MOUNT KLAPPAN ANTHRACITE PROJECT
STAGE II ASSESSMENT

VOLUME III

ENVIRONMENTAL ASSESSMENT

1987

GULF CANADA CORPORATION
COAL DIVISION

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Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources

MEMORANDUM

To: Participants
Mine Development Review Process
(see attached Distribution List)

7 April 1987

Re: Mount Klappan Coal Project -
Formal Stage II Submission (April, 1987)

Following a screening, the MDSC has accepted a 5-volume Stage II submission from Gulf Canada Corp. for formal detailed review. The volumes are as follows:

I - Summary
II - Development Plan
III - Environmental Assessment
IV - Socio-Economic
V - Community Profiles

The submission addresses the mine, optional on-site power plant and settlement/transportation/worker rotation strategy, and review is being coordinated by the MDSC. The goal is to seek one overall project approval-in-principle decision from the Cabinet ELUC. However, the Environmental Working Group of the Northwest Task Force, not the MDSC, is handling the environmental review of off-site project components. The EWG has already reached the point where it is prepared to support approval-in-principle for the optional transmission line hookup to the integrated grid at Aiyansh. It is now about to review major engineering and environmental submissions for the proposed road access through the Bell-Irving/Sweeny corridor. To date, it is not clear when and in what form a proposal for a coal shipping facility in Stewart would be presented, but it would likely be handled by the EWG.

Bearing in mind the umbrella decision which is ultimately intended, you are asked to review the enclosed Stage II submission, and to convey review comments to me by no later than 1987-06-16. Specifically with respect to the project components addressed in the submission, please respond to the following questions:

1. Does you agency support Stage II approval-in-principle? If not, please explain in detail the issues and information gaps which are the basis for withholding support. Issues should be those which cast doubt on the overall technical acceptability of the project. Other issues can be addressed at Stage III.

.../2

2. Does your agency have any outstanding permitting or non-regulatory concerns which should be addressed at Stage III? Permitting agencies should indicate their permitting requirements. Stage III concerns, whether permitting or non-regulatory, are those which do not cast doubt on the overall acceptability of the mining project, but which require resolution before project construction.

Please consult your Stage I review comments, copied to you under cover of my 1985-11-20 letterto Gulf, in conducting your Stage II review.

Raymond L Crook

Raymond L. Crook
Chairman
Mine Development Steering Committee
c/o Mineral Policy and Evaluation

Attachment: Selected volumes, Stage II submission (see Distribution)

ccs: L. Sivertson
B. McRae
E. Pietraszek
T. Schroeter
R. Smyth

DISTRIBUTION

REVIEW AGENCY	VOL I	VOL II	VOL III	VOL IV	VOL V	MAP OF WATER MAN.
MEMPR (Inspection)						
– Vic Dawson	1	1	1	–	–	–
– Ralph McGinn	1	1	1	1	1	–
– Bryan Goad	1	1	1	1	1	–
– John Errington	1	1	1	–	–	–
– Terry Martin	1	1	1	–	–	–
– Brendan Gordon	1	1	1	–	–	–
MEMPR (Geology)	1	1	1	–	–	–
Environment (Vic)	10	10	10	–	–	~~4~~ 3
Environment (PG)	4	4	4	–	–	1
Agric & Fish	1	–	–	–	–	–
Forests	1	–	–	–	–	–
Lands	1	1	1	1	1	–
Parks	1	1	1	1	1	–
Transp./Hwys	1	1	1	1	1	–
Heritage	1	1	1	–	–	–
DOE	2	2	2	–	–	–
DFO	2	2	2	–	–	–
Munic. Affairs	1	–	–	1	1	–
Advanced Educ.	1	–	–	1	1	–
Econ Devel (Vic)	1	–	–	1	1	–
Econ Devel (Vanc)	1	1	1	1	1	–
Health	1	1	1	1	1	–
INAC	1	1	1	1	1	–
Intergovt (Native)	1	1	1	1	1	–
Education	1	–	–	–	–	–
AG (Court Services)	1	–	–	–	–	–

MOUNT KLAPPAN ANTHRACITE PROJECT

STAGE II ASSESSMENT

VOLUME III - ENVIRONMENTAL ASSESSMENT

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ENVIRONMENTAL ASSESSMENT - EXECUTIVE SUMMARY

Following Gulf's submission of the Stage I Assessment in 1985, a number of additional environmental studies were conducted in 1985 and 1986. These studies have expanded the baseline information available on the natural environment of the Mount Klappan area while at the same time addressing a number of particular concerns raised following the Stage I submission.

This volume provides the data, analysis and impact assessment findings resulting from these studies. The volume has been segregated into six parts. Part One provides introductory comments, Part Two - Atmospheric Environment presents additional climate data and an assessment of the potential impacts of air emissions from an on-site thermal generating power plant. Part Three - Aquatic Environment contains the assessment of water quality impacts associated with the project. In Part Four, implications of the Project on the soils, vegetation and wildlife aspects of the Terrestrial Environment are assessed. Heritage Resources are addressed in Part Five. Finally, a summary of impacts and proposed mitigation measures is presented in Part Six.

The following sub-sections review the principal conclusions of the environmental assessment program.

ATMOSPHERIC ENVIRONMENT

The climate in the Mount Klappan area is in many ways ideal for mining. Rainfall and snowfall are modest, temperatures are cool and winds are light. Extreme conditions are relatively rare and are not expected to cause any operational problems.

The principal source of potential impact on the atmospheric environment associated with the Mount Klappan project would be power plant stack emissions. Sulphur dioxide is the emission of greatest concern. However, the combination of low sulphur fuel, sulphur capture by calcium during combustion and the small scale of the plant will result in only about 0.6 tonnes of sulphur dioxide release per day. Nitrogen oxides emissions, which are a secondary concern, would be even less. These low discharge levels are far below many common industrial process facilities operating in British Columbia with discharges ranging from 7 to 65 tonnes of sulphur dioxide per day.

The ambient annual average concentrations of sulphur dioxide will for the most part be only a small fraction of British Columbia's strictest air quality objectives and will probably be undetectable in most areas. Even in the restricted zone where the maximum annual concentration is predicted, the sulphur dioxide levels will only be about 30 percent of the B.C. Pollution Control Objective of 0.01 ppm. Concentrations in the Spatsizi Plateau Wilderness Park will be about 3 percent or less of the objective.

Worst case 1-hour concentrations of sulphur dioxide were also studied. This would occur when a very strong inversion and very light winds persist such that the power plant plume spreads to fill the valley in a thin, concentrated band. The peak concentrations would occur where this band comes into contact with the valley walls. Analysis of the meteorological data indicates that the frequency of events when all the necessary conditions are met for sufficient time to allow the plume to fill the valley is exceedingly rare. Nevertheless, if the phenomenon should occur, the concentration is still predicted to be less than one-fifth of the most stringent 1-hour maximum pollution control objective. The ambient annual average and 1-hour concentrations for sulphur dioxide, nitrogen oxides and carbon monoxide are summarized below.

Maximum Ambient Concentrations - Power Plant Emissions

Parameter	Unit*	B.C. Pollution Control Objective	Mount Klappan Maximum Ambient Concentration
Sulphur Dioxide			
Annual Average	ppmv	0.01 - 0.03	0.003
1 hr. Maximum	ppmv	0.17 - 0.34	0.032
Nitrogen Oxide			
Annual Average	ppmv	0.04**	0.005
1 hr. Maximum	ppmv	0.16 - 0.4	0.055
Carbon Monoxide			
Annual Average	ppmv	-	0.002
1 hr. Maximum	ppmv	5.7 - 11.2	0.033

* Parts per million volumetric

** Federal Standard - Maximum Desirable

The overall small scale of the plant, along with the air quality control features inherent in the power plant design and operating procedures will result in negligible effects on air quality in the Mount Klappan area.

Sulphur deposition on soil and surface waters was also modelled. Due to the very small amount of sulphur released from the power plant, deposition rates were also found to be very low. Trace metal emissions were found to be orders of magnitude below control objectives. The impact on soils, water chemistry and vegetation in the area will be negligible.

AQUATIC ENVIRONMENT

Water quality in the Mount Klappan area is good. Discharges to the Little Klappan River and Fox Creek from the project area are not expected to change this situation. An extensive system of drainage diversion channels and sediment ponds will reduce suspended solids concentrations to the B.C. Pollution Control Objective of 50 mg/l. These surface water management facilities will result in negligible impacts on stream biota in site watercourses.

In addition to the surface runoff, all other effluents from the project would be passed through the sediment and treatment ponds, or in the case of mine office/dry complex sewage, a tile field. These effluents include tailings, sewage, water drained from the plant or maintenance areas, pit water and drainage from the waste rock disposal area.

Analysis of the waste rock materials has shown that they contain an abundance of acid-consuming rock and accordingly, acid mine drainage is not expected. Trace concentrations of nitrogen will be added to the Little Klappan River due to soluble, unconsumed residuals from explosives in the waste rock. It is expected however that the levels will not exceed water quality criteria and may in fact be beneficial to the nutrient deficient system. All discharges will meet final effluent objectives and the effects on water quality are expected to be negligible.

While drainage patterns in the area will be altered somewhat to divert and collect runoff, the hydrology of streams downstream of the immediate project would remain essentially unaltered. Fish populations and fish habitat in area streams are limited or non-existent. Water quality will not be significantly affected and as a result, fisheries impacts are expected to be negligible.

TERRESTRIAL ENVIRONMENT

Effects on vegetation and wildlife in the project area will be localized and minimal apart from the direct loss of the land used by the project. A survey was conducted to identify rare plant species which would be affected. Fourteen species classified as rare were identified in the project area but it was also determined that these plants are not rare in the region. The impact of the Lost-Fox Mine will be limited to the loss of a few individuals. No populations of rare plants will be lost as these species occur in other locations unaffected by the development.

Impacts on vegetation due to power plant stack emissions in the form of sulphur dioxide (SO_2) concentrations or sulphur deposition are predicted to be negligible. At Mount Klappan, the worst case maximum 1-hour concentration, which would rarely occur, is predicted to be about 0.03 ppm. This is less than 10 percent of the concentration (0.4-0.5 ppm) where damage could be observed in the most sensitive species.

Studies of long-term exposure of lichens to SO_2, lichens being the most sensitive plant species, indicate that relatively low annual concentrations may affect lichen health. All areas in the Mount Klappan region will be exposed to levels that are far below levels where observable influences on lichen would be detected.

The predicted maximum sulphur deposition rate of 5.5 kg/ha annually is also far below levels where significant change in soil chemistry or plant vitality would occur. No aspect of power plant stack emissions has been discovered which would have other than negligible impacts on vegetation.

Caribou and grizzly bear are the wildlife species in the region potentially most sensitive to mine development. Extensive site investigations and radio-collar tracking studies have shown that caribou do not utilize the project area during any of the sensitive stages of their seasonal activities. There are no rutting areas, birthing sites or winter range activities in the Mount Klappan area. There is some migration through the area in the spring and late summer but no intense use of the project area and no concentrations of enimals during this period. It is expected that caribou will probably simply skirt areas of mining activity during their movements through the region and overall impacts on the Spatsizi area caribou will be minimal.

Grizzly bear hunt and forage over extensive territories and have been observed in the Mount Klappan area on occasion. The grizzlies are most sensitive to disturbance during the winter and spring when they are in their dens or have new-born cubs. No denning by grizzlies has been discovered in the project area. Grizzly bear will generally avoid the project area and largely be unaffected by the development.

The basic impact on caribou, grizzly bear and other wildlife species in the project area will be the temporary loss of use of the land that the project occupies. These lands however presently represent zones of only modest wildlife utilization. They do not encompass any uniquely valuable habitat and no intense or critical use by any species has been identified.

PART ONE - INTRODUCTION

FIGURES

PART ONE - INTRODUCTION

1.0 BACKGROUND

The Stage II environmental assessment for the Mount Klappan Anthracite Project is focussed on the issues raised by the mine Development Steering Committee following the review of the Stage I submission. The specific issues are identified in their review document dated June, 1986.

This submission does not incorporate the Stage I document but uses the environmental information contained therein, along with new information obtained from additional field studies and analysis for the assessment of impact. The reader is directed to that document for additional data on baseline conditions in the natural environment and impact analysis for areas not covered in this volume.

The project development plan described in Volume II, which is based on an extensive engineering feasibility study, allows a more specific assessment of impact than was possible based on the conceptual design in Stage I. The assessment includes an evaluation of alternatives where appropriate.

The project development plan described in Volume II of this submission provides essential background for placing the environmental evaluations contained in this volume into context. In particular, Part Six of Volume II - Environmental Management, describes many of the environmental impact mitigative features incorporated in the assessment analyses described in this volume.

This environmental assessment volume is structured as a set of relatively independent reports each addressing particular aspects of the environment. The assessment is structured as follows:

Part Two - Atmospheric Environment
Part Three - Aquatic Environment

Part Four - Terrestrial Environment
Part Five - Heritage Resources
Part Six - Summary - Impacts and Mitigation

The Terrestrial Environment includes a discussion of wildlife and vegetation impacts.

Gulf has been assisted in the Stage II program by a number of consulting organizations who have contributed to studies completed in 1985 and 1986. While Gulf has drawn extensively from the work of these consultants, Gulf is solely responsible for the preparation of this Stage II assessment. Those organizations that have had primary responsibility for gathering and analyzing the data are noted below:

Atmospheric, Water Quality and Wildlife Assessment	Environmental Management Associates
Vegetation and Soils	Norecol Environmental Consultants Ltd.
	Hardy BBT Limited.
Reclamation Planning	Polster Environmental Services
Anthracite Burn Test	Pyropower Corporation
Water Management	Ker, Priestman and Associates Ltd.
Environmental Management Planning	Rescan Environmental Services Ltd.
Heritage Resources Assessment	Aresco Ltd.
Report Preparation and Coordination	Rescan Environmental Services Ltd.

Gulf Canada Corporation has been working with the Northwest Economic Development Task Force to evaluate options and assess impacts of the off-site components of this project: the mine access road, port facilities and a possible electric transmission line. Work on these items has been conducted in parallel with the Stage II work. The government review and approval process for these items will be directed by the Task force and will not be the responsibility of the Mine Development Steering Committee.

2.0 PROJECT SETTING AND SUMMARY OF DEVELOPMENT PLAN

2.1 LOCATION AND SETTING

Gulf Canada Corporation's Mount Klappan Anthracite Property covers a total of 51 693 hectares in the northwest region of British Columbia. The property is comprised of mountainous terrain at the northern extremity of the Skeena Mountain Range about 150 km northwest of Stewart and 530 km northwest of Prince George. Figure 1-1 provides a location map for the Mount Klappan Property.

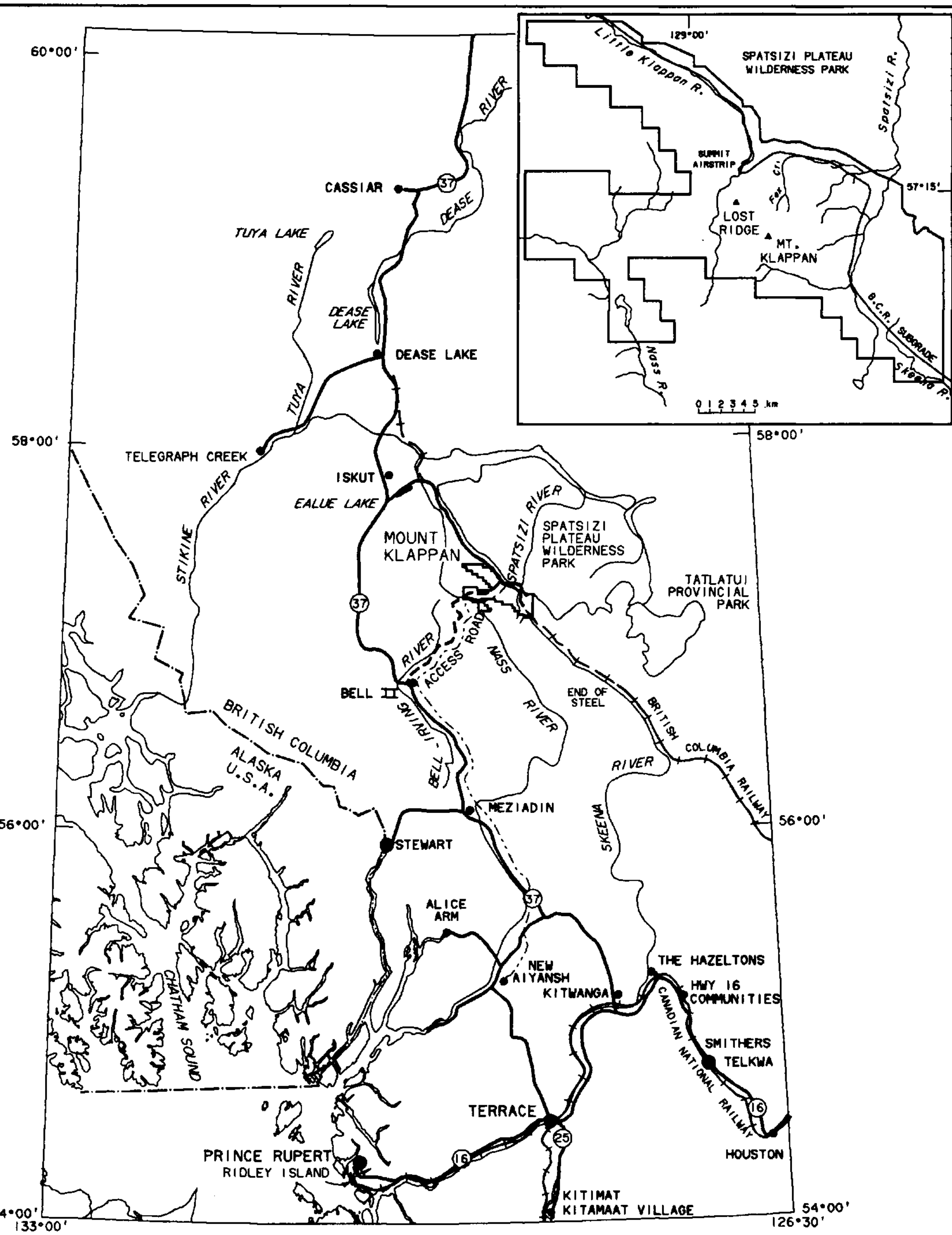
The property is immediately southwest of the Spatsizi Plateau Wilderness Park. Topographically, the area is characterized by several broad valleys of about 1000 metre elevation with surrounding ridge tops rising to over 2200 metres.

The area is within the northern portion of the Skeena Mountains physiographic region which is characterized by mountainous terrain with ridges trending northwest to southeast separated by the valleys and plateaus. Different portions of the property are drained by the Little Klappan, Klappan, Nass, Skeena and Spatisizi river systems. The tree line in the area is at approximately 1500 metres elevation. Valley bottoms tend to be covered with scattered stands of coniferous trees, grasses, bogs, shrubs and meadow. Higher elevations are characterized by alpine vegetation such as lichen, mosses and sparse grasses or exposed, barren rock.

The partially completed British Columbia Railway line between Prince George and Dease Lake runs through the property and the rail subgrade presently provides road access to the site from Highway 37 near Iskut.

