for study, the statistical power of the assessment would not be sufficient to provide meaningful results). Consequently, the preliminary risk assessment conducted was based on the use of mathematical models representing how people would be exposed and respond to chemicals. These mathematical models are based on various parameters (*i.e.,* body weight, amount of air breathed per day, amount of soil accidentally ingested each day, amount of wild game consumed each day, *etc.*) that would determine exposure and responses to chemicals. Input parameters for the mathematical formulae used to estimate exposures consist of environmental and receptor parameters. Environmental parameters were largely based on the environmental concentrations of the various chemicals already measured at the site and reported in the site investigation reports. Parameters such as physical constants and bioavailability were acquired from literature sources.

All mathematical formulae and assumed parameter values are provided in Appendix B.

2.2.2.2 Summary of Important Elements of the Exposure Assessment Methodology

The degree of exposure of organisms to chemicals from the environment therefore depends on the interactions of a number of parameters, including:

- the various physical, chemical and biological factors that determine the ability of the receptor to take the chemicals into the body from the exposure pathways (*e.g.*, bioavailability of the chemicals from particles, soil, air);
- the physical/chemical characteristics of the chemical which determine the interaction and behaviour of a chemical with its surrounding environment (*e.g.,* water solubility, volatility, tendency to bind to particles);

- the concentrations of chemicals in various compartments of the environment (*e.g.*, surface soil) impacted by activities from the site as well as the normal ambient, or background concentrations;
- the behavioural and lifestyle characteristics of the human receptors in the environment that determine the actual exposures through interactions of the receptors with the various pathways (*e.g.*, respiration rate, food intake, soils/dusts consumed); and,
- the various exposure pathways for the transfer of the chemicals from the different environmental compartments to the organisms such as humans (*e.g.*, inhalation of air, soils and dusts; ingestion of soils/dusts; dermal exposure to dust/soil).

The above mentioned parameters are discussed in greater detail below.

Bioavailability

The bioavailability of a chemical defines that portion of the exposure concentration of chemical (*e.g.*, the quantity inhaled or ingested) that enters the body and is assumed to be available to produce toxic effects in target tissues. In other words, the toxic effects of a chemical are determined by the actual concentration of the chemical at the site of action rather than the amount that gains access to the body. In the majority of cases, however, the available data are inadequate to define the concentrations of chemicals at their site of action. Therefore, the bioavailable dose is used as a first approximation of the amount of the chemical at its site of action.

The bioavailability of a chemical is dependent on the chemical form as well as the tissue/animal species with which the chemical interacts. Thus, when applying exposure limits derived from animal studies to estimate potential risks following exposures of humans, it is necessary to consider the bioavailability of each chemical to the test animal, and its bioavailability to the human receptors. This allows normalization of exposures with respect to the route and allows the bioavailable doses to humans to be compared with acceptable bioavailable doses determined from animal studies or human epidemiological data. For example, if the exposure limit for a particular chemical was established from animal studies where the chemical was injected into the trachea in a solution, but the exposure pathway considered was the inhalation of chemical adsorbed to airborne particles (dusts/soils) by humans, both the exposure limit and exposure would be adjusted by the amount of chemical absorbed via tracheal injection in animals, and via dust inhalation of dust in humans.

The bioavailability of chemicals following oral ingestion, inhalation, or dermal contact, were estimated from the published literature, where available. In situations where chemical specific data were lacking, it was assumed that the chemical was 100% bioavailable. This assumption would tend to over-estimated exposure rates and therefore over-estimate the potential health risks associated with chemicals. The issue of soil-adjusted bioavailability is discussed in Section 2.4.

Physical/Chemical Characteristics

The physical/chemical characteristics of chemicals (*e.g.,* water solubility, volatility, tendency to bind to particles) determine their behaviour in the environment. Therefore, knowledge of the physical/chemical characteristics of the chemicals considered is critical to the selection of appropriate exposure pathways and to the estimation of the magnitude of exposure to chemicals through these pathways. Physical/chemical characteristics were selected from the published literature, where available. The most recent values reported were selected, using reasonable scientific judgement.

Chemical Concentrations at the Site

The chemicals that were evaluated at the site were discussed earlier in Section 2.2.1.3. For the deterministic risk assessment, chemicals were assumed to exist at: (i) the mean concentration at each of the 7 sites; and, (ii) the maximum concentration ever measured at each of the 7 sites. The assumed chemical concentrations are provided in Table 2.1.

Receptor Characteristics

The contribution of each exposure route (*i.e.,* ingestion, inhalation, dermal) to the total exposure is based on the individual characteristics of each of the human receptors (*e.g.,* soil/dust consumption, breathing rate, body weight, food consumption, time spent on-site, *etc.*). Receptor characteristics were based on published literature sources but also through correspondence with local people. Indeed, a survey (in the form of a questionnaire) of typical land use patterns and receptor characteristics was completed by representatives of the Ross River Dena Council who contacted representatives of the various communities in the vicinity of the sites of concern. Thus, characteristics were selected to reflect local behaviours and life style activities based on local data when available. However, data for individuals from other regions were used when local data were insufficient. Depending on the pathway of exposure, different receptors may have a potentially greater exposure (*e.g.,* children consuming more chemically-impacted soil/dust than other receptors). Thus, significant age or sex specific differences in receptor characteristics that affect chemical exposures, must be taken into account.

For this deterministic assessment, mean values were selected from the distribution data for receptor parameters that were assumed to be correlated with body weight (*e.g.,* exposed surface area). For consumption parameters (*e.g.,* amount of soil ingested, amount of air inhaled), the upper bound values (*e.g.*, 95th percentile or maximum) were selected from the data in these tables to reflect variations in habits, rather than "normal" variations within a population.

The assumptions related to estimating the exposure to chemicals that persons may receive from the site if it is used for Traditional Land Use purposes are summarized in Tables 2.2 and 2.4.

2.2.3 *Toxicity Assessment*

Toxicity assessment (or hazard identification) involves identification of the potentially toxic effects of chemicals and the determination of the maximum dose of chemicals which human receptors can be exposed to without experiencing adverse health effects. The toxicity assessment provided an estimate of how much exposure to chemicals from the site could occur either without any adverse health effects associated with a given rate of exposure of chemicals from the site, depending on the toxicological characteristics of the chemical. These toxicity estimates are known as exposure limits: an estimate of exposure that is likely to be without appreciable risks of deleterious effects during a lifetime.

The exposure limits were expressed in the same units as the estimated exposures from the site (*i.e.,* μg/kg body weight/day). Chemicals assessed in the current assessment act via a threshold response mechanism (non-carcinogens) and exposure limits were expressed as reference doses (RfDs) or tolerable daily intakes (TDIs). In the current assessment, none of the chemicals evaluated were identified to be carcinogens.

A TDI is used to estimate the toxic potency of threshold response chemicals (*i.e.,* non-carcinogens or non-genotoxic carcinogens). A TDI may be defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be experienced during a lifetime without an appreciable risk of deleterious effects. For example, in this assessment, the TDI for lead is estimated to be 3.57 μg/kg body weight/day by Health Canada (1996). This means that exposure to a daily dose rate of lead that is less than 3.57 μg/kg body weight/day is likely to be without an appreciable risk of deleterious effects during a lifetime.

The following hierarchical approach was used to identify toxicity estimates for use in the risk assessment:

- obtain the toxicity estimate from an appropriate Canadian regulatory agency (*e.g.,* Health Canada, Environment Canada);

- obtain the toxicity estimate from another recognized regulatory authority or expert organization [*e.g.,* US EPA, World Health Organization, American Conference of Governmental Industrial Hygienists (ACGIH)]; and,

- develop the toxicity estimate through review and evaluation of the scientific literature.

As was the case for exposure estimates (see discussion in Section 2.2.2), it was necessary to estimate bioavailability associated with the toxicity estimates.

It should be noted that the above hierarchal approach was followed in essentially all cases. However, it is possible that more recent or appropriate toxicological data may not be incorporated into the toxicity estimates developed by these various agencies. Thus, it must be clear that the toxicity estimates used in this assessment reflect the above hierarchal approach and are not necessarily the product of recent literature reviews completed by CANTOX ENVIRONMENTAL INC.

Table 2.3 provides a summary of the toxicity estimates used in the human health risk assessment and Appendix A provides further information on the toxic potential of these chemicals.

2.2.4 Risk Characterization

Risk characterization is the quantification and evaluation of the estimated risks from exposure to chemicals from the site. Risk characterization involves: (i) the estimation of risks associated with site-related exposure to chemicals of concern by comparisons between the estimated exposure and the toxicity estimate of the chemical; and, (ii) the description and evaluation of the estimated risks associated with exposure to chemicals of concern.

Risks associated with chemicals were expressed as Exposure Ratio (ER) values which were estimated according to the following formula:

$$\text{Exposure Ratio} = \frac{\text{Bioavailability - Adjusted Exposure Estimate } (\mu g / kg / day)}{\text{Bioavailability - Adjusted Exposure Limit } (\mu g / kg / day)}$$

Based on the above formula, an ER value (from all sources including background) that are less than 1 indicates that the exposure is less than the exposure limit (*i.e.,* TDI) for the chemicals of concern and no measurable adverse health effects would occur. An ER value (from all sources including background) that is greater than 1 indicates that the exposure limit has been exceeded and adverse health effects may occur. However, due to the large number of conservative factors typically employed in risk assessment procedures, ER values that are greater than 1 do not necessarily indicate that measurable adverse health effects will occur. Instead, Exposure Ratio values 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. The criteria for evaluation of Exposure Ratio values for which a complete background assessment has not been completed are discussed in greater detail below.

2.2.5 Criteria for Evaluation of Risk Estimates

2.2.5.1 <u>Evaluation of Risk Estimates</u>

Relevance of Background Exposures to the Risk Assessment

An important issue in the evaluation of risk estimates for persons living in the North is that some of the chemicals evaluated may already be present in the background environment. Therefore, the possibility exists that certain members of the population may already be exposed to amounts of chemicals which pose a possible health concern. This may likely be the case for lead, although it is noted that lead was found to be a chemical of concern only at MP 124.5 and not at the other sites that were evaluated in the current assessment.

A limited literature review has identified that heavy metal exposure to people living in the North has also been a concern related to typical background conditions. In a study of cardiovascular disease and heavy metals in the Eastern Arctic, lead was identified as a possible weak risk factor for high blood pressure; however, no direct association between long range environmental pollutants and cardiovascular disease in the Arctic for any other metals (*i.e.*, methyl mercury, cadmium). The relationship between lead and atherosclerosis and ischemic heart disease has been reported to be well established (Foa and Ferioli, 1992). It is interesting to note, however, that the primary concerns of adverse effects from lead exposure are effects on infants and children, and no discussion of such effects was presented in the above study.

With respect to LEPH and HEPH, there is not as much information regarding concentrations in the background environment compared to the information available for background metal concentrations. It is likely that any LEPH and HEPH exceedances in the North are a result of site related activities. These chemicals are not expected to be present naturally as a result of specific regional geochemistry, which can often be the case with certain metals such as lead. Therefore, the current risk assessment assumed that potential background concentrations of LEPH and HEPH would not be an issue.

Establishment of a TDI is inherently a conservative process which is intended to error on the side of safety. For some chemicals large safety factors to account for differences between species and sensitive population groups have been employed to derive TDIs and, therefore, exceeding the TDI does not necessarily mean that adverse effects will occur but instead the margin of safety is not as great as might be desired..

For the purposes of the preliminary quantitative human health risk assessment, the Project Team has assumed that for LEPH and HEPH, 100% of the TDI could be can accounted from spending time at any of the 7 sites without posing unacceptable risks. In the case of potential lead exposures at MP 124.5, the Team has assumed that no more than 20% of the TDI should arise from spending time at this site. Due to potential lead exposures which may be occurring from the background environment, it was felt inappropriate to assume that all of the exposures from the site could be equal to the TDI for lead. The allotment of only 20% of the TDI from one particular environmental source is an approach which is often used by Health Canada for setting Drinking Water Guidelines and is also used by the CCME for setting soil quality guidelines. From a toxicological perspective, this value of 20% of the TDI could be argued to be a relatively arbitrary value; however, it would also be unlikely to present additional toxicological concerns in most circumstances even when background exposures exceed the TDI.

2.2.5.2 Evaluation Criteria

Based on the rationale provided above, the following criteria were used to evaluate risk estimates:

- LEPH and HEPH with total Exposure Ratio (ER) values greater than 1.0 calculated using deterministic procedures were identified as chemicals presenting potential health risks for which either: (i) risk management options should be considered; or (ii) should be re-evaluated in a stochastic risk assessment and/or when further data is collected;

- LEPH and HEPH with total ER values less than 1.0 evaluated using deterministic procedures could be excluded from future risk management plans or future risk assessment;

- lead with a total ER value of greater than 0.2 at MP 124.5 calculated using deterministic procedures were identified as presenting potential health risks for which either: (i) risk management options should be considered; or (ii) should be re-evaluated in a stochastic risk assessment and/or when further data is collected;

- lead with a total ER value less than 0.2 evaluated using deterministic procedures could be excluded from future risk management plans or future risk assessment.

2.2.6 Conservative Assumptions Used in the Human Health Risk Assessment

Due to the many conservative assumptions, the current human health risk assessment is unlikely to underestimate the risks of exposure to chemicals. For the current risk assessment, a series of additional conservative assumptions were employed which decrease the likelihood of underestimating risks. Some of the most important assumptions are discussed below but are also summarized in Table 2.4.

- Based on information available, the time spent on each of the sites was assumed to be the same; for each site, it was assumed that persons would use the site for 14, 120 or 180 days (entire summer).

- For each site, it was assumed that the entire site would have soil at either the average or maximum concentrations at each of the sites.

- It was assumed that the child at the site exhibited very high soil ingestion tendencies. Although some regulatory agencies (*e.g.*, US EPA) recommend that upper bound soil ingestion estimates for children to be in the range of 0.4 g soil per day, recent studies (*e.g.*, Calabrese *et al.*, 1997) have expressed concerns that these soil ingestion rates may not be sufficiently protective for certain children who have a high tendency to ingest soil. In addition, the proposed land use (*i.e.*, living in tents which may not be completely covered by floors) and the fact that much of ground is exposed soil (*i.e.*, children are exposed to bare earth), it was the Project Team's opinion that this scenario would be considered to have a very high soil contact potential. Thus, for these 2 main reasons, the assessment has utilized a soil ingestion rate (*i.e.,* 1.3 g soil per day) which is considerably higher than average soil ingestion rates which have been reported in the literature for other activities.

- A series of conservative assumptions (*e.g.,* large safety factors, linear extrapolation, *etc.*) are generally adopted by regulatory agencies in the assignment of exposure limits/potency factors which may also contribute to a significant overestimation of health risks.

2.3 Results

The results of the human health risk assessment for 7 sites are presented below. For each site assessed, the following pathways were identified to be relevant pathways of potential chemical exposure to human receptors:

1) soil pathway (*e.g.,* ingestion, inhalation of dusts, skin contact);
2) consumption of vegetation grown on site;
3) consumption of wild game caught on site; and
4) hypothetical drinking water pathway (*e.g.,* ingestion, skin contact) (where data was available).

The risks associated with each of the above exposure pathways were assessed using the data that was available for the chemicals of concern (*i.e.,* LEPH and HEPH for all sites; lead was assessed only for MP 124.5). In the assessment of risks for the soil and water pathways, both the calculated average (based on measured samples) and maximum concentrations were used. The concentrations used for the current assessment are shown in Table 2.1. For the assessment of risks associated with the consumption of wild game on site, the body burden of animals were predicted through environmental fate modelling. Similarly, chemical concentrations in berries were modelled for the assessment of risks associated with berry consumption.

In general, similar assumptions were applied to each of the 7 sites to predict the potential human health risks associated with Traditional Land use of these areas. A complete list of the assumptions that were used in the human health assumption are provided in Table 2.4. Based on the responses of the population to the VEC questionnaire and in discussions with Gartner Lee staff, it was determined that people would be expected to use the sites for variable periods of time. Therefore, the human health risk assessment was conducted assuming that each of the 7 sites could be used for a minimum of 14 days (2 weeks), 120 days (4 months) or 180 days (6 months) during the year. It was recognized that use of a particular site for a period of 14 days, would be the most common practice among the community.

The results of the assessment are discussed on a site-by-site basis in the following section. In addition, the potential health risks associated with each exposure pathway are summarized in Tables 2.5 to 2.8. Specific ER values estimated for each exposure pathway, according to different times spent on site are provided in Appendix B.

2.3.1 MP 73 - Pump Station 10

The human health assessment for MP 73 was conducted with the assumption that persons would use the site for the purpose of Traditional Land Use. For this assessment, exposure to chemicals via the soil, consumption of wild game in the area, and berry consumption were considered. In addition, since ground water data was available for this site, the potential risks associated with LEPH and HEPH from drinking the groundwater were included in the assessment. It should be noted that there are currently no groundwater wells, and therefore, the groundwater would not be accessible as a drinking water source. The drinking water pathway is not a relevant pathway of chemical exposure but was assessed only as a hypothetical scenario. Therefore, the results of this scenario are reflective of hypothetical risks only, and are not representative of actual risks present at the site.

Soil Pathways

Both the calculated average and maximum soil concentrations were used to assess the potential health risks associated with the soil pathways. In both cases in was conservatively assumed that these concentrations were representative of the soil conditions for the entire site, although the soil concentrations are more reflective of localized areas of chemical contamination. When the risk assessment was conducted with the assumption that the site would be used for 14 days for the purposes involved in Traditional Land Use, there were no unacceptable health risks associated with the soil pathways that were assessed (*i.e.,* soil ingestion, inhalation of soil dusts, and dermal contact). Risk estimates were below 1.0 for LEPH and HEPH, and thus, it can be concluded that there are no unacceptable health risks associated with the soil pathways, when this site is used for 14 days for the purposes involved in Traditional Land Use.

Similarly, the results indicated that there are no unacceptable health risks associated with the soil pathways, when it is assumed that the site is used for a period of 120 days. The ER values were below 1.0 for both the female child and the female adult. Therefore, for persons spending 120 days on site, no adverse health effects are expected to occur from exposure to LEPH and HEPH via the soil pathways.

When the risk assessment was conducted with the assumption that persons were expected to use the site for 180 days, it was found that no unacceptable risks were associated with HEPH for both the female child, and female adult when the average and maximum soil concentrations were assumed. Similarly, acceptable health risks were estimated for both receptors when the average concentration of LEPH was used in the assessment. However, when the maximum concentration of LEPH was assumed to exist at the site, an ER value of 1.2 was estimated for the female child. It is unlikely that this minor exceedance of the acceptable risk level (*i.e.*, ER = 1.0) would result in chronic adverse health effects given the conservative assumptions adopted in the risk assessment. Therefore, based on the results of this assessment it is unlikely that the LEPH concentrations in the soil would result in adverse health effects for persons using this site for the purposes involved in Traditional Land Use.

Consumption of Wild Game

For this preliminary assessment, only the consumption of rabbit, grouse and caribou were assessed. The responses to the VEC questionnaire indicated that some aquatic receptors (*e.g.*, several species of fish, ducks) are hunted and consumed. Since there was not enough information available to assess the risks associated with the consumption of any water aquatic receptors, this pathway of exposure was not included in the current assessment. It should also be noted that the animals that were chosen for inclusion in this assessment were based on information relating to which animals were hunted, and not necessarily on specific game consumption patterns. In assessing the potential health risks associated with game consumption, it was assumed that 20% of the total daily meat consumption would come from meat caught from the site while people were on the site. Of this 20%, it was assumed that consumption of caribou would account for 50%, and rabbit and grouse would each account for 25%. In addition, it was conservatively assumed that caribou would spend 25% of their time on site, and rabbit and grouse would spend 100% of their time on the site. These values were based on responses to the VEC questionnaire which indicated that caribou is hunted to a greater extent than either the rabbit or grouse. In addition, for the preliminary assessment, it was assumed that wild game caught from the site would not be consumed when persons are not using the site. For the current assessment, the body burdens of chemicals for each of the game receptors were predicted through modelling exercises, using both the calculated average and maximum soil concentrations from the site.

The results of this assessment indicated that ER values were all below the critical risk value of 1.0 for LEPH and HEPH for both the female child and female adult. This was the case when all time periods (*e.g.*, 14, 120 or 180 days) on site were considered. Therefore, it can be concluded that persons using this site for the purposes involved in Traditional Land Use are not expected to experience any adverse health effects associated with consumption of wild game from the site.

Consumption of Berries

In assessing potential risks associated with berry consumption, it was conservatively assumed that 100% of the total berry consumption would come from berries that are grown on site. This is a conservative assumption since it would be expected that at least some portion of the berries eaten by persons would come from off site sources. Based on the responses to the VEC Questionnaire, it was found that berry consumption constituted a large portion of the total amount of vegetation that is consumed while on site. For the preliminary human health assessment, the potential health risks associated with the consumption of other types of vegetation from the site was not included in the preliminary assessment since there was not enough information. However, if further information can be obtained regarding other vegetables or plants that are consumed at the site, as well as estimated consumption rates for members of the population, then additional risk assessment would be warranted.

The ER values for LEPH and HEPH were below 1.0 for both the female child and female who were assumed to eat berries from the site. ER values for both chemicals were 1.0 when all time periods (*i.e.,* 14, 120 and 180 days) were assessed for these receptors. Thus, it can be concluded that there are no potential health risks that would be expected to occur for persons that eat all their berries from those grown on site, even if they spend the entire summer (*e.g.,* 180 days) in the area.

Potential Groundwater Consumption

Several samples of the groundwater were obtained from this site and the average and maximum chemical concentrations of LEPH and HEPH were used in the current human health risk assessment. At this site, there are currently no groundwater wells, and therefore, the groundwater would not be accessible as a drinking water source. Therefore, at this time, the drinking water pathway is not a relevant pathway of chemical exposure but was assessed as a hypothetical scenario where it was assumed that the groundwater would be used for drinking water purposes. Thus, it should be noted that the results of this scenario are reflective of hypothetical risks only, and do not represent actual risks at the site.

The results of the risk assessment showed that there are no unacceptable risks associated with this hypothetical scenario when receptors are assumed to spend 14 days on site. However, when longer durations of time were considered (*i.e.,* 120 and 180 days), the results indicated that some ER values for LEPH for the female toddler and female adult were in exceedance of the critical risk value of 1.0. Although the exceedances were relatively minor, it is possible that unacceptable risks are associated with this pathway. Again, this was considered a hypothetical scenario, and the risks estimated for this pathway do not represent actual risks at this site. However, if the groundwater is expected to become accessible as a drinking water source in the future, additional sampling of the groundwater should be conducted and a subsequent assessment of risks is recommended.

2.3.2 MP 124.5 - Pump Station 9

Similar to the health assessment that was conducted for MP 73, the risks associated with using this site for the purposes involved in Traditional Land Use of MP 124.5 were assessed by examining the soil pathway, consumption of wild game from the site, consumption of berries grown on site. There was no water data available for this site, and therefore, any potential risks associated with the water pathways were not assessed. Although LEPH and HEPH were the only chemicals identified as potential chemicals of concern for all the sites, the lead concentrations in the soil measured at this site, prompted the inclusion of this chemical in the preliminary risk assessment. Several soil samples indicated that lead was present at levels exceeding Yukon Territory Parkland Soil Criteria (Yukon, Territory, 1996), and these exceedances were suspected to be related to previous site related activities, and not to the background geology of the site. Similar to the methods used for assessing LEPH and HEPH, both the average and maximum lead concentrations were used to evaluate potential health risks.

Soil Pathways

Evaluation of the soil pathways associated with Traditional Land Use of this site indicated that the ER values for LEPH and HEPH were below the critical ER of 0.2, when the female child and female adult were assumed to spend 14 days on site. For the female adult, the risk estimates associated with average and maximum lead concentrations were below 0.2 indicating that adverse health effects would not be expected to occur for the female adult. However, the risks associated with lead for the female child were 1.0 and 3.7 when using the average and maximum soil concentrations, respectively. Therefore, both the average and maximum lead concentrations at this site may result in adverse health effects for the female child spending 14 days on site. Based on these results, unacceptable risks to lead for female toddlers would exist for these receptors when spending greater lengths of time on-site (*i.e.*, 120 and 180 days). Based on these results, it is likely that some form of risk management may be required for areas of lead contamination on this site.

When the female adult was assumed to spend 120 days on site, it was found that no unacceptable health risks would be expected for any of the chemicals assessed. The maximum lead concentration was associated with an ER of 0.33 for this receptor, which is marginally above the critical value of 0.2. Given the conservative assumptions used in the assessment, this slight exceedance of the critical risk value is not likely to result in adverse health effects. There were no unacceptable risks associated with LEPH and HEPH for the female adult when these receptors were assumed to spend 120 days on site. For the assessment of the female child, unacceptable health risks to LEPH and lead were found for the same time period. The average and maximum LEPH concentrations measured on the site resulted in ER values of 1.52 and 3.59, respectively for this receptor. Based on these results, it can be concluded that both average and maximum concentrations of LEPH and lead may pose unacceptable levels of risk to persons using the site for Traditional Land Use for periods of 120 days or greater.

For persons expected to spend 180 days on site, the previous conclusions made regarding the risks associated with LEPH and lead also apply. In other words, the soil concentrations of LEPH and lead may pose an unacceptable level of risk to persons using the site for 120 days or greater, for the purposes involved in Traditional Land Use. Under this scenario, the ER value for the female child was estimated to be 1.2 when the maximum HEPH soil concentration was used. This minor exceedance of the critical risk value of 1.0 is not likely to be associated with adverse health effects, when the conservative assumptions of the assessment are considered. Acceptable risks were predicted for the female adult for all chemicals when they were assumed to spend 180 days on site.

Based on the above results, it can be concluded that some form of risk management may be required for localized areas of LEPH and lead contamination.

Consumption of Wild Game

Similar to the assessment that was conducted for MP 73, this scenario considered the health risks associated with the consumption of caribou, rabbit and grouse from the area. It was assumed that the consumption of wild game would account for 20% of the total meat intake by persons at the site. For persons that were assumed to spend 14, 120 or 180 days on the site, the results indicated that the consumption of wild game from this area could potentially result in health risks from lead for both the female child and the female adult since ER values were at or above the critical risk levels. However, these results should be considered preliminary since it is not known whether or not the incorporation of the assumptions used in the assessment are accurate representations of the situation at the site. Again, the assumptions used to assess this exposure pathway were based in part, on the degree to which the animals were hunted, and not necessarily on specific consumption information obtained for this site. Some possible methods for addressing these issues are discussed in detail in Section 2.4.

Consumption of Berries

The results of the assessment of berry consumption indicated that no unacceptable risks were associated with consuming berries in the area for either the female child or female adult, when all relevant time periods were assumed. The ER values estimated for berry consumption were all below 1.0 for LEPH and HEPH, and were at or below the critical value of 0.2 for lead.

2.3.3 MP 174 - Pump Station 8

Similar to the assessments completed for the previous sites, the human health assessment for MP 174 was conducted using the assumption that persons could potentially spend 14, 120 or 180 days on site for the purposes involved in Traditional Land Use. For this site, the potential risks associated with the soil pathway, consumption of wild game, and berry consumption were considered. Exposure to chemicals present in either surface water or groundwater was not assessed since there was not enough information regarding chemical concentrations in water sources.

Soil Pathways

When it was assumed that persons would use the site for a period of 14 days, there were no unacceptable risks associated with any of the chemicals assessed for either the female child or female adult. For the assessment of persons using the site for a period of 120 days, no unacceptable risks to the female adult were identified, although unacceptable risks were associated with both the average and maximum LEPH concentrations for the female child. The average LEPH soil concentration resulted in an ER value of 1.5 for the female child, and the maximum soil concentration resulted in a risk value of 3.4 for the same receptor. These results indicate that an unacceptable level of risk is associated with LEPH for persons using the site for the Traditional Land Use, for periods of 120 days or longer. Therefore, based on these results, it is likely that some form of risk management for localized areas of LEPH contamination may be required for persons using this area. However, if it can be subsequently ensured that persons would not spend time the assumed amount of time at this site, then this would lead to the prediction that no human health risks exist at this site.

For the assessment of human health risks associated with persons spending 180 days on site, unacceptable risks are associated with both the average and maximum concentrations of LEPH, and possibly for maximum concentrations of HEPH. The ER value for the female child when the maximum HEPH concentrations was used was estimated to be 1.5. Thus, it is possible that risk management options may need to be considered for localized areas of HEPH contamination, if it can be ascertained that humans would spend the entire summer on this site.

Consumption of Wild Game

The results of this assessment indicated that ER values were all below the critical risk value of 1.0 for LEPH and HEPH for both the female child and female adult. For persons expected to spend the entire summer on this site (*i.e.,* 180 days), there are no unacceptable risks associated with the consumption of wild game in this area. Therefore, it can be concluded that adverse risks would not be predicted for persons using this site for any time period during the summer months.

Consumption of Berries

Similar to the conclusions determined for the consumption of wild game, there were no unacceptable risks associated with berry consumption for either the female child or female adult. Risks associated with human exposure to LEPH and HEPH via berry consumption were all below 1.0, even when it is assumed that berries from the site are consumed for 180 days spent on site.

2.3.4 MP 213 - Military Camp/Dump

The human health risk assessment for MP 213 was conducted with the assumption that persons would use the site for the purpose of Traditional Land Use. For this assessment, exposure to chemicals via the soil, consumption of wild game in the area, and berry consumption were considered. There were no data available regarding chemicals concentrations in surface water or groundwater, and thus, these pathways of chemical exposure could not be assessed. Risks to chemicals as a function of variable periods of time spent on site were incorporated into the current assessment, similar to that conducted for other sites.

Soil Pathways

The results of the assessment indicated that ER values for LEPH and HEPH were well below 1.0 for both the female child and female adult. This was the case even when it was assumed that receptors would spend the entire summer on the site (*i.e.*, 180 days). Therefore, it can be concluded that no unacceptable risks would be posed to persons using this site for the purposes involved with Traditional Land Use.

Consumption of Wild Game

The results of this assessment indicated that ER values were all below the critical risk value of 1.0 for LEPH and HEPH for both the female child and female adult. For persons expected to spend the entire summer on this site (*i.e.*, 180 days), there were no unacceptable risks associated with the consumption of wild game in this area.

Consumption of Berries

Similar to the conclusions determined for the consumption of wild game, there were no unacceptable risks associated with berry consumption for either the female child or female adult. Risks associated with human exposure to LEPH and HEPH via berry consumption were all below 1.0, even when it was assumed that berries from the site are consumed for 180 days spent on site.

2.3.5 MP 233 - Pump Station 7

Similar to the assessments completed for the previous sites, the human health risk assessment for MP 233 was conducted using the assumption that persons could potentially spend 14, 120 or 180 days on site for the purposes involved in Traditional Land Use. For this site, the potential risks associated with the soil pathway, consumption of wild game, and berry consumption were considered. Exposure to chemicals present in either surface water or groundwater was not assessed since there was not enough information regarding chemical concentrations in water sources.

Soil Pathway

The results of the assessment indicated that ER values for LEPH and HEPH are well below 1.0 for both the female child and female adult. This was case even when the time spent on site was assumed to be 180 days. Therefore, it can be concluded that no unacceptable risks would be posed to persons using this site for the purposes involved with Traditional Land Use.

Consumption of Wild Game

The results of this assessment indicated that ER values are all below the critical risk value of 1.0 for LEPH and HEPH for both the female child and female adult. For persons expected to spend the entire summer on this site (*i.e.*, 180 days), there are no unacceptable risks associated with the consumption of wild game in this area.

Consumption of Berries

Similar to the conclusions determined for the consumption of wild game, there are no unacceptable risks associated with berry consumption for either the female child or female adult. Risks associated with human exposure to LEPH and HEPH via berry consumption were all below 1.0, even when it is assumed that berries from the site are consumed for 180 days spent on site.

2.3.6 MP 234 - Military Camp/Pump Station

The human health assessment for MP 234 was conducted with the assumption that persons would use the site for the purpose of Traditional Land Use. For this assessment, exposure to chemicals via the soil, consumption of wild game in the area, and berry consumption were considered. In addition, ground water data were available for this site. Thus, the potential risks associated with LEPH and HEPH via drinking the groundwater were included in the assessment. It should be noted that at this site, there are currently no groundwater wells, and therefore, the groundwater would not be accessible as a drinking water source. Therefore, the drinking water pathway is not a relevant pathway of chemical exposure but was assessed only as a hypothetical scenario where it was assumed that the groundwater would be used for drinking water purposes. Thus, it should be noted that the results of this scenario are reflective of hypothetical risks only, and are not representative of actual risks present at the site.

Soil Pathways

The ER values were estimated to be less than the critical value of 1.0 for both the female child and the female adult when these receptors were assumed to spend 14 days on site for the purpose of Traditional Land Use. Thus, it can be concluded that no adverse health effects would be associated with exposure of LEPH or HEPH to humans, via the soil pathways, when the site is used for a period of 2 weeks during the summer months. When longer periods of time are considered (*i.e.,* 120 and 180 days), the maximum LEPH concentration results in ER values of greater than 1.0 for the female child. Therefore, if it can be ascertained that this site will be used for more than 2 weeks, it is likely that some form of risk management may need to be considered for localized areas of LEPH contamination. If there is assurance that no humans would spend these greater amounts of time on this site, then no unacceptable human health risks exist at this site, and risk management options would not need to be exercised.

Consumption of Wild Game

The ER values for the consumption of wild game were all below 1.0 for both the female child and female adult. This was the case when assessing risks for humans spending 14, 120 or 180 days on site. Therefore, it can be concluded that there are no unacceptable risks to LEPH and HEPH for persons consuming wild game in this area during the summer months.

Consumption of Berries

Similar to the conclusions determined for the consumption of wild game, there were no unacceptable risks associated with berry consumption for either the female child or female adult. Risks associated with human exposure to LEPH and HEPH via berry consumption were all below 1.0, even when it was assumed that berries from the site were consumed for the entire summer (*i.e.,* 180 days).

Potential Groundwater Consumption

One sample of the groundwater was obtained from this site and the chemical concentrations of LEPH and HEPH determined were used in the current human health risk assessment. The potential risks to LEPH and HEPH via the drinking water pathway were assessed. As mentioned previously, there are currently no groundwater wells, and therefore, the groundwater would not be accessible as a drinking water source. The drinking water pathway is not a relevant pathway of chemical exposure but was assessed only as a hypothetical scenario where it was assumed that the groundwater would be used for drinking water purposes.

The result of the risk assessment showed that there are no unacceptable risks associated with the hypothetical consumption of the groundwater at this site. The risk estimates were well below the critical ER value of 1.0, for both the female child and female adult, for all time periods that were assessed (*i.e.,* 14, 120 and 180 days). Thus, if the groundwater were currently available as a source of drinking water, persons using the site would not be expected to experience adverse health effects as a result of chemical exposure. In the event that the groundwater becomes accessible in the near future, it is recommended that additional sampling be conducted especially if the water is expected to be used for drinking.

2.3.7 MP 208 - NWT - Pump Station 6

The human health risk assessment for MP 208 (NWT Site) was conducted with the same methodology and assumptions used for the assessment of the other Yukon Territory sites. The risks associated with Traditional Land Use of the site were evaluated. For this assessment, exposure to chemicals via the soil, consumption of wild game in the area, and berry consumption were considered. In addition, surface water data were available for this site. Thus, the potential risks associated with LEPH and HEPH via drinking the surface water were included in the assessment. It should be noted that based on the responses to the VEC Questionnaire, many persons using the site would likely bring their own drinking water to the site (*e.g.,* bottled water), Therefore, it is not likely that the surface water would be used for drinking purposes to any large extent, particularly if the surface water is shallow, not free-flowing, and is not aesthetically pleasing. Thus, the risks associated with the consumption of drinking surface water should be interpreted with these considerations in mind.

Soil Pathways

Both the calculated average and maximum soil concentrations were used to assess the potential health risks associated with the soil pathways. In both cases, it was conservatively assumed that these concentrations were representative of the soil conditions for the entire site, although the soil concentrations are more reflective of localized areas of chemical contamination. When the risk assessment was conducted with the assumption that the site would be used for 14 days for the purposes involved in Traditional Land Use, there were no unacceptable health risks associated with average and maximum HEPH concentrations, and average LEPH concentrations. However, the maximum LEPH concentration resulted in an ER of 2.8 for the female child, indicating an unacceptable level of risk. Therefore, an unacceptable level of risk to LEPH is present for persons using the site for Traditional Land Use for a period of 2 weeks and longer. Subsequently, unacceptable risks to LEPH would also occur for the female child if this receptor spends longer periods of time on site.

When it was assumed that the site would be used for 120 days, maximum concentrations of LEPH and HEPH indicated an unacceptable health risk to the female child. ER values of 12 and 3.0 were estimated for maximum LEPH and HEPH concentrations, respectively. Thus, for persons spending 120 days on site, or longer, an unacceptable level of risk is associated with localized areas of HEPH contamination. Based on these results, it is likely that some form of risk management may be required for localized areas of LEPH and HEPH contamination. Again, if there is absolute assurance that the site is not used by any humans, then it can be predicted that no health risks exist at the site.

When the female adult was assumed to spend 180 days on site, the maximum HEPH concentrations was associated with an ER of 1.5 which exceeds the critical risk value of 1.0. This is a relatively minor exceedance, and considering the conservative assumptions used in the risk assessment, it is not expected that this exceedance would result in adverse health effects.

Consumption of Wild Game

The ER values for the consumption of wild game were below 1.0 for the female child and female adult with respect to potential risks to LEPH and HEPH. This was the case when assessing risks for humans expected to spend up to 180 days on site. Therefore, it can be concluded that there are no unacceptable risks to LEPH and HEPH for persons consuming wild game in this area during the summer months.

Consumption of Berries

Similar to the conclusions determined for the consumption of wild game, there are no unacceptable risks associated with berry consumption for either the female child or female adult. Risks associated with human exposure to LEPH and HEPH via berry consumption were all below 1.0 for both receptors, even when it was assumed that berries from the site are consumed for the entire summer (*i.e.,*180 days).

Potential Surface Water Consumption

The results of the risk assessment indicate that potential risks to LEPH may exist for the female child from drinking the surface water. This is the case only when the receptor is assumed to spend the entire summer (*i.e.,* 180 days) on the site. However, the exceedance of the ER is marginally above 1.0, and thus it is unlikely that adverse health effects would occur. These risks are based on the assumption that persons on site will obtain all of their drinking water from the surface water on the site. However, this is not likely since it is recognized that persons bring their own drinking water to the site, and it is possible that the surface water would not be aesthetically appealing enough (*e.g.,* if visible hydrocarbon staining is present) which would deter persons from drinking it. Based on these results, it can be concluded that it is not likely that risks would be associated with the consumption of surface water at the site. However, if it can be determined that this site is used to a great extent, then persons should be encouraged to bring their own supply of drinking water.

2.4 Uncertainty Analysis

Since human health risks are essentially "driving" the overall risk assessment (*i.e.,* human health endpoints are more sensitive than ecological endpoints in this assessment), a sensitivity analysis has been completed for the human health risk assessment. For the reasons provided below, the sensitivity analysis indicates it is likely that the current human health risk assessment has overestimated health risks from the 7 sites. However, it is also felt that these risk estimates can be modified at the current time.

2.4.1 Important Assumptions Used in the Risk Assessment

The following have been identified as important parameters in the conduct of the human health risk assessment which are "driving" the risk assessment at the 7 sites evaluated.

2.4.1.1 Time Spent at Each Site

It was assumed that each site could potentially be used for either 14, 120 or 180 days during the summer months, with the recognition that the different sites would most commonly be used for a period of 14 days. These assumed times were used to represent the minimum, average, and maximum times that persons would spend on site, for Traditional Land Use purposes. It is noted that the risks associated with certain chemicals, via specific exposure pathways are greatly influenced by the time spent on site. That is, there is a lower risk of chemical exposure, and subsequently, a lower potential for risk, if persons use the sites for shorter time periods. It should be noted that the times spent on site assumed for the current assessment were used to apply to all the sites, and therefore, may not necessarily reflect the actual site usage pattern by the population. Thus, if it can be subsequently ensured that no humans would spend time at these sites or less than assumed in the assessment, this should be factored into the assessment and will lead to the prediction that of lower human health risks at the site.

2.4.1.2 Current and Future Use of Site

Traditional Land Use (*i.e.,* families living in tents on the site) is the most sensitive possible land use which could be evaluated in the risk assessment. Other land uses would not be as stringent and would produce lower risk estimates; however, these other uses did not seem appropriate for the current assessment.

2.4.1.3 Soil Ingestion Rate

Due to lack of data available on Northern populations, the Project Team used a soil ingestion rate for children which is very high when compared to soil ingestion rates for Southern populations (note: the adult soil ingestion rate is not as important since children with a smaller body mass and greater tendency to consume soil are the "drivers" of the risk assessment). Although CEPA (1994) and CCME (1997) recommend soil ingestion rates on the order of 0.05 to 0.08 g/day for children, these did not seem appropriate for the current assessment. Instead, the Project Team used a soil ingestion rate of 1.3 g/day based on a combination of scientific data and professional judgement. Briefly, it was felt by the Project Team that a higher than normal soil ingestion rate was justified since: (i) Traditional Land Use would offer much greater exposure to soil than normal residential/parkland use in the South; and (ii) recent scientific literature has indicated that acute toxicity may be an additional concern at contaminated sites which may not be addressed using a default soil ingestion rate of 0.08 g/day. As a result of these two factors, the Project Team used a much higher soil ingestion rate than is normally used in risk assessments in Southern environments.

As indicated above, the soil ingestion rate used by the Project Team is approximately 6-times greater than the upper 95%ile of 0.217 g soil per day estimated by Stanek and Calabrese (1995) for typical Southern children (i.e, 6 x 0.217 g = 1.3 g). It was the Project Team's opinion that a Northern child could easily spend 6-times as much time in contact with soil as a Southern child (*e.g.,* 12 hours per day versus 2 hours per day). In addition, living in only partially floored tents, as well as reduced opportunity for body washing while camping, may also contribute to a higher soil contact rate. As a result, it did not seem unreasonable to use a higher soil ingestion rate than typically used in risk assessments completed for sites in the South and a value of 1.3 g of soil per day was selected for use in this preliminary quantitative risk assessment. This soil ingestion rate may also address some soil pica (i.e, short-term episodes of high soil ingestion) issues which may be of greater relevance in the North.

It is noted that no studies on soil ingestion rates in the North are currently available and, therefore, it is possible that our default value may not be accurate and could overestimate soil ingestion. However, given all the factors mentioned above, it was believed that some factor was required to account for this possible increased rate of exposure to soil.

2.4.1.4 Sources of Toxicity Estimates

Although regulatory-derived toxicity estimates were available for some chemicals, there were few toxicity estimates available for the specific durations of exposure. More specifically, chronic toxicity estimates were available for HEPH and lead from the TPHCWG (1997) and Health Canada (1996), respectively, whereas the toxicity estimate for LEPH was derived by CANTOX ENVIRONMENTAL INC. However, the exposure situation of concern included repeated acute exposures (14 days/summer, every summer) and repeated subchronic exposure (120 days/summer, every summer). There were generally no toxicity estimates available which "matched" these repeated exposures and, thus, these short-term exposures were amortized over the summer and compared to chronic toxicity estimates.

2.4.1.5 Acceptable Risk

The Project Team felt that an appropriate target risk should be 100% of the TDI for LEPH and HEPH (*i.e.*, ER value of 1.0) and 20% of the Tolerable Daily Intake (*i.e.*, ER value of 0.2) for lead. Since it was noted that any risks associated with LEPH and HEPH would result almost exclusively from site related activities (*i.e.*, no relevant background sources of these chemicals), selection of a critical risk value of 1.0 was considered appropriate. For lead, using an risk estimate of 0.2 as the critical ER is standard practice in most CCME-style risk assessments which do not complete a full background risk assessment for chemicals expected to be present in the background environment. Although risk acceptability varies from region to region, the Project Team has found the above to be suitable targets for the current risk assessment.

2.4.1.6 Concentrations Used in Risk Assessment

The Project Team used average and maximum concentrations in the risk assessment for soil and water samples. These concentrations were assumed to be representative of the soil and water conditions for the entire site. It is recognized that this approach may tend to skew concentrations higher than actual levels because the sampling program at the site was not entirely random and instead was designed to collect samples in areas of higher contamination (*e.g.*, stained soils).

2.4.1.7 Consumption of Wild Game

The Project Team assumed that caribou, rabbit and grouse would be consumed at all the sites assessed. However, there was much uncertainty in estimating tissue concentrations of wild game through models and the best manner for addressing this concern would be to actually measure wild game concentrations for these chemicals. Other potential food sources such as the consumption of fish and ducks may also need to be considered. Such a tissue monitoring program would greatly assist our understanding of the risks posed by consuming animals caught near the sites. In addition, the assumptions used to assess this pathway of exposure were based largely on information related to hunting activities, and not necessarily on specific consumption patterns. Thus, obtaining more detailed information regarding specific animals eaten, as well as the amounts of each animal for each site may address this concern.

2.4.1.8 Consumption of Berries (and other Vegetation)

Although this could be a major source of exposure in the risk assessment, the Project Team did not find any evidence that consumption of berries from any of the 7 sites would be associated with unacceptable risks. The Project Team did not have enough information regarding the consumption of other types of vegetation (*e.g.*, root vegetables, Labrador Tea) from the sites, and therefore, consumption of other vegetation was not evaluated for the preliminary risk assessment. However, if there is evidence that other plants are consumed by members of the population, these pathways should be evaluated. Similar to issues associated with the consumption of wild game however, it would be most desirable to have direct measurements of chemical concentrations of vegetation on-site, versus attempting to predict values through modelling exercises.

2.4.1.9 Consumption of Groundwater or Surface Water

It was recognized that this pathway would not likely be relevant since persons do bring other sources of drinking water (*e.g.*, bottled water) to the site. However, this pathway was not assessed for all the sites, since water data was not available in all cases. In addition, other potential pathways associated with the surface water (*e.g.*, cooking and washing purposes) were not included in the preliminary assessment. However, if there is an indication that persons would be using the water on site for these purposes, these pathways should be evaluated. Since there is some concern associated with exposure to chemicals via the water, it would be most desirable to have additional water measurements from all the sites, which would allow for a complete assessment of potential risks associated with chemicals in the water.

2.4.1.10 Bioavailability of Chemicals from Soil

Chemicals bound to soil will likely be less absorbed into the body than chemicals in media such as food or water. Although it would be desirable to include this factor in the risk assessments, the Project Team did not include a soil-adjusted bioavailability factor in the risk evaluation process. It is clear by evaluating the current literature that assuming that the bioavailability of chemicals in a soil matrix is equal to that in food or water is quite conservative. If soil-specific bioavailability could be used in the risk assessment, it could reduce risk estimates by 4-fold according to some researchers (Calabrese, 1998, personal communications); however, at this time there is not the scientific data to accurately estimate the decrease in bioavailability of chemicals in most soils including Northern soil. Various scientists have indicated that the current studies lack a structural approach for investigating the effect of the soil matrix on bioavailability (Sips and Eijkeren, 1996; Canady *et al.*, 1997; Schoof and Nielsen, 1997; Paustenbach *et al.* 1997; Calabrese, 1998 [personal communication]). Thus, although recognized as possibly important, no reduction in bioavailability was assumed for chemicals in soil for either assessment. It should be noted that this bioavailability adjustment for soil-bound chemicals has not typically been included in CCME-style risk assessments.

2.4.1.11 Background Exposure

By setting the critical risk value of 1.0 (*i.e.,* 100% of the TDI) for LEPH and HEPH, the assumption is that background sources of these chemicals would not be of concern. This was a reasonable assumption since these chemicals would almost be entirely be present on the site as a result of previous site related activities. In other words, it was considered unlikely that there would be relevant background sources of these chemicals while persons are spending time on-site.

By setting the target risk level at 20% of the TDI (*i.e.,* ER value of 0.2) for lead at MP 124.5, background exposure was dealt with effectively. In other words, background exposure could still account for 80% of the TDI at this site. Furthermore, even if background exposure exceeded 80% of the Tolerable Daily Intake, it was felt that a further 20% contribution would not have an appreciable impact on human health risks.

2.4.2 Summary of Most Important Factors Used in the Assessment

From our perspective, it is likely that the Project Team has overestimated health risks from the 7 sites. The 4 important parameters where an overestimation of exposure and risk may have occurred are: rate of soil ingestion; soil concentration; bioavailability of chemicals in soil; and, number of days spent at site. Although the Project Team has used high-end estimates for these parameters, it is difficult to revise these at this time primarily due to lack of data specific to these sites and life activities in the North. The soil ingestion rate is currently our best estimate of the maximum reasonable exposure. For soil concentration, both average and maximum chemical concentrations were modelled so depending which set of results are considered, this parameter may represent average or high end values. It is noted that the site investigations did attempt to sample from many of the stained areas such that the results may be skewed high. Oral bioavailability from soil ingestion (assumed to be similar to that in food or water) is currently the best estimate of the maximum reasonable exposure although future research may indicate that this could be a 4-fold overestimation; however, preliminary quantitative risk assessments have historically not included this modification in their risk assessment process and the current scientific gaps would likely lead to debate over any factor selected. The only factor which could be adjusted immediately is the time spent at some of the sites. If it can be subsequently ensured that no humans would spend reduced amounts of time at the 7 sites, this could be factored into the assessment and will lead to the prediction that no lower human health risks exist at the site. It is noted that wild game consumption has not been adequately assessed at this time which may actually contribute to an underestimation of risks.

Thus, there remains some uncertainty at this time in the risk assessment process used at these sites. However, at this time it appears that only future data collection (*e.g.*, monitoring of concentrations of chemicals in wild game/berries, completion of a soil ingestion study specific for the people, monitoring of persons using the sites, completion of water sampling, *etc.*) will allow future adjustment of risk estimates in a preliminary quantitative risk assessment. A preliminary quantitative (or screening level) risk assessment should err on the side of conservatism and it is not felt that our risk estimates should be modified at the current time. The risk assessment that the Project Team has completed closely resembles a CCME-style risk assessment aside from the elevated soil ingestion rate. The Project Team feels that these are justified given the uniqueness of life in the North and, if they are not included, the risk assessment would be subject to criticism from many perspectives.

2.5 Conclusions

The results of the human health assessment completed for the 7 sites indicate that there may be some potential health risks associated with the current soil conditions at certain sites. The potential for health risks were found to be dependent on the site, as well as on the intended use of each site, and the time spent on site. The overall conclusions for the assessment are provided in Tables 2.5 to 2.8. Again, it should be noted that deterministic, worst-case analyses were used to assess potential health risks and, therefore, considered to be preliminary quantitative estimates. Since a worst-case approach was used, chemicals were identified as posing an acceptable level of risk if the risk estimate was below the critical values of concern.

For scenarios where no unacceptable risks have been predicted, no further evaluation is considered to be necessary. For scenarios determined to exceed the critical values of concern, 4 general options are available:

1) collection of additional site-specific data and revision of the preliminary quantitative human health risk assessment (highly recommended);
2) completion of a more comprehensive risk assessment in order to evaluate the potential for human health effects using more realistic methodology (*i.e.*, stochastic risk assessment) (highly recommended);
3) institute restricted land use of the site; or,
4) remediation of the site.

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Table 2.1 Summary of Soil, Water and Vegetation Concentrations

		Site Location						
Chemical		**MP 73**	**MP 124.5**	**MP 174**	**MP 213**	**MP 233**	**MP 234**	**MP 208**
				Soil Concentration (mg/kg)				
LEPH	AVE	2918	7601	7733	602	817	2417	2791
	MAX	3900	18,000	17,000	1800	2100	18,000	59,600
HEPH	AVE	1575	1741	10,333	2859	136	972	5417
	MAX	2800	17,000	21,000	8500	220	8000	61,400
Lead	AVE	---	292	---	---	---	---	---
	MAX	---	1110	---	---	---	---	---
				Water Concentration (mg/L)				
LEPH	AVE	4.43	---	---	---	---	1.8	2.8
	MAX	12.8	---	---	---	---	1.8	10
HEPH	AVE	1	---	---	---	---	8	3.4
	MAX	2	---	---	---	---	8	12
Lead	AVE	---	**1**	---	---	---	---	---
	MAX	---	**1**	---	---	---	---	---
				Vegetation Concentration (mg/kg)				
Lead	AVE	---	**1**	---	---	---	---	---
	MAX	---	**1**	---	---	---	---	---

note: bolded values represent half of detection limit

Table 2.2 Receptor Characteristics Used in the Human Health Risk Assessment

Parameter	Female Preschool Child	Female Adult	Units	Reference
Body Weight	16.4	63.1	kg	O'Connor, 1997
Air Inhalation Rate	8.8	14.4	m^3/d	O'Connor, 1997
Area of Exposed Skin (outdoor)	0.214	0.384	m^2	O'Connor, 1997
Total amount of wildlife consumed	75	220	g/day	O'Connor, 1997
Amount of caribou consumed (10% of total meat consumption)	7.5	22	g/day	estimated
Amount of rabbit consumed (5% of total meat)	3.8	11	g/day	estimated
Amount of grouse consumed (5% of total meat)	3.8	11	g/day	estimated
Total berry consumption	4	15	g/day	Wein, 1989
Daily water consumption rate	0.6	1.5	g/day	O'Connor, 1997
Soil Adherence Factor	5.85	5.85	m^2	US EPA, 1992
Soil/Sediment/Dust Ingestion	1.3	0.10	g/d	estimated

Table 2.3 Exposure Limits for Chemicals Assessed in the Human Health Risk Assessment

Chemical	Route of Exposure	Exposure Limit Type	Point Estimate (μg/kg/day)	Reference
LEPH	Inhalation	RfD	344	CANTOX, 1999
HEPH	Inhalation	RfD	2000	TPHCWG, 1997
Lead	Oral	TDI	3.57	Health Canada (1996)
	Inhalation	RfD	1.85	OMEE, 1994

Table 2.4 Selected Scenario Assumptions and Parameters Used in the Human Health Risk Assessment

Assumptions and Parameters	MP 73 / MP 234	MP 174 / MP 213 / MP 233	MP 124.5	MP 208 (NWT Site)
Human receptors evaluated	female preschool child, adult female	female preschool child, adult female	female preschool child, adult female	female preschool child, adult female
Chemicals concentrations	average and maximum soil concentrations modelled/predicted vegetation concentrations average and maximum groundwater concentrations	average and maximum soil concentrations modelled/predicted vegetation concentrations average and maximum groundwater concentrations	average and maximum soil concentrations modelled/predicted vegetation concentrations for LEPH and HEPH; measured vegetation concentrations for lead	average and maximum soil concentrations modelled/predicted vegetation concentrations average and maximum surface water concentrations
Exposure pathways evaluated	Indoor / Outdoor soil: - ingestion - inhalation - dermal contact Ingestion of rabbit (5% of meat in diet), grouse (5% of meat in diet) and caribou (10% of meat in diet) Consumption of berries (100% from site while on site) Consumption of water (100% from site, while on site)	Indoor / Outdoor soil: -ingestion -inhalation -dermal contact Ingestion of rabbit (5% of meat in diet), grouse (5% of meat in diet) and caribou (10% of meat in diet) Consumption of berries (100% from site while on site)	Indoor / Outdoor soil: - ingestion - inhalation - dermal contact Ingestion of rabbit (5% of meat in diet), grouse (5% of meat in diet) and caribou (10% of meat in diet) Consumption of berries (100% from site while on site)	Indoor / Outdoor soil: - ingestion - inhalation - dermal contact Ingestion of rabbit (5% of meat in diet), grouse (5% of meat in diet) and caribou (10% of meat in diet) Consumption of berries (100% from site while on site) Consumption of water (100% from site, while on site)
Time spent on site	2 weeks, 120 days or 180 days per summer; female child and adult assumed to spend 100% of their time at the site.	2 weeks, 120 days or 180 days per summer; female child and adult assumed to spend 100% of there time at the site.	2 weeks, 120 days or 180 days per summer; female child and adult assumed to spend 100% of their time at the site.	2 weeks, 120 days or 180 days per summer; female child and adult assumed to spend 100% of their time at the site.
Amount of time spent within a shelter (tent)	8 hrs/day	8 hrs/day	8 hrs/day	8 hrs/day