2.2 PROJECT DEVELOPMENT PLAN

Six years of exploration work by Gulf Canada at Mount Klappan have identified a potentially economic mine reserve in the Lost-Fox Area near the



SCALE 0 20 40 60 80 100 km

LEGEND

- EXISTING ROAD ACCESS
- PROPOSED ROAD ACCESS
- TRANSMISSION LINE
- EXISTING RAILWAY
- EXISTING RAILWAY SUBGRADE
- MOUNT KLAPPAN LICENCE AREA

FIGURE 1-1

MOUNT KLAPPAN ANTHRACITE PROJECT

LOCATION MAP

GULF CANADA CORPORATION

GULF CANADA CORPORATION
21/01/87
KLAP:[205057]87000B011.LOC

centre of the property. Gulf proposes to develop the so-called Lost-Fox Mine at this site to extract and process anthracite products.

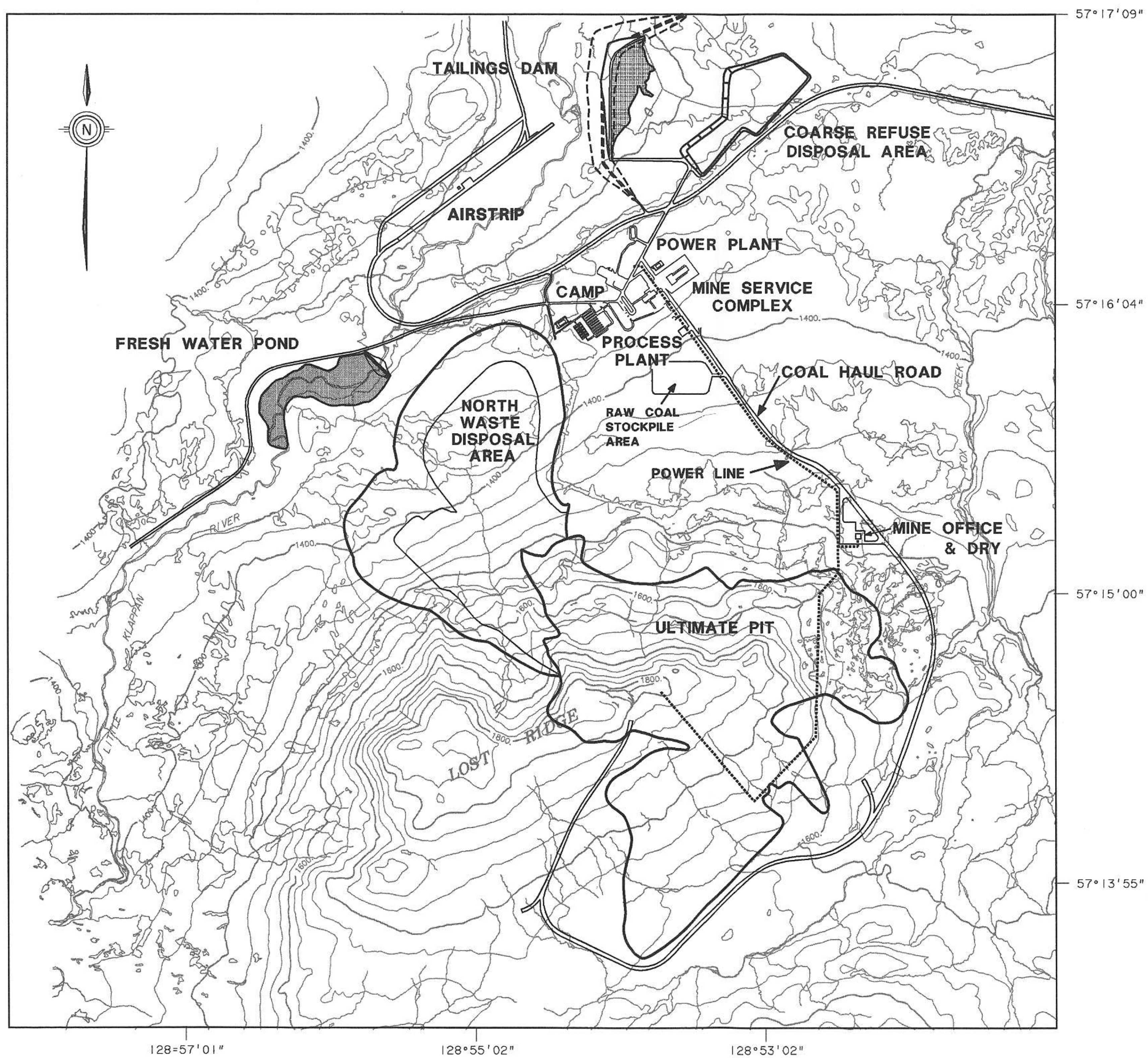
Mine facilities planning has been predicated on a shipping rate of 1.5 million tonnes of anthracite product per year over the planned 20 year life of the mine for a total of 30.0 million tonnes. Approximately 315 million cubic metres of material will be excavated from the mine.

Mining of this resource will require development of an open pit with related facilities, a waste rock disposal area, a haul road from the mine to the plant area, an anthracite preparation plant and site infrastructure facilities. Off-site developments include a new access road from the project site to Highway 37, a new or improved ship loading terminal in Stewart and possibly a new electric transmission line from New Aiyansh north of Terrace.

The mine area will encompass much of the eastern portion of Lost Ridge, a prominent topographical feature in the area. Waste rock will be disposed of in an area immediately northwest of the mine covering the northwest flank of Lost Ridge. Total disturbed area in the mine will be about 400 hectares and the waste rock disposal area will ultimately cover another 365 hectares. The total area disturbed will be about 1 000 hectares.

The anthracite haul road will exit the pit area towards the south down the gentler sloping side of Lost Ridge before turning north towards the preparation plant area. Figure 1-2 illustrates the general layout of project site facilities.

The anthracite preparation plant will be located north of the mine area. Trucks will place run-of mine anthracite in a receiving hopper which feeds anthracite washing and beneficiation circuits in the plant. Coarse refuse from the processing plant will be dewatered and trucked to the coarse refuse disposal area north of the plant site or to the tailings dam for use as additional fill material.



SCALE

0 1000 2000 m

CONTOUR INTERVAL = 25 METRES

FIGURE 1-2

MOUNT KLAPPAN ANTHRACITE PROJECT

PLAN OF PROJECT FACILITIES

KILBORN ENGINEERING (B.C.) LTD.

GULF CANADA CORPORATION
11/12/86
KLAP:[205057]860601028.LOC

Process water containing fine anthracite and mineral particles will be discharged via pipeline to a tailings pond immediately west of the coarse refuse disposal area. Water will be reclaimed from the pond and recycled for use in the plant.

Two alternative power sources are currently under consideration for the Mount Klappan project. One option would entail construction of a 280 kilometre 138 kV overhead transmission line from a connection with the B.C. Hydro grid at New Aiyansh north of Terrace. The other alternative is an on-site 15 MW thermal generating plant. The boiler for this plant would be the best available technology for sulphur and nitrogen emission control. It would be of the circulating fluidized bed combustion design and would burn, high ash reject anthracite from the process plant. Power from either source will be stepped down at an on-site substation and distributed to the pit area and all other site facilities requiring power.

A mine office and dry facility will be located adjacent to the haul road and northeast of the pit area. A mine service complex will be located at the plant site and will include facilities for heavy equipment repair, work shops, maintenance and administrative offices, dry facilities for maintenance crews, warehouse and laboratory. The gatehouse complex will house security and first-aid personnol as well as tho fire truck and ambulance.

The mine workforce will be recruited from or will settle in existing communities in northwestern British Columbia. Bus transportation to the mine site will be provided for work crews which will be scheduled on a 12-hour shift, 7 days on, 7 days off basis. A 442 man camp with catering, recreation and entertainment facilities will accommodate the two shifts that will be at the site.

Two options are under consideration for the supply of process, fire and potable water. The first would involve construction of a small dam on the Little Klappan River to form a reservoir about 1.5 kilometres west of the plant complex. The second option would be an infiltration gallery intake which would also be supplied by the Little Klappan River.

Some of the existing roads and the airstrip will be upgraded during the construction phase of the work. Other roads will be constructed around the mine site area to provide access to the various facilities.

Estimated total operations workforce will be about 680. Of these, 235 will be engaged in the truck haul operations between the mine site and Stewart and port operations in Stewart. Pit operations will require 70 workers per shift and another 30 per shift will work at the plant complex, maintenance facilities and camp. Two shifts will be on site at all times such that the normal complement at the mine site during operation will be up to about 240 including management and staff personnel.

Assuming receipt of approval-in-principle for this project in the Spring of 1987, the conclusion of long term contracts, and a decision to proceed by Gulf's Board, the project could be in full operation by the beginning of 1989. The construction period will span about 18 months.

PART TWO - ATMOSPHERIC ENVIRONMENT

FIGURES

TABLES

PART TWO - ATMOSPHERIC ENVIRONMENT

1.0 INTRODUCTION

Climatological data is available for the mine development area beginning in 1979. A meteorological station was established at Didene Creek in that year by the Ministry of Environment and was operated by B.C. Hydro until October, 1984. This data is summarized in the Stage I submission.

Preliminary air quality data was collected by Gulf in 1984. This data indicated that the air shed of the area is of generally pristine quality.

The atmospheric program was continued in 1985 and 1986 to answer, in part, requirements identified by the Mine Development Steering Committee in the Stage I review comments. The program was designed to continue characterization of the pre-operational quality of the air shed and to predict air quality impacts as a result of project developments.

The Didene weather station was reactivated in 1985. In addition to temperature, precipitation, snow pack, and wind speed and direction data, meteorological data required for dispersion modelling was collected. A dustfall monitoring network was also established.

2.0 CLIMATE

2.1 METEOROLOGICAL PROGRAM

The existing Didene meteorological station owned by the Ministry of Environment was reactivated in June, 1985. Instrumentation was supplied and installed by the Ministry of Environment for measuring temperature, total precipitation, wind speed and direction, and snowpack. Gulf provided the servicing and chart changing for this station with charts changed monthly.

Instrumentation required to collect meteorological data for dispersion modelling was installed in June 1985 on the same tower as the Ministry of Environment's meteorological equipment. The equipment installed consisted of an anemometer and vane for recording horizontal winds at 10 m above ground; a propeller anemometer for recording vertical winds at 10 m above ground; a micrologger for data processing and storage; and a solar panel for the power source.

An expanded snowpack monitoring network was established for the winter of 1985-1986.

2.2 TEMPERATURE

Temperature data are presented for the 15 months commencing June 1, 1985 (Table 2-1). These observations supplement the data presented in the Stage I submission.

Mean daily temperatures during 1985 were cooler in the summer months and warmer in the winter months when compared to the previous data. The notable exception was November 1985. The mean daily temperatures for this month represent the coldest monthly average temperature reported at the Didene weather station since data collection commenced. November 1985, in Western Canada was an extremely cold month with many stations reporting record or near record low temperatures. The November data can be inter-

Table 2-1

METEOROLOGICAL DATA
TEMPERATURE AND PRECIPITATION

Year/Month	Mean Daily Temperature (^oC) Max	Mean	Min	Extreme (^oC) Max	Min	Total (mm) Precipitation
1985						
06 (26 d)	10.5	5.3	0.0	19.8	-5.8	16.0
07	15.1	8.2	1.3	24.1	-3.0	68.0
08	12.5	6.6	0.7	19.6	-4.5	27.5
09	8.7	3.6	-1.5	17.2	-11.0	50.5
10	a	a	a	a	a	37.0
11 (22 d)	-16.3	-20.9	-25.6	-2.0	-40.7	7.5
12	-4.5	-8.1	-11.6	4.0	-29.5	16.0
1986						
01	-5.8	-9.5	-13.3	1.6	-22.2	8.5
02	-9.3	-14.9	-20.4	2.0	-44.7	5.5
03 (12 d)	-1.3	-4.5	-7.6	2.7	-12.0	17.0 (31 d)
04	a	a	a	a	a	19.0 (31 d)
05	a	a	a	a	a	28.5 (31 d)
06 (15 d)	12.9	7.1	1.2	19.8	-3.5	13.5 (31 d)
07 (16 d)	14.3	8.4	2.6	21.1	-1.6	41.5 (31 d)
08 (16 d)	a	a	a	a	a	15.5

a Data missing

(15d) Number of days for which records were available when the number of days was less than all days in the month.

Data analyzed by Ministry of Environment preted as near the extreme low monthly mean temperature that can be expected for the area. A record daily low of -44.7^{o}C was recorded in February, 1986. This is 3.7 Celsius degrees colder than the previous recorded low.

In general, the 15 months of additional temperature data reinforce the pattern observed in the Stage I data. This pattern indicates a temperature regime which is cool year round with the influence of the Pacific air mass serving to moderate the extremes of temperature observed further inland. As a result, the summers are not as hot and the inversions of cold, dry air from the Arctic are less frequent. Mean temperatures during the summer are expected to be between 6^{o} and 10^{o}C and winter daily means will generally be in the -5^{o} to -20^{o}C range. Such a temperature regime is very suitable for mining operations.

2.3 PRECIPITATION

Monthly precipitation data are also presented in Table 2-1. Comparing the results to previous years indicates that the June through October total precipitation values are similar to the historical data. The November through March data indicate a lower than average total precipitation. This result is confirmed by the snowpack value of only 99 cm obtained in March 1986 at the Didene weather station. Total precipitation for the year June 1985 to May 1986 was only 301 mm which is below the range established for the preceding five years of between about 350 mm to 500 mm. Normal precipitation patterns would generally result in a total of about 400 mm per year with over half of this amount falling as rain in the summer and early fall. The remainder is in the form of snow and peak snowpack accumulations achieved by about March would be about 1.5 metres.

The records indicate that precipitation in the area is relatively modest and that much of the moisture in the Pacific air is removed in the costal ranges west of Mount Klappan. The moderate rainfall and relatively small snow accumulations will serve to make mining operations in this area relatively easy.

Snowpack data for four additional sites in the area are provided in Table 2-2. These values represent the first data on the overall snowfall regimes for the Klappan lease. The valley locations, as expected, had generally higher snowpack levels. The data confirm the information presented in Stage I.

2.4 WIND SPEED AND DIRECTION

Additional wind speed and direction data were collected for 14 months between July, 1985 and August, 1986. This additional program expanded the existing 38 month data base considerably. Table 2-3 provides a revised monthly breakdown of wind frequencies that includes all of the data collected at Didene. The new data does not appreciably change the initial wind rose patterns. On a yearly base, 50 percent of the winds are from the east-southeast and 30 percent from the west-southwest. Average wind speeds are very similar but a new peak hourly wind of 51.6 km/h was observed in August 1986. This peak hourly value is 10.0 km/h greater than the previous peak.

Table 2-2

SNOW PACK

	Snow Depth (cm)						
	1985				1986		
	Sep 9	**Oct 22.**	**Nov 28**	**Dec 18**	**Jan 14**	**Feb 10**	**Mar 11**
Klappan Camp[a]	0	40	55	55	88	92	116
Little Klappan River[a]	0	28	38	40	40	50	56
Lost Fox Ridge[a]	0	24	31	29	44	52	74
Upper Spatsizi[a]	0	40	48	53	66	76	93
Didene Weather Station[b]	-	32	38	47	62	78	99

a Snow depth is the average of two snow stakes.

b Snow depth is the average of five swow stakes.

Table 2-3

% WIND FREQUENCY AND MEAN MONTHLY SPEED
JULY 1, 1979 - AUGUST 31, 1982 AND JUNE 1, 1986 - AUGUST 16, 1986

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
N	1.2	1.8	2.2	2.1	3.0	3.2	2.8	2.7	4.6	2.4	3.2	2.1	2.6
NE	5.4	9.3	7.4	7.1	10.5	10.2	6.7	8.7	6.1	4.1	7.3	5.4	7.4
E	45.8	42.8	39.4	38.6	29.9	21.4	11.9	18.3	33.0	43.9	49.8	38.9	34.5
SE	26.6	22.9	19.2	16.2	10.6	6.2	4.9	6.5	12.2	16.0	19.8	29.0	15.8
S	1.3	3.3	3.2	4.5	3.9	4.4	2.7	2.2	2.8	3.0	2.2	2.1	3.0
SW	7.4	4.6	10.0	13.0	16.3	23.1	25.2	19.9	15.3	13.7	4.7	7.8	13.4
W	6.6	8.0	15.0	14.4	21.5	22.4	30.0	26.1	16.0	12.1	8.6	7.4	15.7
NW	5.3	7.2	3.6	4.0	4.5	9.0	15.8	15.6	10.0	4.8	4.3	7.0	7.5
Calm	.6	.1	0	0	0	0	0	0	0.1	0	0.3	0.1	0.1

MEAN WIND SPEED IN KILOMETRES/HOUR

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
ALL DIRECTIONS	12.6	11.7	11.0	12.1	9.4	10.8	11.2	10.0	10.2	10.4	11.9	10.5	11.0
MAXIMUM HOURLY SPEED	40.8 E	37.8 SW	40.5[a] W	38.0 W	33.8 W	32.0[a] W	33.0[a] W	51.6[a] W	37.5 W	36.3 SW	39.5[a] NE	38.3[a] SE	51.6[a] W

[a] Maximum occurred in 1985-1986 program.

2.5 DIFFUSION PARAMETERS

The collection of specific meteorological data for use in the modelling of the dispersion of emissions commenced in June, 1985. The data collected included wind speed (in both the horizontal and vertical planes), wind direction and turbulence. Data was collected from June, 1985 until September, 1985 and February, 1986 to September, 1986. Problems with the data logger electronics resulted in unreliable or no data during October through February.

Turbulence is actually a derived measurement sinoe it is calculated as the standard deviation of the vertical wind velocity divided by the standard deviation of the horizontal wind velocity. Under this construct, as the variability of vertical speed increases for a given horizontal wind speed, it can be said that turbulence also increases. Atmospheric turbulence is an important factor in determining how rapidly pollutant emissions are dispersed.

Based on the influence of vertical wind speed velocities, a seasonal distribution of stability classes was calculated as provided in Table 2-4. This analysis indicates that there is a high frequency (approximately 60 percent) of Classes D and E year round suggesting only slight instability during these periods. During the winter and spring seasons, a high frequency (approximately 26 percent) of Stability Class F was observed. This fact probably suggests that temperature inversions are reducing vertical wind conditions at this time of year. However, it should be noted that average horizontal wind velocities during the winter and spring generally exceed the annual average wind velocity. During the summer and fall, a high frequency (31 to 39%) of Classes A, B and C representing generally unstable conditions was observed.

These stability classifications and frequencies are utilized in the air emission dispersion models discussed in Section 3.2 in order to predict ambient levels of SO_2 and NO_x emissions in the vicinity of the Mount Klappan project.

TABLE 2-4

SEASONAL DISTRIBUTION OF
STABILITY CLASSES
(Percent of Observations in Each Class)

Stability Class

Season	A Extremely Unstable >0.12*	B 0.12-0.09*	C 0.09-0.07*	D 0.07-0.04*	E 0.04-0.03*	F Stable <0.03*
June-August 1985	19	8	12	34	21	6
September 1985	10	7	14	32	31	6
February 1986	1	3	9	26	37	24
March-May 1986	4	5	10	25	28	28

Data: Promet Meteorological Instruments installed at the Didene weather station.

*Note: Stability classes are defined by the quotient of standard deviation of vertical speed over horizontal speed.

3.0 AIR QUALITY

3.1 DUSTFALL

3.1.1 Dustfall Monitoring Network

A dustfall monitoring network consisting of five stations was established in June, 1985. It replaced the four station 1984 network in order that the monitoring better reflect the potential areas of development. The Little Klappan station was relocated at a point approximately two kilometres northwest of the proposed plant site. The Upper Spatsizi station is located near the Hobbit Pit area and represents the easternmost station. A station was established south of Lost Ridge near the mining area. Additional stations were maintained at the Gulf Klappan Camp and at the Didene Weather station. The dustfall stations were changed periodically throughout 1985 and 1986. Results were adjusted to provide daily dustfall levels.