Table 2.5 Summary of Potential Human Health Risks Associated with the Soil Pathways as a Function of Time Spent on Site

Area	Time Spent on Site (days)	Conclusions [a]
MP 73	14	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	120	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	180	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
MP 124.5	14	Potential unacceptable health risks associated with direct exposure to soil from average and maximum lead concentrations
	120	Potential unacceptable health risks associated with direct exposure to soil from average and maximum concentrations of LEPH and lead
	180	Potential unacceptable health risks associated with direct exposure to soil from average and maximum concentrations of LEPH and lead, and maximum concentrations of HEPH
MP 174	14	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	120	Potential unacceptable health risks associated with direct exposure to soil from average and maximum concentrations of LEPH, and maximum concentrations of HEPH
	180	Potential unacceptable health risks associated with direct exposure to soil from average and maximum concentrations of LEPH, and maximum concentrations of HEPH
MP 213	14	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	120	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	180	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
MP 233	14	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	120	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	180	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
MP 234	14	No unacceptable health risks associated with direct exposure to soil from average or maximum concentrations measured.
	120	Potential unacceptable health risks associated with direct exposure to soil from maximum concentrations of LEPH
	180	Potential unacceptable health risks associated with direct exposure to soil from maximum concentrations of LEPH
MP 208 (NWT Site)	14	Potential unacceptable health risks associated with direct exposure to soil from maximum concentrations of LEPH
	120	Potential unacceptable health risks associated with direct exposure to soil from maximum concentrations of LEPH and HEPH
	180	Potential unacceptable health risks associated with direct exposure to soil from maximum concentrations of LEPH and HEPH

[a] shading indicates area/land use of possible concern

Table 2.6 Summary of Potential Human Health Risks Associated with Consumption of Wild game as a Function of Time Spent on Site

Area	Time Spent on Site (days)	Conclusions [a]
MP 73	14	No unacceptable health risks associated with consumption of wild game were identified for all time scenarios considered in the current assessment.
	120	
	180	
MP 124.5	14	No unacceptable health risks associated with consumption of wild game were identified in the current assessment.
	120	Potential unacceptable health risks associated with lead, from the consumption of wild game.
	180	Potential unacceptable health risks associated with lead, from the consumption of wild game.
MP 174	14	No unacceptable health risks associated with consumption of wild game were identified for all time scenarios considered in the current assessment.
	120	
	180	
MP 213	14	No unacceptable health risks associated with consumption of wild game were identified for all time scenarios considered in the current assessment.
	120	
	180	
MP 233	14	No unacceptable health risks associated with consumption of wild game were identified for all time scenarios considered in the current assessment.
	120	
	180	
MP 234	14	No unacceptable health risks associated with consumption of wild game were identified for all time scenarios considered in the current assessment.
	120	
	180	
MP 208 (NWT Site)	14	No unacceptable health risks associated with consumption of wild game were identified for all time scenarios considered in the current assessment.
	120	
	180	

[a] shading indicates area/land use of possible concern

Table 2.7 Summary of Potential Human Health Risks Associated with Consumption of Berries Grown on Site as a Function of Time Spent on Site

Area	Time Spent on Site (days)	Conclusions
MP 73	14 120 180	No unacceptable health risks associated with consumption of berries grown on site were identified for all time scenarios considered in the current assessment.
MP 124.5	14 120 180	No unacceptable health risks associated with consumption of berries grown on site were identified for all time scenarios considered in the current assessment.
MP 174	14 120 180	No unacceptable health risks associated with consumption of berries grown on site were identified for all time scenarios considered in the current assessment.
MP 213	14 120 180	No unacceptable health risks associated with consumption of berries grown on site were identified for all time scenarios considered in the current assessment.
MP 233	14 120 180	No unacceptable health risks associated with consumption of berries grown on site were identified for all time scenarios considered in the current assessment.
MP 234	14 120 180	No unacceptable health risks associated with consumption of berries grown on site were identified for all time scenarios considered in the current assessment.
MP 208 (NWT Site)	14 120 180	No unacceptable health risks associated with consumption of berries grown on site were identified for all time scenarios considered in the current assessment.

Table 2.8 Summary of Potential Human Health Risks Associated with Consumption of Surface Water or Groundwater on Site as a Function of Time Spent on Site

Area	Time Spent on Site (days)	Conclusions
MP 73	14	No unacceptable risks associated with the consumption of groundwater, if groundwater wells were present on site.
	120	Potential unacceptable risks associated LEPH from the consumption of groundwater, if groundwater wells were present on site.
	180	Potential unacceptable risks associated LEPH from the consumption of groundwater, if groundwater wells were present on site.
MP 124.5	14 120 180	Risks not assessed. Water data not available
MP 174	14 120 180	Risks not assessed. Water data not available
MP 213	14 120 180	Risks not assessed. Water data not available
MP 233	14 120 180	Risks not assessed. Water data not available
MP 234	14 120 180	No unacceptable health risks associated with consumption of groundwater from the site for all time scenarios considered in the current assessment
MP 208 (NWT Site)	14	No unacceptable health risks associated with the consumption of surface water from the site.
	120	No unacceptable health risks associated with the consumption of surface water from the site.
	180	Potential unacceptable risks associated LEPH from the consumption of surface water.

[a] shading indicates area/land use of possible concern

3.0 ECOLOGICAL RISK ASSESSMENT

3.1 Introduction

An ecological risk assessment (ERA) was conducted for 7 sites located along the Canol Road and MacMillan Pass area. The sites assessed were as follows:

1) MP 73 - Pump Station 10
2) MP 124.5 - Pump Station 9
3) MP 174 - Pump Station 8
4) MP 213 - Military Camp/Dump
5) MP 233 - Pump Station 7
6) MP 234 - Military Camp/Pump Station
7) MP 208 - NWT - Pump Station 6

The ERA was based on frameworks described by the Canadian Council of Ministers of the Environment (CCME) and Environment Canada (Gaudet *et al.*, 1994; CCME, 1996), and was conducted to identify the potential risks to Valued Ecosystem Components (VECs) found at the seven sites. VECs are resources or environmental features that are: (1) important to human populations (*i.e.,* intrinsic, economic, and/or social value); (2) have local, regional, provincial, national, and/or international profiles; or (3) if altered from their existing status, will be important in evaluating the impacts of development and in focussing management or regulatory policy (CCME, 1996).

The ERA was conducted to determine the potential risks to ecological receptors as a result of on-site contamination of soils with petroleum hydrocarbons and lead. Given the nature and location of the chemical contamination, the ERA focussed on potential risks to terrestrial organisms. In addition, it is conceivable that the contaminants in soil may have migrated down gradient to surface waters in the vicinity of the various sites. However, due to data limitations, an aquatic ERA was not conducted.

This chapter of the report presents the objectives, methods and results of the ecological risk assessment of chemicals identified at the seven abandoned sites. The methodology is presented in Section 3.2. The results of the risk assessment are presented in Section 3.3 and discussed in Section 3.4.

3.1.1 Objectives of the Ecological Risk Assessment

The objectives of the ERA were:

(i) to determine whether the on-site soil contamination at the abandoned sites would likely pose risks to indigenous terrestrial wildlife species; and,

(ii) to identify areas within the abandoned sites which may potentially require remediation (based on potential ecological risks).

3.2 Methodology

The methods used to identify potential risks to terrestrial wildlife species and aquatic organisms were based on ecological risk assessment procedures endorsed by regulatory agencies including the Canadian Council of Ministers of the Environment (CCME), British Columbia Ministry of the Environment (BCME), the Ontario Ministry of Environment and Energy (MOEE) and the United States Environmental Protection Agency (U.S. EPA). The terrestrial wildlife risk assessment followed the framework of a preliminary quantitative ERA (Gaudet *et al.*, 1994; CCME, 1996). While the methods for conducting a human health and ecological risk assessment are similar, the terminology used for these two types of assessment differ slightly. In an ecological risk assessment, the problem formulation stage, as outlined in the following pages, is divided into the Planning Stage and Receptor Characterization Stage. To be consistent with the concurrent human health assessment, however, the terminology used in this chapter will be that used for human health assessments. The risk assessment frameworks include the following steps:

(i) Problem Formulation: In this step, information is gathered to characterize the sites and to identify valued ecological receptors, potential exposure pathways, chemicals of concern, and appropriate assessment and measurement endpoints.

(ii) Exposure Assessment: In this step, site-specific rates of exposure to ecological receptors are estimated for the chemicals of concern. In addition, possible rates of exposure to chemicals of concern at non-contaminated (*i.e.*, background) areas are determined.

(iii) Toxicity (or Hazard) Assessment: In this step, the toxicity of the chemicals of concern to the selected ecological receptors is determined through identification and assessment of dose-response information obtained from the scientific literature. Recommended upper limits of exposure (*i.e.*, maximum exposure rates below which significant ecological health risks are not expected to occur) are derived from this assessment.

(iv) Risk Characterization: In the final step, the potential risks to terrestrial and aquatic wildlife are estimated by comparing the chemical exposures (both site-specific and background) derived in the exposure assessment to the exposure limits established in the toxicity assessment. Site-specific risk factors are compared to background risk factors in the final assessment of risk.

In this risk assessment, these steps were followed, and at each stage, conservative, yet realistic, assumptions were used in an effort to ensure that predicted risks associated with the abandoned sites would not be underestimated.

3.2.1 Problem Formulation

The problem formulation phase of an ERA acts as an information gathering and interpretation stage. It is conducted to plan and focus the approach of the assessment on critical areas of concern for the sites being evaluated. Key tasks requiring evaluation within the problem formulation phase include the following:

(i) Identification of VECs (*i.e.*, identify potential ecological receptors of chemical exposures).

(ii) Exposure Pathway Analysis (*i.e.*, identify possible routes by which organisms may be exposed to chemicals at the site).

(iii) Identification of Chemicals of Concern (*i.e.*, select chemicals which pose the greatest potential risk to receptors due to their toxic potency and measured concentrations); and,

(iv) Identification of Assessment and Measurement Endpoints (*i.e.*, focus risk assessment on individual, population or ecosystem level effects and select practical measurements of those effects).

For the purpose of this ERA, it was assumed that in the future, the sites would have a residential/parkland usage (the term "residential/parkland" loosely classifies land use that includes humans in a "natural" setting). Therefore, VECs associated with such a land use were selected. The following text discusses the rationale for the selection of the chemicals, receptors and exposure pathways.

3.2.1.1 Receptor (VEC) Identification

During the receptor identification stage of the ERA, key terrestrial wildlife receptors were identified following consideration of the indigenous species which are expected to utilize the habitat around the abandoned sites. Emphasis was placed on those animals most likely to receive the greatest exposure to on-site contamination due to their habits and diet. Further confirmation of the relevance of the receptor choices was accomplished following site visits and review of the Valued Ecosystem Component Characterization Community Questionnaire.

Special consideration was given to any species which are classified as "endangered or threatened". From information provided by COSWIC (Committee on the Status of Endangered Wildlife in Canada), it was determined that the woodland caribou (*Rangifer tarandus caribou*) in the Northwest Territories are considered "vulnerable" (COSWIC, 1999). While there are serious management concerns over barren land caribou in the Yukon and NWT (*i.e.*, the Porcupine herd), the Yukon woodland herds are considered to be "not at risk" (COSWIC, 1999). No other animal species from the Ross River/MacMillan Pass regions were identified as "at risk".

Terrestrial Wildlife Receptors

The selection of receptors was conducted to ensure assessment of susceptible species, while also retaining realism in the overall ERA process. This was done by including representative species that have the greatest potential for exposure through various media, including the food chain, on-site habitation, trophic position and diet, as well as behavioural and physiological factors which may result in increased exposure. Where data were available, consideration of chemical exposure sensitivity was also included in the selection process for wildlife receptors.

For the current assessment, five representative species selected as receptors at the sites were the hare, caribou, grouse, wolf, and bear. Justification for the selection of these species is presented in the following paragraphs.

Table 3.1 Features of Receptor Selection Process

Wildlife Receptors Evaluated [a]	Related Wildlife Receptors considered jointly	Justification	Locations
Caribou	Moose, sheep, caribou	Used caribou body and toxicology parameters with moose home range	All Sites
Grouse	Grouse, ptarmigan	Species are similar	All Sites
Hare	Hare, rabbit	Species are similar	All Sites
Black bear	Black bear		All Sites
Wolf	Wolf, fox	Used wolf body size, fox home range	All Sites

[a] Note that the "evaluated receptors" represent, in some cases, a "surrogate" animal. For example, characteristics of two or more animals were combined to make the "surrogate" receptor which consisted of the most sensitive combination of toxicological and ecological characteristics. For the "caribou" (for example), the use of the smaller home range of the moose would result in higher estimates of exposure to site conditions, and therefore the risk estimates for caribou would be higher than expected (and protective of all three species evaluated jointly via the surrogate).

The snowshoe hare (*Lepus americanus*) was selected for assessment for several reasons. This animal, native to the sub-arctic regions of Canada, is a herbivorous medium-sized mammal which is valued by humans and utilized by predatory wildlife species as a food item. The hare does not migrate, has a relatively small home range, and has a high potential for exposure *via* contaminated vegetation and direct contact with soil.

The caribou is representative of a large ungulate, found throughout Canada's arctic and sub-arctic. This assessment considers the woodland caribou (*Rangifer tarandus caribou*), which ranges over a considerably smaller area than the barren land caribou (which migrates seasonally over a wide area). Considerations for the selection of this species included its value as a food source for both humans and other wildlife.

The grouse was selected because of its position in the food chain and relatively small home range (similar in size to the sites being assessed). The consumption of "grit"for digestion in the crop (the main organ of physical food breakdown in birds) is a physiological aspect unique to the grouse among the receptors considered for this risk assessment. Therefore, via the additional exposure pathway (consumption of contaminated grit), the grouse could be particularly vulnerable at the contaminated sites.

The wolf (*Canis lupus occidentalis*) is perhaps the most important predatory animal in the sub-arctic. The wolf is considered to be a top predator, feeding on regionally-important species of small mammals such as the hare as well as larger ungulates such as caribou and moose. By virtue of its location at the top of the food chain, the wolf is susceptible to contaminants which accumulate in the tissues of its prey. While not considered "at risk" in the Yukon or Northwest Territories, the wolf is ecologically important.

The black bear (*Ursus americanus*) was selected as the final receptor for this assessment. Bears are known to be attracted to the odour of refined hydrocarbons such as naphtha (white gas). Previous site examinations identified disturbances at the sites from bears clawing and possibly eating the oil-laden soils (Gartner Lee, 1999).

In summary, the selection of receptors for the ERA included important animal species from different, representative, levels of the terrestrial food chain. In addition, two receptor species (grouse and bear) were identified that might be exposed to site contamination to a greater degree than other receptors. Their inclusion in the ERA was intended to add a further conservative (protective) element to the assessment.

3.2.1.2 Exposure Pathway Screening

Terrestrial Wildlife Receptors

The possible pathways which terrestrial wildlife receptors could be exposed to chemical contaminants in soil, vegetation and water were evaluated for their contribution towards the total predicted exposure rate from the site. Pathways were selected based on the behavioural characteristics of the receptors, site characteristics, the source of contamination, the types of receptors present, and chemical fate. The following sections summarize the pathways selected for the wildlife receptors identified for the ecological assessment:

(i) Hare, grouse, bear, and caribou

Potential exposure pathways for hare, grouse, bear, and caribou were reviewed based on the nature of the site and the contaminants. Due to similarities in behavioural characteristics, the following major exposure pathways were identified for these species:

- ingestion of contaminated soils or dusts;
- ingestion of contaminated surface water;

- ingestion of potentially contaminated vegetation; and,
- direct dermal contact with soils or dusts.

(ii) Wolf

Potential exposure pathways for the wolf were reviewed. The following major exposure pathways were identified for this species:

- ingestion of contaminated soils or dusts;
- ingestion of contaminated surface water;
- direct dermal contact with soils or dusts; and,
- ingestion of potentially contaminated prey species (caribou and hare).

3.2.1.3 Chemical Screening

Extensive soil sampling has been conducted as part of the environmental study of the sites of concern. The existing data was compiled to aid in chemical selection for the ERA using the methodology described below.

Chemicals advanced to the quantitative phase of the assessment if maximum site concentrations of chemicals exceeded regulatory criteria for soil. More specifically, chemicals in the surface soil (upper 1.0 m) were included in the ERA if the chemical concentrations at the site exceeded Yukon Contaminated Sites Regulation (1996) soil criteria for parkland use. Using this methodology, the following chemicals were for evaluation in the risk assessment for each of the sites:

- LEPH (C10-C18);
- HEPH (C19-C32);
- lead (only for MP 124.5)

Terrestrial Wildlife Receptors

Surface soil chemicals detected in concentrations above regulatory criteria and/or background concentrations were further screened based on toxic potency to terrestrial wildlife and bioaccumulative potential. A detailed methodology of this screening is presented in Appendix B.

3.2.1.4 Selection of Assessment and Measurement Endpoints

In order to narrow the focus of the risk assessment, it was necessary to select assessment endpoints in terms of the individual, the population, the community, or the ecosystem. The assessment endpoints for the ERA should be relevant to the site-specific contamination and should be capable of being assessed with available data (CCME, 1996). For the purposes of this ERA, assessment endpoints were selected to evaluate the potential for site-specific toxic effects that could result in reduction of populations of VECs.

Assessment endpoints must be translated into measurement endpoints in order to conduct an ERA practically. Measurement endpoints are measurable environmental characteristics that are related to the assessment endpoint (CCME, 1996). For the ERA, individual and population level measurement endpoints (*i.e.*, effects on survival, reproduction, growth, *etc.*) were selected for the chemicals of concern in the toxicity assessment in order to determine exposure limits and toxicity benchmarks for the selected ecological receptors.

3.2.2 Exposure Assessment

Exposure assessment involves the estimation of the amount of chemical received by ecological receptors per unit time (*i.e.*, the quantity of chemical and the rate at which that quantity is received). Exposure assessment was conducted for all chemicals, ecological receptors and exposure pathways short-listed during the problem formulation phase of the ERA.

3.2.2.1 Exposure of Herbivorous Terrestrial Organisms

The rate of contaminant exposure to herbivorous terrestrial organisms was evaluated based on mean and maximum soil concentrations from each of the seven abandoned sites.

A summary of the contaminant concentrations in soil is provided in Table 2.1.

3.2.2.2 Exposure of Predatory Wildlife Receptors

The objective of the exposure assessment for predatory wildlife (characterized in this assessment by the wolf) was to determine the exposure rates for chemicals of concern *via* ingestion of hare and caribou contaminated from feeding on site vegetation. In addition, as appropriate, soil ingestion was included as a potential route of exposure. Exposure was estimated for the site sources *via* quantitative exposure modelling.

The exposure assessment for terrestrial wildlife was conducted using a deterministic risk analysis technique developed by Environment Canada and referred-to as the Wildlife Contaminant Exposure Model (1997). A deterministic approach was selected since it is relatively time and cost efficient method for predicting exposure based on the narrow range of input parameters available for wildlife receptors selected for the ERA.

Exposure rates were estimated based on the interactions of a number of parameters, including:

- the various physical, chemical, and biological factors that determine the uptake of chemicals into biological organisms (*e.g.*, bioconcentration, bioaccumulation, bioavailability of the chemicals from particles, foods, water, air);

- the physical/chemical characteristics of the chemicals that determine their interaction and behaviour with the surrounding environment (*e.g.*, water solubility, K_{OW}, volatility, tendency to bind to particles); and,

- the behavioural lifestyle and the physical characteristics of the selected ecological receptors that determine the dose rates through the various exposure pathways (*e.g.*, respiration rate, food intake, dietary composition, soil/dust intake, migratory patterns, *etc.*).

Chemical Bioavailability

Every attempt was made to assess chemical bioavailability on a chemical specific, receptor specific and site specific basis. When ranges of data are indicated in the literature, maximum values were used in exposure modelling. However, if limited data on the bioavailability of chemicals was available in the published literature, it was assumed that the chemical is 100% bioavailable, in order to provide a conservative assessment of the potential risk.

Physical/Chemical Characteristics

The physical/chemical characteristics of chemicals (*e.g.*, water solubility, volatility, and tendency to bind to particles) determine their behaviour in the environment and their tendency to enter pathways by which receptors are exposed. Therefore, knowledge of the physical/chemical characteristics is critical to the estimation of the importance of exposure pathways and the magnitude of subsequent exposures. The most current physical/chemical characteristics were selected from the published literature for the chemicals of concern.

Receptor and Parameter Assumptions

For each receptor, a number of conservative but realistic assumptions were used to facilitate the quantitative modelling process helping to ensure that the exposure levels predicted were not underestimated. Every attempt was made to ensure that the conservative assumptions used in the current screening level assessment were realistic in nature. The following section discusses the assumptions used for each receptor of concern.

Caribou

The woodland caribou was assessed in the ERA. As such, the migratory aspects of the ecology of the caribou were de-emphasized, and it was assumed that the home range of the caribou was 69.5 km^2 (Appendix B). In part, this choice of home range reflects the use of the caribou as a surrogate for all the ungulates that might use the sites. Since it was not technically feasible to assess all ungulates (caribou, sheep, and moose) that might be exposed on-site, the incorporation of the moose home range of 69.5 km^2 into the assessment was one means to assure conservatism in the assessment.

Exposure is influenced by the amount of time spent on site by the receptor. For the assessment, the time spent by a receptor on-site was estimated to be the ratio of the site area and the receptor's home range. By using a minimal home range (69.5 km^2) for the caribou, the ratio is maximized, thereby assuring a conservative estimate of risk that should be applicable to all ungulate receptors. With the total site area being approximately 0.46 km^2, it can be assumed that the caribou would be on site 0.66% of the time. While on-site, the caribou's diet was conservatively assumed to consist of vegetation taken entirely from within the boundaries of the site.

<u>*Grouse*</u>
The grouse was used as a surrogate for both grouse and ptarmigan. Based on the estimated home range of the grouse (Appendix B) it was assumed that the grouse was on-site 100% of the time. The exposure pathways assessed for the grouse were vegetation consumption and incidental soil ingestion. All of the vegetation and soil ingested was (conservatively) assumed to be from the site.

<u>*Wolf*</u>
For the purpose of the current assessment, the wolf was assumed to spend 2.9% of its time within the site boundary area (Appendix B). Because the wolf was a surrogate species used to screen for both fox and wolf, the home range of the wolf was assumed to be that of the fox (Appendix B). On this basis, the assumed time-on-site estimate of 2.9% is, once again, conservative. The exposure of the wolf *via* the food chain was estimated by assuming dietary breakdown of 25% hare and 75% caribou. The chemical concentrations in these prey items were derived according to the individual exposure scenarios for those animals.

<u>*Hare*</u>
Hare were assumed to spend 100% of their time on the site. Diet was assumed to consist of vegetation (seeds, leaves, and berries).

Receptor Parameters

The estimation of exposure to terrestrial receptors was based on the individual physiological characteristics of each receptor species (*e.g.*, soil/dust consumption, respiration rate, body weight, and food consumption). Where possible, receptor parameters published by regulatory agencies (*i.e.,* from the U.S. EPA) were used for hare, caribou, grouse, bear, and wolf. When data for these receptors were not available, data from similar species were used to represent the specific ecological receptor of concern. When ranges of data were reported in the literature, values resulting in the most realistic scenario were assumed for the current ERA.

3.2.3 Toxicity Assessment

3.2.3.1 Screening Benchmarks for Entry to Ecological Risk Assessment

Before entering the preliminary quantitative ecological risk assessment, a screening level toxicity assessment was conducted to determine whether the chemicals of concern represent a potential concern in need of further analysis. This screening examined site soil concentrations of chemicals of potential concern with reference to soil quality guidelines, regulatory limits selected to be protective of wildlife (CCME, 1997a). The relevant soil guidelines are those of the Canadian Council of Ministers of the Environment (CCME) Environmental Soil Quality Guidelines (SQG_E) based on soil contact using data from toxicity studies on plants and invertebrates (CCME, 1997). As discussed previously, the final decision for inclusion of chemicals in the ERA was the exceedance of Yukon Contaminated Sites Regulation (1996) soil criteria for parkland use.

3.2.3.2 Toxicity in Terrestrial Wildlife Receptors

A wildlife toxicity assessment was conducted to determine exposure limits for hare, caribou, grouse, wolf, and bear for the chemicals of concern. The NOAEL (No Adverse Effect Level) exposure limit refers to the rate at which a receptor can be exposed to a given chemical without the occurrence of adverse health effects. The LOAEL (Lowest Adverse Effect Level) exposure limit is the rate of exposure which is associated with the occurrence of some adverse effect in the test species. The actual threshold of the occurrence of adverse in test species lies somewhere between the NOAEL and LOAEL. Exposure limits are expressed in terms of the quantity of chemical per body weight per day (*e.g.*, mg chemical/kg body weight/day), and are presented in Appendix B.

The following hierarchical approach was used to identify exposure limits for use in the ERA for terrestrial wildlife:

(i) Toxicological benchmarks for wildlife derived by Oak Ridge National Laboratory for the U.S. Department of Energy for the ecological risk assessment of U.S. hazardous waste sites (Sample *et al.*, 1996).

(ii) Exposure limits derived by CANTOX ENVIRONMENTAL INC. based on a review and evaluation of the scientific literature.

These exposure limits were derived from published toxicity studies involving the receptor species or similar wildlife species, where available. Alternatively, in the absence of such data, exposure limits used information from laboratory studies. In cases in which more than one study was available and suitable for derivation of an exposure limit, the data yielding the most conservative exposure limit was used. In some situations, only a NOAEL or a LOAEL might be available from the scientific literature. In such cases, uncertainty factors were used to derive exposure limits (*i.e.*, ten-fold uncertainty factors were applied for the use of a LOAEL to a NOAEL). The use of uncertainty factors is discussed in Sample *et al.* (1996). It was assumed that the exposure limits were protective of the mean or average population of hare, caribou, grouse, wolf, and bear, and that the application of additional uncertainty factors, if necessary, for species sensitivity would result in a relatively conservative assessment.

Table 3.2 Wildlife Exposure Limits used in the Ecological Risk Assessment

Receptor	Eicosane (HEPH) (mg/kg/d)	Nonane (LEPH) (mg/kg/d)	Lead (mg/kg/d)
Caribou	NOAEL 1400 LOAEL 14000	NOAEL 120 LOAEL 330	NOAEL 0.017 LOAEL 0.170
Grouse	NOAEL 500 LOAEL 5000	NOAEL 44 LOAEL 120	NOAEL 0.77 LOAEL 7.7
Hare	NOAEL 4300 LOAEL 43000	NOAEL 370 LOAEL 1000	NOAEL 5.312 LOAEL 53.12
Black Bear	NOAEL 1600 LOAEL 16000	NOAEL 140 LOAEL 370	NOAEL 0.019 LOAEL 0.19
Wolf	NOAEL 1800 LOAEL 18000	NOAEL 150 LOAEL 420	NOAEL 0.03 LOAEL 0.30

3.2.4 Risk Characterization

The final process in the ERA for terrestrial wildlife consisted of a comparison of the exposure limits (*i.e.*, either the NOAEL, the rate of exposure that would not produce adverse effects or the LOAEL, the rate of exposure that would potentially produce adverse effects) against the total estimated exposure. This comparison is expressed as an Exposure Ratio (ER) and is calculated by dividing the predicted exposure by the exposure limit, as indicated in the following equation:

$$\text{Exposure Ratio} = \frac{\text{Estimated Exposure}}{\text{Exposure Limit}}$$

An ER value less than 1.0 indicates that the estimated total exposure is less than the upper limit of total exposure, and therefore no risk of adverse health effects is predicted. An ER value greater than 1.0 indicates that the estimated exposure level exceeds the exposure limit, and may pose an unacceptable adverse health risk to the wildlife receptors. ER values that are slightly less than or greater than 1.0 require re-evaluation of the conservative nature of the assumptions before the potential risks to terrestrial wildlife can be characterized.