The results (Table 2-5) indicate low total dustfall values for most of the monitoring area. Readings at Lost Ridge and Upper Spatsizi indicate very little dustfall and are indicative of a pristine environment. Readings at the three remaining stations are generally also low with only the occasional high values. One reading collected at the Didene Weather station representing approximately 50 days in the summer of 1986 was equal to the B.C. Pollution Control Objective of 1.7 $mg/dm^2.d$. This reading was surprising because there was no intense activity near the station during this period. The following period, August 4 - September 24, encompassed much more activity since the trial cargo and associated truck movements were occurring at this time. Yet, the dustfall readings are substantially lower. The expected seasonal trend was evident from the data with the June through October time period having the higher values. Overall background levels are in the 0.01 to 0.3 $mg/dm^2.d$ range in the winter and 0.1 to 1.0 $mg/dm^2.d$ range in the summer.

Table 2-5

TOTAL DUSTFALL ($mg/dm^2.d$)*
MOUNT KLAPPAN BASELINE MONITORING, JUNE 1, 1985 - SEPTEMBER 24, 1986

	Jun 1- Jul 4	Jul 4- Aug 1	Aug 1- Sep 15	Sep 15- Oct 23	Oct 23- Nov 27	Nov 27- Dec 17	Jan 16- Feb 12	Feb 12- Mar 12	Jun 16- Aug 6	Aug 4- Sep 24
Klappan Camp	1.32	0.58	1.37	0.28	0.24	0.07	0.18	0.24	0.18	1.15
Little Klappan River	0.65	0.55	0.80	0.27	ND	0.01	0.34	0.33	0.13	1.30
Lost Fox Ridge	0.02	0.08	0.05	ND	0.04	0.02	0.21	0.20	0.03	0.09
Upper Spatsizi	0.09	0.04	0.06	ND	ND	ND	0.04	0.05	0.13	0.12
Didene Weather Station	0.06	0.28	0.16	ND	ND	ND	0.38	0.40	1.70	0.24

ND - Not Detectable
* - milligrams per square decimeter per day

Objective: 1.7 $mg/dm^2.d$ (Pollution Control Board 1979).

3.1.2 Fugitive Dust

Fugitive dust emissions will result from both construction and operational activities. During construction, both earthmoving activities and vehicle movement, can result in high localized concentrations and of particulates. Control measures, such as water spraying, and the short term nature of the construction activity will limit the impact on the atmospheric environment.

Dust sources during the operational phase will be from drilling, blasting, material movement, and vehicle movement during mining; from vehicle movement on the roads; from tho handling of anthracite at the anthracite preparation plant and the power plant; and from the handling of coarse reject anthracite and powerplant ash. These activities could produce high particulate concentrations in the immediate vicinity of the plant.

Specific measures to control fugitive dust are addressed in Volume II, Part VI, Environmental Management. These measures include water sprays, vehicle covers, enclosed conveyors and baghouses. These measures are expected to reduce the ambient air concentration of particulates to below the B.C. Pollution Control Objective of 1.7 $mg/dm^2.d$ within a very short distance from the activity site. Analysis compiled for the Hat Creek Project (B.C. Hydro, 1981) predicts that dust fall levels from that project's activities, which included coal blending, would fall below the objective within 500 metres of the dust source.

The scale of operation proposed for Mount Klappan should result in impacts on the ambient air quality from dustfall that would be much lower.

3.2 AIR EMISSIONS

3.2.1 Introduction

In the Stage I submission reference was made to the potential use of on-site generation of electricity to meet the power requirements of the mining development. It was proposed that a thermal generating plant, burning reject anthracite in a circulating fluidized bed burner, would provide the required electricity, while meeting the B.C. Pollution Control Objectives for atmospheric emissions.

In the Stage I review comments, prepared by the Mine Development Steering Committee, the nature and impacts of emissions from the proposed power plant were identified as a concern. In particular, the possibility of using high ash reject anthracite as a fuel in a circulating fluidized bed burner, the quantity and quality of the anticipated emissions, and the dispersion of these emissions required assessment.

The feasibility of using the high ash reject anthracite is addressed in Volume II, Part V, Infrastructure; the quantity and quality of the air emissions from the powerplant and the impacts on the atmospheric environment are addressed below.

The assessment approach was to predict stack emissions from the power plant on the basis of a trial burn of coarse reject anthracite in a fluidized burner test facility, to use mathematical models to estimate the dispersion of the emissions and the effects on the ambient air quality, and to compare these effects with the B.C. Pollution Control Objectives.

3.2.2 Test Burn Results

The principal components of the stack emissions which are of concern from an environmental impact standpoint are sulphur dioxide, nitrogen oxides and particulates. As was noted in the description of the circulating fluidized bed combustion test program found in Volume II, Part Five, a key objective of the experiment involved identification of operating parameters which would help control air emissions and obtain empirical data on the characteristics of the emissions.

As was expected, a key finding of the test program was that the proposed power plant design and operating parameters inherently produce much lower levels of air emissions than would be expected in a conventional power plant. The principal factors contributing to this effect are as follows:

- Stable combustion is achieved at about 850°C which retards NO_x formation when compared with conventional boilers operating at over 1600°C.

- Calcium inherent to the ash content of the fuel along with supplemental limestone effectively captures 75% of the sulphur in the fuel. The sulphur is then removed as CaS with the ash.

- Hot cyclones remove much of the coarser particulate matter entrained in the combustion gases and baghouses capture most of the fine particulate matter exhausted with the flue gases.

The stack emissions resulting from the test burn program are summarized in Table 2-6. These emission levels are compared with the British Columbia Pollution Control Objectives and the burner manufacturer's guaranteed performance specification.

It was determined that a calcium:sulphur ratio of about 75 percent was required to meet the objective and the calcium in the ash and limestone was very effective in reducing sulphur emissions. Nitrogen oxide emissions were consistently less than 20 percent of the most stringent objective. Particulate emissions are predicted to be less than the objective on the basis of the baghouse specifications mass balance calculations from the test program and the manufacturer's experience with operational boilers.

The total volumes of pollutants associated with the power plant stack emissions are exceedingly small. SO_2 emissions are expected to be less than 0.6 tonnes per day which is equivalent to 0.3 tonnes of sulphur per day. Test burn results indicate that NO_x volumes are even less at about .35 tonnes per day. Although particulate volumes were not measured in the test program, performance of other similar facilities indicates that these levels will certainly be below the provincial objective. Even if particulates equal the objective, the total volume would be only about 75

Table 2-6

POWER PLANT STACK EMISSIONS

Component	B.C. Pollution Control Objective (mg/kJ)	Mount Klappan Test Burn Results (mg/kJ)	Mount Klappan Performance Specification[3]	
			(mg/kJ)	(kg/h)
SO_2	0.09-0.34	0.073-0.086[1]	0.09	25.7
NO_x	0.35-0.70	0.038-0.057	0.35	51.4
Particulates	0.01-0.04	- [2]	0.01	3.1

Notes:

1. Limestone added to bed material to achieve sulphur capture rate of 75-80 percent.
2. Particulate concentrations were not directly recorded in the test program.
3. Pyropower Corporation warrants that its commercial scale boilers will meet or exceed these performance specifications.

kg per day. Because the scale of the proposed plant is so small, the total emission volumes are also quite small. As such, the components such as CO, fluorides, trace metals and hydrocarbons are also expected to be quite minor.

To place these pollutant quantities in context, it should be noted that many industrial boiler installations common in B.C. and Western Canada generate volumes measured in terms many times those predicted for the Mount Klappan power plant. For example, the oil refineries in the Lower Mainland produce about 2.5 tonnes of sulphur daily. Prince George pulp mills release about 3.5 tonnes per day. Mills at Powell River and Port Alice average over 10 tonnes per day. The smelter at Trail is the largest source of sulphur emissions in B.C. at 32.5 tonnes.

The thermal power plant proposed by B.C. Hydro at Hat Creek was predicted to have sulphur emissions of about 75 tonnes per day. Sour gas treatment plants produce large volumes of sulphur as well. In Fort Nelson, the plant releases about 15 tonnes of sulphur per day while some of the larger plants in Alberta produce over 70 tonnes per day. The oil sands treatment plants at Fort McMurray, Alberta, generate over 400 tonnes per day.

Compared with any of these operations, the proposed power plant at Mount Klappan represents a very minor emission source and if it were not for the proximity of the Spatsizi Plateau Wilderness Park, further investigation and modelling of air emissions impacts would not have been warranted.

3.2.3 Air Emissions Dispersion Modelling

Despite the very low emission volumes indicated by the burn tests, a computer-assisted plume dispersion model was employed to predict possible environmental impacts on air quality in the Lost-Fox basin from power plant stack emissions. The model utilizes the data on flue gas composition as developed from the test burn activities previously described. It then incorporates meteorological data and topographic parameters to predict the concentration of pollutants at ground level where these are significant. For this study the primary pollutants of concern were SO_2 and NO_x.

The power plant would be sited between the anthracite preparation plant and the tailings pond, adjacent to the BCR grade. The site lies in the valley of the Little Klappan River. Ridges rise 500 to 600 metres above the site elevation at 3 km to the southeast and 4 km to the northwest. The valley rises to the southwest, and descends to the northeast, turning to the northwest about 1 km from the plant. There is a pass leading into the eastward flowing Didene Creek valley about 3 km to the east-northeast of the plant. This terrain feature is only about 50 m above plant elevation. The steepest slopes in the area are about 25 degrees on Lost Ridge, 3 km south of the plant. The terrain beyond the immediate valley is rugged. The large scale topography is mountainous in all directions, so considerable mechanical turbulence occurs when it is windy. This turbulence enhances the dispersion as compared to a smoother area.

Besides topography, there are a number of climate and meteorological factors that will influence air emission dispersion at the project site. The most noteworthy weather feature of this area is the occurrence of light winds. Shaw et al (1972) found that persistent light winds in Canada occur most frequently in northern British Columbia.

Local wind flows are associated with the daily cycle of heating and cooling of the ground. At night under clear skies, the ground radiates heat. The air near the ground cools, becomes denser and thus tends to flow down hill. Strong drainage winds have been observed on several occasions at the Didene weather station. A return, cross-valley flow of air occurs at higher elevations to replace the air flowing down the slope. Pollutants emitted at this height may impinge on the slopes in a narrow band. This phenomenon was first reported by Dean and Swain in 1944 based on studies of the smelter emissions at Trail and is evident from the pattern of vegetation in that area.

In winter, temperature inversion layers often occur several hundred metres above the valley floor. This happens when mild Pacific air overruns colder air in the valley. The inversions can trap pollutants which are emitted into the cold surface layer of air.

Mechanical turbulence is caused by the air moving over the terrain features. This turbulence is characterized by larger unsteadiness of the wind than would occur in the absence of the rough terrain. Hanna et al (1982) describe observations of 60 to 160 percent increases in horizontal wind fluctuations due to these effects. Because of this greater variability of the wind, effluents emitted into the air will disperse faster.

Another phenomenon is associated with the turbulent component along the mean wind direction. The along-wind turbulence is much greater than over flat terrain. This can cause the initial plume rise from the stack to pulsate as lulls in the wind are followed by strong eddies. The variation in plume rise causes the plume to be dispersed through a deeper layer.

A second factor which enhances dispersion is wind direction/shear, that is the change of wind direction with height. There are often large changes of direction in the vertical as the along-valley wind adjusts to the winds above the terrain. This effect causes an emission plume to turn as it rises from the chimney and to spread out more in the horizontal than it would without wind shear.

The trajectory of a plume can be affected by the airflow over steep topographic features resulting in a phenomenon known as topographic downwash. The emissions can be trapped in an eddy to the lee of the steep slope, or brought to the ground in the descending airflow. The terrain is gently sloping within 3 km (100 stack heights) of the plant site with a typical slope of only 4^{0}. As such, a lee eddy problem is not possible.

Strong downward air motions have been observed a few times at the site. For example, on the night of 3-4 June 1986, vertical velocities of up to -0.5 m/s were recorded. Winds of this magnitude could have a significant effect on plume elevation if they occur aloft and persist far enough downwind.

Drainage winds are downslope flows of colder, denser air. They usually are initiated by differentials in radiational cooling rates over large snow or ice fields as compared to the valley terrain. Depth of the drainage wind would typically be about 20 m based upon the formula given by Briggs (1979). This calculation method agrees within 25 percent with observations made at Woodfibre, British Columbia (Murray 1976). This depth is not sufficient to cause a downward motion of the plume. However, the drainage wind has an influence on dispersion, in that it causes a mixing of the valley air and consequent weakening of the nocturnal inversions (Munn 1964).

The plume could be trapped in an eddy to the lee of the plant building. If the source is high enough above the building however, the effluents will completely escape the building wake. The 60 m proposed stack height will be sufficient to avoid building effects.

The wind speed and stability of the atmosphere determine if the airflow goes around hills, or over them. Under stable, light wind conditions, a plume follows a horizontal trajectory, and tends to go around the terrain. When the air is unstable, or if winds are strong, the airflow tends to move over, and may impinge upon the terrain.

Horizontal plume spread can be restricted due to the valley walls in a deep, narrow valley. This effect can be modelled in the same way that the vertical restriction of dispersion by temperature inversions is modelled by the eddy reflection method (Harvey and Hamawl, 1986).

3.2.3.1 Description of Models

Given the wide range of phenomena that can influence plume dispersion, prediction of concentrations of air pollutants at various points in the area of a pollutant source can be an exceedingly complex undertaking. In general, the approach has been to use mathematical models which hold constant or make no allowance for several of the phenomena known to assist in dispersion. Factors such as along-wind turbulence, mechanical turbulence or wind shear are generally not given any weight in order to simplify the modelling task. This also results in more conservative predictions of dispersion.

Various modifications of the Gaussian model have been accepted as being the most appropriate tools for determining the long term effects of air emissions. After a review of the models available and discussions with Ministry of Environment staff, two models were selected for the Mount Klappan Project - the Promet Environmental Group Ltd. Gaussian "SSAQ" model and the U.S. Environmental Protection Agency "Valley" model. Each is discussed below:

Valley Model

VALLEY is one of the U.S. Environmental Protection Agency User's Network for Applied Modelling of Air Pollution (UNAMAP-5) series of dispersion models. It was originally developed to assess the effects of emissions from large copper smelters in complex terrain in the U.S. southwest. It was designed to give representative calculations of the effect of the emissions of an elevated terrain feature under stable, light wind conditions.

This scenario was judged to be the most important factor in determining the long term air quality.

VALLEY is a steady state Gaussian model which calculates pollutant concentrations from the emission characteristics of the source(s), and the frequencies of occurrence of meteorological conditions. The latter are described as an array of six stability classes, 16 wind directions, and six wind speeds. Results are produced at 112 receptor sites, that is at seven distances from the origin at each of the 16 compass points. The Pasquilli-Gifford vertical dispersion coefficients and Briggs (1975) plume rise equations are used. Plume height is adjusted based upon receptor elevation. A technical description of the model is given in the Valley Model User's Guide (Burt 1977).

SSAQ Model

The SSAQ model is also a modified Gaussian model which uses the frequency of meteorological classes, topographic heights, and emission conditions as inputs. The concentrations are calculated on a radial grid at 16 directions and at distances specified by the user. The Smith (1972) vertical dispersion coefficients and Brigg's (1975) plume rise equations are used. The Egan (1975) "half height" method is used to adjust plume height for topographical variations. Ground level concentrations were calculated using the approximation technique of Yarmartino (1977) for each dispersion class and grid point. Seasonal averages then were found by weighting the class concentrations by the number of hours of occurrence similar to the way Turner (1969) calculates long term concentrations. Annual values are calculated by averaging the four seasonal values.

3.2.3.2 Capability of Models

Neither of these models allows for increased dispersion due to along-wind turbulence, channelling, terrain downwash, or wind direction shear effects. SSAQ treats fumigations to the extent that the diurnal variation of mixing height is incorporated in the synthesis of mixing height statistics.. Terrain downwash may not be of concern as the depth of the drainage flow would appear to be below the physical stack height. The enhanced dispersion due to mechanical turbulence would be accounted for in both models by using the on-site turbulence data to select the dispersion classes. Both models treat plume impingement. The VALLEY Model limits how close the plume centerline can approach the terrain to 10 metres for stable atmospheric conditions, whereas with the Egan method used by SSAQ it can never get closer than half the difference in elevation between the stack base and the receptor point.

All mathematical models must incorporate certain simplifications in order to describe complex phenomena and the air dispersion models discussed here are no different. Certain factors must be held constant, or ignored, in order to isolate and predict the influence of more important variables of interest to the problem.

The result is that no model can perfectly predict the exact air quality parameters resulting from a point source in complex terrain. There will be sources of over-estimation and under-estimation of pollutant levels. On balance, the model is designed to over-estimate air emission concentrations but this result cannot be guaranteed.

VALLEY and SSAQ have similar limitations in describing dispersion from a point source over complex terrain. Both are modified Gaussion models developed for relatively flat valleys at limited distances from the source. Neither model makes allowances for potential increased dispersion mechanisms such as along-wind turbulence or wind direction shear at height. Near surface weather data may not be representative of conditions at and above stack height. Wind velocities would normally be greater at altitude and the spatial distribution of ground level concentrations could be quite different due te variation of wind direction with height.

The effect of vertical wind velocities on plume rise are also not treated. Concentrations may be under-estimated or over-estimated depending on the local conditions.

Straight line plume trajectories are used. The tendency of the plume to follow the valley and curved trajectories resulting from changes in wind directien between the source and the receptor point are not modelled. The result is that concentrations greater than would be likely are predicted for the valley slopes.

When the models predict that the plume centreline is above the mixing height at some distance from the source, then ground level concentrations are assumed to be zero beyond that point. This is a simplification which is not necessarily physically accurate since it is possible that some of the plume is below the mixing height such that there could be an influence on ground level concentrations.

The VALLEY model limits the dispersion coefficients arbitrarily after a certain downwind distance. Neither model specifically incorporates a horizontal limitation of dispersion by the valley walls although the VALLEY model does include mixing in the cross-valley direction by averaging over a 22.5^0 sector.

Trapping of pollutants by inversions is dealt with in the models by imposing mixing height limits derived from Portelli's (1979) mapping for northern British Columbia. The seasonal mixing heights provided on these small scale maps however do not account for local topographic effects. Diurnal variation of convective mixing height is simplified to two states - zero at right and the seasonal average for daytime. This may result in some under-estimation of concentrations in the early morning and evening, when the mixing height is actually between these levels. Over-estimation of concentrations would occur when the plume height is actually above the mixing height.

Mixing heights have an effect on maximum ground level concentrations only for a limited range of plume height (Csanady 1973). If the plume height is less than half the mixing height, the ground level concentrations will not be affected by a ceiling on vertical dispersion. If the plume is above the mixing height ceiling, ground level concentrations below the ceiling will be zero. Heins and Peters (1973) have estimated that the worst case effect of an inversion ceiling is a doubling of concentrations predicted for the no inversion case.

These characteristics of the models cause both positive and negative errors in the calculated concentrations. Empirical data on the accuracy of the VALLEY model indicates that model prediction agreement with actual observations varies from low by a factor of about two to high by a factor of six. Ratios of calculated to observed concentrations was reported to vary from 0.44 to 6.1 by Burt and Slater (1977). A similar level of accuracy has been found to apply to SSAQ. A standard error of 50 percent of the mean and correlation coefficient of 0.7 was found between SSAQ predicted values of annual averages and air monitoring results at six trailers in the Ram River area on the east slope of the Rocky Mountains over a 10 year period.