For receptors spending a fraction of their time on-site, the calculation of the ER value must reflect the potential for exposure from sources other than the site (*i.e.*, from background sites). To this end, the calculations of the total exposure and the ER are weighted to account for 100% of the receptor's time, and to reflect the proportion of time spent on-site and off-site.

For example, if a receptor spends 5% of its time on the site, the overall ER is derived *via* cumulative exposures from on- and off-site; 95% of exposure would be based on background concentrations, and 5% of exposure would be based on the on-site concentrations. In cases of chemicals not detected at background sites, or for compounds of predominantly synthetic origins (*e.g.*, LEPH, HEPH), the contribution to overall risk by background would be negligible, and it would be appropriate to consider that 100% of exposure would be derived from the site.

As discussed earlier, the actual dose rate where adverse effects begin to occur in the test species lies somewhere between the NOAEL and the LOAEL. Therefore, ER values based on NOAEL-derived exposure limits provide an indication of the likelihood that adverse effects will not occur in the receptor species, while ER values based on LOAELs indicate the likelihood of occurrence of adverse effects in receptor species if future predicted exposures are not overestimated. Therefore, ER values associated with on-site exposures were calculated based on:

(i) ER values for the Protection of Ecological Health (ER_{NOAEL}): The predicted exposure was compared to the exposure limits derived from study NOAELs. ER values calculated in this manner indicated the likelihood that adverse effects will not occur in terrestrial wildlife.

(ii) ER values for the Likelihood of Adverse Effects (ER_{LOAEL}): The predicted exposure was compared to the exposure limits derived from study LOAELs. ER values calculated in this manner indicated the likelihood that adverse effects may occur in terrestrial wildlife.

3.2.5 Criteria for Evaluation of Exposure Ratio Values

The evaluation of the results of the risk characterization can become somewhat subjective due to the numerous assumptions and parameter estimations. Subsequently, a set of criteria has been derived in order to provide a more rigorous approach. The criteria used to evaluate results obtained using the modelling techniques were as follows:

(i) All chemicals with ER_{NOAEL} values less than 1.0 represent scenarios which would not be expected to pose a health risk to terrestrial wildlife receptors living on-site.

(ii) Chemicals for which ER_{NOAEL} values exceed 1.0 indicate exposures of potential concern which require re-evaluation based on the ER_{LOAEL}, since the estimated exposure exceeded the highly conservative NOAEL exposure limit.

It is essential to consider that the ER_{LOAEL} and ER_{NOAEL} represent mathematical calculations of risk based on conservative assumptions. An ER greater than 1.0 does not immediately mean that a site is dangerous as a whole. It should be remembered that site means and maxima for soil and vegetation are used as model inputs. Therefore, the sampling effort and distribution of contaminants on-site can have profound impacts on the model output (the ERs). If only a small number of samples are collected and one of them (the site maximum) contains chemicals in great excess of the other samples, this value will make the ER_{max} an extreme value, and will also drive the ER_{mean} upwards. As a result, in some cases, the ER_{max} is not representative of the site. In addition, in all cases, the ER_{mean} will be more representative of the site than the ER_{max}. Therefore, the ER_{max} provides an extreme risk estimate which can be used initially. ER_{max} values greater than 1.0 should be examined in greater depth, both in terms of the site means and in terms of data gaps. Even when the ER_{max} is extremely high, there may still be little reason for concern at a site.

The ER_{LOAEL} is the primary exposure ratio of interest in an ecological setting, as it represents the point at which species-level effects may occur. For the purposes of this preliminary quantitative ERA, the ER_{LOAEL} is more relevant than the ER_{NOAEL}, as it indicates the threshold above which adverse effects may occur in animals. For endangered animals, discussion would focus on the ER_{NOAEL}, which is protective of individuals.

3.2.6 Conservative Assumptions Used in the Ecological Risk Assessment

Attempts to estimate absolute risk levels from a single exposure situation are affected by the uncertainties in the estimation of the exposure limits, chemical concentrations in various media, receptor characteristics, and the ultimate exposure levels predicted. In particular, in cases where data availability is limited, the resulting concentrations used to derive ERs may be quite unrepresentative of the general conditions at the site. Therefore, it is necessary to outline a set of assumptions to guide the ERA process. The underlying basis of these assumptions in an ERA is to conduct an assessment which is conservative and yet realistic, taking into account these uncertainties. The conservative assumptions used in the current ERA are presented in the following sections.

3.2.6.1 Assumptions Associated with Exposure Estimations

The following conservative assumptions were used in the estimation of exposures to terrestrial wildlife (see Section 3.2):

(i) Mean and maximum surface soil concentrations detected within each of the sites were used to estimate exposure for ecological receptors.

(ii) (Estimated) mean and maximum chemical concentrations in vegetation within each of the sites were used to estimate exposure for ecological receptors (estimation methods are outlined in Appendix B).

(iii) Oral, inhalation and dermal bioavailability parameters used for estimating chemical exposure in terrestrial wildlife were based on mammalian data where no species-specific data were available. Dermal bioavailability was assumed to be 40% higher in fur-bearing animals than in humans. In the absence of chemical-specific data, bioavailability was assumed to be 100%.

(iv) The most conservative values for chemical and biological parameters (*e.g.*, maximum chemical bioavailability, maximum food consumption) were used where ranges were reported in the literature.

These assumptions are thought to provide conservative, yet realistic, estimates of chemical exposure in the receptors.

3.2.6.2 Assumptions Associated with Derivation of Exposure Limits

The following conservative assumptions were used in the derivation of exposure limits for terrestrial receptors:

(i) A literature review was conducted to identify appropriate exposure limits for rodents, large mammals and avian species. Due to the limited toxicity database for large mammals, the exposure limits used for the current assessment were derived *via* dose-scaling based on toxicity studies conducted with other mammalian species (usually rodent).

(ii) Uncertainty factors were used where applicable in the calculation of reference doses for threshold-type chemicals. These uncertainty factors were applied to exposure levels from toxicological studies where LOAELs were reported or to account for uncertainties in estimating chronic effects from sub-chronic studies. It was assumed that application of additional uncertainty factors for species sensitivity would result in an overly conservative assessment.

(iii) The exposure limits selected for terrestrial wildlife were assumed to be protective of the mean or average population.

3.3 Results and Discussion

A separate ERA was conducted for each of the 7 sites located along the Canol Road/MacMillan Pass Area. Although the approaches used for each site share a number of common points, every attempt was made to utilize data collected on-site and to consider site-specific characteristics in order to provide an assessment of risk which was relevant to the unique features of each ecosystem.

3.3.1 MP 73 - Pump Station 10

A preliminary screening of the chemical concentrations quantified in soil at this site indicated that light extractable petroleum hydrocarbons (LEPH) were the primary chemicals of potential concern (see Table 2.1 for site-specific soil data). Both the average (n = 4) and maximum soil concentrations of these compounds exceeded soil quality guidelines (1000 mg/kg) for parkland land-use established in the Yukon Contaminated Sites Regulations (1998).

The assessment of LEPH used a surrogate approach characterized by MDEP (1997) and CCME (1997b). In the surrogate approach, the total mass of all hydrocarbons in the group was assumed to be due to the surrogate, which is the most toxic hydrocarbon in the group. In the case of LEPH, nonane was assumed to be the surrogate toxicant. By expressing the mass of entire group of hydrocarbons in this way, the toxicity is overestimated, and the risk estimates are conservative.

With the exception of LEPH in grouse, the risk estimates for all receptors were all below 1.0 (for both the ER_{NOAEL} and the ER_{LOAEL}) (Table 3.3). For grouse, the ER_{NOAEL} was 1.1 for the maximum LEPH concentration. Risk estimated from the average soil LEPH concentration was 0.88, and both ERs based on the LOAEL were also less than 1.0. These findings indicate that there are very minor expected risks to individual animals from LEPH in soil at MP 73. It is of interest that these soil samples were all collected between 1 and 2 m depth in the soils. Therefore, the risk estimates are probably quite conservative, in that exposure to these deeper soils in unlikely. Uptake of hydrocarbons from depths below 1 m into plant matter is likely to be minimal, so the calculated risks are expected to be overestimates. Thus, animal exposures derived from these soil contaminant levels are indicative of a worse-case scenario. In this instance, even the conservative nature of the risk estimation procedures indicate that remediation of the site is not required from an ecological risk perspective.

Table 3.3 Exposure Ratios calculated for each contaminant and wildlife receptor at the MP 73 Site

Receptor	Chemical	NOAEL		LOAEL	
		Mean	Max	Mean	Max
Caribou	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Grouse	Nonane (LEPH)	0.8	**1.1**	0.3	0.4
	Eicosane (HEPH)	<0.05	0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Hare	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Wolf	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Bear	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05

Bold type indicates ERs greater than 1.0.

Groundwater sampling at the MP 73 site in 1998 indicated that one of three wells at the dump area (approximately 250 m from Gravel Creek) had hydrocarbons in excess of freshwater life criteria (Gartner Lee, 1999). Without clear knowledge of the groundwater flow characteristics in the area, it is difficult to assess the importance of these data. It is possible that the distance from Gravel Creek is adequate to attenuate hydrocarbon transfer to the creek. At any rate, much higher concentrations of hydrocarbons were measured in site soils between well #3 and Gravel Creek, so it is likely that the groundwater would ameliorate the situation as it currently stands.

Finally, one water sample (73-1) collected in 1997 (Gartner Lee, 1997) exceeded criteria for Zn in freshwater. This sample was collected at a point in Gravel Creek that was adjacent to POL tank location. Although the collection of one sample precludes a detailed evaluation, the fact that a downstream sample (73-2) was acceptable suggests that any Zn due to sources near the POL area is attenuated in the river flow. More detailed sampling would be necessary to make specific conclusions about aquatic contamination at MP 73. The limited sampling to date suggests no problems in the aquatic environment due to the presence of contamination at the MP 73 site.

3.3.2 MP 124.5 - Pump Station 9

The MP 124.5 site along the Lapie River had soil contamination due to LEPH, HEPH, and lead (Table 2.1). Two samples in area "A" (samples SS-1 and SS-2) were separated by approximately 50 metres at either end of the area. These samples had LEPH concentrations of 15,000 and 18,000 mg/kg, respectively, and HEPH concentrations of 13,000 and 17,000 mg/kg, respectively. Given the limited sampling effort available for site investigation, it is not possible to accurately determine the heterogeneity of hydrocarbon concentrations in the surface soil. However, preliminary site assessment identified discretely stained patches in area A (Gartner Lee, 1997), suggest that heterogeneity is significant at the site. In addition to LEPH and HEPH, lead concentrations in soil at the site were well in excess of criteria (Table 2.1).

An examination of the ERs for the five receptors at MP 124.5 (Table 3.4) indicates potential concerns for LEPH and lead. ERs for lead were greater than 1.0 for the wolf, the bear, and the grouse. For the bear and wolf, only the ER_{NOAEL} for the maximum soil lead concentration was greater than 1.0. The ER_{LOAEL} values are less than 1.0 for both the site average and the site maximum. For grouse, the ER_{NOAEL} values for the average and the maximum lead concentrations were 3.98 and 15.0, respectively. The ER_{LOAEL} for the maximum lead concentration was 1.51 for the grouse. Considered together, the weight-of-evidence from these ERs suggests minimal ecological risk for lead at MP 124.5. Even for the grouse (apparently the most sensitive receptor in this assessment), ERs were less than 1.0 for the average soil lead concentration (based on the LOAEL assessment end-point). Interpolation between the ER_{LOAEL} of 1.5 for grouse based on the site maximum (1,110 mg/kg) and the ER_{LOAEL} of 0.39 based on the site average (292 mg/kg) suggests that risks from lead to individual animals may occur if these animals spent most of their time at the site. However, from a population level perspective, it is unlikely that this contamination would pose unacceptable risks to any of these species.

Table 3.4 Exposure Ratios calculated for each contaminant and wildlife receptor at the MP 124.5 Site

Receptor	Chemical	NOAEL		LOAEL	
		Mean	Max	Mean	Max
Caribou	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Grouse	Nonane (LEPH)	**2.2**	**5.1**	0.8	**1.9**
	Eicosane (HEPH)	0.14	0.32	<0.05	<0.05
	Lead	**4**	**15**	0.4	**1.5**
Hare	Nonane (LEPH)	0.1	0.2	<0.05	0.1
	Eicosane (HEPH)	<0.05	0.05	<0.05	<0.05
	Lead	0.2	0.9	<0.05	0.1
Wolf	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	0.5	**1.9**	0.05	0.2
Bear	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	0.8	**2.8**	0.1	0.3

Bold type indicates ERs greater than 1.0.

For LEPH, ERs greater than 1.0 were calculated only for the grouse. The trends observed in the ERs for different end-points and soil concentrations were similar to those mentioned above for lead. No effects from a population level perspective are expected from this contamination while removal of LEPH to 9600 mg/kg would be sufficient to protect the health of individual animals from LEPH. No removal of soil would be necessary to protect the other receptors considered.

3.3.3 MP 174 - Pump Station 8

Risk estimates for this site are presented in Table 3.5. Only ERs for LEPH were greater than 1.0, and as with other sites, these only occurred for one receptor, the grouse. The ERs based on the maximum concentration exceeded 1.0 for both the LOAEL and NOAEL end-points. The ER_{LOAEL} for the average concentrations of LEPH at site 174 was 0.81. While not exceeding 1.0, this ER is sufficiently close to 1.0 to be suggestive of risk to individual receptors but not entire populations. It is worthy to note that the site was characterized by only three soil samples (Table 2.1). Therefore, the maximum concentration significantly elevates the average site concentration. In turn, this impacts on the assessment. A greater number of soil samples would have allowed for a more representative site average LEPH concentration, which would have undoubtedly decreased the risk estimates for the site as a whole.

Table 3.5 Exposure Ratios calculated for each contaminant and wildlife receptor at the MP 174 Site

Receptor	Chemical	NOAEL		LOAEL	
		Mean	Max	Mean	Max
Caribou	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Grouse	Nonane (LEPH)	**2.2**	**4.9**	0.8	**1.8**
	Eicosane (HEPH)	0.2	0.4	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Hare	Nonane (LEPH)	0.1	0.2	<0.05	0.1
	Eicosane (HEPH)	<0.05	0.06	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Wolf	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Bear	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05

Bold type indicates ERs greater than 1.0.

The assessment of this site is influenced by a small number of samples. The influence of the site maximum is significant. Based on the preliminary site investigation (Gartner Lee, 1997) the site maximum is from an oil-stained area 3 to 5 m in diameter. It seems reasonable that removal of this stained area would be sufficient to reduce the ERs for individual grouse to acceptable values; however, no population level effect is expected to occur from current chemical concentrations for any of the receptors considered.

3.3.4 MP 213 - Military Camp/Dump

The preliminary site investigation (Gartner Lee, 1997) indicated that the site had two areas of concern, characterized by surficial oil staining. The chemical analyses at this site were not complete for all samples, so the data set allows for only sketchy interpretation of trends in site chemistry. The site maximum for LEPH was from test pit TP-1, not from the stained areas A and B. Regardless, the ERs for the site (Table 3.6) indicate no need to remediate the site for ecological protection of either populations or individual animals.

Table 3.6 Exposure Ratios calculated for each contaminant and wildlife receptor at the MP 213 Site

Receptor	Chemical	NOAEL		LOAEL	
		Mean	Max	Mean	Max
Caribou	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Grouse	Nonane (LEPH)	0.2	0.52	0.1	0.2
	Eicosane (HEPH)	0.1	0.2	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Hare	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Wolf	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Bear	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05

Bold type indicates ERs greater than 1.0.

3.3.5 MP 233 - Pump Station 7

Table 3.7 (below) indicates that there are no ecological concerns due to soil contamination at the site.

Table 3.7 Exposure Ratios calculated for each contaminant and wildlife receptor at the MP 233 Site

Receptor	Chemical	NOAEL		LOAEL	
		Mean	Max	Mean	Max
Caribou	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Grouse	Nonane (LEPH)	0.2	0.6	0.1	0.2
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Hare	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05

Table 3.7 Exposure Ratios calculated for each contaminant and wildlife receptor at the MP 233 Site

Receptor	Chemical	NOAEL		LOAEL	
		Mean	Max	Mean	Max
Wolf	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Bear	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05

Bold type indicates ERs greater than 1.0.

3.3.6 MP 234 - Military Camp/Pump Station

The ERs for grouse in Table 3.8 indicate that the site maximum soil concentration of LEPH represent potential risk to individual animals. No other receptors had elevated risk estimates. The corresponding ER_{mean} values for LEPH in grouse were below 1.0. At this site, a relatively large sample size (16 soil samples) allowed for a thorough chemical characterization of the site. Two samples (14,700 and 18,000 mg/kg) were responsible for skewing the site mean LEPH concentration upwards to 2417 mg/kg. Regardless, the ERs based on mean concentration were all below 1.0. Given the lack of predicted risk for four of the five receptors, and the influence of the site maximum on the risk estimates for the remaining receptor (grouse), removal of stained soils would protect individual animals while population effects are not expected from any of the contamination reported.

Table 3.8 Exposure Ratios calculated for each contaminant and wildlife receptor at the MP 234 Site

Receptor	Chemical	NOAEL		LOAEL	
		Mean	Max	Mean	Max
Caribou	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Grouse	Nonane (LEPH)	0.7	**5.1**	0.3	**1.9**
	Eicosane (HEPH)	<0.05	0.2	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Hare	Nonane (LEPH)	<0.05	0.2	<0.05	0.1
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Wolf	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05

Table 3.8 Exposure Ratios calculated for each contaminant and wildlife receptor at the MP 234 Site

Receptor	Chemical	NOAEL		LOAEL	
		Mean	Max	Mean	Max
Bear	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05

Bold type indicates ERs greater than 1.0.

3.3.7 MP 208 - NWT - Pump Station 6

Site MP 208 was chemically well-characterized, with 34 soil samples analysed for LEPH. One sample contained LEPH at a level of 59,600 mg/kg (test pit TP-3). This sample accounts for the elevated risk estimates for grouse, based on the site maximum (Table 3.9). The grouse ERs were less than 1.0 when using the site mean as the concentration for estimating on-site exposure. Furthermore, no other receptors had ERs above 1.0 for either assessment end-point (using either the site mean or maximum). Therefore, the minor ecological risks estimated in this assessment would be minimized further by remediation targeted at the removal of the contaminated soils around TP-3 and SS-5. Consideration of the risk estimates for four of the five receptors suggests no ecological risks for the site and no population level effects are anticipated for any of the contaminant levels.

Table 3.9 Exposure Ratios calculated for each contaminant and wildlife receptor at the MP 208 Site

Receptor	Chemical	NOAEL		LOAEL	
		Mean	Max	Mean	Max
Caribou	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Grouse	Nonane (LEPH)	0.8	**17**	0.29	**6.2**
	Eicosane (HEPH)	0.1	**1.2**	<0.05	0.1
	Lead	<0.05	<0.05	<0.05	<0.05
Hare	Nonane (LEPH)	<0.05	<0.05	<0.05	0.26
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Wolf	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05
Bear	Nonane (LEPH)	<0.05	<0.05	<0.05	<0.05
	Eicosane (HEPH)	<0.05	<0.05	<0.05	<0.05
	Lead	<0.05	<0.05	<0.05	<0.05

Bold type indicates ERs greater than 1.0.

3.4 Conclusions of the Ecological Risk Assessment

Preliminary quantitative ecological risk assessments have been conducted for the 7 sites along the Canol Road and MacMillan Pass area. Gaps or patchiness (heterogeneity) in site data have, in some instances, influenced the ERA results. These data issues were sometimes revealed either in terms of maxima that were significantly higher than site means, or via means that were calculated from a small number of samples (and therefore may not have been representative). In such cases, differences in ERs for means, maxima, NOAELs, and LOAELs reveal common patterns that can be treated as a whole to provide weight-of-evidence supporting the conclusions. The sites were commonly found to have small areas of hydrocarbon contamination that influenced the assessments and may cause unacceptable risks to individual animals (as opposed to populations). Often, site clean-up by removal of these areas would be sufficient to remove ecological health risks for individual animals. A summary of these conclusions is presented in Table 3.10.

Overall, ecological risk assessment of the 7 sites indicated that none of the sites would likely cause a population level effect on any ecological receptors. However, some of the sites may have effects on individual animals.

Table 3.10 Conclusions for the Ecological Risk Assessment

Site	Conclusions
MP 73	No unacceptable risks would be expected from a population level perspective. Potential unacceptable risks to individual grouse from exposure to LEPH. Risks are for NOAEL end-point, but not for the LOAEL end-point. Weight-of-evidence suggests that ecological risk is minimal for this site.
MP 124.5	No unacceptable risks would be expected from a population level perspective. Potential unacceptable risks calculated for individual grouse, wolf, and bear based on exposure to lead and LEPH. Risk estimates are influenced by small areas on-site with elevated concentrations of lead and hydrocarbons. Removal of these areas would likely be sufficient to remove apparent risk to individual wildlife receptors.
MP 174	No unacceptable risks would be expected from a population level perspective. Potential unacceptable risks calculated for individual grouse based on exposure to LEPH (but no risk for other receptors). Risk estimates are influenced by small areas on-site with elevated concentrations of hydrocarbons. Removal of these areas would likely be sufficient to remove apparent risk to individual wildlife receptors.
MP 208	No unacceptable risks would be expected from a population level perspective. Potential unacceptable risks calculated for individual grouse based on exposure to LEPH (but no risk for other receptors). The risk estimates are influenced by small areas on-site with elevated concentrations of hydrocarbons. Removal of these areas would likely be sufficient to remove apparent risk to individual wildlife receptors.
MP 213	No unacceptable risks would be expected from a population level perspective. No unacceptable risks to individual ecological receptors.
MP 233	No unacceptable risks would be expected from a population level perspective. No unacceptable risks to individual ecological receptors.

Table 3.10 Conclusions for the Ecological Risk Assessment

Site	Conclusions
MP 234	No unacceptable risks would be expected from a population level perspective. Potential unacceptable risks calculated for individual grouse based on exposure to LEPH (but no risk for other receptors). The risk estimates are influenced by small areas on-site with elevated concentrations of hydrocarbons. Removal of these areas would likely be sufficient to remove apparent risk to individual wildlife receptors.

Where available, aquatic sampling was limited. Exceedances of freshwater criteria occurred at some sites. These exceedances were typically very close to the criteria levels. Although, detailed discussion of risks to the aquatic ecosystems would require more data collection, preliminary analysis of the aquatic data suggests that damage to aquatic systems near the sites would be minimal.

3.5 References

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4.0 CONCLUSIONS

A site-specific human health and ecological risk assessment has been completed for 7 sites located along the Canol Road and MacMillan Pass. The risk assessment has indicated that human health risks from these sites are the more sensitive determinant of whether these sites require remediation. Human health risk was directly dependent upon usage patterns and time spent on-site. For scenarios where no unacceptable risks have been predicted, no further evaluation is considered to be necessary. For scenarios determined to exceed the critical values of concern, 4 general options are available:

1) collection of additional site-specific data and revision of the preliminary quantitative human health risk assessment;
2) completion of a more comprehensive risk assessment in order to evaluate the potential for human health effects using more realistic methodology (*i.e.,* stochastic risk assessment);
3) institute restricted land use of the site; or,
4) remediation of the site.

Although the risk assessment represents the best estimate of human health and ecological risks that can be provided within the context of the required scope of work, it is noted that a series of conservative assumptions and methods have been used to estimate risks. If more detailed site-specific data were collected, it is possible that the risk assessment could be revised. However, at this time, it is still possible to view the risk assessment as protective of human health and the environment. Thus, incorporation of the results of the risk assessment into the risk management plan of the sites will ensure protection of humans and the environment from unacceptable health risks related to these chemicals.

APPENDIX A

APPENDIX A

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A-1.0 *n*-EICOSANE (SURROGATE FOR C_{19}- C_{32})

There is a paucity of information on the pharmacokinetics and toxicity of eicosane in the published literature. However, there is a limited amount of data available on white mineral oils, which are complex mixtures of C_{15} to C_{50} saturated aliphatic hydrocarbons. White mineral oil is essentially a heavily refined mixture of pure long chain aliphatic hydrocarbons (straight, branched or cyclic) with aromatic and other contaminants typically comprising less than several percent of the mixture (MDEP, 1994). These oils have been used commercially as food additives, in cosmetics, as dust control agents, as defoamers in foods, and in pharmaceutical products for decades. As *n*-eicosane is a common constituent of the lower molecular weight white mineral oils, data on white mineral oils was considered to be representative of *n*-eicosane for the purposes of this assessment.

A-1.1 Fraction Absorbed *Via* Different Routes

A-1.1.1 Fraction Absorbed Via Ingestion

No information on the gastrointestinal absorption of eicosane was identified in the literature reviewed. Data on the absorption of white mineral oil from the gastrointestinal tract is also limited, although evidence indicates that a small percentage is actually absorbed (Nash *et al.*, 1996). Ebert *et al.*, (1966) reported that a maximum of 1.5% of an orally administered dose of [^{3}H] mineral oil was absorbed over a 48 hour period in rats. Chronic administration did not alter the absorption efficiency. Low *et al.* (1992) orally administered branched, cyclic, and straight chain paraffins (which are alkanes found in white mineral oils) to F344 rats and obtained a similar absorption efficiency. Studies with long-chained aliphatics found in white mineral oils have found that the body is able to metabolize and clear much of what is absorbed in the absence of further intake (Smith *et al.*, 1996). It has been suggested that the absorption of mineral hydrocarbons is dependent, at least in part, on the physical-chemical properties of the compounds, such that the amount absorbed is inversely proportional to the length of the carbon chain (Low *et al.*, 1992) and that branched or cyclic compounds are generally absorbed more efficiently than straight chain compounds.

For the current assessment, it is assumed that 1.5% of ingested *n*-eicosane is absorbed from the gastrointestinal tract.

A-1.1.2 Fraction Absorbed Via Inhalation

Due to its extremely low vapour pressure (Cavender, 1994) and high boiling point (*i.e.*, 344 ^{o}C), *n*-eicosane is not considered volatile, suggesting that the inhalation route would not contribute significantly to total *n*-eicosane exposure. However, due to the paucity of data and the possibility that some of the chemical could be present in its vapour phase, the vapour inhalation pathway could not be entirely ignored.

Based on various studies on chemicals in the gas/vapour phase, approximately 50 to 80% of the examined chemicals were retained by the respiratory system (Chin *et al.*, 1980; Cohr and Stokholm, 1979; Astrand *et al.*, 1978; Toftgard and Gustafsson, 1980). Assuming a bioavailability of 100% for gases/vapours retained in the lung (*i.e.*, gases/vapours would not be cleared by the mucociliary apparatus and swallowed), the total percentage of gaseous *n*-eicosane absorbed into the body following inhalation could range anywhere between 50 to 80%.

Although the inhalation of *n*-eicosane is more likely to occur in its airborne particulate phase (which would correspond to a bioavailability of 13%, Brain and Mosier, 1980), an inhalation bioavailability of 50% was chosen for the current assessment to ensure that exposure via inhalation would not be underestimated.