3.2.3.3 Input Data

Terrain Characteristics

The same input data were used with each model. Receptor sites were specified at 1 to 7 km from the source at 1 km intervals, in each of 16 directions. Elevations of the 112 receptor points are given in Table 2-7. These receptor points and the assigned elevations provide a topographic grid which will identify for the model where the plume will impinge on the ground.

Stability Classes

Stability classes, which have a significant effect on plume dispersion in the models, were calculated from wind data retrieved from the 10 metre tower near the proposed plant site. Stability class calculations were based on 360 samples of wind speed and direction each hour.

Two methods were utilized to describe the frequencies of stability classes.

1. Azimuth variability method of Mitchell and Timbre (1979).
2. Vertical velocity variability method.

The first methodology classifies stability according to the standard deviation of azimuth angle (direction). If there are frequent, large changes in wind direction, this method would classify the conditions as relatively unstable. At night, an empirical adjustment is applied to this method that limits the frequency of unstable conditions by assuming that much of the azimuth change is associated with nocturnal meandering of the wind rather than turbulent, unstable conditions. As a result of this assumption, all night time observations are placed in the more stable classes of D, E and F.

The vertical velocity method classifies stability in terms of standard deviation of vertical velocities relative to wind speeds. As changes in vertical velocities increase for a given wind speed, this method would describe the condition as increasingly unstable. This method uses a measure of atmospheric turbulence which is directly related to the vertical dispersion of effluents emitted to the atmosphere.

Stability classes are used to calculate the thickness and breadth of the plume at specified distances downwind of the power station. In stable atmospheric conditions, the plume is thinner and narrower and hence more concentrated. Consequently, higher ambient ground level concentrations will be realized where such a plume comes into contact with the ground. For relatively unstable conditions, the plume is thicker and more spread out and therefore concentrations are reduced at the point of ground contact. Increased concentrations will occur in a larger area however, because the plume is spatially more extensive.

These methods appear to provide relatively conservative estimates of stability which are somewhat at odds with the rough terrain and constant winds observed in the area. The first method assumes very little turbulence at night while the second method tends to describe high wind conditions as stable since the standard deviation of vertical velocity is divided by the horizontal velocity such that the quotient becomes a smaller number as wind speed increases.

Both dispersion models use Gifford's method to calculate long term concentrations (see Turner 1969). In this method the long term or seasonal concentration depends only on the vertical dispersion coefficient, and not at all on the horizontal one. Consequently, the selection of classes based on vertical velocity rather than azimuth is likely the better of the two.

No adjustment was made for the variation of stability class with height. This could be done if information were available about surface heat fluxes.

Table 2-7
MODEL RECEPTOR SITES
(Elevations in Feet Above Sea Level)

Distance from Source (km)

	Site Distance From Source (km)						
Direction	1	2	3	4	5	6	7
N	4232	4183	4183	4232	4364	5282	5676
NNE	4199	4199	4364	4790	5052	5052	5052
NE	4216	4331	4462	4757	4757	4757	4757
ENE	4314	4396	4413	4462	4495	4528	4724
E	4429	4495	4495	4495	4478	4396	4364
ESE	4478	4626	4757	4757	4839	4938	4938
SE	4495	4741	4970	4954	5003	5495	6266
SSE	4495	4856	5479	5545	5331	5692	6299
S	4511	4790	5479	5807	5495	5463	5266
SSW	4462	4590	4839	5020	4938	4905	4872
SW	4347	4593	4511	4495	4708	4774	4905
WSW	4380	4429	4774	4954	5036	5118	5184
W	4396	4495	4856	5217	5889	6496	6496
WNW	4429	4642	5167	5676	5840	5938	5938
NW	4462	4724	5167	5248	5348	5643	5299
NNW	4446	4495	4577	4429	4232	4035	4035

Ambient Temperature and Pressure

Seasonal average temperatures of -16.7, 1.1, 9.3 and 5.5°C observed at the weather station were used for winter, spring, summer and fall, respectively. A "standard atmosphere" pressure of 92.3 kP for the plant elevation of 1295 m was used regardless of season. The use of seasonal average and standard values has a negligible effect on the results as the models are relatively insensitive to these parameters.

Mixing Heights

Seasonal mean maximum daily mixing heights were abstracted from Portelli's (1979) mappings. Values of 300, 1500, 1800 and 700 m were used for the winter through fall seasons, for stability classes A through C. In the SSAQ model, a "mechanical" mixing height was calculated for each dispersion class as well. Mechanical mixing results from air movement over a rough surface and is a function of wind speed and roughness of the surface.

In SSAQ, for the unstable classes, the greater of the mechanical and seasonal average values was used for the calculation of concentrations in a particular dispersion class. The mechanical mixing height was used for the neutral and stable cases (D through F). Ground level concentrations were calculated using the approximation technique of Yamartino (1977). VALLEY uses the seasonal mixing heights for the unstable categories, but does not incorporate mechanical mixing heights.

Although greatly simplified, this treatment of the mixing height, together with the use of observed dispersion statistics allows for a simulation of the effect of the persistent winter time inversions which trap cold air in the valley.

Emission Data

Stack emission characteristics were devoloped from test burns of Mount Klappan refuse anthracite conducted on a pilot scale circulating fluidized bed combustion facility in San Diego, California. The test program was designed to demonstrate the feasibility of producing electric power from the high ash reject anthracite using this technology. The tests were also conducted to obtain key environmental data such as ash and air emission characteristics. Details of this test program are provided in Part Five of Volume II on Infrastructure.

The emission data used in the air dispersion calculations are provided in Table 2-8. The operating parameters associated with the point source data indicated in the table include the use of limestone to control SO_2 emissions.

The emission rates shown for sulphur dioxide and nitrogen oxides are the equivalent of the maximum output guaranteed by the manufacturer of the circulating fluidized bed boiler. These levels correspond to the lower limit of the B.C. Pollution Control Objectives. Actual test burn results indicate that SO_2 emissions would be less than the levels shown here and used in the dispersion modelling. Test burn NO_x levels were less than 20 percent of the concentration shown in Table 2-9 and used in the dispersion models. Not only do the emission levels used in the dispersion model exceed those indicated by the test turn, but they also represent the expected peak emissions when the plant is operating at full power. In actual practice, the emissions will be less because the boilers will not routinely and continuously be operated at peak output. Furthermore, it has been assumed in the dispersion modelling that the peak load emission rate shown in Table 2-8 is constant. This represents a worst case scenario for the simulation of ambient pollutant concentrations since it is assumed that the maximum pollutant load is discharged from the stack on a continuous basis.

3.2.3.4 Model Results

The results of the dispersion calculations are summarized in Table 2-9 for SO_2 and Table 2-10 for NO_x. VALLEY gives a maximum annual average sulphur

Table 2-8

DISPERSION MODEL

EMISSION SPECIFICATIONS

Emission Rate SO_2	7.1 g/s
Emission Rate NO_x	14.3 g/s
Physical Height of Stack	60.0 m
Effluent Temperature	138.0 ^oC
Effluent Velocity	30.0 m/s
Stack Diameter	1.346 m
Volumetric Flow Rate	42.7 m^3/s
Ground Elevation of Source	1295 m
Tree Distance	500 m
Tree Height	10 m

Base data provided by Pyropower Corporation.

dioxide concentration of 0.0026 to 0.003 parts per million volumetric (ppmv) on the slope 2 km west-northwest of the plant. The result from the SSAQ model is very similar - 0.0029 ppmv at 3 km in the same direction. Similar comparisons can be made for NO_x. The method for calculating stability classes had only a minor effect on the results.

The spatial variation of annual average SO_2 concentration calculated by VALLEY (Mitchell stability), VALLEY (stability from vertical velocity) and SSAQ (stability from vertical velocity) are shown in Figures 2-1 through 2-3 and for NO_x in Figure 2-4. Concentrations of SO_2 at the boundary of the Spatsizi Plateau Wilderness Park were calculated to be 0.0003 ppmv by the VALLEY Model and 0.0004 ppmv by SSAQ. These levels at the park boundary represent less than 5 percent of the British Columbia Level A ambient air quality guideline of 0.01 ppm as an annual average for sulphur dioxide. Furthermore, even the maximum annual average concentrations predicted to occur to the west-northwest of the power plant are only about 30 percent of British Columbia's strictest ambient air quality standard and these peak levels only affect an area of about 1 square kilometre. All other areas in the basin would have annual concentrations that are even lower.

3.2.3.5 Short-Term Concentration Calculations

The VALLEY and SSAQ models calculate annual average concentrations but do not deal with short term events which can result in much higher concentrations. Worst case short term concentrations of SO_2 have been calculated using the approach suggested by Hanna et al (1982).

The highest hourly concentration would require extremely stable and persistent atmospheric conditions such as would occur with light winds and a strong winter inversion ceiling which would limit vertical dispersion.

Table 2-9

SUMMARY OF DISPERSION MODEL RESULTS
FOR ANNUAL AVERAGE SO_2 CONCENTRATIONS

	VALLEY Model Mitchell Method	VALLEY Model wl Method	SSAQ Model wl Method
Maximum concentration (ppmv)	0.003	0.0026	0.0029
Sector with maximum	WNW	WNW	WNW
Distance to maximum (km)	2	2	3
Altitude of maximum (m ASL)	1460	1460	1575
Other sectors with concentration greater than 0.001 ppmv			SE
Maximum concentration at Park Boundary (ppmv)	0.0003	<0.0003	0.0004

Mitchell (1979) method of stability classification is based upon the standard deviation of azimuth angle of the wind. At night, an adjustment is made to the class based upon wind speed.

The w^1 method sorts according to the quotient of the standard deviation of vertical velocity (m/s) and the horizontal wind speed (m/s). Boundaries between classes are as follows:

A - B	0.12
B - C	0.09
C - D	0.07
D - E	0.04
E - F	0.03

Table 2-10

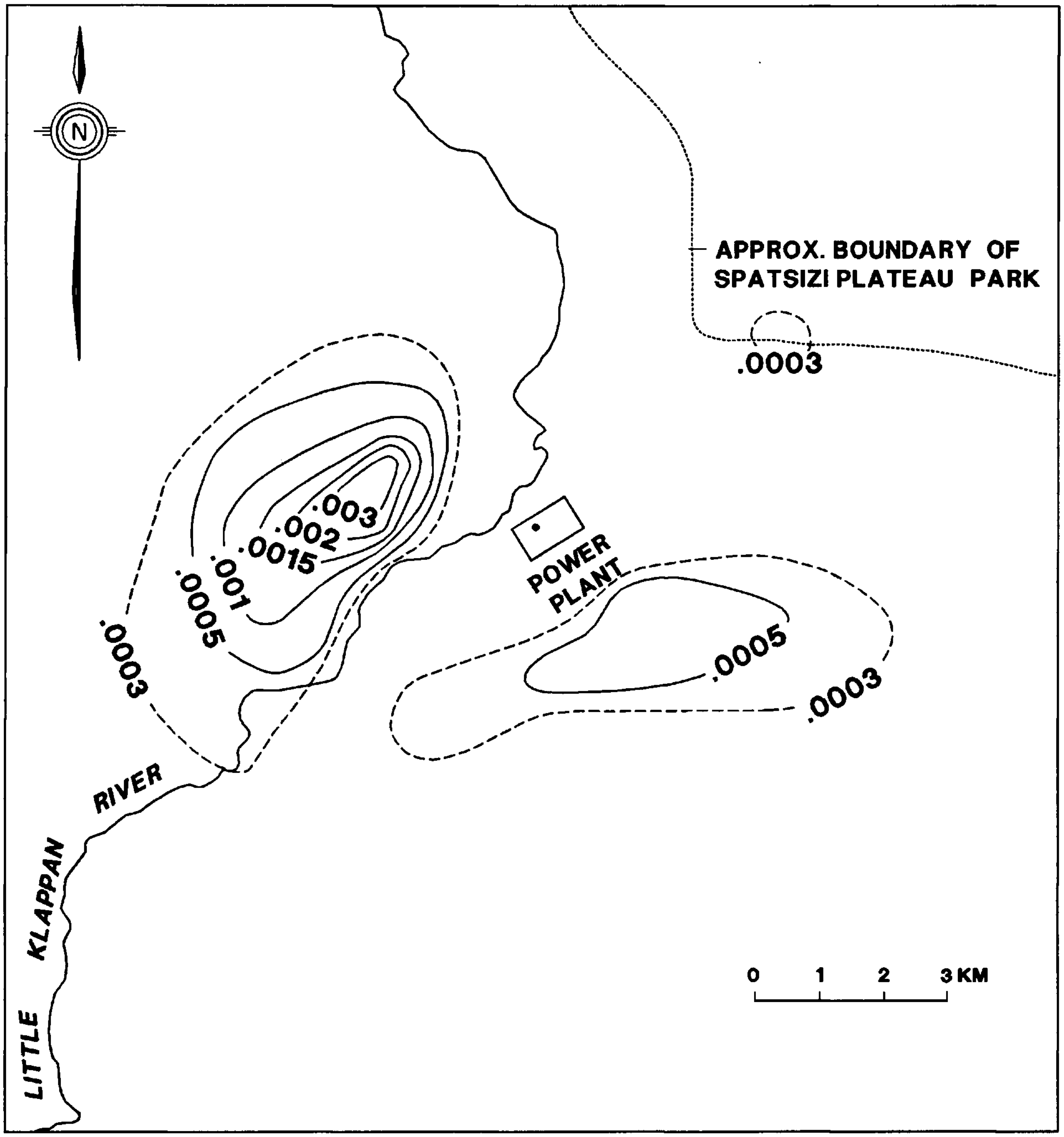
SUMMARY OF DISPERSION MODEL RESULTS FOR ANNUAL AVERAGE NO_x CONCENTRATIONS

	VALLEY Model Mitchell Method	VALLEY Model wl Method	SSAQ Model wl Method
Maximum concentration (ppmv)	0.0059	0.0052	0.0057
Sector with maximum	WNW	WNW	WNW
Distance to maximum (km)	2	2	3
Altitude of maximum (m ASL)	1460	1460	1575
Other sectors with concentration greater than 0.001 ppmv	SE, SSE		SE
Maximum concentration at Park Boundary (ppmv)	<0.001	<0.001	<0.001

Mitchell (1979) method of stability classification is based upon the standard deviation of azimuth angle of the wind. At night, an adjustment is made to the class based upon wind speed.

The w^1 method sorts according to the quotient of the standard deviation of vertical velocity (m/s) and the horizontal wind speed (m/s). Boundaries between classes are as follows:

A - B	0.12
B - C	0.09
C - D	0.07
D - E	0.04
E - F	0.03



NOTE:
STABILITY CLASSES WERE DETERMINED BY MITCHELL (1979) METHOD.

FIGURE 2-1

MOUNT KLAPPAN ANTHRACITE PROJECT

ANNUAL AVERAGE GROUND LEVEL CONCENTRATIONS OF SULPHUR DIOXIDE (ppmv) VALLEY MODEL.

ENVIRONMENTAL MANAGEMENT ASSOCIATES

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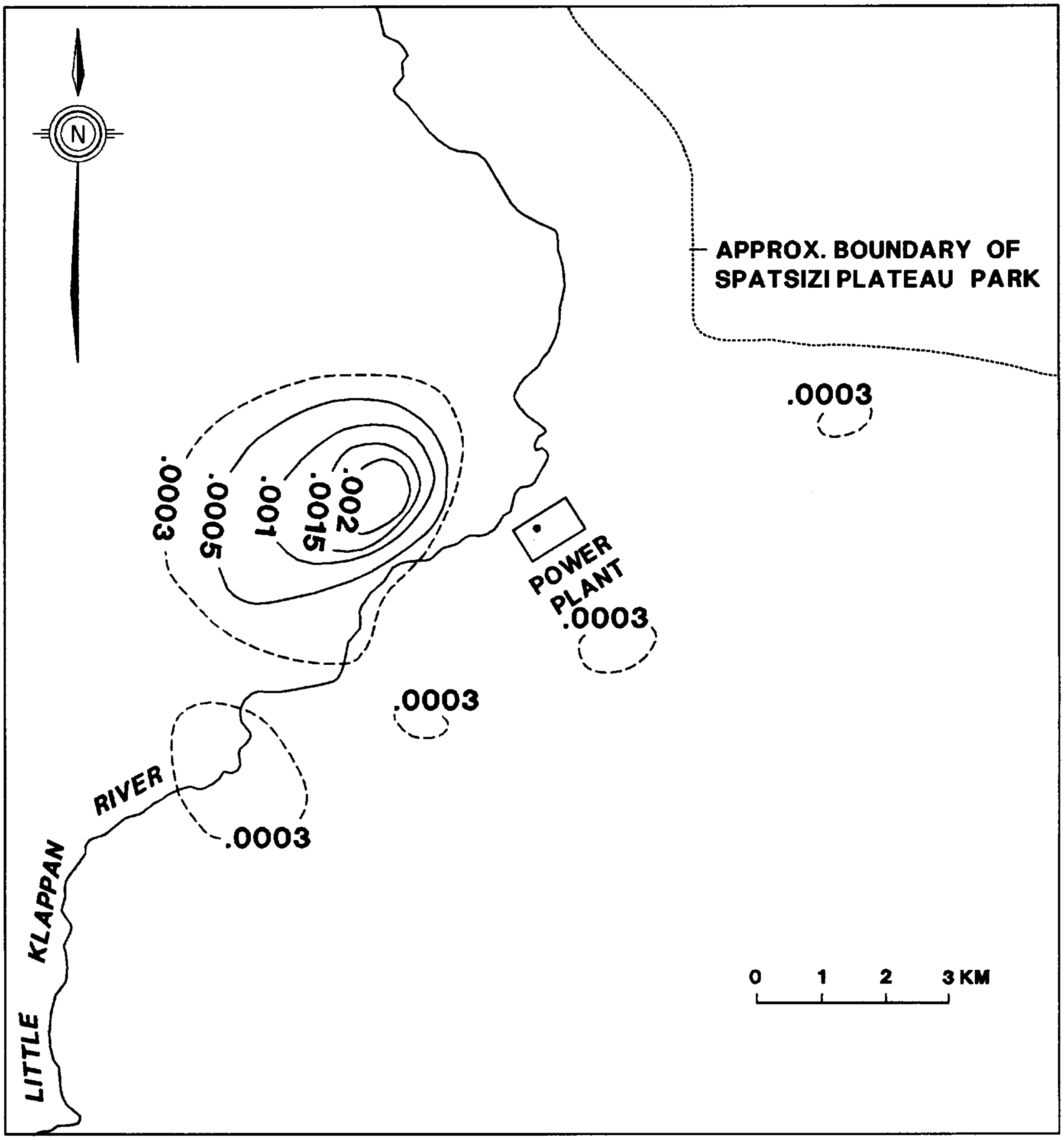

NOTE:
STABILITY CLASSES WERE DETERMINED FROM THE STANDARD DEVIATION OF VERTICAL VELOCITY.