A-1.1.3 Fraction Absorbed Via Dermal Exposure

No data on the potential absorption of *n*-eicosane through the skin were identified in the literature reviewed. Data is also limited on the dermal absorption of white mineral oils; however the available data suggests that the amount absorbed following dermal application is less than that following oral administration (Nash *et al.,* 1996). Dermal absorption studies with C_{16} (hexadecane), C_{18} (octadecane), and C_{22} (docasane), which are mineral oil alkanes similar to eicosane (C_{20}) in terms of physical/chemical properties, found that very small percentages of the applied dose were absorbed, ranging from less than 0.1% to less than 1% (Rossmiller and Hoekstra, 1966; Brown *et al.,* 1995; Diembeck and Duesing, 1993; Diembeck and Grimmert, 1993). Studies on mice and humans demonstrated that these types of mineral hydrocarbons are unable to penetrate the skin beyond the stratum corneum layer, resulting in less than 1% absorption of white mineral oils after topical (dermal) exposure (Ghadially *et al.,* 1992; Zesch and Bauer, 1985). For the purposes of this assessment, dermal bioavailability of *n*-eicosane was assumed to be 1%.

A-1.2 Health Hazard Assessment

Studies examining the toxicity of *n*-eicosane or other individual long-chain alkanes were not identified in the literature reviewed for the current assessment. However, limited toxicological information is available on white mineral oil, a complex mixture of C_{15} to C_{50} saturated aliphatic hydrocarbons. The Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) has recommended that toxicity criteria developed for white mineral oils be used in developing toxicity benchmarks or toxicologically based exposure limits (*e.g.*, RfDs) for fractions containing aliphatic hydrocarbons C_{17} or higher (TPHCWG, 1996).

A-1.2.1 Animal Studies

A-1.2.1.1 Oral Studies

McKee *et al.*, (1987) conducted a 90-day subchronic study where male and female Sprague-Dawley rats were administered mineral oil by gavage at a dose of 2964 mg/kg body weight/day, five times a week for 13 weeks. There were no observed histological effects on any organ or tissue system.

Shubik *et al.*, (1962) conducted two year chronic studies using male and female Sprague-Dawley rats fed five different petroleum waxes. The diet was comprised of 10% petroleum waxes. No significant toxicological or pathological effects were observed.

Several 90-day subchronic dietary or gavage toxicity studies with white mineral oil have been conducted by Exxon Biomedical Sciences Inc., Atlantic Richfield Company (ARCO), and Shell Oil Company. The Exxon studies tested four white mineral oils in rats and dogs and one medicinal grade mineral oil in rats only (MDEP, 1994). No signs of toxicity were observed in any of these experiments and the lowest reported no-observed adverse-effect-level (NOAEL) was 125 mg/kg body weight/day for the white mineral oils. For the medicinal grade oil, the NOAEL was 4350 mg/kg body weight/day.

Lifetime and subchronic dietary feeding studies with white mineral oils in rats showed no evidence of chronic toxicity or carcinogenicity, with NOAELs ranging from 1200 to 6000 mg/kg body weight/day (API, 1992).

In a Shell Oil Company study, Hernandez (1989) exposed male and female rats to two white mineral oils (obtained from two different distillation processes) at dietary concentrations ranging from 5000 to 20,000 ppm (approximately 288 to 1150 mg/kg body weight/day). A second study exposed female rats only to dietary concentrations ranging from 10 to 20,000 ppm (0.6 to 1150 mg/kg body weight/day). In the first study, hyperphagocytic granulomas were detected in the livers of female rats at dose levels of 5000 ppm and higher. Males showed Kupffer cell hypertrophy and slight multifocal granulomas at the 20,000 ppm dose level. In the second study, one female rat displayed frequent granulomatous macrophage syncytia at the 100 ppm dose level. These lesions were not observed at the 10 ppm dose level, while three of five female rats in the 5000 ppm group had granulomatous lesions similar to those observed in the single female rat from the 100 ppm group. The authors suggested that the cause of the hepatic lesions observed in these studies was related to the absorption of high molecular weight hydrocarbons. Once absorbed, these relatively inert hydrocarbons may cause local inflammation arising from difficulties in metabolizing or excreting these compounds (MDEP, 1994). The Hernandez (1989) study was criticized for not providing chemical speciation data, making it impossible to determine whether more toxic compounds (*i.e.*, aromatics) were present as contaminants in the white mineral oils tested, and may have contributed to the effects seen (MDEP, 1994). As this study produced results that were contradictory to those obtained in a number of other studies, it was not considered to be representative of white mineral oil toxicity (MDEP, 1994).

In a subchronic dietary feeding study conducted by The British Industrial Biological Research Association (BIBRA), Smith *et al.*, (1996) exposed male and female F344 rats to seven white mineral oil samples of varying molecular weight and viscosity, at doses of approximately 2, 20, 200, and 2000 mg/kg body weight/day for 90 days. The mineral oil samples with the lowest molecular weight (*i.e.*, approximately 240 to 480 g/mol for C_{17-34} mineral oils) and viscosity produced mesenteric lymph node histiocytosis at doses of 20 mg/kg/day and higher, and liver granulomas at the 2000 mg/kg/day dose level. The degree of response was found to be inversely proportional to the size of the mineral oil compounds tested; high molecular weight (approximately >480 g/mol for $>C_{27}$ mineral hydrocarbons) and viscosity mineral oils produced essentially no signs of toxicity in male or female rats, even at the highest tested dose of 2000 mg/kg body weight/day. In general, female rats were found to be more sensitive than males.

Other 90-day subchronic feeding studies with F344 rats also showed treatment-related effects in the liver and mesenteric lymph nodes which included increased organ weights, microscopic inflammatory changes, and the accumulation of saturated mineral hydrocarbons in the affected tissues (Baldwin *et al.*, 1992; Freeman *et al.*, 1993). Subsequent studies suggested that the magnitude of these effects was related to an absorption reaction arising from the large molecular size of the hydrocarbons within the white mineral oil formulations (Worrell, 1992; Freeman *et al.*, 1993; Simpson, 1993).

Previous 90-day subchronic feeding studies conducted in 1977 and reported by Smith *et al.*, (1995) involved the administration of four highly refined white mineral oils to male and female Long-Evans rats and beagle dogs at dietary dose levels of 300 and 1500 ppm (w/w). The dietary concentrations corresponded to doses of approximately 21 and 108 mg/kg/day (female rats), 25 and 125 mg/kg/day (male rats), 10 and 50 mg/kg/day (male female beagles). No statistically or biologically significant treatment related effects were observed. Observations of beagle dogs suggested that the white mineral oils may have caused a mild laxative effect. Gross and histopathological examination revealed no signs of toxicity or mineral oil deposition. Contrary to what was observed in the above studies with F344 rats, there were no signs of liver granulomas or mesenteric lymph node histiocytosis in Long-Evans rats or beagle dogs. There appears to be significant species and strain differences in response to ingested mineral hydrocarbons (Firriolo *et al.*, 1995; Smith *et al.*, 1995).

Differences in strain response of rodents to white mineral oils was demonstrated by Firriolo *et al.*, (1995), who conducted a 90-day subchronic dietary study of a low viscosity white mineral oil with F344 and Sprague-Dawley-derived CRL:CD rats. All animals were fed paraffinic white oil at 0, 0.2 or 2% of the diet for 30, 61, or 92 days. The equivalent doses were 0, 161 and 1582 mg/kg/day for F344 rats and 0, 148 and 1624 mg/kg/day for CRL:CD rats. No significant adverse clinical effects were observed in any of the animals tested. In F344 rats, occasional treatment-related effects on hematological and clinical chemistry parameters were noted at both the 0.2 and 2.0 % dose levels. However, these changes were marginal, not dose-related, and were within the historical ranges observed in F344 rats; thus they were not considered to be of clinical significance. Upon necropsy, F344 rats from both dose groups displayed enlarged mesenteric lymph nodes, increased liver, spleen and mesenteric lymph node weights, liver and mesenteric lymph node microgranulomas, and mesenteric lymph node histiocytosis. These effects were more pronounced in the 2.0% dose group. In CRL:CD rats, the only observed effects were accumulations of chronic inflammatory cells in the liver at the highest dose tested. No granulomatous lesions were observed. Given that F344 rats appear to be uniquely sensitive in their response to ingested white mineral oils, the use of this strain for human health risk assessment has been considered questionable by some authors (Firriolo *et al.,* 1995; Miller *et al.,* 1996; Nash *et al.,* 1996).

A recent review of the available human and laboratory animal toxicology studies on white mineral oil concluded that the lesions observed in F344 rats following mineral oil ingestion appear to have no significance for human disease, due to differences in pathogenesis between humans and rats; although, the possibility of atypical granulomatous hepatitis occurring in humans may require further investigation (Fleming *et al.,* 1998). To date, a mechanism for the particular sensitivity of F344 rats has not been established, although it is likely that pharmacokinetic and immune response factors are involved (Miller *et al.,* 1996). It is also noteworthy that granuloma formation in rats is not unique to mineral oil exposure; granulomas are also a common response to diets that are high in vegetable or animal fats (Herting *et al.,*1959).

A-1.2.1.2 Dermal Studies

Acute skin sensitization experiments using guinea pigs showed that the dermal application of white mineral oil did not produce any skin sensitization reactions (Mahagaokar, 1996).

Nash *et al.,* (1996) reviewed several lifetime topical exposure studies of petroleum distillates and oils, where white mineral oil was used as the negative control. Generally, these studies used male C3H mice that were topically exposed to white mineral oil on their shaved dorsal surface two to three times weekly for 24 months. The average dose of white mineral oil was 296 mg/kg body weight/day. There was no evidence of any histopathological changes in any organ system, nor were there any signs of tumour formation either at the site of application or in any organ system.

The National Toxicology Program (NTP, 1992) conducted a number of subchronic 90-day studies where highly refined mineral oil hydrocarbons were used as negative controls. In these studies, male and female F344/N rats and C3H mice were dermally exposed to a mineral oil dose of approximately 41 and 143 mg/kg body weight/day, respectively, for 91 days. An increase in liver and kidney weights was observed in both male and female F344/N rats, and liver weights were increased in both sexes of C3H mice. Neither test species showed any significant histopathological changes. Slight cutaneous irritation was observed in the mice, and the NTP concluded that this observation was the only evidence of treatment-related toxicity. However, this finding is inconsistent with other dermal exposure studies (Nash *et al.,* 1996).

New Zealand white rabbits that were dermally exposed to products containing either 16 or 99% white mineral oils at a dose of 2000 mg product/kg body weight/day over 10% of the body surface area for 20 days showed no evidence of any cutaneous, hematological, or histopathological changes (Johnson and Johnson Consumer Products, 1992).

Based on the results of the available dermal studies, as well as the long history of human use of white mineral oils in food and pharmaceutical applications, Nash *et al.,* (1996) concluded that there was no evidence of significant adverse effects from topical exposure to white mineral oils, at any dose tested, in multiple species.

A-1.2.1.3 Genotoxicity and Mutagenicity Studies

No genotoxicity or mutagenicity studies with *n*-eicosane or white mineral oil hydrocarbons were identified in the literature reviewed for the current assessment.

A-1.2.1.4 Carcinogenicity Studies

No carcinogenicity studies with *n*-eicosane were identified in the literature reviewed for the current assessment. It has been suggested that aliphatic hydrocarbons in the C_{12} to C_{30} range may commonly act as co-carcinogens or promoters of carcinogenic effects, possibly the result of their solvent properties, but are not initiators of carcinogenesis (Horton and Christian, 1974).

The carcinogenicity potential of medium viscosity liquid paraffin was examined in male and female F344 rats (Shoda *et al.,*1997). Rats were administered the liquid paraffin in the diet at dose levels of 0, 2.5% or 5% for 104 weeks. The highest dietary concentration (5%) corresponds to a daily dose of 1942 mg/kg body weight/day (males) and 2292 mg/kg body weight/day (females), while the 2.5% dietary concentration corresponds to approximately 971 and 1146 mg/kg body weight/day for males and females, respectively. Slight increases in food consumption and body weight were observed in both sexes at the highest dietary concentration. However, no significant effects on clinical chemistry, hematology or mortality were observed at any of the dose levels tested. A variety of tumours were observed in all dose groups, including controls, and all neoplastic lesions were histologically similar to those known to occur spontaneously in F344 rats. There were no statistically significant increases in tumour incidence for any of the treated groups, relative to controls. It was concluded that white mineral oil is not carcinogenic in F344 rats. In the 2.5% and 5% dose groups, both males and females showed granulomatous inflammation of the mesenteric lymph nodes. However, this is widely believed to be a reaction to absorption of large hydrocarbons, and is not generally considered an adverse health effect. Rather, in F344 rats, this effect is considered a normal adaptive response to the ingestion of aliphatic hydrocarbons as mesenteric lymph nodes which drain the gut-associated lymphoid tissue typically show granulomatous inflammation or histiocytosis (Schuurman *et al.*, 1994).

A-1.3 Human Studies

No human studies with *n*-eicosane were identified in the literature reviewed for the current assessment. Acute skin sensitization experiments with human subjects found that the dermal application of white mineral oil did not produce any skin sensitization reactions (Mahagaokar, 1996).

Studies of human subjects who had prolonged or excessive exposure to white mineral oil showed structural and functional changes in liver, lung and spleen cells, and mesenteric lymph nodes, as well as accumulation of mineral oil hydrocarbons in these tissues and lipid granulomas in the liver, spleen, lymph nodes and bone marrow (Fleming *et al.*, 1998). Hepatic lipid granulomas have been reported in a number of clinical reports where human subjects ingested white mineral oils (Boitnott and Margolis, 1970; Cruickshank and Thomas, 1984; Stryker, 1941). They are characterized as benign lesions containing mineral oil in the centre, with no signs of inflammation, fibrosis, or liver dysfunction (Wanless and Geddie, 1985). There have also been a few rare reports of atypical granulomatous hepatitis in humans following ingestion of white mineral oil (Fleming *et al.*, 1998). However, none of these white mineral oil-induced changes are generally considered to be of toxicological significance for humans (Hernandez, 1989; MDEP, 1994; TPHCWG, 1996; Fleming *et al.*, 1998; Miller *et al.*, 1996). These observed effects have never been associated with clinically significant adverse effects in humans. Furthermore, there are differences in the pathogenesis of lesions observed in humans and similar types of lesions observed in F344 rats (Fleming *et al.*, 1998).

A-1.4 Exposure Limits

There are presently no federal U.S., Canadian, European or international regulatory exposure limits for *n*-eicosane or white mineral oil hydrocarbons with a similar molecular weight to *n*-eicosane.

The Massachusetts Department of Environmental Protection (MDEP, 1994) derived an oral RfD of 6 mg/kg body weight/day for white mineral oil. This RfD was based on the highest reported NOAEL of 6000 mg/kg/day in a lifetime feeding study with rats. A 1000-fold uncertainty factor (10-fold for subchronic exposure; 10-fold for interspecies differences; 10-fold for sensitive individuals or subpopulations) was applied to the NOAEL.

The TPHCWG (1996) derived an oral RfD for aliphatic fractions C_{17} to C_{34} based on the NOAEL of 200 mg/kg/day from the Smith *et al.*, (1996) study. The reported LOAEL for liver granuloma formation was 2000 mg/kg/day. Although mesenteric lymph node histiocytosis was observed at a lower dose (20 mg/kg/day), this effect was not considered to be an adverse in F344 rats; rather it is a normal adaptive response to the ingestion of aliphatic hydrocarbons (Schuurman *et al.*, 1994). Mesenteric lymph nodes which drain the gut-associated lymphoid tissue typically show this histiocytosis effect in F344 rats. An uncertainty factor of 100 (3-fold for animal to human extrapolation; 10-fold for sensitive individuals; 3-fold for subchronic study) was applied to the NOAEL to yield an oral RfD of 2 mg/kg body weight/day. A higher uncertainty factor was considered unnecessary as F344 rats are known to be more sensitive to granulomatous effects of white mineral oils than humans. Also, F344 rats appear to be more sensitive to white mineral toxicity than other laboratory animals (TPHCWG, 1996; Firriolo *et al.,* 1995). Furthermore, F344 rats have high incidences of spontaneous granulomas when used as controls, suggesting that this strain of rats is predisposed to the development of inflammatory granulomatous lesions (Ward *et al.,* 1993; Miller *et al.,* 1996). Despite this apparent predisposition, F344 rats do not generally experience any significant adverse health effects as a result of the granulomatous response (TPHCWG, 1996).

For the purposes of this assessment, the oral RfD of 2 mg/kg body weight/day derived by the TPHCWG (1996) was selected. Although the significance of effects of white mineral oil exposure observed in F344 rats to human health is considered questionable by some (*e.g.*, Firriolo *et al.,* 1995; Miller *et al.,* 1996; Nash *et al.,* 1996; Fleming *et al.,* 1998), the principal study (Smith *et al.,* 1996) was able to demonstrate a dose-response relationship and estimate both LOAEL and NOAEL values. Furthermore, the rationale provided by the TPHCWG (1996) in their derivation of this oral RfD appears to adequately account for the unique response of F344 rats to ingested white mineral oil. In light of the low bioavailability of white mineral compounds, the lack of significant human clinical effects, and the long history of human use of these compounds in food and pharmaceutical applications, this oral RfD is considered to provide an adequate margin of safety for the protection of human health.

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A-2.0 N-NONANE (SURROGATE FOR C10-C18)

A-2.1 Fraction Absorbed by Different Routes

A-2.1.1 Fraction Absorbed Via Ingestion

For the purposes of this assessment, it is assumed that 100% of ingested n-nonane and n-decane will be absorbed from the gastrointestinal tract into the body.

A-2.1.2 Fraction Absorbed Via Inhalation

Fugacity modelling has demonstrated that approximately 98.4% of n-decane exists in the vapour phase and 1.6% found in the soil compartment (Mackay *et al.*, 1993). Therefore, it is expected that of inhaled n-decane, 98.4% exists as a gas, and 1.6% bound to airborne particulates. Studies on the dynamics of inhalation and exhalation have demonstrated that 50 to 80% of inspired chemicals in the vapour phase are retained in the lungs (see introduction to this report). Therefore, assuming 100% bioavailability for gases in the lungs, it is expected that 49.2 to 78.7% [(50 to 80) x 98.4%] of n-decane inhaled in the gaseous state would be absorbed through the respiratory system. In addition, of the particulate-bound n-decane, 13% is expected to be retained in the respiratory system, and 60% cleared to the gastrointestinal tract. Assuming 100% 0bioavailability for both routes, the contribution would be 1.17% [1.6% x (13% + 60%)]. Therefore the total absorption of n-decane via inhalation would be 50.4 to 79.9% [(49.2+1.17) (78.7+1.17)]. Due to the structural similarity of n-nonane and n-decane, it is expected that these values for n-decane also are applicable to n-nonane.

A-2.1.3 Fraction Absorbed Via Dermal Exposure

Considering the large Henry's law constants (>3x105) of n-nonane and n-decane (Mackay *et al.*, 1993), no more than 3% is expected to be absorbed via dermal exposure (see introduction to this report).

A-2.2 Health Hazard Assessment

A-2.2.1 Animal Studies

<u>Acute Studies</u>

Acute lethal concentrations following a single exposure to n-nonane have not been reported (Low *et al.*, 1987). Rats have been observed to tolerate air concentrations of 880 ppm for 4 hours without visible discomfort (Carpenter *et al.*, 1978). In the same study, rats exposed to 1,500 ppm n-nonane vapour for 6 hours/day over 7 days developed mild tremors, slight incoordination, and slight irritation of the eyes and extremities. These authors reported that the LC50 in rats exposed by inhalation to n-nonane for 4 hours and then observed for 2 weeks (no treatments) was 3,200 ppm. Time of death was not reported.

Exposure of mice to 540 ppm n-decane for 3.75 hours was not associated with deaths in the first 24 hours; however, by the fourth day 16% of the animals had died (Nau *et al.*, 1966). The cause of death in these studies was not reported. The 2-hour LC50 in mice has been reported as 73.3 mg n-decane/L (RTECS, 1992). Gerarde (1963) reported that the aspiration of 0.2 ml n-decane was lethal in rats within 24 hours. Death was due to pulmonary edema and haemorrhaging. Signs of dyspnea, tachypnea, and cyanosis as well as a 4-fold increase in lung weight also were noted.

Anaesthetic doses for n-nonane and n-decane in mice were reported to be 2.68 mmol/kg body weight and 4.10 mmol/kg body weight, respectively, based on the average time required to cause cardiac arrest following intravenous infusion (0.04 ml/minute) (Jeppson, 1975).

Oral and dermal LD50 values have not been reported for n-nonane and n-decane. However, based on studies of mixtures of isoparaffinic hydrocarbons, n-nonane and n-decane are not considered to be potent acute toxicants following oral and dermal exposures. For various mixtures of C9-C11 hydrocarbons, the oral LD50 values in rats ranged from approximately 10 to 34.6 g hydrocarbon/kg body weight, and dermal LD50 values in rabbits ranged from 3.2 to 15.4 g hydrocarbon/kg body weight (Mullin *et al.*, 1990). It is expected that oral and dermal LD50 values for n-nonane and n-decane would fall in these ranges.

Application of n-decane on the skins of rabbits for 1 hour was associated with haemorrhage and erythema in the first 2 days, followed by encrustation, reduced elasticity and cracking in subsequent days. By day 14, the skin appeared normal (Komatsu *et al.*, 1979).

Small effects on isolated nerves or axons have been demonstrated following in vitro exposures to n-decane. The nerve impulse of isolated frog nerves decreased 10% after about 4 hours of exposure to a Ringer solution containing 0.30 mol n-decane/L (0.042 mg/L) (Haydon *et al.*, 1977). In the same experiment, treatment with an emulsion rather than a true solution of n-decane caused irreversible blockage of action potentials. Similarly, n-decane has been shown to block the action potentials in frog sciatic nerves after 20 hours of exposure. Changes in the structure of the myelin sheaths, as measured through x-ray diffraction, included time-related increases in membrane bilayer thickness. After prolonged exposure, the effect on the myelin structure was irreversible (Padron *et al.*, 1980). The primary metabolite n-decanol has been shown to block nerve impulses in vitro (Richards *et al.*, 1979). In a preparation of the lateral olfactory nerve from guinea pigs, 1 mmol n-decanol/L blocked nerve impulses after 100 minutes of exposure. This nerve blocking effect was reversible. The metabolites n-decanal and n-decanoic acid caused a blocking of the ciliary movements in cultures of embryo chicken trachea at a concentration of 5 mmol/L (Pettersson *et al.*, 1982). These effects indicate an increased risk of impairment of the respiratory defence system from exposure to n-decane metabolites.

Repeated intraperitoneal administration of 1.0 ml n-nonane/kg body weight/day for 7 days caused decreased cytochrome P-450 activity in the livers of female albino rats (Khan *et al.*, 1980). Benzo[a]pyrene hydroxylase, benzphetamine-N-demethylase, p-nitroanisole-Odemethylase and glutathione S-transferase activities were reduced 50 to 80%, relative to controls. Liver cytochrome P-450 and free sulfhydryl content were significantly decreased, while a 3-fold increase in lipid peroxidation was observed. In 2 similar studies, Khan and Pandya (1980, 1985) reported that n-nonane significantly reduced the activities of aminopyrene-N-demethylase, aniline hydroxylase, glucose 6-phosphatase, acetylcholinesterase, carboxylesterase, fructose 1,6-diphossphate aldolase, and 5'-nucleotides.

Subchronic/Chronic Studies

Dermal effects assessed in mice receiving skin applications of 0.1 to 0.15 g n-decane/mouse, 3 times per week on alternate days for 1 year (total dose of 16.33 g n-decane/mouse) included fibrosis (43%), pigmentation (29%), and ulceration (18%). Haemorrhage, pigmentation, and inflammation of the lungs and kidney were observed as well. Rats exposed via inhalation to 540 ppm n-decane for 18 hours/day, 7 days/week showed a significant increase in body weight gain and a significant decrease in the white blood cell (WBC) count after 57 days of exposure. After 123 days of exposure, a positive effect on weight gain was still observed, as well as an increase in the WBC count. The polymorphonuclear-lymphocyte ratio was unaffected (Nau *et al.*, 1966).

Exposure of Fischer 344 rats via inhalation to a C10-C11 isoparaffinic solvent at concentrations of 0, 1.83, or 5.48 g/m^3 for 6 hours/day, 5 days/week, for up to 12 weeks was associated with changes in the weight and structure of male kidneys (Phillips and Egan, 1984). Changes included increased kidney weights, increases regenerative tubular epithelium, accumulation of protein in the renal tubular epithelium and medulla, and tubular dilation. The kidney effects observed in this study are similar to renal changes that have been associated with exposures to other groups of hydrocarbons (*e.g.,* C12-15 straight and branched chain hydrocarbons, alicyclic hydrocarbons, etc). However, the appropriateness of extrapolating these findings to the human scenario is questionable, since the kidney effects appear to be unique to the male rat, and similar effects have not been observed in females rats, nor in other mammalian species such as rabbits, mice, dogs etc (Alden, 1986).

Groups of 25 male Harlan-Wistar rats exposed, via inhalation, to n-nonane at concentrations of 0, 360, 590, and 1,600 ppm for 6 hours/day, 5 days/week for 13 weeks showed lung congestion and haemorrhaging (Carpenter *et al.*, 1978). Two rats died in the high-dose group on the first day of exposure. Two rats in the 590 ppm exposure group died during the 9th and 10th week. Both deaths occurred after the animals registered weight gains during the preceding week. Gross and histopathological examination revealed suppurative bronchopneumonia as the cause of death; but was not regarded as treatment-related. Rats from the greatest dose group showed mild incoordination and fine tremors throughout the first 4 days of exposure, while salivation and lacrimation was observed through 8 weeks. In addition, the mean body weight of the high-dose rats was significantly lower than that of controls. Clinical chemistry, urinalysis, haematology, gross and histopathological examination revealed no abnormalities or indication of organ or tissue toxicity for any of the 3 treatment groups.

Genotoxicity Studies

Prokaryotic Test Systems

n-Decane treatment did not increase the frequency of mutations in Salmonella typhimurium TA100. However, an enhancement of the mutagenicity of N-methyl-N'-nitro-N-nitrosoguanidine, a known mutagen and carcinogen, was observed in 8-azaguanine resistance organisms treated simultaneously with n-decane (Feng *et al.*, 1981).

Eukaryotic Test Systems

n-Decane treatment did not increase the frequency of mitogenic effect in murine spleen lymphocytes; however, it was co-mitogenic with phytohemaglutinine (Baxter *et al.*, 1981). This mitogenic effect is considered to be an immune reaction. n-Decane was not mutagenic in V79 Chinese hamster cells. However, incubation with n-decane after treatment with the known mutagen and carcinogen, methylazoxymethanol acetate (MAM), produced a 24% increase in the ouabain-resistant mutants compared to MAM alone (Lankas *et al.*, 1978).

Interpretation of Genotoxicity Studies

The available studies indicate that n-decane lacks mutagenic or genotoxic activity. The genotoxicity of n-nonane has not been adequately studied; however, it is presumed to be similar to n-decane. In the presence of known mutagens, n-decane has been reported to have a synergistic effect. While this fact alone is insufficient to conclude that n-decane is mutagenic; it indicates that n-decane may act as a promoter of mutagenicity.

Carcinogenicity Studies

Twenty-seven percent (8/30) of surviving mice pretreated dermally with non-carcinogenic quantities of 7,12-dimethylbenz[a]anthracene (DMBA), followed by 4 mg of n-decane or decanol dissolved in cyclohexane applied 3 times a week for 60 weeks (total dose was 720 mg) had skin tumours (Sice, 1966). Thirty-two percent (16/50) of surviving mice in the non-initiated group (did not receive DMBA) had tumours. Similarly, of the mice exposed to n-decanol, 17/30 (57%) of survivors in the initiated group had tumours, whereas 18/50 (36%) of survivors in the non-initiated group had tumours. The authors concluded that n-decanol caused promotion of papillomas in the skin of mice, whereas n-decane did not.

In another experiment examining co-carcinogenesis and tumour promotion, 50 mice received dermal application of 25 mg n-decane and 5 μg benzo[a]pyrene (B[a]P) in 0.1 ml of acetone 3 times a week for 440 days (a total of 4.7 g n-decane and 0.9 mg B[a]P) (Van Duuren and Goldschmidt, 1976). Papillomas were present in 38/50 (34 squamous carcinomas) in mice treated with n-decane and B[a]P, compared to 16/50 (12 squamous carcinomas) mice in the B[a]P control group. Only a single squamous carcinoma was observed in mice treated with n-decane alone. The authors concluded that n-decane displayed potent co-carcinogenic and tumour-promoting activity with B[a]P.

Interpretation of Carcinogenicity Studies

Although the carcinogenicity studies of n-nonane and n-decane are not adequate by today's standards, and in view of the observation that 2 studies examining the co-carcinogenic activity of n-decane have produced conflicting results, the weight-of-evidence suggests there is insufficient evidence to conclude that n-nonane nor n-decane possess carcinogenic potential. However, n-decane may be a promoter of carcinogenesis.

A-2.2.2 Human Studies

Effects were reported at all treatment levels in a human dose-response study conducted in a climate chamber using a double blind design (Kjaergaard *et al.*, 1989). Four subjects per day were exposed 6 hours to either 0, 58.2, 203.7 or 582 mg n-decane/m^3 (100% pure). Exposure groups did not differ significantly with regard to age, sex, number of smokers, and level of school education. Results indicated dose-dependent changes in irritation of mucous membranes, and increased sensation of odour intensity in response to a questionnaire. Physiological measurements showed decreased tear film stability at all exposure concentrations. This has been shown to be associated with dry eye syndromes and the sensation of irritation and may be of importance for protection against irritants (Norn, 1983; Franck, 1986). The number of conjunctival polymorphonuclear leukocytes increased in a dose-related manner. Increased numbers of these leukocytes are an indication of irritation of mucous membranes of the eye (Stokholm *et al.*, 1982; Kjaergaard *et al.*, 1987). Predictors of the sensitivity to exposure (*i.e.*, mucous membrane irritation threshold and skin irritation demonstrated by the Stingers test) were correlated to subjective ratings of odour intensity and irritation of mucous membranes.

Burn-like dermatitis was observed in a 22 year-old female after about 210 minutes contact with residual n-decane in a dry-cleaned shirt made of artificial leather (Saito, 1989). Dermatitis was observed on the waist, thigh, buttocks and abdomen. An irritant reaction was induced on the upper arm of the woman by means of patch test occlusion for 30, 60, or 90 minutes; or for 3, 5, or 24 hours. In 7 control subjects, patch testing was performed in the same manner. All subjects had a positive reaction. The odour thresholds (the concentration detected by 50% of persons) for n-nonane and n-decane are 3,412 mg/m^3 and 11.3 mg/m^3, respectively (Verschueren, 1983; Ruth, 1986).

A-2.3 Exposure Limit

The current ACGIH TLV-TWA (Threshold Limit Value Time-Weighted-Average) and the NIOSH REL-TWA for n-nonane is 200 ppm (1,050,000 μg/m^3) (ACGIH, 1997). These occupational exposure criteria are considered to be safe (no adverse effects) for human occupational exposure 8 hours a day and 5 days a week.

The Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG, 1996) recommends an exposure limit of 0.1 mg/kg/day. This value was calculated by obtaining a LOAEL of 500 mg/kg/day from a subchronic toxicity study where rats were dosed orally with C9-C12 isoparaffins/n-alkanes/naphthenes. The LOAEL was based on microscopic changes in the kidneys of male rats that were observed at all dose levels tested (*i.e.*,500, 2500 and 5000 mg.kgday), and hepatocellular hypertrophy which was seen in both male and female rats, at all dose levels. The LOAEL from this study was adjusted by a total uncertainty factor of 5000 (10-fold factor each, to account for subchronic to chronic extrapolation, animal to human extrapolation, and interindividual variation; and a 5-fold factor to account for LOAEL to NOAEL extrapolation). The authors used a 5-fold uncertainty factor to account for the LOAEL to NOAEL extrapolation since the effects observed at the 500 mg/kg/day dose level were reversible within 28 days. However, this study is stated to be unpublished in the TPHCWG document. At this time, we are not able to obtain additional details regarding this unpublished study and it could not be determined if this study had been published since the release of the TPHCWG document. As such, since the conclusions and interpretations of this study (as reported in the TPHCWG document) could not be verified, it was deemed inappropriate to use the exposure limit proposed by the TPHCWG for the purposes of the current assessment. No chronic exposure limit was proposed for n-nonane or n-decane by the major regulatory or recommendatory agencies. Therefore, a provisional exposure limit was derived by CanTox. Based on the available studies, the study by Carpenter *et.al.,* (1978) was determined to be the best study for deriving an exposure limit, based on dose levels tested, number of animals used, and overall study methodology.

Since the available information indicates that *n*-nonane and *n*-decane are not genotoxic nor carcinogenic, a threshold-type dose-response relationship is recommended for the estimation of a reference dose (RfD). The no-observed-adverse-effect level (NOAEL) values critical to the derivation of the RfD for *n*-nonane and *n*-decane are based on the study by Carpenter *et al.* (1978). In this study, treatment-related adverse effects were observed at the greatest exposure group of male Harlan-Wistar rats exposed via inhalation, to 0, 360, 590, or 1,600 ppm *n*-nonane for 6 hours/day, 5 days/week for 13 weeks. Lasting effects included salivation, lacrimation and a significantly lower body weight, relative to controls. The NOAEL for this study, based on the depression of body weight gain, is 590 ppm (3,108,000 $\mu g/m^3$). This concentration is adjusted for duration of exposure to yield a NOAEL of 343,223 μg *n*-nonane/body weight/day [3,108,000 μg n-nonane/m^3 x (6/24) x (5/7) x (0.329 m^3/day)/0.532 kg body weight]. The mean body weight reported in the study for the no-effect-level test group at the conclusion of the exposure period was used to calculate the inhalation rate, according to the following equation (Sample, 1996):

$$\text{inhalation rate} = 0.5457 * (\text{body weight})^{0.8}$$

Application of a 1,000-fold safety factor (10 to account for sensitive individuals of the population, 10 for interspecies variation, and 10 for the subchronic length of study) yields an RfD of 343 μg *n*-nonane/kg body weight/day.

The RfD value of 343 μg/kg/day was used in the current assessment as a chronic exposure limit for each chemical within the C_{10} to C_{18} (*i.e.*, LEPH) group.

For the purposes of this assessment, the human bioavailability of *n*-nonane and *n*-decane was assumed to be 100% for ingestion, 50.4 to 79.9% for inhalation and 3% for dermal exposures.

A-2.4 References

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A-3.0 LEAD

A-3.1 Bioavailability

In clinical studies, adults have been found to absorb approximately 10 to 15% of their total oral lead intake (Kehoe, 1961; Thompson, 1971; Karhausen, 1973; Blake, 1976; Chamberlain *et al.*, 1978). Estimated absorption values are dependent on both the chemical and physical forms of lead ingested (Barltrop and Meek, 1975), as well as age and diet. In a recent review, Mushak (1991) reported that small children and infants absorb as much as 42 to 53% of their lead intake (Karhausen, 1973; Alexander, 1974; Ziegler *et al.*, 1978). Dietary deficiencies such as iron, Vitamin C or D, as well as composition of food and diet (*e.g.*, fibre, milk content) can significantly increase lead absorption (Garber and Wei, 1974; Stephens and Waldron, 1975; Sorrell *et al.,* 1977; HWC, 1980), which could significantly affect the gut absorption fraction for nursing infants. Based on the information given above, the fractions of ingested lead absorbed were assumed to be 10 to 15% and 42 to 53%, for exposure assessment of adults and children, respectively.

The average Canadian adult has been reported to absorb approximately 31 to 38 μg lead/day, of which 30 to 45% has been attributed to inhalation (NRCC, 1978). The World Health Organization (WHO, 1984) estimated that approximately 20 to 60% of the total amount of lead inhaled is deposited in the lung, with the majority of this being absorbed. Kehoe (1961) and Gross (1981) obtained respiratory system deposition rates for humans of 30 to 70% (mean of 48%) while Nozaki (1966), Chamberlain *et al.* (1975), Morrow *et al.* (1980), and Hammond *et al.* (1981) cited similar values of 30 to 50%. Values can vary depending on the respiration rates of the subjects used in the studies, and the actual particle size. It is estimated that most of the lead deposited in the pulmonary region is either absorbed or cleared, since autopsies on human lungs have shown that very little lead is accumulated in the lung (Barry, 1975). Specific absorption values of lead from the respiratory system of children were not available, but Barltrop (1972) estimated that children inhale 40% more lead than adults. The actual lead deposition rate in 10-year-old children was given by James (1978) as 1.6 to 2.7 times that of adults, based on a number of modifying factors, including the differences in metabolic rates and airway dimensions. The percentage of inhaled lead swallowed following clearance from the respiratory system from the action of the mucociliary apparatus was cited by Chamberlain *et al.* (1975) as 6%.

For the purpose of the current exposure assessment, lead was assumed to be adsorbed to airborne particles or adsorbed to soil particles which have become suspended in the air. Therefore, the bioavailability of lead following inhalation would be determined by the dynamics of deposition, retention and clearance of airborne particles by the respiratory system. Based on particle dynamics, 13% of lead emissions on airborne particles would be retained in the respiratory system, while 60% of airborne particles would be cleared from the respiratory system and swallowed. In adults, if 10 to 15% of the lead on the swallowed particulates were absorbed from the gastrointestinal tract, then 6 to 9% of airborne lead would be bioavailable by this route (10% of 60%; 15 of 60%). Assuming 100% bioavailability for the retained fraction of lead, 13% of inhaled lead would be absorbed by the respiratory system. Therefore, for adults, the total fraction of airborne lead that would be bioavailable following inhalation would be 19 to 22% (13% from the respiratory tract plus 6 to 9% from the gut). For children, if 42 to 53% of the lead on the swallowed particles were absorbed, then an additional 25.2 to 31.8% of airborne lead would be bioavailable by this route (42 of 60%; 53 of 60%). Therefore, for children the total fraction of airborne lead that would be bioavailable following inhalation would be 38.2 to 44.8% (13% from the respiratory tract plus 25.2 to 31.8% from the gut). These bioavailability values are in reasonable agreement with those discussed above.

The absorption of inorganic lead compounds through the skin was considered insignificant compared to that occurring from either inhalation or ingestion. Skin absorption of lead acetate was estimated to approach 0.06% (Moore *et al.*, 1980) while later studies reported up to 5% when in aqueous solution and up to 8% when in organic form as tetraethyl lead. An absorption fraction of 0.06% was selected for the exposure assessment for lead. This estimate is considered appropriate in that the lead at the site will not be in the form of soluble salts, as free ion, or as an organic compound, but will be intrinsically bound within a soil-like matrix and thus would be minimally absorbed.

A-3.2 Toxicology

A-3.2.1 Animal Studies

In an *in vitro* study, glial blastoma cells were incubated with 1 μm lead for 3 to 4 days and the results of the study indicated impairment of glial cell differentiation and induction of undifferentiated cell growth (Stark *et al.*, 1992). In turn, this may lead to neurotoxic effects during embryonic development if lead is able to access developing glial cells by passing through the blood-brain barrier.

Many studies have been conducted to assess the subchronic and chronic effects of lead. Exposure of rodents to lead has resulted in intranuclear inclusion bodies in the proximal tubular epithelium of the kidney, as well as functional and ultrastructural changes in the kidney mitochondria leading to hyperaminoaciduria, glycosuria and hyperphosphaturia, at concentrations of lead in the blood of >70 μg/dL (Nutrition Foundation, 1982). Cooke *et al.* (1990) reported that administration of 200 mg lead/L as $Pb(NO_3)$ to wood mice in drinking water for 30 days resulted in significantly greater concentrations of lead in the femur tissue and kidneys; the later is associated with inclusion bodies accompanied by degeneration of tissue. In addition, accumulations of lead in the bone tissue may adversely affect the ability of bone to accumulate fluoride (Cerlewski and Ridlington, 1987). Newborn male Sprague-Dawley rats treated intraperitoneally with lead acetate showed delayed eye opening and decreased balance (Luthman *et al.*, 1992). In another study, male Sprague-Dawley rats dosed with lead showed decreased body weight gains, increased incidence of spinal cord lesions, and increased concentrations of lead in brain tissue (Yagminas *et al.*, 1992).

In several studies, extreme dietary exposures to lead salts which produced nephrotoxicity have been shown to induce renal neoplasms in rats, mice and hamsters (Boyland *et al.*, 1962; Van Esch *et al.*, 1962; Zawirska and Medras, 1968; Jessup and Shott, 1969; Van Esch and Kroes, 1969; NCI, 1978; Koller *et al.,* 1985). It is doubtful, however, that the extreme exposures and renal tissue concentrations of lead necessary for carcinogenicity in rodents would ever occur in humans because of the degree of toxicity of lead to the central nervous system (CNS) (Nutrition Foundation, 1982). No other target sites for tumour formation from lead have been identified, therefore, lead was not considered a carcinogenic hazard in this hazard assessment.

Species differences in the susceptibility to behavioural effects of lead in laboratory animals is quite apparent, with monkeys being one of the most sensitive species (Nutrition Foundation, 1982). Rats developed signs of hyperactivity at blood level concentrations (BLC) of 40 to 60 μg/dL (Overmann, 1977) with transient hyperactivity observed at BLC of 20 to 59 μg/dL. Similarly, Golter and Michaelson (1975) reported increased activity in rats orally administered 1.09 mg lead/day as lead acetate solution. Monkeys demonstrated enhanced agitation at blood lead concentrations (PbB) ranging from 33.1 to 42.9 μg/dL (Levin *et al.*, 1988). When PbB concentrations were 11 to 13 μg/dL, 3-year-old monkeys, exposed to lead from birth, showed impaired responses in discrimination reversal tasks, non-spatial form discrimination and non-spatial colour discrimination (Rice, 1985). However, the PbB concentrations in these monkeys had been much greater as infants when fed milk-only diets. Monkeys with average PbB concentrations of 33.1 to 42.9 μg/dL experienced decreased visual attentiveness (Levin *et al.*, 1988). Monkeys showed impaired learning and decreased visual acuity for a variety of tasks at PbB concentrations of less than 40 to 85 μg/dL (Bushnell *et al.,* 1977; Bushnell and Bowman, 1979; Rice *et al.,* 1979; Rice and Willes, 1979).

Rice (1992a) examined the behavioural effects of lead on newborn monkeys orally dosed with lead acetate to yield a blood concentration plateau of 33 dg/μL. No discrimination reversed, and no differences in behavioural delayed alternation were observed; however, differences were observed in performance on the differential reinforcement of low rate schedule (DRL) behavioural test and with respect to the monkeys ability to learn visual discrimination. In further work with monkeys, Rice (1992b) gave oral doses of lead in groups characterized by the following dosing regimes: Group 1, vehicle only (control); Group 2, lead continuously from birth (PbB 32 to 36 μg/dL); Group 3, lead continuously from birth to 400 days followed by vehicle only (PbB 32 to 36 μg/dL); and, Group 4, vehicle only from birth to 300 days of age followed by exposure to lead (PbB 19 to 26 μg/dL). Two different non-spatial discrimination reverse tasks were used to determine lead behaviour effects on treated monkeys indicated significant impairment in Groups 2 and 4 for tests used to assay these tasks, while Group 3 was marginally impaired on some tests.

In a reproductive and developmental study, the effects of lead on growth in female rats and on growth and skeletal development in their offspring were investigated by Hamilton and O'Flaherty (1994). No alteration in growth rate was observed in weanling females continuously exposed to lead in drinking water and fed a replete diet. After 49 days of exposure, rats were mated with control males. At parturition, 1 group of previously exposed lactating dams given control drinking water, while other lactating dams from the control group were given lead in drinking water. The authors indicated that lead exposure prior to parturition caused greater maternal tibial lead accumulation than lead exposure after parturition. In contrast, lead exposure prior to parturition had a lesser impact on offspring tibial lead accumulation than lead exposure after parturition. Also, offspring body weight was depressed and continuous lead exposure caused a greater decrease in offspring body weight than lead exposure only prior to or after parturition. Other effects reported include decreased tail length growth, increased weanling growth-plate width, disruption of chondrocyte organization, and wider metaphyseal trabeculae were observed.

In a study by Hamilton *et al.* (1994) offspring of pregnant female rats exposed to lead in their drinking water during gestation had decreased fetal body weight. Similar results were reported for mice exposed *via* drinking water (Pinon-Lataillade *et al.*, 1995). The exposed offspring were then mated with unexposed mates to determine lead exposure on subsequent generations. The authors reported reduced litter sizes for females and reduced body, testes, epididymes, seminal vesicle and ventral prostate weights in males. Junaid *et al.* (1997) exposed mice to lead acetate by oral gavage to examine ovarian follicular development. Results showed that small, medium and large follicles were significantly affected by the lead and atresia also occurred in the medium follicles. A study by Kristensen *et al.* (1995) indicated a synergistic effect causing suppression of the development of primordial oocytes during fetal life and a longer gestation period in mice exposed to lead and benzo[a]pyrene (BaP) in drinking water. These results were not found in mice exposed to lead or BaP alone. In order to assess endocrine effects of lead, Kempinas *et al.* (1994) acutely and chronically exposed pubertal rats to lead acetate *via* drinking water and injection. Following acute exposures, the animals had increased levels of testosterone in both plasma and in testes; however, circulating levels of leuteinizing hormone (LH) were not affected in either group. Another reproductive study by Ronis *et al.* (1996) exposed rats to lead acetate in drinking water during *in utero*, prepubertal or postpubertal development stages. Results reported for males include decreased secondary sex organ weights (prepubertal) and suppressed prepubertal growth and serum testosterone levels (*in utero*). Female rats were reported as having delayed vaginal opening and disrupted estrus cycling (prepubertal) as well as suppressed prepubertal growth and circulating estradiol (*in utero*).

In a chronic study by Azar *et al.* (1973), rats were administered dietary lead acetate in doses of up to 500 ppm for 2 years. In a second 2-year study rats were given diets of lead acetate in doses of 0, 1,000, and 2,000 ppm. No renal tumours were reported in animals receiving 10 to 100 ppm lead acetate; however, males fed 1,000 and 2,000 ppm lead acetate had an increased renal tumour incidence. US EPA (1998) considered this study to be limited by the lack of experimental detail.

Various biochemical effects have been associated with lead exposure and elevated blood lead concentration. The cytoplasmic enzymes, *delta*-amino-levulinic acid dehydratase (ALAD) and haem synthetase are inhibited by lead and result in the increase of their respective substrates delta-amino-levulinic acid (ALA) in serum and urine and "free" erythrocyte protoporphyrin

(FEP) in blood (Nutrition Foundation, 1982; Zareba and Chmielnicka, 1992) An increase in urine coproporphyria has also been associated with elevated PbB (Zareba and Chmielnicka, 1992). The presence of lead in blood reduces the bioavailability of iron for haem synthesis. In response to reduced haem formation, the rate-limiting enzyme *delta*-amino-levulinic acid synthetase (ALAS) is increased. Other responses include erythroid hyperplasia, reticulocytosis and microcytosis. ALAD is present in excessive amounts and is not the rate-limiting enzyme in the biochemical pathway of haem synthesis. As a result, partial inhibition of ALAD is not considered to be toxicologically significant (Nutrition Foundation, 1982).

A-3.2.2 Human Studies

Similar biochemical effects of lead exposure to humans have been described. The threshold PbB concentration for lead-induced elevation of FEP is in the range of 25 to 30 μg/dL whole blood in women and children (Nutrition Foundation, 1982) and in adult males (Landrigan, 1991). Studies of children living in proximity to a lead smelter, indicated an apparent threshold of 60 μg/dL or greater for effects on FEP (McNeil *et al.*, 1975; Landrigan *et al.*, 1976). The apparent discrepancy in the PbB concentration threshold for children resulted from the presence of an iron deficiency in children with the lesser threshold compared with those living near the smelter. PbB concentrations of about 5 μg/dL have been associated with inhibited ALAD activity in children (Chisolm *et al.*, 1985), although this is of doubtful toxicological significance (Nutrition Foundation, 1982). PbB concentrations are directly related to anaemia (Landrigan, 1991) resulting from impairment of haem synthesis and acceleration of red blood cell destruction. The threshold for this effect in children has been reported to be 50 μg/dL (Tsuchiya, 1979; Nutrition Foundation, 1982). Ferrochelatase, which catalyses the transfer of iron from ferritin into protoporphyrin to form haem is inhibited by lead (Landrigan, 1991), which results in an increased excretion of coproporphyrin in the urine and accumulation of protoporphyrin as FEP. Elevated *delta*-amino-levulinic acid and coproporphyrins in the urine were reported in children and adults with PbB concentrations in the range of 30 to 40 μg/dL.

In an environmental exposure study (Staessen *et al.*, 1990), London civil servants not exposed to heavy metals on an industrial basis had PbB concentrations which were positively correlated with the number of cigarettes smoked per day, with serum *gamma*-glutamyltranspeptidase, and, in men only, with serum creatinine concentration (possibly due to lead effects on renal functions). PbB concentration was higher in men and in postmenopausal women than in women before menopause, which suggests sex differences in lead handling by the body, which disappear at an older age. The authors indicated that there seems to be postmenopausal demineralization of bone, which can increase PbB by 25%.

In a critical review of the neuropsychological effect of lead in occupationally exposed workers, Ehle and McKee (1990) considered the results to be inconclusive relating psychological and neuropsychological effects to low-level exposure in adults (PbB <60 μg/dL); however, the authors point out that subtle changes or differences in psychomotor and cognitive functions may serve as early warning signals. Workers exposed to lead have exhibited symptoms of fatigue, irritability, inability to concentrate for prolonged periods of time as well as neurological problems which include disorders in verbal intelligence, memory, and perpetual speed (Baker *et al.*, 1990). PbB concentrations in excess of 100 to 120 μg/dL in adults have been associated with acute lead encephalopathy which can cause effects such as confusion, disorientation, stupor, convulsions, coma and even death (Ehle and McKee, 1990). These cases have often resulted from exposure to lead through consumption of contaminated alcohol; thus, symptoms reflect both lead and alcohol toxicity.

In a study by Fischbein (1992) lead concentrations in the air and in the blood of individuals at firing ranges were examined. In 1978, it was reported that 26% of subjects showed CNS symptoms and 16% showed gastrointestinal symptoms. In another study, Lin and Lim (1992) examined the potential association between lead urinary levels and renal diseases in Chinese patients. The authors concluded that the development of renal failure may be a result of exposure to elevated lead concentrations; however, confounding factors could not be ruled out.

The potential of lead to impair neurobehavioural development in children is the subject of concern. Lead was reported to cross the placental barrier and be present in the umbilical cord at a concentration of 80 to 90% of that in maternal blood (Inouye, 1989). In general, epidemiological studies of the relationship between PbB levels and neurotoxic effects in the pre- and post-natal child's brain are hampered by the complexity of mental developmental processes, and the questionable sensitivity and significance of IQ tests to subtle differences in neuropsychologic performance. Therefore, despite the great number of epidemiological concentrations of lead neurotoxicity, as discussed below, it is not possible to make definitive conclusions regarding potential adverse effects associated with PbB concentrations less than 25 μg/dL. Needleman *et al.* (1979) studied the effects of lead exposure was estimated from concentrations measured in the dentine of deciduous teeth in a cross-section of first and second graders in 2 Massachusetts communities (n=270). The neuropsychological performance of each child was evaluated using a number of tests including the Wechsler Intelligence Scale for Children - Revised. The high dentine lead exposure performed significantly worse on the Full Scale and Verbal Subscale of the Scale, with verbal and auditory processing, attention and classroom behaviour most sensitive indicators. In 1988, Needleman *et al.* (1990) reevaluated to determine whether neurological deficits noted earlier persisted into adolescence. The subjects in the 1988 study differed from the earlier cohort in many covariates (such as socioeconomic factor); 10 covariates were controlled for in the 1988 analysis. The 1988 reevaluation determined that those who had 1979 dentine lead concentrations above 20 ppm had a higher risk of failing to graduate from high school, of having a reading disability, lower class marks, absenteeism, and decreased vocabulary and reading skills. The authors concluded that the early exposure to lead had an enduring effect on children. Recently, the Needleman studies have been the subject of controversy. Criticisms of the statistical analysis include improper control of confounding variables, improper exclusion of data such that groups of cases from the original sample of children tested were systematically excluded, and failure to give adequate consideration to the issue of multiple comparisons in the analyses of a large number of variables. Furthermore, there has been some difficulty in obtaining copies of the original data for peer review (Ernhart and Scarr, 1991). In the review of health effects of low concentration exposure to lead (Needleman and Bellinger, 1991), a relatively convincing argument is presented implicating low PbB concentrations and numerous neurobehavioural effects on infants and children. It is noteworthy that often further statistical analysis to control for confounding variables, multivariate analysis or power analysis, weakens the relationship to below significant or slightly significant levels.

Decreased IQ values among children with PbB concentrations from 5.6 to 25 μg/dL have been reported (Yule *et al.*, 1981; Fulton *et al.*, 1987; Hatzakis *et al.* 1987). Cooney *et al.* (1989) reported that at PbB concentrations of 0.25 μg/dL, there were no adverse effects on neurobehavioural development. Several authors suggest a LOAEL of 10 to 15 μg/dL perinatal PbB concentrations (Wolf *et al.*, 1985; Bellinger *et al.*, 1987; Dietrich *et al.*, 1987; Wigg *et al.*, 1988).

Bellinger *et al.* (1987) conducted a prospective cohort study of children (n=249) living in the Boston area, from birth to 2 years of age. While postnatal exposure was not associated with detrimental effect, prenatal exposure was reported to impair early cognitive development [assessed using the Bayley Mental Development Index (MDI)]. In a follow-up to this Boston perspective study, Bellinger *et al.* (1991) found that prenatal PbB concentrations $\geq$10 μg/dL in cord blood was associated with a slower cognitive development in children up until at least 2 years of age. After 57 months of age, however, prenatal exposure was not related to intelligence tests results.

Based on a study to assess the effects of chronic low to moderate fetal lead exposure in lead-hazardous areas of Cincinnati (n=305), Dietrich *et al.* (1987) considered that there was a direct relationship between prenatal, umbilical and newborn PbB concentrations and deficits on the Bayley MDI at either 3 or 6 months. Male infants and infants from the poorest families were especially sensitive to lead. However, once the regression analysis was adjusted for confounding variables, no significant effects of fetal lead exposure on Bayley Psychomotor Developmental Index (PDI) were found. Further study suggested that the neurobehavioural deficits were partly mediated by lead-related reductions in birth weight and gestation. However, in a further follow-up study of the Cincinnati lead study cohort, Dietrich *et al.* (1993) found that even after adjustments were made for covariates, there remained a statistical significance between postnatal lead blood concentrations and Performance IQ when compared to children with mean blood concentrations (<10 μg/dL).

Studies of the effect of environmental exposure to lead were conducted on a cohort of 537 children born near a lead smelter, near Port Pirie in South Australia, results demonstrated that child development at ages 2, 3 and 4 appeared to be inversely related to postnatal PbB concentrations based on the McCarthy Scales of Children's Abilities (McMichael *et al.*, 1988). Reductions in perceptual performance and memory scores were also reported. The authors caution that the data are still circumstantial due to the difficulties in defining and controlling for confounding variables and effects. In a follow-up to the McMichael *et al.* (1988) cohort study, an increase in PbB concentration from 10 to 30 μg/dL was shown to cause a decrease in General Cognitive Index score on the McCarthy Scales (combines scores for verbal, perceptual-performance, and memory and motor performance subscales) for girls and boys (McMichael *et al.*, 1992). However, no significant differences in children's abilities with respect to blood concentrations of lead and mental development effects, were observed when considering different environmental modifying factors. However a significantly stronger inverse relationship between PbB concentrations and children's abilities was observed for girls compared to boys.