FIGURE 2-2

MOUNT KLAPPAN ANTHRACITE PROJECT

ANNUAL AVERAGE GROUND LEVEL CONCENTRATIONS OF SULPHUR DIOXIDE (ppmv) VALLEY MODEL

ENVIRONMENTAL MANAGEMENT ASSOCIATES

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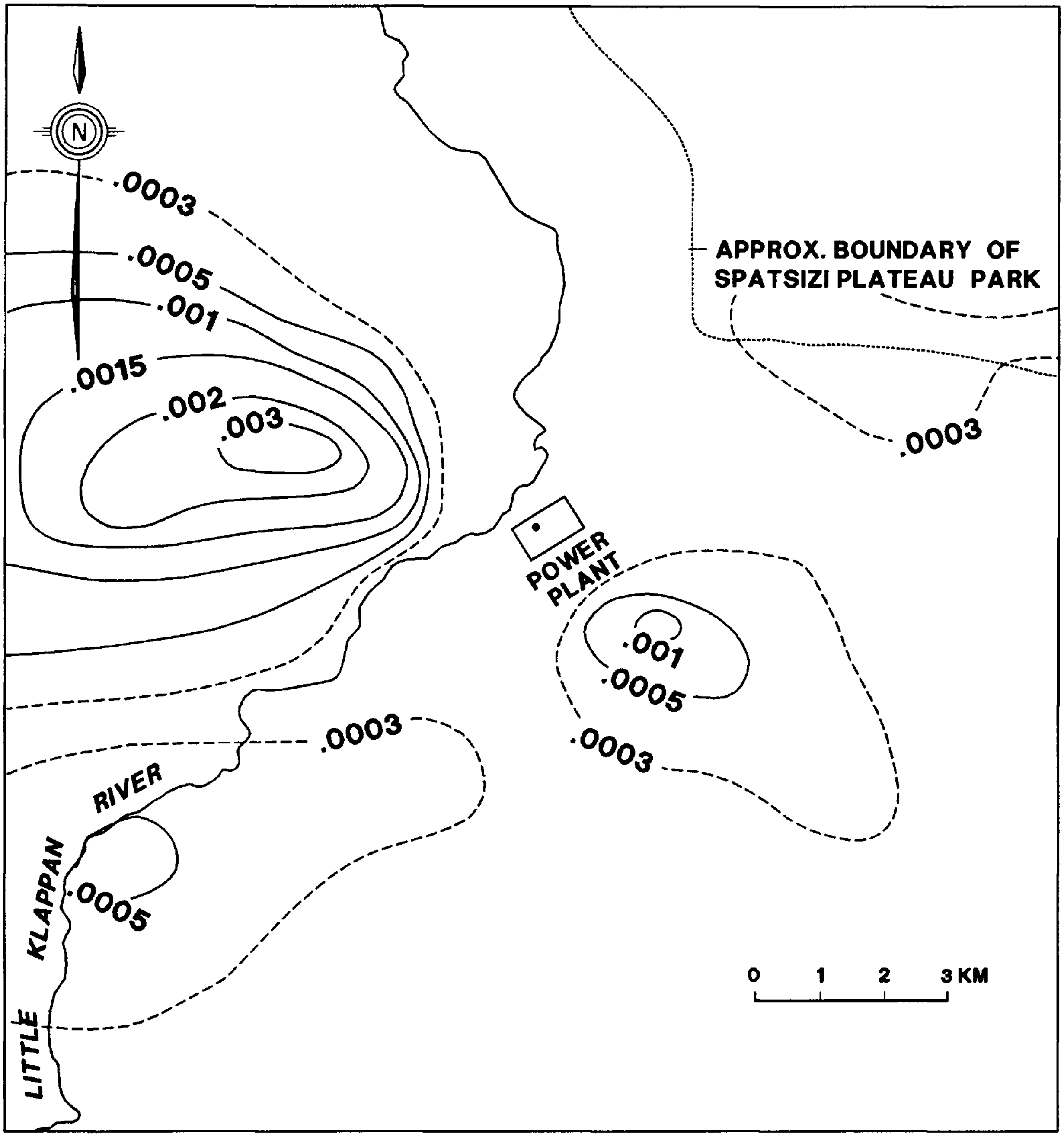

NOTE:
STABILITY CLASSES WERE DETERMINED FROM THE STANDARD DEVIATION OF VERTICAL VELOCITY.

FIGURE 2-3

MOUNT KLAPPAN ANTHRACITE PROJECT

ANNUAL AVERAGE GROUND LEVEL CONCENTRATIONS OF SULPHUR DIOXIDE (ppmv) SSAQ MODEL

ENVIRONMENTAL MANAGEMENT ASSOCIATES

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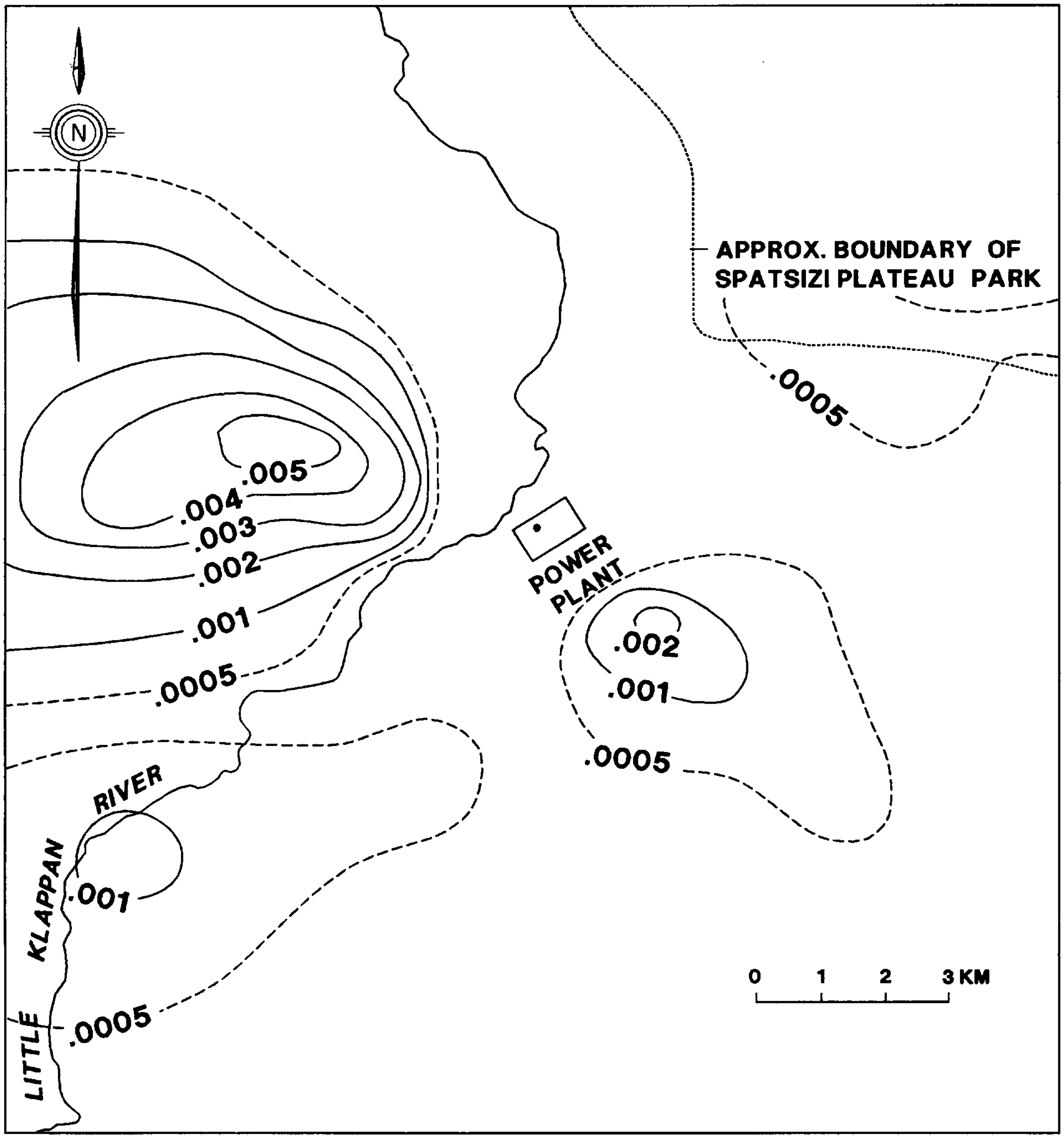

NOTE:
STABILITY CLASSES WERE DETERMINED FROM THE STANDARD DEVIATION OF VERTICAL VELOCITY.

FIGURE 2-4

MOUNT KLAPPAN ANTHRACITE PROJECT

ANNUAL AVERAGE GROUND LEVEL CONCENTRATIONS OF NITROGEN OXIDES (ppmv) SSAQ MODEL

ENVIRONMENTAL MANAGEMENT ASSOCIATES

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The plume is trapped below the inversion boundary in a very thin zone that spreads to fill the valley horizontally. Under very light wind conditions with horizontal dispersion enhanced by "meander" (Mitchell 1982), the plume could contact valley walls in a thin concentrated band. The Pasquill stability classes for this situation would be A for horizontal dispersion and F for vertical dispersion.

The highest concentrations would occur where the valley width is narrow enough such that the plume actually contacts the valley walls. The most likely scenario for all the necessary conditions would involve light or calm winds carrying the plume down the Little Klappan River valley. The plume would drift, generally following the river, and spreading horizontally. After a downwind travel distance of about 9500 metres, the plume will have dispersed horizontally sufficiently to impinge on the valley walls. This would occur at the narrowest point in the valley about 2000 metres southeast of where Conglomerate Creek flows into the Little Klappan River. The valley walls rise steeply on both sides of the river at this point. The high ground between Conglemerate Creek and Butler Creek inside the Spatsizi Plateau Wilderness Park is the northeastern wall of the valley at this point.

Hanna et al (1982) give a formula to calculate the concentration (C) on the valley sides at this point:

$$C = (2/\pi)^{1/2} \quad (Q/\delta_z uW)$$

where: Q is the pollutant source strength,

δ_z is the vertical dispersion coefficient,

u is the wind speed,

W is the valley width.

Pollutant source strength is derived from the emission data specification of 7.1 g/s converted to a volume of 0.0028 m^3/s. Vertical dispersion is a function of stability class and travel distance. For stability class F and a travel distance of 9500 metres, the δ_z would be about 45 metres (Gifford

1976). Calm winds are defined at 0.5 m/s based on the experience of Hanna et al (1982). Briggs plume rise formulations suggest that the plume elevation would be about 140 metres above stack base which is assumed to be below the mixing height ceiling. The valley width at this elevation is about 3000 metres.

Maximum valley wall concentrations under these circumstances are calculated to be 0.032 ppmv. This value is less than one-fifth of the British Columbia Level A Pollution Control Objective for 1 hour concentrations of 0.17 ppmv.

The other circumstance that would result in increased ground level concentrations is the so-called "morning fumigation" associated with the break-up of the nocturnal inversion that has trapped pollutants during the night. The thin concentrated layer analyzed above will break up as ground heating begins to cause vertical mixing in the stable air. Basically, the plume starts to mix with the air below such that the concentrations noted in the calculation of valley wall impingement will decrease but concentrations will increase in the surrounding air. Naturally, this maximum concentration would be less than the impingement concentration.

The formula for calculating the maximum ground level concentration for this morning fumigation event is given as:

$$C = Q/uhW$$

All terms are the same as in preceding formula except h which is defined as the plume height. This formulation predicts a peak ground level concentration of 0.013 ppmv which is about 2.5 times lower than the valley wall impingement concentration and far below the B.C. Pollution Control Objectives.

Not only are these 1 hour predicted concentrations very low, but the frequency of events which would cause these peak concentrations is also exceedingly low. Calm winds over extended periods of time are a critical prerequisite of these scenarios. Assuming winter nights are 16 hours long, the existing wind velocity data for the project site were reviewed. In the 11 months in 1985 and 1986 of Gulf data, there are zero occurrences of 16 hour calm wind runs (i.e. continuously calm nights). There were 10 occurrences of 12 hour calm runs. Calm winds were defined as equal to or less than 1 km/h. In addition, winds at 2 km/h that were preceded and followed by calms were considered to be calm.

Fifty-one months of wind data from the B.C. Government Didene Station were also reviewed. This data indicated very few observations of "calm", that is, winds of less than 1 km/h. The definition of calm was thus expanded to include winds equal to or less than 2 km/h. Furthermore, in the interests of insuring a conservative analysis, winds up to 3 km/h that occurred in conjunction with significant periods of 2 km/h or less winds were also classified as calm periods. These data suggest that between zero and three 16-hour or greater episodes of "calm" winds would occur each winter. The frequency of 12-hour calm runs was similar at between one and three events each year.

This wind data suggests that very few incidents of impingement or fumigation concentrations as high as those calculated above can occur. In order for such an incident to occur, the required horizontal and vertical stabilities, worst case operating conditions and an extended period of calm wind must all occur simultaneously. The need for all these requirements to obtain the concentrations calculated suggests that the model maximum is conservative.

These results, summarized in Table 2-11, indicate that the effect of NO_x and SO_2 emissions on the ambient air quality of the Lost-Fox basin will be negligible in a few isolated locations and practically undetectable in most of the area. Land inside the Spatsizi Plateau Wilderness Park would be in the latter category.

Table 2-11

MAXIMUM AMBIENT CONCENTRATIONS - POWER PLANT EMISSIONS

Parameter	Unit	B.C. Pollution Control Objective	Maximum Ambient Concentration
Sulphur Dioxide			
Annual Average	ppmv	0.01 - 0.03	0.003
1 hr. Maximum	ppmv	0.17 - 0.34	0.032
Nitrogen Oxide			
Annual Average	ppmv	0.04*	0.005
1 hr. Maximum	ppmv	0.16 - 0.4	0.055
Carbon Monoxide			
Annual Average	ppmv	-	0.002
1 hr. Maximum	ppmv	5.7 - 11.2	0.033

* Federal Standard - Maximum Desirable.

3.2.4 Air Emissions Deposition Modelling

3.2.4.1 Description of Models

The deposition of atmospheric emissions from the power plant is also of concern in the assessment of potential environmental impacts. In particular sulphur deposition is of interest because of the potential effects on vegetation and soil pH.

Sulphur deposition was calculated using a version of the Promet SSAQ model, called MSAQ. Dry deposition, D is estimated using the deposition velocity concept, when:

$$D = V_G * C$$

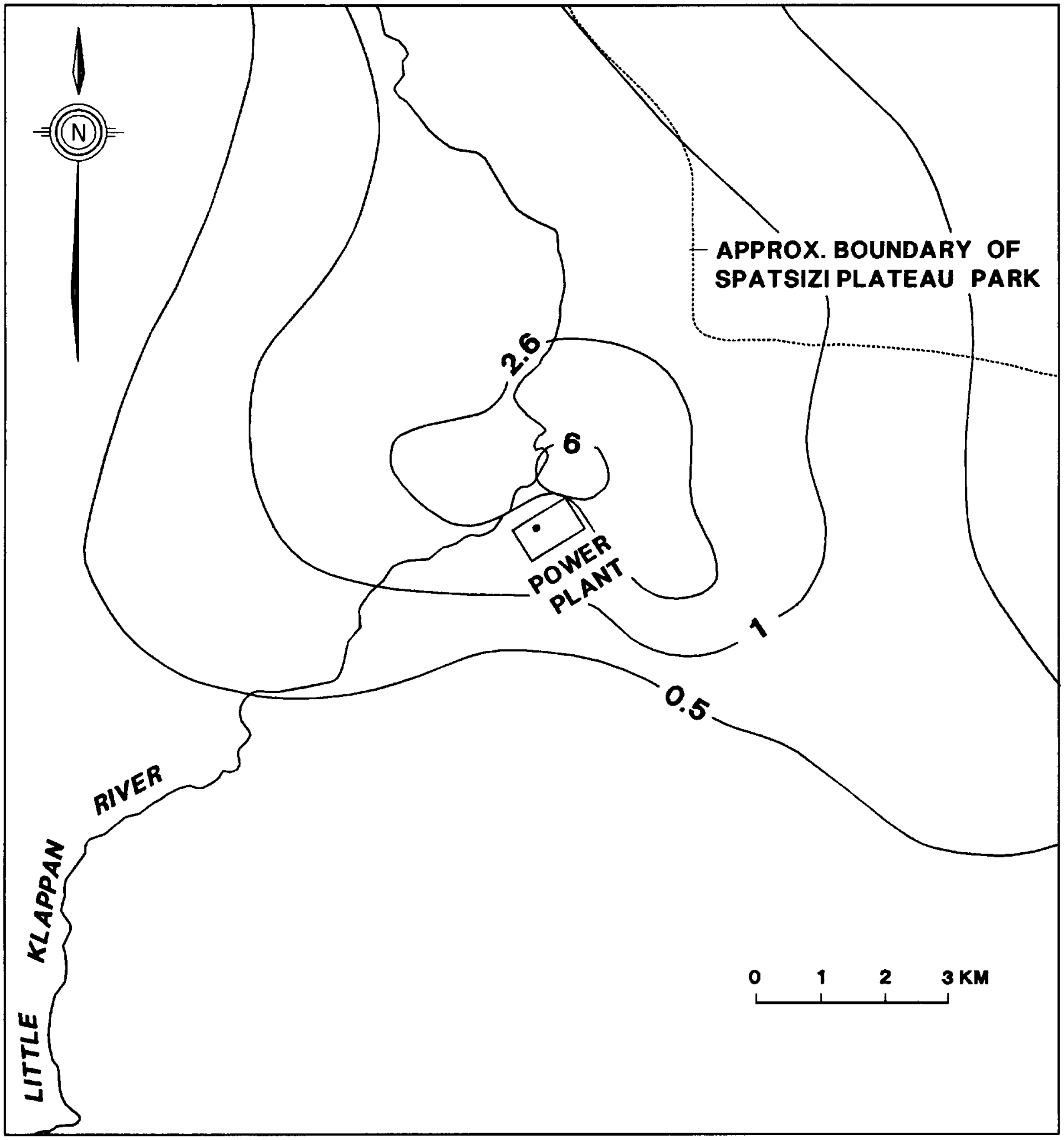
where V_G is the deposition velocity and C is the ambient concentration. Deposition velocity is related to stability class in order to mimic the observed variation of V_G from day to night, and summer to winter.

Wet deposition is estimated by the equilibrium scavenging method. It is assumed that wet deposition occurs under neutral (D) atmospheric stability conditions.

Deposition values are calculated at each spatial grid point for each dispersion class (wind speed, stability). Then these values are weighted by the hours of occurrence of each dispersion class to determine deposition over a one year period. Total deposition is the sum of the calculated wet and dry deposition.

3.2.4.2 Model Results

The results show maxima of total sulphur deposition of 5.5 kg/ha to the northeast of the source, 3.8 to the west-northwest, 2.9 to the east-southeast. The calculated value at the Spatsizi Plateau Park boundary is 1.6 kg/ha. The distribution of predicted sulphur deposition is illustrated in Figure 2-5.



NOTE:
STABILITY CLASSES WERE DETERMINED FROM MEASURED VERTICAL VELOCITIES.

FIGURE 2-5

MOUNT KLAPPAN ANTHRACITE PROJECT

ANNUAL TOTAL SULPHUR DEPOSITION
IN KILOGRAMS / HECTARE
MSAQ MODEL

ENVIRONMENTAL MANAGEMENT ASSOCIATES

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The maxima on the ridges are somewhat less pronounced than in the spatial distribution of annual concentration because high concentrations on the ridges were associated with stable conditions with low deposition velocities. Conversely the pattern is more pronounced to the north because relatively high deposition velocities were associated with downvalley winds.

The implications of these levels of sulphur deposition are discussed in detail in Volume III, Part Four, Terrestrial Environment. The deposition quantities are considered too small to result in any significant changes in soil chemistry or impacts on vegetation. Natural weathering and leaching will ultimately remove much of the sulphur that is deposited.