No relationship was evident between the PbB concentrations and child development in a cohort of 260 disadvantaged preschool children in the Cleveland, Ohio area (Ernhart and Greene, 1990). Variables related to the caretaking environment of the child seemed to have the most effect on development. In particular, these authors controlled for maternal alcohol use during pregnancy, which can result in similar development problems to those reported following lead exposure.

A neuropsychological study of 162 Danish school children with elevated dentine lead concentrations among different socioeconomic groups demonstrated significantly lower scores on the Wechsler Intelligence Scale for Children (especially on the Verbal IQ and Full Scale IQ) the Bender Visual Motor Gestalt Test and on a behavioural rating scale (Hansen *et al.*, 1989).

The potential association between the physical and behavioural characteristics of infants, and maternal and umbilical cord PbB concentrations was investigated among a sample of 42 mother-baby pairs from a heavily industrialized area of Mexico (Rothenberg *et al.*, 1989) indicated that as maternal lead at birth increased, the consolability and self-regulating behaviour of the infant decreased for as long as 30 days after birth. Increased maternal PbB concentrations were also associated with decreased gestational age. Nevertheless, maternal lead concentrations were also associated with stressful pre- and post-natal situations and thus, the authors suggested that these problems of pregnancy may act with or independently of increased lead concentrations to affect autonomic, self-regulating behaviour of the infant and gestational age.

The growth of a cohort of infants from Cincinnati from birth to 15 months demonstrated a statistically significant negative regression between PbB concentrations in infants and the growth rate of those infants whose mothers had high PbB concentrations during pregnancy (Shukla *et al.*, 1989). Infants who had a 10 μg/dL PbB increase during the 3- to 15-month age period were approximately 2.0 cm shorter in height at 15 months than infants who had no increase in PbB concentrations, even though both sets of infants were born to mothers with pre-natal blood concentrations greater than 7.7 μg/dL.

It was noted in a European multi-center study on lead neurotoxicity in children by the World Health Organization, Regional Office for Europe (WHO/EURO) and the Commission of the European Communities (Winneke *et al.*, 1990) that neurobehavioural effects of environmental lead exposure in children represent weak signals in a noisy background and consequently many published cross-sectional studies suffer from insufficient power to detect subtle effects.

School-aged children (with PbB concentrations of <5 to 50 μg/dL) were found to have detectable exposure-related behavioural and cognitive effects. Based on this study, no threshold could be identified from the data for neurotoxicity in school-aged children.

A report to the U.S. Congress on childhood lead poisoning in the U.S. (Mushak *et al.*, 1989) indicates that PbB concentrations of 10 to 15 μg/dL are associated with many effects, including alterations in neurobehavioural development and electrophysiological function, disturbances in haem biosynthesis and deficits in growth and maturation, may occur both prenatally and later in childhood.

A-3.3 Exposure Limit

The US EPA (1998) has classified lead as a probable human carcinogen based on sufficient animal evidence. However, the Carcinogen Assessment Group (US EPA, 1998) did not recommend derivation of a quantitative estimate of oral carcinogenic risk, due to a lack of understanding pertaining to the toxicological and pharmacokinetic characteristics of lead. In addition, the neurobehavioural effects of lead in children were considered to be the most sensitive and relevant endpoint in determining an exposure limit.

Most of the available information on the potential adverse effects of lead to humans is, therefore for this current assessment an oral RfD was derived based on these effects.

Most of the available information on the potential adverse effects of lead to humans is based on relationships between PbB concentrations and, in some cases, dentine lead concentrations, and various health effects observed. These parameters are accepted because of the lack of alternate data and the differences in lead absorption (Nutrition Foundation, 1982). The actual rates of exposure to humans where adverse effects are known from lead exposure are unknown. Therefore, the potential health effects of lead have been correlated with PbB concentrations, and an exposure limit has been estimates from the PbB concentrations.

Based on an analysis of the results of the Bellinger *et al.* (1987, 1991), Dietrich *et al.* (1987, 1993), McMichael *et al.* (1988), Cooney *et al.* (1989), and Ernhart and Greene (1990), it has been concluded that lead exposure resulting in PbB concentrations of below 25 μg/dL does not seem to be associated with neurobehavioural deficits in children (Volpe *et al.*, 1992). Inconsistencies were noted in the 5 reports, and common analyses should be conducted to address and examine these inconsistencies. A PbB concentration of 10 μg of lead/dL was the NOAEL determined by Hernberg (1980) and the Nutrition Foundation (1982) for effects from lead on blood concentrations of FEP in adults. This corresponds to the lower end of the range where no neurotoxicological effects have been reported and where effects on the enzyme systems involved with haemoglobin synthesis are reversible. Some authors (Mushak *et al.*, 1989) have observed marginal behavioural effects at PbB concentrations of 15 μg/dL.Therefore, to be conservative, a PbB concentration of 10 μg/dL (Hernberg, 1980) is often used to calculate the RfD for lead. Based on the above, Health Canada (1996) has determined that a Tolerable Daily Intake of 3.57 μg/kg body weight/day would ensure that blood lead concentrations would be maintained at acceptable concentrations.

For the purposes of this assessment, the human bioavailability was assumed to be 10 to 15% for adults and 42 to 53% for children/adolescents for ingestion, 19 to 22% for adults and 38.2 to 44.8% for children/adolescents for inhalation, and 0.06% for dermal exposure. The bioavailability from the study used to determine the RfD was assumed to be 10 to 15% for adults and 42 to 53% for children/adolescents. For deterministic risk assessment, the high end of the range of bioavailability estimates was selected.

A-3.4 References

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APPENDIX B

TECHNICAL INFORMATION RELATED TO THE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

APPENDIX B
TECHNICAL INFORMATION RELATED TO THE RISK ASSESSMENT

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B-1.0 INTRODUCTION TO APPENDIX B

This Appendix provides technical information related to the assessment of the potential human health and ecological risks associated with exposures to chemicals found in surficial soil and water at each of the seven sites along the Canol Road and MacMillan Pass area:

1. MP 73 - Pump Station 10
2. MP 124.5 - Pump Station 9
3. MP 174 - Pump Station 8
4. MP 213 - Military Camp/Dump
5. MP 233 - Pump Station 7
6. MP 234 - Military Camp/Pump Station
7. MP 208 - NWT - Pump Station 6

The estimation of exposures to chemicals of concern at the sites were based on the following parameters:

- the chemical-specific physical, chemical and biological factors that determine the ability of the organism to take the chemicals into the body;
- the chemical-specific physical/chemical characteristics which determine the interaction and behaviour of a chemical with its surrounding environment (*e.g.*, water solubility, volatility, tendency to bind to particles);
- the characteristics of the site and surrounding area;
- the characteristics of the environmental compartments at the site (*e.g.*, air, soil, subsurface soil and water), as well as the quantities of chemicals entering the compartments from various sources, and their persistence in these compartments;
- the behavioural and lifestyle characteristics of the human and ecological receptors that determine the actual exposures through interactions of the receptors with the various pathways (*e.g.*, respiration rate, body weight); and,
- the equations and algorithms used to predict exposures to the receptors.

B-2.0 CHEMICAL CONCENTRATIONS

Refer to the main report for details regarding on-site soil and water chemical concentrations.

B-3.0 MODEL INPUT PARAMETERS

The various model input parameters and assumptions to estimate exposures are provided below.

B-3.1 Scenario and Exposure Pathway Assumptions for Human Receptors

The "Traditional Land Use" exposure scenario assumes a family may live on the land (*i.e.*, one of the 7 sites) in a tenting environment for a period of up to 180 days during the summer. For this land use, exposures from chemicals in surface soil were estimated for a variety of different pathways of exposure. In addition, exposures from consuming a variety of animals (*i.e.*, caribou, rabbit and grouse) caught in the vicinity of the site were also considered. Under this land use scenario, it was assumed that the receptor most at risk to chemicals from the site would be a female preschool child; however, exposures to female adults were also considered.

Based on the Traditional Land Use of the site and receptor characteristics for this land use scenario, the following exposure pathways were included:

- inhalation of chemicals which resuspend as dusts from the soil surrounding the site;
- ingestion of chemicals in soil, airborne dusts, wildlife (*e.g.*, caribou) and vegetation (*e.g.* berries), and water;
- dermal contact with chemicals in soil, airborne dusts and air.

For the current human health risk assessment, both a female adult and female preschool child were evaluated. Consideration was given to identifying receptors that will be at the greatest potential risk from the site, either through having the greatest probability of exposure to chemicals from the site or through having the greatest sensitivity to these chemicals. The potential health risks associated with individuals visiting each site were assessed for a female adult (20 to < 70 years) and a female preschool child (6 months < 5 years). The female preschool child (6 months < 5 years) receptor was selected for the current scenario, as it typically has a greater exposure to weight ratio therefore making it a sensitive residential receptor.

It should be noted that the total wildlife consumption rates, supplied by the Compendium of Canadian Human Exposure Factors, O'Connor Associates, 1997 were based upon Native Canadian populations (Amerindians and Inuit, combined). Consumption rates conservatively reflect the arithmetic average for eaters of wild game only. For the purpose of the current assessment, it has been conservatively assumed that 20% of a human receptor's total daily meat intake is comprised solely of chemically impacted caribou, rabbit and grouse.

Specific receptor characteristics that were incorporated into the human health risk assessment are presented in the following table. Full details on the assumptions used in the preliminary assessment can be found in the main report.

Table B-1 Receptor Characteristics Used in the Human Health Risk Assessment

Parameter	Female Preschool Child	Female Adult	Units	Reference
Body Weight	16.4	63.1	kg	O'Connor, 1997
Air Inhalation Rate	8.8	14.4	m^3/d	O'Connor, 1997
Area of Exposed Skin (outdoor)	0.214	0.384	m^2	O'Connor, 1997
Total amount of wildlife consumed	75	220	g/day	O'Connor, 1997
Total berry consumption	4	15	g/day	Wein, 1989
Daily water consumption rate	0.6	1.5	L/day	O'Connor, 1997
Soil Adherence Factor	5.85	5.85	m^2	US EPA, 1992
Soil/Sediment/Dust Ingestion	1.30	0.10	g/d	U.S. EPA, 1998; Calabrese *et al.*, 1997

B-4.0 EQUATIONS AND ALGORITHMS USED TO ESTIMATE EXPOSURES

This section provides the equations and algorithms that were used to estimate exposure rates to human receptors from the site. Depending on the receptor and scenario to be considered, different exposure pathways and equations were used to estimate exposure rates.

The following is a worked example of a female preschool child residing at MP 124.5 for a duration of 180 days during the summer season exposed to chemically impacted soils and wildlife.

B-4.1 Assumptions Defining Dust Levels Generated by Soils

Background outside dust levels: - 42 $\mu g/m^3$ (MOEE, 1994)
Percent of dust produced from soil: - 50% (Hawley, 1985)
Percent of outside dust level indoors: - 75% to 85% (Roberts *et al.*, 1974)

The following example illustrates the methodology used to estimate ambient dust levels generated from soil alone.

outside: $42\ \mu g/m^3 \times 0.50 / 1{,}000{,}000\ \mu g/g = 2.1e\text{-}05\ g/m^3$
indoors: $42\ \mu g/m^3 \times 0.50 \times 0.85/1{,}000{,}000\ \mu g/g = 1.79e\text{-}05\ g/m^3$

For the purpose of the current exposure scenario the upper end of the indoor dust level (*i.e.*, 85% of outdoor levels) were used to represent a tenting/camping environment.

B-4.2 Calculation of Exposure from Soil/Dust

Exposure contributions from soil on the site were considered for 3 routes of exposure: inhalation of soil/dusts, incidental ingestion, and dermal contact with surficial soils.

Inhalation Exposure from Dust on Outdoor Summer Days

Contribution from outside airborne dust:

$$EXP_{SIAO}\ (\mu g/kg/day) = \frac{AI\ (m^3/d) \times SL\ (\mu g/g) \times AF_{inh} \times SODL\ (g/m^3) \times SOD\ (day/yr)}{BW\ (kg) \times AF \times FOS}$$

where:

EXP_{SIAO}	=	inhalation exposure to chemical from summer outside airborne dust ($\mu g/kg/day$)
AI	=	amount of air inhaled (8.80 m^3/day)
SL	=	concentration of chemical in soil (1110 $\mu g/g$)
AF_{inh}	=	fraction of chemical absorbed by receptor by inhalation (0.45 Child, 0.22 Adult)
SODL	=	background dust level in outside air (2.1e-05 g/m^3; calculated above)
SOD	=	number of summer days spent outside per yr (120 days/yr)
BW	=	receptor body weight (16.40 kg)
AF	=	averaging factor (180 days/yr.)
FOS	=	fraction of time on site (1 unitless)

Thus, according to the above equation and input parameters, exposure to lead from inhalation of outside dust was estimated to be 3.75e-03 μg/kg body weight/day.

Contribution from Indoor Airborne Dust:

$$EXP_{SIAI}\ (\mu g/kg/day) = \frac{AI\ (g/d) \times SL\ (\mu g/g) \times AF_{inh} \times SIDL\ (g/m^3) \times SID}{BW\ (kg) \times AF \times FOS}$$

where:

EXP_{SIAI}	=	summer inhalation exposure to chemical from summer indoor airborne dust (μg/kg/day)
AI	=	amount of air inhaled (8.8 m^3/day)
SL	=	concentration of chemical in soil (1110 μg/g)
AF_{inh}	=	fraction of chemical absorbed by receptor by inhalation (0.45; Child)
SIDL	=	indoor dust level derived from soil (2.1×10^{-5} g/m^3 $\times$ 0.85 = 1.79e-05 g/m^3)
SID	=	number of summer days spent indoors (60 days/yr)
BW	=	receptor body weight (16.4 kg)
FOS	=	fraction of time on site (1 unitless)
AF	=	averaging factor (180 days/yr)

According to the above equation and input parameters, the exposure to Lead from indoor dust was estimated to be 1.60e-03 μg/kg body weight/day (adjusted for bioavailability).

Total Exposure (Inhalation)

$$EXP_{INH}\ (\mu g/kg/day) = EXP_{SIAO} + EXP_{SIAI}$$

EXP_{INH}	=	total inhalation exposure (μg/kg/day)
EXP_{SIAO}	=	summer inhalation exposure to cadmium from outside airborne dust (3.75e-03 μg/kg/day)
EXP_{SIAI}	=	summer inhalation exposure to cadmium from indoor airborne dust (1.60e-03 μg/kg/day)

The total inhalation exposure to lead from soil was estimated to be 5.35e-03 μg/kg/day.

Incidental Soil/Dust Ingestion

Hwang *et al.* (1997) and Calabrese (unpublished, as reported in Walker and Griffin, 1998) have undertaken comprehensive studies which in part examine the relationship of interior surface dust levels to outdoor soil concentration. Both Hwang *et al.* (1997) and Calabrese (unpublished) sampled interior dust and outdoor soil concentrations using different methodologies from the same subset of 25 households in Anaconda, Montana. The reported average outdoor soil and interior dust concentrations were significantly different, 192 mg/kg and 75.14 mg/kg, respectively from the Hwang *et al.* study, versus 75 mg/kg and 29 mg/kg from the Calabrese study, respectively. However, the relationship between the average interior surface dust concentration and outdoor soil concentrations were very similar. The ratio of the average interior dust to outdoor soil concentrations were calculated to be 0.391 and 0.389 for the Hwang and Calabrese studies, respectively. Due to the unique nature of the current land use (*i.e.,* a traditional land use), interior dust concentrations were consider equivalent to outdoor soil concentrations.

Incidental Outdoor Soil Ingestion During Summer Months

Contribution from outside soil:

$$EXP_{SGAO}\ (\mu g/kg/day) = \frac{AO\ (g/d)\ x\ SL\ (\mu g/g)\ x\ FRSOIL\ x\ AF_{oral}\ x\ SOD}{BW\ (kg)\ x\ AVT}$$

where:

EXP_{SGAO}	=	exposure from incidental ingestion of soil during summer (µg/kg/day)
AO	=	amount of dust ingested (1.30 g/day)
SL	=	concentration of chemical in soil (1110 µg/g)
FRSOIL	=	fraction of the soil/dust ingestion rate originating from soil (45%)
AF_{oral}	=	fraction of chemical absorbed by receptor by ingestion of dust/soil (0.53)
SOD	=	total number of days spent on the site (indoors and outdoors; 180 days) during the summer
BW	=	receptor body weight (16.4 kg)
AVT	=	averaging time (180 days)

According to the above equation and input parameters, the exposure to Lead from outdoor soil ingestion was estimated to be 21.0 µg/kg body weight/day (adjusted for bioavailability).

Incidental Indoor Dust Ingestion During Summer Months

Contribution from indoor dust:

$$EXP_{SGAI}\ (\mu g/kg/day) = \frac{AO\ (g/d)\ x\ DSL\ (\mu g/g)\ x\ FRDUST\ x\ AF_{oral}\ x\ SOD}{BW\ (kg)\ x\ AVT}$$

where:

EXP_{SGAI}	=	exposure from incidental ingestion dust during summer (µg/kg/day)
AO	=	amount of soil/dust ingested (1.30 g/day)
DSL	=	concentration of chemical in dust (1110 µg/g × 1.0 = 1110 µg/g)
FRDUST	=	fraction of the soil/dust ingestion rate originating from indoor dust (55%)
AF_{oral}	=	fraction of chemical absorbed by receptor by ingestion of dust/soil (0.53)
SOD	=	total number of days spent on the site (indoors and outdoors; 180 days) during the summer
BW	=	receptor body weight (16.4 kg)
AVT	=	averaging time (180 days)

According to the above equation and input parameters, the exposure to Lead from indoor soil ingestion was estimated to be 25.65 µg/kg body weight/day (adjusted for bioavailability).

Total Exposure (Ingestion)

$$EXP_{ING} = EXP_{SGAO} + EXP_{SGPI}$$

EXP_{ING}	=	total oral exposure to lead from incidental ingestion of indoor soil/dust
EXP_{SGAO}	=	oral exposure to lead from incidental ingestion of summer outside dust/soil (21.0 μg/kg/day)
EXP_{SGPI}	=	oral exposure to lead from incidental ingestion of summer indoor dust/soil (26.7 μg/kg/day)

Given the above equation, the total exposure to lead from incidental ingestion of indoor/outdoor, soil/dust was estimated to be 46.65 μg/kg body weight/day.

Dermal Exposure from Soil/Dust on Outdoor Summer Days

Contribution from outside soil/dust:

$$EXP_{SDAO}\ (\mu g/kg/day) = \frac{EO\ (m^2)\ x\ DSO\ (g/m^2/day)\ x\ SL\ (\mu g/g)\ x\ AF_{dermal}\ x\ SOD}{BW\ (kg)\ x\ AF}$$

where:

EXP_{SDAO}	=	dermal exposure to chemical from contact with outside soil/dust in summer (μg/kg/day)
EO	=	area of exposed skin when outside (0.350 m^2)
DSO	=	soil/dust adherence factor (5.85 g/m/day)
SL	=	concentration of chemical in soil (1110 μg/g)
AF_{dermal}	=	fraction of chemical absorbed by receptor by dermal contact with soil/dust (0.0006; unitless)
SOD	=	number of summer days spent outdoors (120 days)
BW	=	receptor body weight (16.4 kg)
AF	=	averaging factor (180 days)

Thus, according to the above equation and input parameters, the exposure to lead from dermal contact with summer outside soil/dust was estimated to be 5.54e-02 μg/kg body weight/day.

Dermal Exposure from Soil/Dust on Indoor Summer Days

Contribution from outside soil/dust:

$$EXP_{SDPI}\ (\mu g/kg/day) = \frac{EI\ (m^2)\ x\ DSO\ (g/m^2/d)\ x\ SDL\ (\mu g/g)\ x\ AF_{dermal}\ x\ SID}{BW\ (kg)\ x\ AF}$$

where:

EXP_{SDPI}	=	dermal exposure to lead from contact with indoor soil/dust in summer (μg/kg/day)
EI	=	area of exposed skin when indoors (0.350 m^2)
DSO	=	soil/dust adherence factor (5.85 $g/m^2/day$)
SDL	=	concentration of lead in dust (1110 μg/g; assumed to equal that of soil)
AF_{dermal}	=	fraction of lead absorbed by receptor by dermal contact with soil/dust (0.0006; unitless)
SID	=	number of days spent indoors on site (60 days)
BW	=	receptor body weight (16.4 kg)
AF	=	averaging factor (180 days)

Given the above equation and input parameters, the exposure to lead from dermal contact with indoor soil/dust was estimated to be 2.77e-02 μg/kg body weight/day (adjusted for bioavailability).

Total Exposure (Dermal)

$$EXP_{DERM} = EXP_{SDAO} + EXP_{SDPI}$$

EXP_{DERM}	=	total dermal exposure to cadmium from contact with outside/dust (μg/kg/day)
EXP_{SDAO}	=	dermal exposure to chemical from contact with summer outside soil/dust (5.54e-02 μg/kg/day)
EXP_{SDPI}	=	dermal exposure to chemical from contact with summer indoor soil/dust (2.77e-02 μg/kg/day)

According to the above equation and input parameters, the total exposure to lead from dermal contact with indoor soil/dust was estimated to be 8.32e-02 μg/kg body weight/day.

Total Exposure to Compounds from all Soil Pathways:

The daily exposure to cadmium from soil was then calculated using the formula shown below.

$$EXP_{TEA} = EXP_{INH} + EXP_{ING} + EXP_{Derm}$$

where:

EXP_{TEA}	=	total exposure to lead from all soil pathways (μg/kg/day)
EXP_{INH}	=	total inhalation exposure to lead (5.53e-03 μg/kg/day)
EXP_{ING}	=	total oral exposure to lead from incidental ingestion of indoor soil/dust (46.65 μg/kg/day)
EXP_{Derm}	=	total dermal exposure to cadmium from contact with outside/dust (8.32e-02 μg/kg/day)

Thus, according to the above equation and input parameters, the exposure to cadmium considering all soil pathways was estimated to be 46.74 µg/kg/day.

B-5.0 EXPOSURE FROM CONSUMPTION OF LOCAL GROWN VEGETATION

The uptake of chemicals into vegetation (*e.g.*, fruits, vegetables, grasses) is a topic that has been extensively reviewed in the literature, since this pathway is a potential source when vegetation is consumed by human and ecological receptors. Chemicals are taken up into vegetation from three principle sources: particulates in air (*e.g.*, dust, or aerosols); vapours in air (*e.g.*, gases); and, subsurface compartments (*e.g.*, soil, water) (Rolfe, 1972; Baes, 1982; Travis and Hattemer-Frey, 1988; Boon and Soltanpour, 1992; Muller *et al.*, 1993; Schroll and Scheunert, 1993; McCrady and Maggard, 1993). The magnitude of uptake from these sources has been correlated with physical/chemical parameters (*e.g.*, vapour pressure, octanol water partition coefficient, *etc.*), with soil parameters (*e.g.*, fraction of organic carbon, soil moisture, clay content, *etc.*), with plant parameters (*e.g.*, lipid content, moisture content, *etc.*) and with chemical concentrations in the principle sources listed above.

The methodology considered for estimation of the contribution of these three routes of chemical accumulation in plants and the resulting dose to ecological receptors from consumption of local grown vegetation are described in the sections that follow.

B-5.1 Root Uptake

A substantial amount of empirical data is available in the literature that demonstrates there is significant uptake of organics into plants. Organic chemicals in soils are reported to be taken up by vegetation (*i.e.*, carrots, tomatoes, potatoes, narcissus) through the roots (Iwata and Gunther, 1976; Cocucci *et al.*, 1979; Bacci and Gaggi, 1985; Travis and Arms, 1988; Schroll and Scheunert, 1993). Travis and Arms (1988) reported that uptake of organic chemicals by vegetation is correlated to octanol-water partition coefficients (K_{OW}).

For the current assessment, the method of Travis and Arms (1988), as modified by Travis and Blaylock (1992), is used to estimate the bioconcentration of organic chemicals from the soil to vegetation *via* root uptake. This method is based on measured data which demonstrated that the bioconcentration factor for an organic chemical in vegetation is inversely proportional to the square root of the octanol-water partition coefficient (K_{OW}). Root uptake of organics has been correlated with K_{OW} and has been shown to decrease as K_{OW} increases (Briggs *et al.*, 1982; in Travis and Blaylock, 1992). A geometric mean regression analysis of data for 29 different organic chemicals demonstrated a relationship between bioconcentration factors in vegetation and octanol-water partition coefficients ($r = 0.73$) (Travis and Arms, 1988).

The first step of the method of Travis and Arms (1988), as modified by Travis and Blaylock (1992), is to calculate a chemical-specific bioconcentration factor for vegetation. The bioconcentration factor for vegetation (BVR) is defined as the ratio of the concentration in the plant (μg of chemical/g of dry plant) to the concentration of the chemical in the soil (μg of chemical/g of dry soil). The BVR was calculated for organic chemicals of concern according to the formula:

$$BVR = 38.73\ K_{OW}^{-0.578}$$

where:

BVR	=	bioconcentration factor for vegetation *via* root uptake (μg/g dry plant/μg/g dry soil)
K_{OW}	=	octanol-water partition coefficient.

Several studies have indicated that inorganic metals are taken up into plants through the roots (Rolfe, 1972; Baes, 1982; Boon and Soltanpour, 1992). Bioconcentration values for plants *via* the roots (BVR) for inorganic chemicals are based on measured values from the study by Baes (1982). For the current assessment lead was found to have a root bioconcentration value of 0.045 (μg/g dry weight plant)/(μg/g dry weight soil)

The concentration of a chemical in vegetation due to root uptake is estimated based on BVR values and the formula:

$$C_{VR} = C_S \times WP \times BVR \times F_{VD}$$

where:

C_{VR}	=	concentration in vegetation from root uptake (μg/g)
C_S	=	concentration in soil (1110 μg/g; lead)
WP	=	Washing and peeling factor of 35%
BVR	=	0.045 (μg/g dry weight plant)/(μg/g dry weight soil; as stated above)
F_{VD}	=	fraction of vegetation that is dry matter (0.15 unitless; environment parameter)

Using the equation above the concentration in vegetation from root uptake was found to be 2.62 μg/g.

Exposure to lead from the consumption of vegetation impacted by contaminated soil *via* root-uptake was calculated using the following methodology:

$$EXP_{root} = C_{vR} \times T_{consp} \times AF_{oral} \times FLP/\ BW$$

where

EXP_{root}	=	exposure due to the consumption of chemically impacted home grown produce *via* root uptake (0.30 μg/kg bw/day)

T_{consp}	=	Total berry consumption rate (4.0 g/day)
AF_{oral}	=	oral bioavailability of compound (0.53)
FLP	=	fraction of vegetables and produce grown locally (100%)
BW	=	body weight (16.4 kg)

B-5.2 Atmospheric Deposition

Chemicals bound to particulate in the atmosphere can be taken up through deposition onto aerial plant surfaces. Atmospheric deposition should only be considered for vegetation whose edible portions are above the ground (*i.e.*, grasses). Furthermore, the vegetation available for deposition should be grouped into two categories: vegetation and exposed fruits (*e.g.*, berries) since these categories have distinct differences in surface areas available for atmospheric deposition. For the current assessment, the contribution of atmospheric deposition of particulate onto outer vegetation surfaces is estimated using the formula presented by Travis *et al.* (1986).

The concentration of chemical in vegetation is then calculated using the formula:

$$C_{VD}\ (\mu g/g) = \frac{AC_{re}\ (\mu g/m^3) \times DV\ (m/s) \times WP \times r \times TGS\ (s/y) \times UCF\ (kg/g)}{Y\ (kg/m^2) \times K\ (d^{-1}) \times 365\ (d/y)}$$

where:

C_{VD}	=	concentration of the chemical in the plant due to deposition of particulate (μg/g)
AC_{re}	=	concentration of the chemical in the air resulting from soil/dust resuspension (2.1e-05 g/m³ × 1110 μg/g = 2.33e-02 μg/m³; as calculated above)
DV	=	deposition velocity of the chemical (0.015 m/s)
WP	=	washing peeling factor (35%; assumed for human receptors)
r	=	intercept fraction (0.15 for leafy crops and 0.052 for exposed produce; Baes *et al.*, 1984)
TGS	=	time length of growing season (3 months/year, rotating; 7.8e+06 seconds/year)
UCF	=	1 kg / 1,000 g
Y	=	annual crop yield (8.6 kg/m² for leafy crops and 12 kg/m² for exposed produce; Stevens and Gerbec, 1988)
K	=	ln(2)/weathering half-life of particulates on outer plant surfaces (based on Stevens and Gerbec (1988) the weathering half-life was assumed to be 14 days for all particulates) (*i.e.*, k= ln(2)/14 days= 0.0495 days^{-1})

Using the equation stated above the estimated vegetation concentration due to deposition of particulate was found to be 9.21e-04 µg/g for leafy vegetables and 2.29e-04 µg/g for exposed produce.

Daily exposure due to particulate deposition onto plant surfaces was calculated using the following equations:

$$EXP = FLP \times (C_{leafy} \times AVC_{leafy}) \times AF_{oral} / BW$$

where

EXP	=	exposure to lead from the consumption of berries (1.19e-04 μg/kg bw/day)
FLP	=	fraction of berries consumed on-site (100%)
C_{leafy}	=	concentration within berries (9.21e-04 μg/g wet weight of plant)
AVC_{leafy}	=	amount of leafy vegetation consumed per day (4.0 g/day)
AF_{oral}	=	oral bioavailability of compound (0.53)
BW	=	body weight (16.4 kg)

B-5.3 Vapour Uptake

A final pathway by which plants may accumulate chemicals is *via* air-to-plant transfer of chemicals in the vapour phase (*i.e.*, non-particulate). Chemicals which do not exist in the vapour phase were not considered for this exposure pathway. Although this pathway does not apply to lead, it is applicable to nonane and eicosane and therefore the following equations and methodologies have been provided below. The equations and methodology used to assess this process have been supplied. The following regression equation is provided by Travis and Hattemer-Frey (1991).

$$BVT = 0.022 \times K_{ow} \Big/ \left(\frac{H\ (Pa\ m^3\ /mol)}{T\ (K)} / 8.314\ (Pa\ m^3\ /Kmol) \right)\ 1000 / 800 (kg / m^3)$$

where:

BVT	=	biotransfer coefficient (μg/g/ μg/m³)
K_{ow}	=	octanol-water partition coefficient
H	=	Henry's Law constant for the compound
800	=	density of plant matter (kg/m³)
1000	=	conversion factor (g/kg)
T	=	room temperature in Kelvins (283° K)
8.314	=	gas constant (Pa m³/K mol)

The daily exposure to a organic compound from vegetation due to vapour phase transfer was then calculated using the following formula.

$$EVV = Cair(ug / m3) \times BVT (mg / g/mg / g) \times \left(AVC_{leafy} + AVC_{exposed} \right) \times WPxFLPxAF_{oral} / BW\ (kg)$$

where:

EVV	=	daily exposure from vegetation per day due to vapour phase transfer (μg/kg/day)
Cair	=	chemical concentration in air derived from soil ($\mu g/m^3$)
BVT	=	bioconcentration vapour transfer coefficient (μg/g (wet plant weight)/ $\mu g/m^3$)
AVC_{leafy}	=	amount of leafy vegetation consumed per day (g/day)
$AVC_{exposed}$	=	amount of exposed produce consumed per day (g/day)
AF_{oral}	=	oral bioavailability of compound (1.0)
BW	=	body weight (kg)
WP	=	washing and peeling factor
FLP	=	fraction of local produce

Exposure to lead via the consumption of wild berries was estimated to be 3.00e-01 (μg/kg bw/day) for a female preschool child.

B-6.0 ESTIMATION OF EXPOSURE FROM WILDLIFE

As indicated above, the receptor's diet was assumed to consist of caribou, rabbit and grouse. The following worked example illustrates how exposure estimates were calculated for the female preschool child *via* consumption of chemically impacted game. As previously mentioned 20% of a receptors total daily wild game consumption was assumed to come from on-site locations. The general equation used to estimate dietary exposures is:

$$GV = \frac{TI \times BIO_{IG}\ F_{VD} \times C_{caribou}}{BW}$$

where:

GV	=	ingestion exposure *via* the consumption of rabbit (μg/kg body weight/day)
TI	=	total daily wildlife consumption (75 g/day $\times$ 20% = 15 g/day)
BIO_{IG}	=	bioavailability *via* ingestion (0.53; lead)
F_{VD}	=	fraction of wildlife diet that is caribou (50%)
$C_{caribou}$	=	concentration in caribou (0.70 μg/g ; calculations shown below)
BW	=	body weight (16.4 kg)

Dietary lead exposure of a female preschool child through the consumption of caribou was estimated to be 0.17 μg/kg body weight/day. Exposure estimates from the consumption of chemically impacted rabbit and grouse were assessed in the same fashion as illustrated above.

B-7.0 RISK CHARACTERIZATION

Exposure Ratios (ERs) were estimated using the equations provided below and the exposure values previously calculated.

The non-cancer risks were estimated as Exposure Ratios and calculated as follows:

$$ER_1 = EI/EL$$

where:

ER_1	=	exposure ratio for ingestion and dermal pathways
EI	=	total daily exposure *via* all exposure pathways evaluated (47.20 μg/kg/d)
EL	=	adjusted exposure limit
	=	3.75 μg/kg/d × 0.53
		1.99 μg/kg/d

The exposure ratio due to ingestion and dermal contact with contaminated surficial soil was estimated to be 23.72.

$$ER_2 = EI/EL$$

where:

ER_2	=	exposure ratio for inhalation pathways
EI	=	total daily exposure *via* all exposure pathways evaluated (5.35e-03 μg/kg/d)
EL	=	adjusted exposure limit
	=	1.85 μg/kg/d × 0.53
	=	0.98 μg/kg/d

The exposure ratio due to inhalation of lead impacted dusts was estimated to be 5.46e-03.

B-7.1 Exposure Ratio Values

The Exposure Ratios (ER) that were estimated for the human health assessment of the 7 Canol Road and MacMillan Pass area sites can be found in Tables B-2 to B-10.

Table B-2 Exposure Ratio Values for Human Health Risks from Direct Soil Pathways - 14 Days on Site

	MP 73		MP 233		MP 124.5		MP 174		MP 213		MP 234		MP 208	
	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average
Female Toddler														
HEPH	0.03	0.02	0.002	0.002	0.2	0.08	0.2	0.1	0.1	0.03	0.09	0.01	0.7	0.06
LEPH	0.2	0.1	0.1	0.04	0.8	0.4	0.8	0.4	0.08	0.03	0.8	0.1	2.8	0.1
Lead	-	-	-	-	3.7	1.0	-	-	-	-	-	-	-	--
Female Adult														
HEPH	0.01	0.01	0.001	0.001	0.06	0.03	0.08	0.04	0.03	0.01	0.03	0.004	0.2	0.02
LEPH	0.01	0.01	0.004	0.002	0.04	0.02	0.04	0.02	0.004	0.001	0.04	0.01	0.13	0.006
Lead	-	-	-	-	0.08	0.02	-	-	-	-	-	-	-	--

\- not assessed

Table B-3 ER Values for Human Health Risks from Direct Soil Pathways - 120 Days on Site

	MP 73		MP 233		MP 124.5		MP 174		MP 213		MP 234		MP 208	
	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average
Female Toddler														
HEPH	0.14	0.08	0.01	0.007	0.83	0.35	1.02	0.50	0.41	0.14	0.39	0.05	2.99	0.26
LEPH	0.78	0.58	0.42	0.16	3.59	1.52	3.39	1.54	0.36	0.12	3.59	0.48	11.89	0.56
Lead	-	-	-	-	15.70	4.14	-	-	-	-	-	-	-	--
Female Adult														
HEPH	0.05	0.03	0.004	0.002	0.28	0.12	0.34	0.17	0.14	0.05	0.13	0.02	1.00	0.09
LEPH	0.04	0.03	0.02	0.01	0.16	0.17	0.15	0.07	0.02	0.01	0.16	0.02	0.54	0.03
Lead	-	-	-	-	0.33	0.09	-	-	-	-	-	-	-	--

\- not assessed

Table B-4 ER Values for Human Health Risks from Direct Soil Pathways - 180 Days on Site

	MP 73		MP 233		MP 124.5		MP 174		MP 213		MP 234		MP 208	
	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average
Female Toddler														
HEPH	0.2	0.11	0.016	0.01	1.24	0.52	1.53	0.75	0.62	0.21	0.58	0.07	4.48	0.4
LEPH	1.17	0.87	0.63	0.24	5.38	2.27	5.08	2.31	0.54	0.18	5.38	0.72	17.81	0.83
Lead	-	-	-	-	23.5	6.19	-	-	-	-	-	-	-	--
Female Adult														
HEPH	0.07	0.04	0.005	0.003	0.41	0.17	0.51	0.25	0.21	0.07	0.19	0.02	1.5	0.13
LEPH	0.05	0.04	0.03	0.01	0.24	0.1	0.23	0.1	0.02	0.01	0.24	0.03	0.8	0.04
Lead	-	-	-	-	0.5	0.13	-	-	-	-	-	-	-	--

\- not assessed

Table B-5 ER Values for Human Health Risks from Consumption of Wildgame - 14 Days on Site

	MP 73		MP 233		MP 124.5		MP 174		MP 213		MP 234		MP 208	
	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average
Female Toddler														
HEPH	0.0006	0.0003	0.00005	0.00003	0.004	0.002	0.005	0.002	0.002	0.0006	0.002	0.0002	0.01	0.001
LEPH	0.007	0.005	0.004	0.001	0.03	0.01	0.03	0.01	0.003	0.001	0.03	0.004	0.1	0.005
Lead	-	-	-	-	0.9	0.2	-	-	-	-	-	-	-	--
Female Adult														
HEPH	0.0005	0.0003	0.00004	0.00002	0.003	0.001	0.004	0.002	0.001	0.0005	0.001	0.0002	0.01	0.0009
LEPH	0.005	0.004	0.003	0.001	0.02	0.01	0.02	0.01	0.002	0.0008	0.02	0.003	0.08	0.004
Lead	-	-	-	-	0.7	0.2	-	-	-	-	-	-	-	--

\- not assessed

Table B-6 ER Values for Human Health Risks from Consumption of Wildgame - 120 Days on Site

	MP 73		MP 233		MP 124.5		MP 174		MP 213		MP 234		MP 208	
	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average
Female Toddler														
HEPH	0.003	0.001	0.0002	0.0001	0.02	0.007	0.02	0.01	0.008	0.003	0.008	0.0009	0.06	0.005
LEPH	0.03	0.02	0.02	0.006	0.1	0.06	0.1	0.06	0.01	0.005	0.1	0.02	0.5	0.02
Lead	–	–	–	–	3.8	1	–	–	–	–	–	–	–	--
Female Adult														
HEPH	0.002	0.001	0.0002	0.0001	0.01	0.005	0.02	0.007	0.006	0.002	0.006	0.0007	0.04	0.004
LEPH	0.02	0.02	0.01	0.005	0.1	0.04	0.1	0.04	0.01	0.003	0.1	0.01	0.3	0.02
Lead	–	–	–	–	2.9	0.8	–	–	–	–	–	–	–	--

– not assessed

Table B-7 ER Values for Human Health Risks from Consumption of Wildgame - 180 Days on Site

	MP 73		MP 233		MP 124.5		MP 174		MP 213		MP 234		MP 208	
	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average
Female Toddler														
HEPH	0.004	0.002	0.0003	0.0003	0.02	0.01	0.03	0.01	0.01	0.004	0.01	0.001	0.09	0.008
LEPH	0.04	0.03	0.02	0.009	0.2	0.09	0.2	0.09	0.02	0.007	0.2	0.03	0.7	0.03
Lead	–	–	–	–	5.6	1.5	–	–	–	–	–	–	–	--
Female Adult														
HEPH	0.003	0.002	0.0002	0.0001	0.02	0.008	0.02	0.01	0.009	0.003	0.009	0.001	0.07	0.006
LEPH	0.03	0.03	0.02	0.007	0.2	0.07	0.1	0.07	0.02	0.005	0.2	0.02	0.5	0.02
Lead	–	–	–	–	4.3	1.1	–	–	–	–	–	–	–	--

– not assessed

Table B-8 ER Values for Human Health Risks from Berry Consumption - 14 Days on Site

	MP 73		MP 233		MP 124.5		MP 174		MP 213		MP 234		MP 208	
	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average
Female Toddler														
HEPH	0.000003	0.000001	0.0000002	0.0000001	0.00002	0.000007	0.00002	0.00001	0.000008	0.000003	0.000008	0.0000009	0.000058	0.000005
LEPH	0.0006	0.0004	0.0003	0.0001	0.003	0.001	0.003	0.001	0.0003	0.00009	0.003	0.0004	0.009	0.0004
Lead	-	-	-	-	0.0266	0.007	-	-	-	-	-	-	-	--
Female Adult														
HEPH	0.000003	0.000001	0.0000002	0.0000001	0.00002	0.00001	0.00002	0.00001	0.00001	0.00000	0.000007	0.0000009	0.00006	0.00001
LEPH	0.0006	0.0004	0.0003	0.0001	0.003	0.001	0.003	0.001	0.0003	0.00009	0.003	0.0004	0.009	0.0004
Lead	-	-	-	-	0.03	0.007	-	-	-	-	-	-	-	--

- not assessed

Table B-9 ER Values for Human Health Risks from Berry Consumption - 120 Days on Site

	MP 73		MP 233		MP 124.5		MP 174		MP 213		MP 234		MP 208	
	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average
Female Toddler														
HEPH	0.00001	0.000006	0.0000009	0.0000006	0.00007	0.00003	0.00008	0.00004	0.00003	0.00001	0.00003	0.000004	0.0002	0.00002
LEPH	0.003	0.002	0.001	0.0005	0.01	0.005	0.01	0.005	0.001	0.0004	0.01	0.002	0.04	0.002
Lead	-	-	-	-	0.1	0.03	-	-	-	-	-	-	-	--
Female Adult														
HEPH	0.00001	0.000006	0.0000009	0.0000005	0.00007	0.00003	0.00008	0.00004	0.00003	0.00001	0.00003	0.000004	0.0002	0.00002
LEPH	0.002	0.002	0.001	0.0005	0.01	0.005	0.01	0.005	0.001	0.0004	0.01	0.002	0.04	0.002
Lead	-	-	-	-	0.1	0.03	-	-	-	-	-	-	-	--

- not assessed

Table B-10 ER Values for Human Health Risks from Berry Consumption - 180 Days on Site

	MP 73		MP 233		MP 124.5		MP 174		MP 213		MP 234		MP 208	
	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average	Max	Average
Female Toddler														
HEPH	0.00002	0.00001	0.000001	0.0000008	0.0001	0.00004	0.0001	0.00006	0.00005	0.00002	0.00005	0.000006	0.0004	0.00003
LEPH	0.004	0.003	0.002	0.0008	0.02	0.007	0.02	0.008	0.002	0.0006	0.02	0.002	0.06	0.003
Lead	-	-	-	-	0.2	0.05	-	-	-	-	-	-	-	--
Female Adult														
HEPH	0.00002	0.000009	0.000001	0.0000008	0.0001	0.00004	0.0001	0.00006	0.00005	0.00002	0.00005	0.000006	0.0004	0.00003
LEPH	0.004	0.003	0.002	0.0008	0.02	0.007	0.02	0.007	0.002	0.0006	0.02	0.002	0.06	0.003
Lead	-	-	-	-	0.2	0.04	-	-	-	-	-	-	-	--

\- not assessed

B-8.0 ECOLOGICAL EXPOSURE ESTIMATES

For the purpose of the current ecological assessment the following terrestrial receptors were evaluated using both qualitative and quantitative techniques:

1. Caribou
2. Rabbit
3. Grouse
4. Bear
5. Wolf

Receptor specific parameters and assumptions used in the current ecological risk assessment have been summarized in Table B-11.

Table B-11 Ecological Assumptions and Parameters

Parameter	Rabbit	Caribou	Bear	Wolf	Grouse
Lung ventilation rate (m^3/d)	0.630 (EC)[1]	24.131	16.9[a]	35.08	0.30712
Mean body weight (kg)	1.351	1143	72.96	469	0.68811
Food consumption (kg/d; wet weight)	0.301	3.14	2.3 (dw)[8] 4.0[1] (ww)	5.5	0.120 (mean)[13]
Estimated water Content of Food (% Water / % Dry Matter)	43% / 57% (young and dry grasses)[1]	52% / 48% (Grasses, dicot plants)[1]	43% / 57%[1] (vegetation)	68% / 32% (mammals)[1]	43% / 57% (young grasses, buds, *etc.*)[13]
Dietary breakdown	100% herbs, forbs, grasses (summer)[1] 100% woody browse, buds (winter)	100% vegetation (woody browse and lichen)[4]	assumed 100% vegetation	25% Hare 75% Caribou[10]	100% vegetation[13] (buds, twigs, berries, grasses)
Soil/dust intake (g/day)	2% of dry weight diet[2];	2% of dry weight diet[2] (based on a white tailed deer);	2% of dry weight diet;	2.8 % of dry weight diet[1] (based on the fox)	8.2% of dry weight diet[1]
	3.42 g/day	28.9 g/day	46 g/day	49 g/day	6.39 g/day
Surface area (m^2)	0.1254 (EC)[1]	2.391	1.791	1.31	0.07661
Average site area (sq. km)	0.46	0.46	0.46	0.46	0.46
Home range (sq. km)	0.031	69.5 (based on a moose)[5]	6.5 (females)[7]	16 (based on fox)[1]	0.12 to 0.22[14]

Table B-11 Ecological Assumptions and Parameters

Parameter	Rabbit	Caribou	Bear	Wolf	Grouse
Time spent within site (calculated based on home range and site size)	100%	0.66%	7.0%	2.9%	100%

EC Based on Eastern Cotton Tail Rabbit

1 EPA, 1993; consumption rates, inhalation rates and skin surface areas have been based on allometric equations for mammals and birds.

2 Beyer *et al.*, 1994

3 Fuller and Keith, 1980; Parker, 1981

4 Boertje, 1990; Crete *et al.*, 1993.

5 Franzman and Schwartz, 1998

6 Smith 1993

7 Bear Den 1999

8 calculated based on allometric equation, Stahl, 1967

9 Bjorge and Gunson, 1989

10 Pimlott, 1975

11 Based on data collected from the Mildred Lake area, Conor Pacific Inc.

12 Based on Lasiewski and Calder (1971) equation for inhalation rate of non-passerine birds. Inhalation rate (in metres cubed/day) = 0.4089 (body weight in kg)$^{0.0.77}$ and assuming a mean body weight = 0.688 kg. To convert from m^3/day to L/day assumed a conversion factor of 1000 (1 m^3/day = 1000 L/day).

13 Based on Nagy (1987) allometric equation for non-passerine birds. Food ingestion (g / g body weight / day dry weight) = 0.301 (body weight in g)$^{0.751}$ / body weight. Assuming a mean body weight of 688 g and a diet consisting of buds, catkins, twigs and berries with a water content of 43% (mean of water content for seeds 9.3% and fruit pulp and skin 77%; EPA, 1993). Therefore wet weight food ingestion = dry weight food ingestion / [100% - 43%].

14 Home range for central Alberta; Rusch and Keith, 1971

B-8.1 Exposure Estimates From Chemically Impacted Soil

The following sections present the methodologies applied to estimating dose rates of ecological receptors from chemically impacted soil and potential terrestrial prey. Dose rate estimates may differs for each receptor, depending on their habits. It should be noted that soil exposures *via* dust inhalation and dermal contact were determined to be negligible relative to soil ingestion and prey/vegetation consumption.

The following is a worked example of an hare attaining exposure *via* direct soil ingestion, dust inhalation, dermal contact with soil and consumption of on-site vegetation, all of which have been impacted by lead.

B-8.2 Exposure *via* Direct Soil Ingestion

Lead exposure *via* the consumption of lead impacted soil was estimated by the following equation:

$$GSOS = \frac{SG \times C_S \times BIO_{IG}}{BW}$$

where:

GSOS	=	ingestion dose from soil/dust on summer days (μg/kg bw/day)
SG	=	soil ingestion rate (3.42 g/day; hare)
C_s	=	concentration in soil (1110 μg/g)
BIO_{IG}	=	bioavailability *via* ingestion (0.10; chemical-specific)
BW	=	body weight (1.35 kg)

Using the equation and parameters above, the estimated cadmium exposure to the hare via soil ingestion was estimated to be 281.2 μg/kg bw/day.

B-8.3 Exposure *via* Dermal Contact with Chemically Impacted Soil

Lead exposure *via* the inhalation of dust was estimated by the following equation:

$$GSIS = SA \times AF \times C_s \times BIO_{dermal} / BW$$

where:

GSIS	=	inhalation dose from dust on summer days (μg/kg bw/day)
SA	=	surface area (0.1254; hare)
AF	=	soil Adherence Factor (46 g/m^2 ; for terrestrial animals)
C_s	=	lead concentration in soil (1110 μg/g)
BIO_{dermal}	=	bioavailability *via* dermal route (0.0008; chemical-specific)
BW	=	body weight (1.35 kg)

Using the equation and parameters above, the estimated lead exposure to the hare via dermal contact with soil was estimated to be 3.79 μg/kg bw/day.

B-8.4 Exposure *via* Inhalation of Chemically Impacted Dust

$$GSDS = INHAL \times AIC \times BIO_{inhal} / BW$$

where:

GSDS	=	inhalation dose from dust on summer days (μg/kg bw/day)
INHAL	=	soil ingestion rate (0.630 m^3 /day; hare)
AIC	=	Lead concentration in dust (0 .023 μg/m^3)
BIO_{inhal}	=	bioavailability *via* inhalation (0.22; chemical-specific)
BW	=	body weight (1.35 kg)

Using the equation and parameters above, the estimated lead exposure to the hare via soil inhalation was estimated to be 2.39e-03 µg/kg bw/day.

B-9.0 EXPOSURE FROM CONSUMPTION OF VEGETATION

Exposures to wildlife receptors from the consumption of chemically impacted vegetation was considered for the current ecological exposure assessment. Predicted vegetation concentrations and receptor-specific food consumption rates were used to estimate potential exposures to wildlife receptors of concern. Vegetation concentrations were estimated using the same methodology as stated above however, the washing and peeling factor of 35% does not apply to ecological receptors. The following outlines the methodology used to estimate daily exposure due to vegetation consumption.
where:

$$DGVG = \frac{VG \times C_V \times BIO_{IG}}{BW}$$

DGVG	=	exposure from the consumption of on-site vegetation (µg/kg body weight/day)
VG	=	vegetation ingestion rate (300 g/day; hare)
C_V	=	predicted chemical concentration in vegetation (2.62 µg lead/g plant / 0.35 = 7.49; plant concentrations were derived according to B-5.1)
BIO_{IG}	=	bioavailability *via* ingestion (0.10; lead)
BW	=	body weight (1.35 kg; receptor-specific)

The above equation estimated cadmium exposure via plant consumption to be 166.44 µg/kg body weight/day.

B-10.0 ESTIMATION OF DOSE RATES FOR ECOLOGICAL RECEPTORS *VIA* INGESTION OF CHEMICALLY IMPACTED PREY SPECIES

In order to estimate exposure and ultimately risk to receptors of higher trophic levels (*e.g.*, wolf) *via* consumption of impacted prey species, estimated hare, caribou and grouse body burdens were first estimated. The following sections describe how body burdens were derived for each prey species and chemical type.

B-10.1 Estimation of Lower Trophic Level Whole Body/Tissue Chemical Concentrations

Steady-state body burdens for lead, eicosane and nonane were estimated for the hare, grouse and caribou using a first-order elimination rate law (described by the following equations). It was assumed that, within the body, steady-state chemical concentrations are attained after an exposure period equal to seven half-lives of a chemical. The biological half-lives used in these calculations are presented in Table B-12. Due to the limited amount of data on biological half-lives in wildlife species, half-lives for laboratory animals have been used in most cases. In the case of eicosane and nonane, which are not generally considered bioaccumulative in nature, the estimated daily absorbed dose was conservatively assumed to be equivalent to a receptor's body burden.

Table B-12 Biological Half-Lives used for Body Burden Calculations

Chemical	Biological Half-Life ($t_{1/2}$)	Test Species	Reference
Lead	39 d	cows	Sharma *et al.*, 1982 (average of muscle, liver, kidney $T_{1/2}$)

The chemical concentration in prey species (*i.e.*, hare and grouse, caribou) after approximately seven half-lives was used to estimate wolf and human exposures *via* the consumption of chemically impacted wildlife/prey. The estimated absorbed dose and the first-order elimination rate equation were used to help derive ecological body burdens:

$$B.R. = k_1/k_2 \times E_r \times (1- e^{-kt})$$

where:

B.R.	=	steady state body residue or body burden (μg/kg)
k_1	=	uptake rate Constant (1 constant rate of exposure)
k_2	=	depletion rate ($\ln2/t_{1/2}$ days^{-1}; $t_{1/2}$ = 39 days)
E_r	=	daily absorbed dose (μg/kg bw/day)
t	=	the length of seven half-lives (273 days)

Using the total estimated absorbed dose of 452 (μg lead /kg bw/day) for the hare and the equation stated above, the estimated body burden was determined to be approximately 25,000 μg/kg or 25 mg/kg lead.

B-11.0 ESTIMATION OF EXPOSURE RATES FROM THE CONSUMPTION OF HARE AND CARIBOU

As mentioned previously, the diet of a wolf was conservatively assumed to consist of 25% hare and 75% caribou, by mass. The following worked example illustrates how exposure estimates were calculated for the wolf *via* consumption of chemically impacted prey.

$$GV = \frac{TI \times F_{VD} \times BIO \times FOS \times C_{hare}}{BW}$$

where:

GV	=	ingestion exposure *via* the consumption of hare (μg/kg body weight/day)
TI	=	total daily intake of food (5500 g/day)
F_{VD}	=	fraction of diet consisting of prey item (25% hare)
BIO_{oral}	=	oral bioavailability of lead (0.1; chemical specific)
FOS	=	fraction of time and prey consumed on-site (2.9%)
C_{hare}	=	concentration of chemical in hare
BW	=	body weight (46 kg; wolf)

Dietary exposures of the wolf to lead through the consumption of exposed prey (hare) was estimated to be 2.18 μg/kg body weight/day.

Dietary exposure of the wolf to lead through the consumption of caribou was assessed using the same methodology as that described above and was determined.

B-12.0 ECOLOGICAL RISK CHARACTERIZATION

Exposure Ratios (ERs) were estimated using the equations provided below and the exposure values previously calculated. The following equation illustrates the calculation of an ER_{NOAEL} for the hare consuming vegetation and exposure to lead impacted soils.

$$ER_{NOAEL} = [EI] / (EL \times Bio_{oral})$$

where:

ER	=	NOAEL Exposure Ratio (0.85)
EI	=	total daily exposure *via* all routes, adjusted for bioavailability (452 μg/kg/d)
Bio_{oral}	=	oral bioavailability of a chemical (0.10; lead)
EL	=	adjusted exposure limit (5310 × 0.10 = 531.0 μg/kg body weight/day)

An exposure ratio, based on a no observed adverse effect level (NOAEL), for an hare due to the consumption of lead impacted vegetation and exposure with impacted soils was estimated to be approximately 0.85.

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