3.2.5 Trace Element Emissions

The Stage I review comments requested information on the quantity and quality of the anticipated trace element emissions, in particular fluoride and mercury, from the proposed power plant. These emissions were not measured directly during the test burn as the Pyropower test facility is not equipped to make such measurements. Alternative approaches, based on chemical analyses of anthracite, fly ash and bed ash, were used instead to estimate the trace element emissions.

Mercury and fluorides are released to atmosphere during the burn cycle mainly as volatiles though some will be released with the particulates. The estimation of the quantity released is based on a simple mass balance calculation, i.e. the difference between the quantity of mercury and fluoride in the feed anthracite and the quantity remaining in the bed and fly ash represents the mercury and fluoride released to the atmosphere.

Other trace elements were considered to be non-volatile and to be released to the atmosphere adsorbed on the surface of or contained within fly ash particles. The chemical analysis of collected fly ash samples should therefore be representative of the fly ash that escapes from the stack.

Anthracite, bed, and fly ash samples were analyzed for mercury and fluorides; fly ash was analyzed for antimony, arsenic, cadmium, copper, lead and zinc. The results of these analyses are summarized below:

Chemical Analyzes, Anthracite, Bed Ash and Fly Ash

Trace Metal	Anthracite (ug/gm)	Bed Ash (ug/gm)	Fly Ash (ug/gm)
Mercury	0.24 ± 0.04	0.02 ± 0.004	0.27 ± 0.02
Fluoride	288.0 ± 3.0	270.0 ± 9.0	1223.0 ± 63.0
Antimony			-0.1
Arsenic			3.6 ± 0.1
Cadmium			-0.1
Copper			43.0 ± 3.4
Lead			15.0 ± 2.0
Zinc			50.0 ± 6.0

Performance criteria for the full scale circulating fluidized bed combustor relevant to the estimation of the trace element emissions are:

Fuel Feed Rate	19 036	Kg/hr
Bed Ash	2 602	Kg/hr
Fly Ash	5 466	Kg/hr
Particulate Emissions	4.3	Kg/hr
Flue Gas Rate	153 838	Kg/hr

The control objectives for gaseous and particulate emissions are expressed in mg/mol (British Columbia Pollution Control Objectives, 1979, Table II). This requires that the flue gas rate be expressed in mols/hr. For the purpose of these calculations the flue gas composition was assumed to be equivalent to ambient air at normal temperature and pressure. The results of the trace element emission calculations and the relevant Pollution Control Objective are summarized below:

Circulating Fluidized Bed Combustor, Trace Metal Emission Rates

Trace Metal	Units	Pollution Control Objective	Emission Rate
Antimony	mg/mol	0.16 - 0.27	<0.0000001
Arsenic	mg/mol	0.16 - 0.27	0.0000029
Cadmium	mg/mol	0.05 - 0.27	<0.0000001
Copper	mg/mol	0.16 - 0.27	0.000035
Fluoride	mg/mol	0.02 - 0.20	*
Lead	mg/mol	0.16 - 0.27	0.000012
Mercury	mg/mol	0.03 - 0.27	0.00057
Zinc	mg/mol	0.16 - 0.27	0.00004

* The mass balance calculation results in a fluoride content of the bed and fly ash greater than in the feed anthracite. The source of this anomalous result is unknown as it does not lie in the chemical analyses of the samples. The most likely source of the fluoride is from bed material, other than anthracite, which is introduced to the fluidized bed at the initiation of the burn cycle. Samples of this material were not available for analysis. The results of the analysis do suggest that fluoride emissions will be very low.

These results indicate that all trace element emissions are significantly less than the most stringent B.C. Pollution Control Objective. The potential impact on ambient air quality is negligible. Similarly the impact from these trace element emissions on water quality, soils and vegetation will be negligible.

4.0 IMPACT ASSESSMENT

With the air quality control features inherent in the power plant design and operating procedures (See Volume II - Part Six, Environmental Management) and the small scale of the facility, the overall impact on the atmospheric environment will be so minimal that it will even be difficult to detect the changes in ambient conditions.

Air quality monitoring equipment typically would only record levels exceeding 0.010 ppmv SO_2, the lower limit of the B.C. Pollution Control Objectives. The analysis presented here indicates that the maximum annual average ground level concentration would only be about 0.003 ppmv and this concentration would be experienced in only a small zone of about 1 square kilometre. All other areas of the Lost-Fox basin would have annual concentrations well below even this level. The maximum annual average SO_2 levels in the Spatsizi Plateau Wilderness Park are predicted to be less than 0.0005 ppmv which is far below concentrations where any impacts would be anticipated.

Sulphur deposition values are also very low, again due to the minor amount of sulphur released from the power plant. In Part Four of this volume (Terrestrial Environment), it is shown that there will be no appreciable impact from sulphur deposition.

With SO_2 emissions predicted to have negligible impact on air quality, the potential impact of all other components of the stack emissions is expected to be even less because the volumes are less and/or the toxicity of the materials is less. As a result, no identifiable effects are expected with respect to NO_x, CO, particulates, fluorides or trace elements.

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PART THREE - AQUATIC ENVIRONMENT

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FIGURES | Page

TABLES

TABLES (Cont'd)

PART THREE - AQUATIC ENVIRONMENT

1.0 INTRODUCTION

The aquatic studies are intended to provide sufficient baseline information to allow predevelopment documentation of the aquatic environment of the Mount Klappan anthracite property for: surface water quality (Section 2.0); surface water hydrology (Section 3.0); and groundwater (Section 4.0). Impacts and mitigations are addressed in Section 5.0. Emphasis has been given to areas which may be affected by the proposed mine development. Some of these studies are still in progress and some will continue well into the development phase of the mine.

These baseline data will be used to predict the potential impacts of the mine development and operation on the aquatic environment of the area and to develop mitigations which will lessen or eliminate such impacts. The data will also be used in the interpretation of related studies: surficial geology and soils, vegetation and forestry and wildlife. Finally the aquatic studies will be used in the design planning of the mine especially regarding process water requirements and water management.

The Mount Klappan licence area is drained by the Stikine, Nass and Skeena River systems although the proposed mine development will occur largely in the upper drainage of the Little Klappan River which is tributary, via the Klappan River, to the Stikine River. The water quality of the Mount Klappan licence area is categorized as good. Surface waters are slightly alkaline and typically soft to moderately hard with low nutrient levels. These cold, steep gradient streams show the typical low biological productivity and depauperate biota of north coastal river system head-waters.

2.0 SURFACE WATER QUALITY

2.1 STUDY OBJECTIVES

The objectives of the surface water quality study were to provide baseline data for the Mount Klappan licence area to enable:

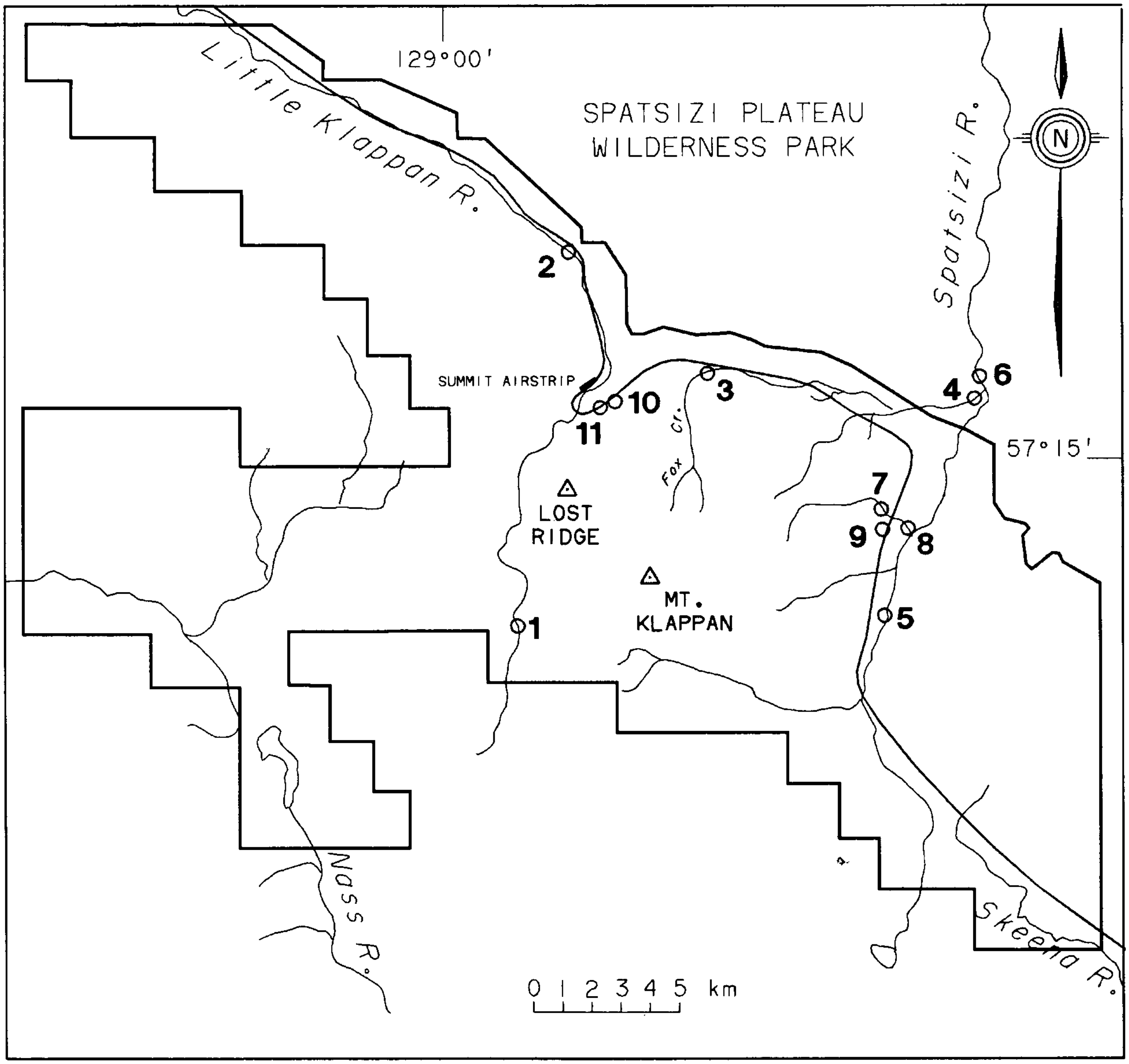
- predevelopment documentation of the water quality;
- prediction of potential imptacts of the proposed development;
- development of satisfactory mitigations of these potential impacts.

2.2 SCOPE OF THE STUDY

The 1985 surface water program was developed from the results of the 1984 Stage I surface water investigation, and Stage II government requirements.

Surface water quality and quantity within and adjacent to Gulf's Mount Klappan licence area were examined on four occasions (winter, spring, summer and fall) in 1984, and several sampling locations (upper and lower Little Klappan River, Spatsizi River, Klappan River, Nass River, Skeena River, Didene Creek). The 1985 program was modified to increase the sampling frequencey at the watercourses which may be affected by mine development. The revised sampling program is shown in Figure 3-1. In general, trace metals which were present in very low concentrations during the intitial (1984) investigation were excluded from the 1985 program. Emphasis was placed on routine water quality characteristics and parameters of potential concern (trace metals and nutrients) during the 1985 investigation.

Sampling commenced in April, 1985, and continued through to the completion of this program in November 1985. An additional station was added in August 1985, at the request of the Ministry of Environment to sample the ponded waters in the Hobbit-Broatch test pit. A wash plant was constructed for the preparation of trial cargo coal which was shipped during the winter



LEGEND

1 U. LITTLE KLAPPAN R.
2 L. LITTLE KLAPPAN R.
3 FOX CR.
4 DIDENE CR.
5 UPPER SPATSIZI R.
6 LOWER SPATSIZI R.
7 UPPER HOBBIT CR.
8 LOWER HOBBIT CR.
9 HOBBIT BROATCH TEST PIT *
10 SETTLING POND *
11 TAILINGS POND *
* WATER QUALITY ONLY

FIGURE 3-1

MOUNT KLAPPAN ANTHRACITE PROJECT

SURFACE WATER SAMPLING LOCATIONS
1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

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of 1985/86. An additional sampling program was initiated in September 1985, to sample supernatant water in the tailings and settling ponds of the facility. This sampling was conducted as a condition of Ministry of Environment Approval Number NE-0205 for the operation of the wash plant facility. The locations of these additional sampling sites are shown in Figure 3-1.

The surface water program carried out in late 1985 and 1986 resulted from the review of the Stage I submission regarding development of the Gulf Mount Klappan licence area, and discussions with the Ministry of Environment. The monthly sampling schedule was extended from November 1985 through to March of 1986, to provide baseline data on a monthly basis for 12 consecutive months. Subsequently, this program was continued on a reduced frequency, with sampling during the freshet (June 1986), mid-summer (August 1986) and fall (September 1986).

The sampling stations established in 1985 were retained during the 1986 study and were located at points appropriate for monitoring potential effects of mine development. Two stations were retained on the Spatsizi River during the 1985 and 1986 programs; these were the control station upstream of the Didene Creek confluence and the station downstream of the confluence.

Stations on the Little Klappan River and Fox Creek remained unchanged. The two stations on Hobbit Creek were monitored during the 1986 sampling program, as was the station on the Hobbit-Broatch Test Pit. Monitoring was also continuod at the tailings and settling ponds located at the wash plant, although this facility was not operative during the 1986 sampling period. Samples were also withdrawn for water quality analyses at the station established on the outflow of the settling pond in October, 1985 when this drainage was active.

2.3 METHODS

The assessment of water quality was extensive and included field and laboratory determination of water quality parameters (Tables 3-1 and 3-2) and nitrogen phosphorous ratios and chlorophyll a content of attached algae.

The investigation of nitrogen/phosphorous ratios (N:P) in attached algae was carried out to assist in determining whether nitrogen or phosphorous was limiting algal growth in these drainages. In addition the chlorophyll a content in attached algae was determined during the 1986 program. Chlorophyll a may be used as an indication of algal density and biomass at sampling stations.

The algal samples were collected opportunistically from natural substrates in 1985 and 1986. In addition artificial substrates (styrofoam blocks) were installed at the water sampling stations in August, 1986. Samples were collected from these blocks in September 1986 following the technique described by Bothwell and Jasper (1983). The samples were frozen, stored in the dark and analyzed for chlorophyll a within 7 days (Table 3-2).

The N:P ratio in attached algae was determined through nitrogen and phosphorous analysis of homogenized algal samples (Table 3-2). Total nitrogen was determined initially by digesting the samples with sulphuric acid and selenium. Subsequent to digestion, copper sulphate was added and the solution was analyzed in an auto-analyser. The detection limit for the analysis was 0.02 mg/l.

A single set of samples was collected from each station during each sampling period, with the exception of the chlorophyll a samples collected in September. During 1985, triplicate samples were collected from each sampling station. This procedure served to provide confidence limits for the interpretation of results, as it highlighted the variations in results which may be expected when examining data from a single sample set. Variations in results may arise from true variations in water chemistry at the time of sample collection, and sample collection, preservation and analytical techniques. Quality control was also evaluated through a split sample procedure, in cooperation with Waste Management Branch. Split samples were collected during August of 1984, and June of 1985 and 1986. The split

TABLE 3-1

WATER QUALITY PARAMETERS MEASURED IN THE FIELD, TECHNIQUES EMPLOYED AND DETECTION LIMITS, MOUNT KLAPPAN LICENSE AREA, SURFACE WATER QUALITY PROGRAM

Parameters	Technique	Detection Limit
Total alkalinity	Potentiometric titration	± 0.5 mg/l
Specific conductance	Conductivity metre	± 2% of reading
pH units	pH metre	± 0.05 pH
Water temperature	Mercury thermometer	± 0.5°C
Dissolved oxygen	Winkler titration	-

TABLE 3-2

PARAMETERS MEASURED IN THE LABORATORY, ANALYTICAL TECHNIQUES EMPLOYED AND DETECTION LIMITS, MOUNT KLAPPAN LICENCE AREA SURFACE WATER QUALITY PROGRAM

Parameter	Analytical Method	Detection Limit (mg/l)
Calcium	Inductively coupled plasma.	0.01
Magnesium	Inductively coupled plasma.	0.01
Sulphate (Naquadat code 16309)	Ion chromatography.	0.1
Total Hardness (Naquadat code 10602)	Calculated from calcium and magnesium values Ca x 2.497 + Mg x 4.117	0.2
Total Suspended Solids (Naquadat code 10405)	Gravimetric method with Whatman GF/C filters. Sample is filtered, dried @ 110^{o}C and residue weighed.	0.4
Nitrite Nitrogen (Naquadat code 07206)	Colorimetry on an auto-analyzer using NEDS reagent @ 550 nm.	0.003
Nitrate Nitrogen (Naquadat code 07111)	Difference of (NO3+NO2)-NO2 by using colorimetry on an auto-analyzer with NEDS reagent and cadmium reduction @ 550 nm.	0.003
Ammonia Nitrogen (Naquadat code 07)	Colorimetry on an auto-analyzer using the Berthelot reaction @ 600 nm.	0.01
Dissolved Phosphorus (Naquadat code 15103)	Colorimetry on an auto-analyzer (after filtration through 0.45 micron filter) using ammonium molybdate, potassium antimony tartrate and ascorbic acid (after autoclaving with K2S208 and H2SO4) measured @ 880 nm.	0.003
Ortho Phosphorus (Naquadat code 15256)	As dissolved above without the digestion step.	0.003
Total Organic Carbon (Naquadat code 06005)	Infrared analysis using an auto-analyzer system. The sampler is first acidified to remove CO3 and then passed over a uv lamp. The resultant CO2 is measured.	0.2
Total Inorganic Carbon (Naquadat code 06052)	Infrared analysis using an auto-analyzer system. The sample is acidified and the CO2 is separated in a stripper and measured.	0.5

Continued...

TABLE 3-2 (Cont'd)

Parameter	Analytical Method	Detection Limit (mg/l)
Turbidity	Hach Model 2100 A Turbidimeter	±2% of full scale
Iron, Chromium, Manganese, Barium	Inductively coupled plasma.	Fe 0.01 Cr 0.001 Mn 0.004 Ba 0.01
Copper (Naquadat code 29305)	Atomic absorption and solvent extraction using APDC and MiBK.	0.001
Zinc (Naquadat code 30305)	Atomic absorption and solvent extraction using APDC and MiBK.	0.001
Lead (Naquadat code 82302)	Atomic absorption and solvent extraction using APDC and MiBK.	0.002
Nickel (Naquadat code 28302)	Atomic absorption and solvent extraction using APDC and MiBK.	0.001
Cadmium (Naquadat code 48003)	Atomic absorption using a graphite tube furnace.	0.0002
Aluminum (Naquadat code 13003)	Atomic absorption with solvent extraction using 8-hydroxy-quinoline and MiBK.	0.01
Mercury (Naquadat code 80011)	Flameless atomic absorption on an auto-analyzer the sample is mixed with KMnO4, K2S2O8 and H2SO4 and digested @ 105^{o}C, then mixed with hydroxly amine hydro-chloride, then SnCl2. This solution is then purged with air and the vapor measured @ 253.7 nm.	0.00005
Chlorophyll *a* (Naquadat code 06716)	Spectrophotometry after acetone extraction from filter paper.	0.001
Phosphorus - Total (Naquadat code 15501L)	Persulphate digestion and colorimetry on an auto-analyzer (as for dissolved phosphorus).	0.003
Nitrogen - Total (Naquadat code 07009L)	Colorimetry on an auto-analyzer using the Berthelot reaction @ 600 nm (following Kjeldahl digestion to ammonia)	0.05

samples were analyzed independently by two laboratories and the results compared for consistency.

2.4 DATA PRESENTATION

The results of the 1984, 1985 and 1986 surface water quality program are summarized in the appendix to this section of the report (Appendix A). The results are summarized on the basis of the following sampling sites: Upstream Station, Little Klappan River; Downstream Station, Little Klappan River; Fox Creek; Didene Creek; Upstream Station, Spatsizi River; and Downstream Station, Spatsizi River.

Turbidity and total suspended solids (TSS) values were determined weekly during freshet, 1985, and are summarized in Table 3-3. The N:P ratios determined from attached algae samples are presented in Table 3-4 while the results of chlorophyll a are shown in Table 3-5. The results of split sample analysis carried out in conjunction with the Waste Management Branch in 1984 and 1985 are summarized in Tables 3-6 and 3-7 respectively.

Water quality results from monitoring at Hobbit-Broatch Test Pit and Hobbit Creek are presented in Section 5.2.2.1. Monitoring results from the wash plant facility are considered in Section 5.2.2.2.

2.5 DISCUSSION

The Mount Klappan water quality investigations conducted between 1984 and 1986 document the nature of the surface waters within the development area. Low concentrations of most parameters were recorded, with many occurring at or below the analytical detection limits.

A number of trends which are indicative of normal cycles in water quality characteristics are apparent at the Mount Klappan licence area. Parameters such as turbidity, total suspended solids (TSS), total organic carbon (TOC), phosphorus, total metals (notably iron, chromium, manganese and

TABLE 3-3

TOTAL SUSPENDED SOLIDS AND TURBIDITY RESULTS, MOUNT KLAPPAN LICENCE AREA, JUNE 11-25, 1985

	June 11		June 18		June 25	
	TSS (mg/l)	Turbidity (NTU)	TSS (mg/l)	Turbidity (NTU)	TSS (mg/l)	Turbidity (NTU)
Spatsizi River upstream station	22.4	38.0	528.0	73.0	39.2	38.0
Spatsizi River downstream station	18.3	5.3	38.4	18.0	22.6	6.2
Hobbit Creek upstream station	57.2	8.6	382.0	50.0	15.4	9.3
Hobbit Creek downstream station	88.8	18.0	626.0	56.0	13.6	9.5
Fox Creek	53.6	6.1	361.0	63.0	4.0	21.0
Didene Creek	9.6	3.6	15.2	9.3	9.2	13.0
Little Klappan River upstream station	46.8	3.0	47.6	5.7	3.2	5.6
Little Klappan River downstream station	23.6	1.6	60.4	18.0	10.8	5.1

TABLE 3-4

NITROGEN:PHOSPHORUS RATIOS IN ALGAE COLLECTED AT THE MOUNT KLAPPAN LICENCE AREA, 1984-1986[a]

		Aug 1984	Aug 1985	Sep 1985	Aug 1986
Spatsizi River upstream station	TN	430.0	38.40	123.00	3.16
	TP	72.0	10.00	11.10	0.91
	N:P	5.97	3.8	11.1	4.1
Spatsizi River downstream station	TN		3.60	1325.00	9.20
	TP		1.64	326.00	5.50
	N:P		2.2	4.1	1.7
Hobbit Creek upstream station	TN		5.04	1041.00	10.90
	TP		0.84	96.90	2.00
	N:P		6.00	10.7	5.5
Hobbit Creek downstream station	TN		8.00	41.87	8.40
	TP		3.80	12.30	3.40
	N:P		2.11	3.4	2.5
Fox Creek[b]	TN		7.20	885.00	
	TP		0.80	138.00	
	N:P		9.00	6.4	
Didene Creek	TN	13.2	5.12	194.00	7.50
	TP	3.25	2.50	19.30	1.70
	N:P	4.06	2.05	10.1	4.4
Little Klappan River upstream station	TN	105.0	80.00	551.00	45.00
	TP	6.8	3.60	64.80	3.10
	N:P	15.4	22.2	8.5	14.5
Little Klappan River downstream station	TN		46.00	396.00	83.80
	TP		12.30	50.20	12.60
	N:P		3.74	7.9	6.7

a N:P Ratios based on Total Nitrogen (TN): Total Phosphorus (TP) concentrations (mg/l) in algae sample.

b Sample container broken during transport.

TABLE 3-5

ALGAL STANDING CROP AS CHLOROPHYLL a FROM PERIPHYTON SAMPLES, MOUNT KLAPPAN LICENCE AREA, AUGUST 1986

Location	Chlorophyll a (ug/cm^2) August
Spatsizi River upstream station	0.16
Spatsizi River downstream station	0.16
Fox Creek	0.90
Didene Creek	0.16
Little Klappan River upstream station	3.70
Little Klappan River downstream station	0.79
Hobbit Creek upstream station	0.69
Hobbit Creek downstream station	0.53

TABLE 3-6

INTER-LABORATORY COMPARISON (AUGUST, 1984)

LOCATION		Al	As	Cr	Cd	Cu	Ba	Fe	Pb	Mn
Spatsizi River downstream station	CHEMEX	0.08	0.004	1.08	<0.0005	<0.001	0.03	0.044	<0.001	<0.01
	MOE	0.03	<0.002	1.11	<0.0002	<0.001	0.05	<0.01	<0.001	<0.004
Didene Creek	CHEMEX	0.08	0.003	0.97	<0.0005	<0.001	0.03	0.064	<0.001	<0.01
	MOE	0.03	<0.0002	1.031	<0.0002	<0.001	0.05	<0.03	<0.001	<0.004
Little Klappan River downstream station	CHEMEX	0.06	<0.001	0.065	<0.0005	<0.001	0.04	<0.001	<0.001	<0.01
	MOE	0.02	<0.002	0.63	<0.0002	<0.001	0.09	0.002	0.002	<0.004

LOCATION		Ni	Zn	Ca	B	Mo	Mg	Co	V
Spatsizi River downstream station	CHEMEX	<0.01	<0.005	10.0	<0.01	0.01	5.48	<0.1	<0.1
	MOE	0.001	0.001	-	-	-	-	-	-
Didene Creek	CHEMEX	<0.01	<0.005	7.97	<0.01	0.01	7.23	<0.1	<0.1
	MOE	0.003	<0.001	-	-	-	-	-	-
Little Klappan River downstream station	CHEMEX	<0.01	<0.005	10.4	<0.01	<0.01	5.83	<0.1	<0.1
	MOE	<0.001	<0.001	-	-	-	-	-	-

[a] All concentrations are for dissolved elements only. Units are mg/l.

TABLE 3-7

INTER-LABORATORY COMPARISON (JUNE, 1985)

Date	Location		Total Hardness	pH (units)	sp. cond. umho/cm	Temp. (°C)	Al	As	B	Ba	Cd
85/06/04	Upper Hobbit Creek	CHEMEX	29.4	7.1	35	1.0	0.03	-	-	0.02	<0.0002
		MOE		7.1	35	1.0	0.007	<0.001	<0.01	0.01	<0.0005
85/06/04	Lower Hobbit Creek	CHEMEX	30.8	7.0	41	1.0	0.03	-	-	0.02	<0.0002
		MOE		7.0	41	1.0	0.08	<0.001	<0.01	0.01	<0.0005
85/06/04	Didene Creek	CHEMEX	19.2	7.2	34	3.0	0.04	-	-	0.01	<0.0002
		MOE		7.2	34	3.0	0.11	<0.001	<0.01	<0.01	<0.0005
85/06/05	Fox Creek	CHEMEX	39.4	7.6	46	1.0	0.03	-	-	0.02	<0.0002
		MOE		7.6	46	1.0	0.15	<0.001	<0.01	0.01	<0.0005
85/06/05	Little Klappan R. upstream station	CHEMEX	22.3	6.8	33	0.0	0.02	-	-	0.01	<0.0002
		MOE		6.8	33	0.0	0.06	<0.001	<0.01	<0.01	<0.0005
85/06/04	Little Klappan R. downstream station	CHEMEX	23.2	7.1	40	1.0	0.04	-	-	0.01	<0.0002
		MOE		7.1	40	1.0	0.07	<0.001	<0.01	<0.01	<0.0005
85/06/04	Little Klappan R. MOE sampling and analysis	MOE		7.3	41	1.0	0.07	<0.001	<0.01	<0.01	<0.0005

[a] Concentrations are for dissolved elements only. Units are mg/l unless indicated otherwise.

Cont'd...

TABLE 3-7 (Cont'd)

Date	Location		Co	Cr	Cu	Fe	Mn	Mo	Mi	Pb	Zn
85/06/04	Upper Hobbit Creek	CHEMEX	-	<0.001	0.001	0.099	0.004	-	<0.001	0.002	0.011
		MOE	<0.1	<0.005	0.001	0.11	0.003	<0.01	<0.01	0.001	0.013
85/06/04	Lower Hobbit Creet	CHEMEX	-	0.001	0.001	0.124	0.005	-	0.001	0.001	0.005
		MOE	<0.1	<0.005	0.001	0.14	0.005	<0.01	<0.01	<0.001	<0.005
85/06/04	Didene Creek	CHEMEX	-	<0.001	0.001	0.163	0.009	-	0.001	<0.001	0.004
		MOE	<0.1	<0.005	0.001	0.17	0.005	<0.001	<0.01	0.001	<0.005
85/06/05	Fox Creek	CHEMEX	-	<0.001	0.001	0.122	0.008	-	0.001	<0.001	0.004
		MOE	<0.1	<0.005	0.004	0.17	0.007	<0.01	<0.01	0.002	<0.005
85/06/05	Little Klappan R. upstream station	CHEMEX	-	<0.001	0.001	0.049	0.003	-	0.001	<0.001	0.005
		MOE	<0.1	<0.005	<0.001	0.05	0.001	<0.01	<0.01	<0.001	<0.005
85/06/04	Little Klappan R. downstream station	CHEMEX	-	0.001	0.002	0.094	0.004	-	0.001	<0.001	0.004
		MOE	<0.1	<0.005	0.001	0.10	0.007	<0.01	<0.01	<0.001	<0.005
85/06/04	Little Klappan R. MOE sampling and analysis	MOE	<0.1	<0.005	0.003	0.12	0.005	<0.01	<0.01	<0.001	<0.005

[a] Concentrations are for dissolved elements only. Units are mg/l unless indicated otherwise.

aluminum), and dissolved metals (notably iron and aluminum) increased in concentration with flow rate. The increase in metals, TOC and phosphorus concentrations is likely due to the increase in TSS, as these substances are often adsorbed on soil particles (Cahill 1977; Forstner 1977).

Several other parameters decreased in concentration during the freshet, as a result of a higher proportion of surface to groundwater. These include specific conductance, total alkalinity, calcium, magnesium, total inorganic carbon (TIC), nitrates and dissolved barium concentrations. These components are generally associated with ground water and natural weathering products (Hackbarth 1981).

The total and dissolved concentrations of lead, which were at or below the detection limit, were generally unaffected by discharge rate of the watercourses. Similarly, dissolved chromium, copper and nickel concentrations were unaffected by the flow rate of the watercourse. Total and dissolved cadmium concentrations were found to be below the detection limit of 0.0002 mg/l.

Total mercury concentrations in 1985 and 1986, with two exceptions, were below the detection limit (0.00005 mg/l). In September, 1986, 0.00007 mg/l of mercury was measured at the lower station on the Spatsizi River and in April, 1985, 0.00010 mg/l was measured. In 1984, total mercury concentrations were found to range from 0.00023 to 0.00063 mg/l on eight occasions, four each during the summer and fall sampling periods. The stations involved were the upper and lower Spatsizi River, Didene Creek and the lower Little Klappan River.

The Waste Management Branch of the B.C. Ministry of Environment prepared a list of water quality criteria and recommended minimum detectable concentrations as one component of the Stage I requirements for the Mount Klappan Project. These criteria, which are presented in Table 3-8, are based on the most sensitive use (i.e., protection of aquatic life, drinking water standards, irrigation use, etc.) of the published water quality criteria.

TABLE 3-8

WATER QUALITY CRITERIA EMPLOYED IN CATEGORIZING THE SURFACE WATER AT THE MOUNT KLAPPAN LICENCE AREA[a]

Parameter	Water Quality Criterion (mg/l)	Recommended Minimum Detectable Concentration[b] (mg/l)
Aluminium	0.050 - 0.100	0.010
Antimony	0.050	0.005
Arsenic	0.050	0.005
Barium	1.000	0.100
Beryllium	0.011	0.003
Bismuth	0.100	<0.100
Boron	0.750	0.100
Cadmium	0.0002	0.0005 (or lower)
Chromium	0.020	0.005
Cobalt	<0.050	0.005
Copper	0.002	0.001
Fluoride	1.000	0.100
Iron	0.300	0.030
Lead	0.005 - 0.030	0.001
Manganese	0.050	0.020
Mercury	0.0001 - 0.0002	0.00005
Nickel	0.025	0.010
Nitrogen, Ammonia	0.007 - 0.016 (un-ionized)	0.010 (Total) (as N)
Nitrate	0.300	0.020 (as N)
Nitrite	0.020	0.005 (as N)
Phenol	0.001	0.001
Phosphorus (all forms)	Any amount can contribute to algal growth.	0.003 (as P) (or lower)
Selenium	0.010	0.001
Silver	0.0001	0.005 (or lower)
Tin	None found.	-
Titanium	0.100	0.010
Vanadium	0.100	0.010
Zinc	0.050 - 0.300	0.005

a This table is taken from the Stage I requirements for the Mount Klappan Project.

b 0.1 of the published water quality criteria for the most sensitive water use (i.e., aquatic life, drinking water, irrigation, etc.), or the lowest concentration routinely detectable by the Environmental Laboratory of the Ministry of Environment.

These criteria for evaluating the water quality at the Mount Klappan licence area, are therefore among the most stringent available.

2.5.1 Water Quality Characteristics

Twenty three metals were analyzed during the three years water sampling period. The results of this analysis, which is a description of the pre-development surface water characteristics, show that 9 of the metals were found, on occasion, to occur naturally at concentrations greater than the criteria listed in Table 3-8. These metals include aluminum, copper, iron, lead, manganese, mercury, nickel, silver and zinc.

Aluminum, iron and manganese concentrations exceeded the water quality criteria established by the Ministry of Environment (Table 3-8) relatively frequently and generally during spring freshet and always during the open water season. As noted previously, this increase is likely due to the increase in total suspended solids. These metals are often adsorbed on the surface of soil particles (Cahill, 1977; Forstner, 1977).

No guideline exists for aluminum concentrations in drinking water, as aluminum has not been shown to be harmful to human health (McNeely et al, 1979), nor does there exist a Canadian guideline for the protection of aquatic biota.

The International Joint Commission (1977) has suggested a tentative limit of 0.1 mg/l. The criterion suggested by the Ministry of Environment is 0.05 to 0.1 mg/l (Table 3-8). Aluminum does not, however, have much practical effect on water use other than to limit some industrial applications.

The water quality criterion suggested by Ministry of Environment (Table 3-8) for total iron is 0.30 mg/l. This is the same criterion as proposed by the Great Lakes Water Quality Board (1976) for the protection of the aquatic environment. The elevated total iron concentrations occurring naturally during freshet are not likely adversely affecting the aquatic ecosystems of the Mount Klappan Licence Area. Drinking water standards for iron (0.05 mg/l) are more rigorous because of the highly objectional taste that iron gives to water in high concentrations (Department of National Health and Welfare,1969).

The criterion for manganese in surface waters suggested by the Ministry of Environment is 0.05 mg/l (Table 3-8). This is the same as the British Columbia water quality standard for drinking water (Clark, 1980). The drinking water standard is established on the basis of taste, concentrations of manganese in excess of 0.2 mg/l make the water distasteful. The only objectives which presently exist for the protection of fresh water ecosystems come from Dawson (1974) and Davies and Goettl (1977) who recommended criteria of 0.1 and 1.0 mg/l respectively. The natural surface water concentrations of manganese at the Mount Klappan River Area are far below the most conservative of these criteria, and therefore pose no threat to the aquatic ecosystems.

The concentration of copper in the surface waters examined during the study period was frequently higher than the criterion of 0.002 mg/l provided by the Ministry of Environment (Table 3-8). The maximum total copper concentration detected during the study was 0.022 mg/l, at the upper station on the Spatsizi River (June, 1986). Concentrations of total copper exceeded 0.002 mg/l in 54 samples taken during the study. High concentrations of copper (1-5 mg/l) makes water distasteful to drink, while large doses may cause liver damage. As a result, the drinking water criterion for copper is 1.0 mg/l (Department of National Health and Welfare 1979). The toxicity of copper to aquatic organisms varies with the chemical speciation of copper, as well as a number of physical and chemical characteristics (e.g., temperature, hardness, turbidity) of the water. The Great Lakes Water Quality Board (1976) recommended a maximum acceptable concentration of 0.005 mg/l for the protection of aquatic freshwater species. Other authors recommend criteria in the range of 0.005 to 0.15 mg/l for the protection of entire freshwater ecosystems (Windom et al 1979). Whereas the background copper concentrations at the Mount Klappan licence area do not pose any concerns in relation to human consumption, they appear to be close to levels where they may begin to inhibit growth in aquatic systems.

The water quality criteria suggested by the Ministry of Environment for lead was a range from 0.005 to 0.030 mg/l (Table 3-8). Total lead concentrations were found to exceed the 0.005 mg/l criterion on a total of seven occasions between 1984 and 1986. In general, both total and dissolved lead concentrations may be categorized as falling near or below the lower range of the Ministry of Environment criterion. Lead is a toxic element which typically accumulates in the skeletal elements of man and animals, and results from long-term ingestion. Drinking water standards have been established to avoid long-term accumulation of lead (McNeely et al 1979). The maximum allowable concentration of lead in drinking water is 0.05 mg/l (Department of National Health and Welfare 1979). The toxic effects of lead on fishes decrease with increasing water hardness and dissolved oxygen content. A proposed guideline of 0.003 mg/l has been developed to protect freshwater life (Environmental Studies Board 1973). It is apparent that the trace quantities of lead in the surface waters at the Mount Klappan licence area do not epproach the maximum acceptable criterlon for drinking water. The concentrations of lead which occasionally exceed the 0.003 mg/l criterion for protection of aquatic life do not appear to occur frequently enough to pose a threat to this resource.

As discussed previously, total mercury concentrations as high as 0.00063 mg/l were detected in surface waters on the licence area during June and August of 1984. However, subsequent comprehensive sampling has not resulted in the detection of mercury above the detection limit employed. This detection limit was lowered from 0.00010 to 0.00005 mg/l in July of 1985. As previously indicated, the sampling results from 1985 and 1986 are considered to be the best data set available from the licence area, indicating background mercury levels below the 0.00005 mg/l level.

The water quality criterion for nickel established by the Ministry of Environment is 0.025 mg/l (Table 3-8). This is the same objective as recommended by Environment Canada (1979) for the protection of aquatic life. This objective was exceeded on two occasions only, in both instances at the upper station on the Spatsizi River. The background levels of nickel in the surface water of the licence area are low.

The Ministry of Environment water quality criterion for silver is 0.0001 mg/l (Table 3-8). On only one occasion was the silver concentration in excess of the detection limit of 0.001 mg/l (downstream station, Spatisizi River, June, 1984). The domestic and drinking water standard for this element is 0.05 mg/l. Freshwater concentrations of silver usually range from 0.002 to 0.039 mg/l (McNeely et al 1979). Silver concentrations at the licence area may therefore be considered relatively low.

The only remaining metal monitored during the study which was found in concentrations greater than the water quality criteria suggested by the Ministry of Environment was zinc. The criteria for this element was 0.050 to 0.300 mg/l (Table 3-8). Total zinc values exceeded the lower criterion at three stations during the monitoring program: at the upper station on the Little Klappan River; at Didene Creek; and, at the downstream station on the Spatsizi River. With the exception of the previously described samples, total zinc concentrations were low in the surface waters of the licence area. This element is relatively non-toxic to man, and concentrations of up to 25 mg/l have shown few adverse effects (McNeely et al, 1979). Zinc concentrations should not exceed 5.0 mg/l in raw and public drinking water supplies (Department of National Health and Welfare 1969). However, zinc is toxic to aquatic organisms with the toxicity dependent on a number of factors (hardness, temperature, oxygen). For protection of the aquatic resource Great Lakes Water Quality Board (1976) specifies total zinc concentrations should not exceed 0.03 mg/l. Zinc concentrations generally fall within this guideline on the Mount Klappan licence area.

The Ministry of Environment (Table 3-8) also provided water quality criteria for ammonia-nitrogen (un-ionized) (0.007 to 0.016 mg/l), nitrate (0.300 mg/l) and nitrite (0.020 mg/l). These nitrogen compounds were found to be present in concentrations which were consistently lower than their respective criteria.

The other nutrient examined was dissolved phosphorus, with both total and the ortho phosphorus components being evaluated. The total phosphorus concentrations were typically in the range of less than 0.003 mg/l to 0.025 mg/l, with a maximum value of 0.092 mg/l recorded at the lower Little Klappan station. Dissolved ortho phosphorus was found at lower concentrations, ranging from a low of less than 0.003 mg/l to 0.012 mg/l, with a maximum of 0.020 mg/l recorded at the Fox Creek station. Any addition of phosphorus to a watercourse is considered undesirable, as this element often controls algal productivity in the watercourse.

Phenolic compounds were examined seasonally during the 1984 program, and again in August, 1986. Phenol concentrations were typically in the range of less than 0.001 mg/l to 0.004 mg/l. The highest concentration recorded was 0.031 mg/l at the upper station on the Spatsizi River. The water quality criterion quoted by the Ministry of Environment (Table 3-8) in the project guidelines is 0.001 mg/l. It is apparent that the background levels of phenolic compounds exceed this criterion on occasion. Phenols are produced naturally, by the release from aquatic plants and decaying vegetation. They are also released by industrial and agricultural activities such as the distillation of coal and wood, oil refining, chemical plants, animal and human waste, and from phenolic pesticides (McNeely et al 1979). Because the primary concern in domestic water supplies is the formation of chlorophenols during the precess of chlorination and the associated bad taste and odour which the water assumes, the guideline of 0.001 mg/l has been developed for public water supplies. However, phenolic compounds are toxic to fish and benthic invertebrates and may produce an undesirable odour in fish flesh. They also have a high oxygen demand which may result in oxygen deprivation in receiving waters. McKee and Wolf (1963) suggest 0.2 mg/l phenolics would not interfere with fish and aquatic life. However, the guideline for the protection of this resource hes been set at 0.001 mg/l, to avoid fish-flesh tainting (United States Environmental Protection Agency 1976). Although the background levels of phenols are somewhat high, such levels do not appear to pose any problems for domestic consumption of the water, or for the well-being of the aquatic resource of the lioence area.

With minor exceptions, it is apparent from these results that the quality of the surface waters at the Mount Klappan licence area may be categorized as good.

Since the water with the greatest potential to be affected by mine development is the Little Klappan River, graphs of several parameters for this stream have been prepared to illustrate seasonal variations in these parameters. Figure 3-2 illustrates the relationship between discharge rate, turbidity and TSS during a 12 month period from April, 1985 to March, 1986. The relationships between conductivity and total alkalinity (Figure 3-3), and the major ions (Figure 3-4) during this period illustrate the influence of groundwater on surface water quality. Total concentrations of iron, aluminum and barium reflect the influence of freshet on these characteristics (Figure 3-5). Dissolved metal concentrations tend to be more erratic than those of the total values, particularly in the headwaters where limited dilution by groundwater occurs (Figure 3-6). Variation in TOC concentration is considerable but shows no relationship with season while the influence en the flow rate on the much higher TIC concentrations is pronounced (Figure 3-7). Phosphorus concentrations during the 12 month period are illustrated in Figure 3-8. The pattern at other sampling stations which display increasing concentrations during freshet and decreasing concentrations the rest of the year, is not reflected at the Little Klappan River stations. Nitrate showed a typical increase during the winter months and a decrease during freshet (Figure 3-9). Ammonia displayed the opposite behaviour, peaking during the summer months, presumably as a result of biological activity.

Dissolved oxygen measurements were conducted from December, 1985 through to September 1986 at all sampling sites. Results show sufficient levels of dissolved oxygen for protection of freshwater aquatic life (4.0 mg/l) in all samples (Appendix A) (McNeely et al 1979).

The inter-laboratory comparison of analytical results between Gulf's consultants and the Ministry of Environment showed good agreement (Tables 3-6 and 3-7). The Provincial Laboratory and Chemex results show excellent

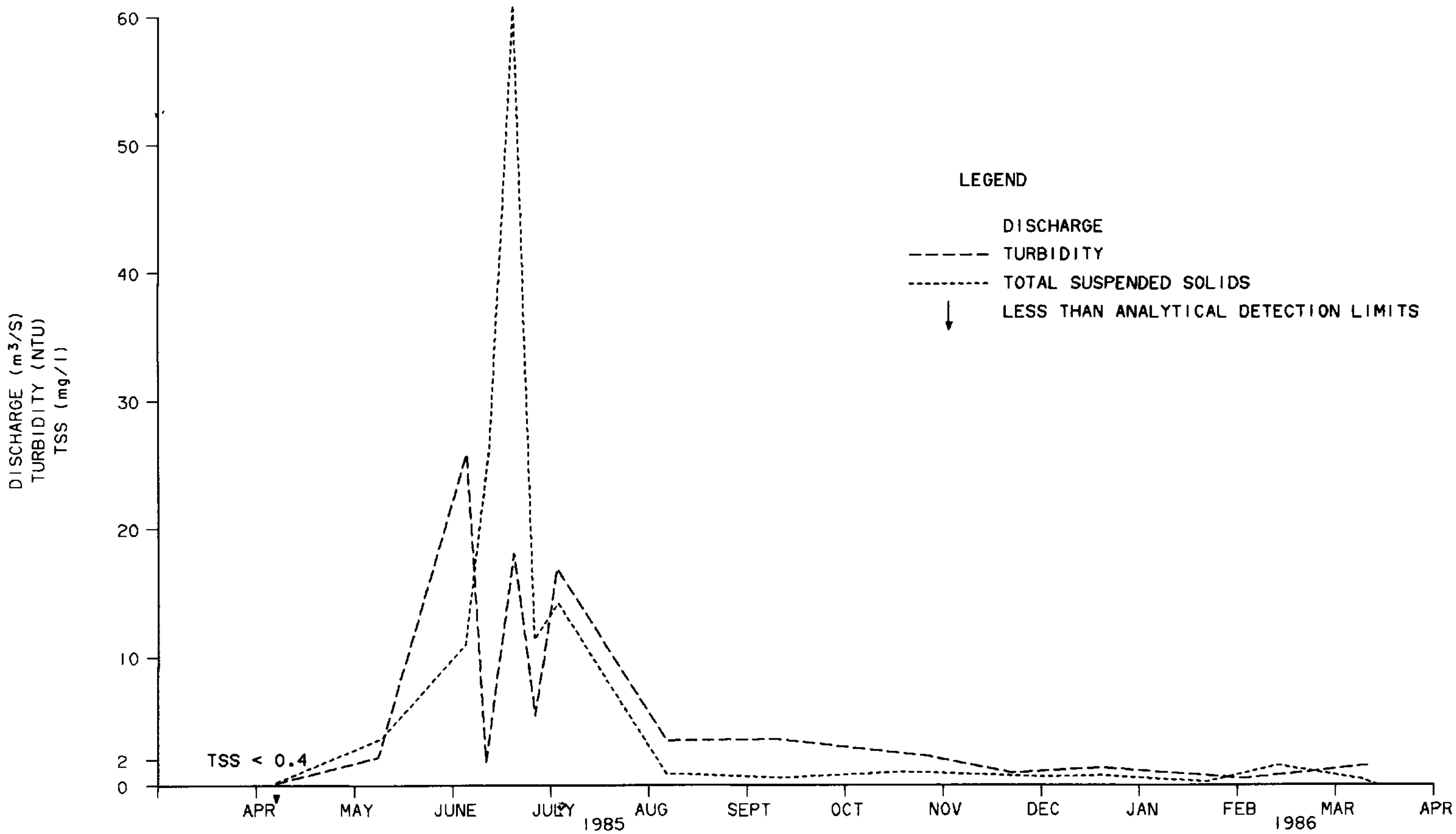


FIGURE 3-2

MOUNT KLAPPAN ANTHRACITE PROJECT

RELATIONSHIP BETWEEN DISCHARGE, TURBIDITY AND TOTAL SUSPENDED SEDIMENT CONCENTRATION, LOWER STATION, LITTLE KLAPPAN RIVER, 1985-86.

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
30/12/86
KLAP:[205057]860601045.LOC

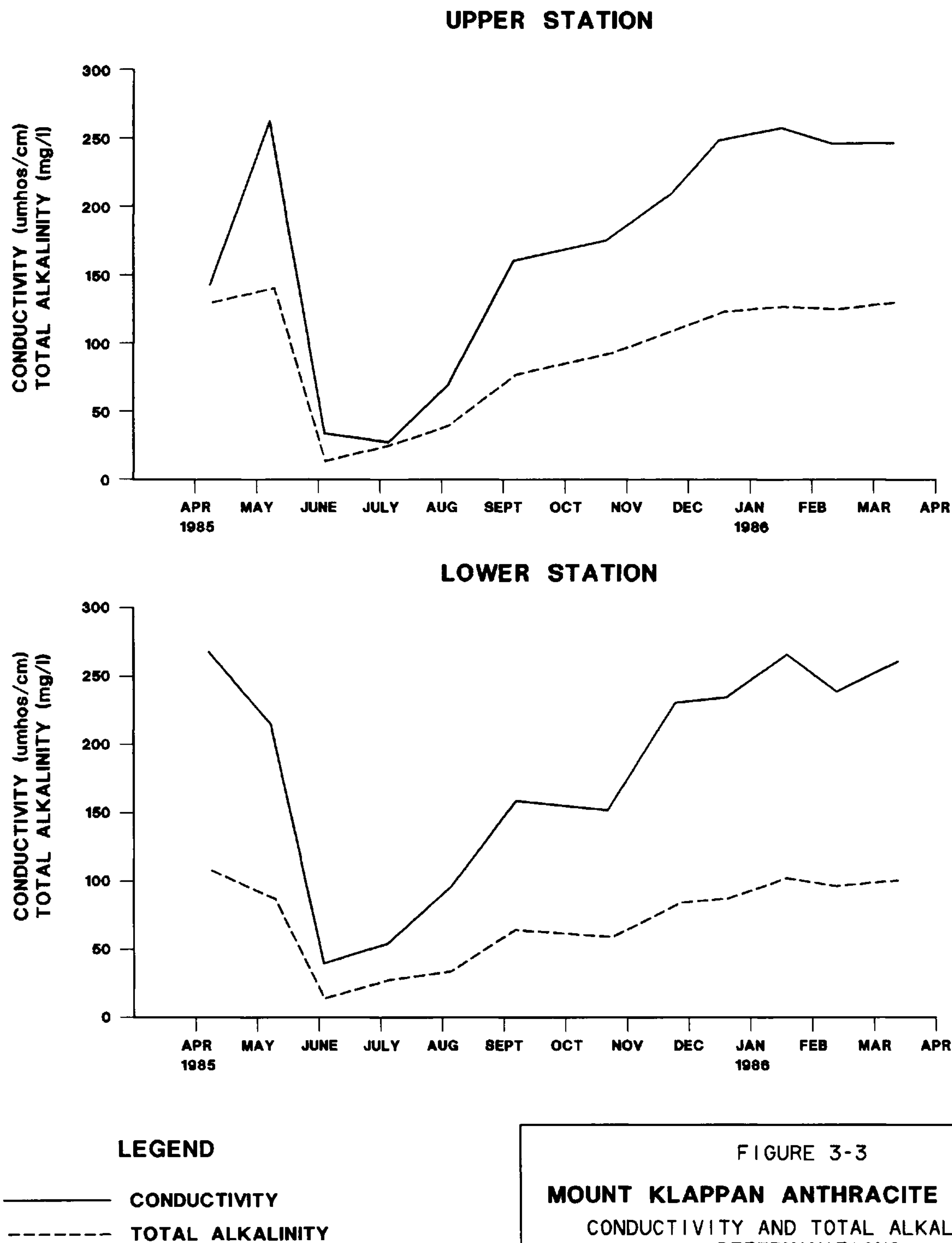


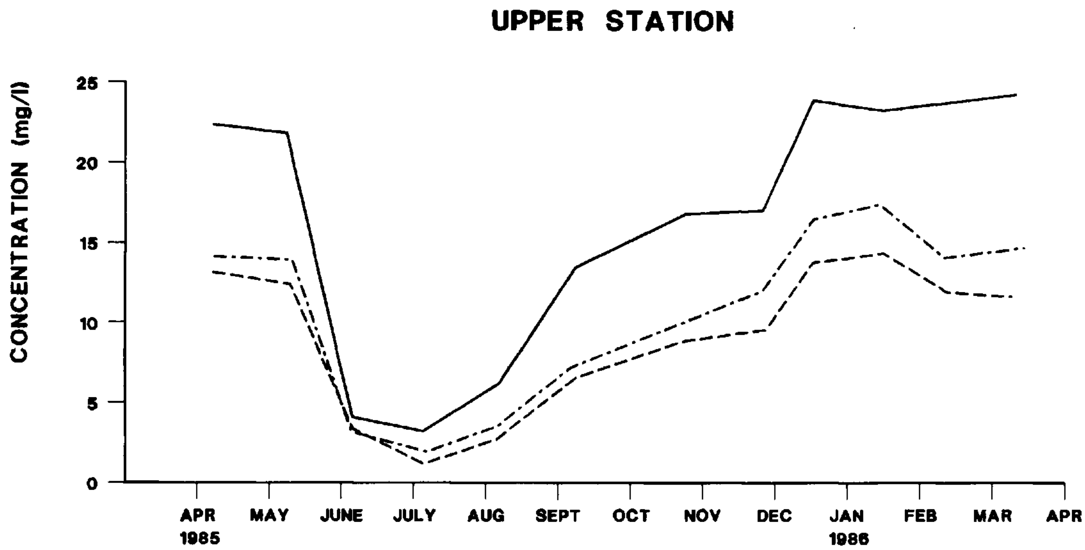
FIGURE 3-3

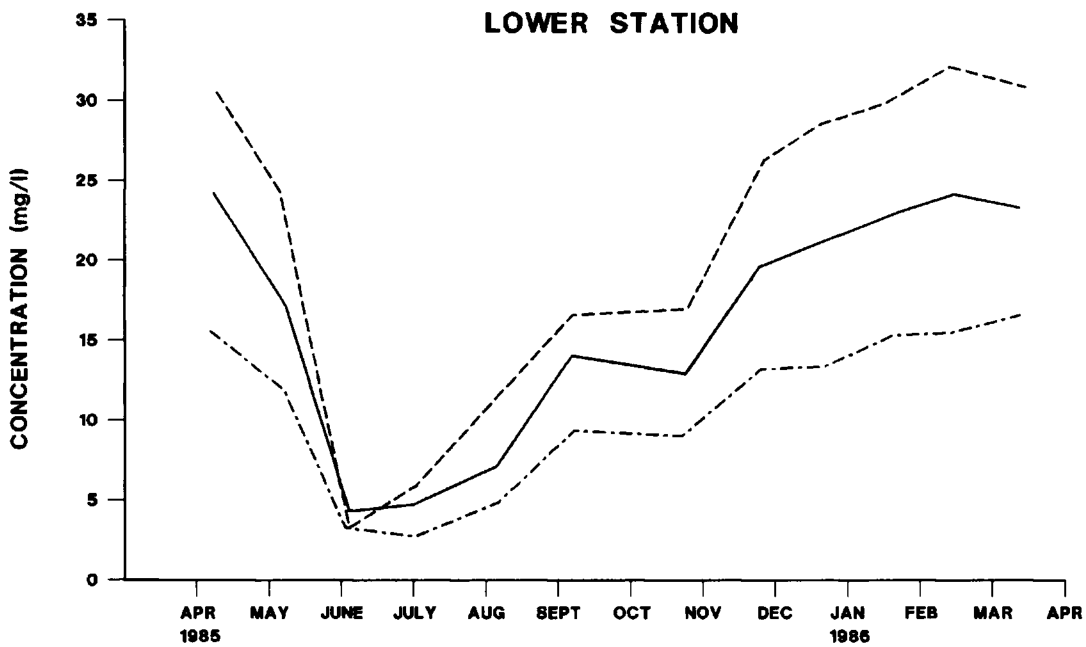
MOUNT KLAPPAN ANTHRACITE PROJECT

CONDUCTIVITY AND TOTAL ALKALINITY DETERMINATIONS
LITTLE KLAPPAN RIVER, 1985-86

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
29/10/86
KLAP:[205057]86060100I.CHT





LEGEND

- CALCIUM (solid line)
- SULPHATE (dashed line)
- MAGNESIUM (dash-dot line)

FIGURE 3-4

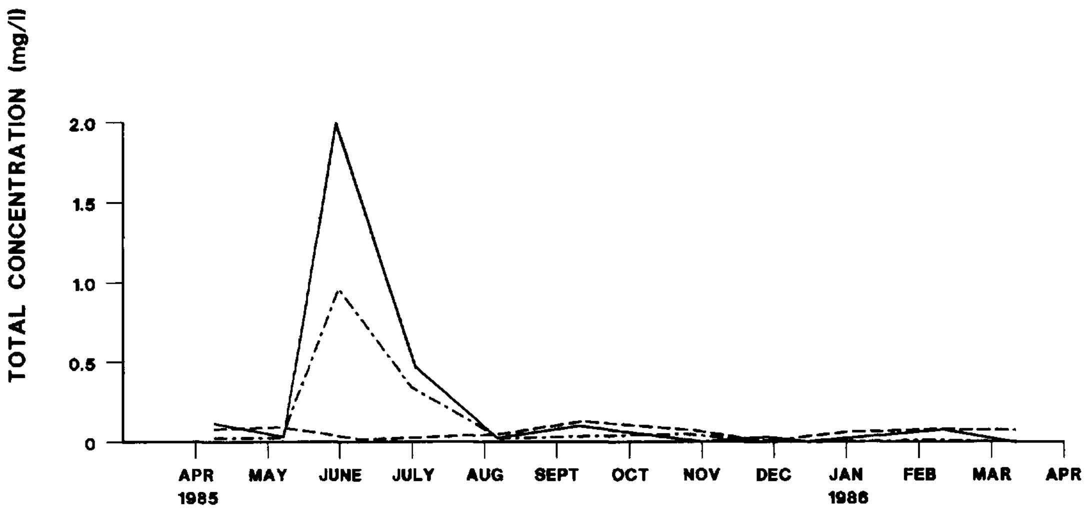
MOUNT KLAPPAN ANTHRACITE PROJECT

CALCIUM, MAGNESIUM AND
SULPHATE CONCENTRATIONS
LITTLE KLAPPAN RIVER, 1985-86

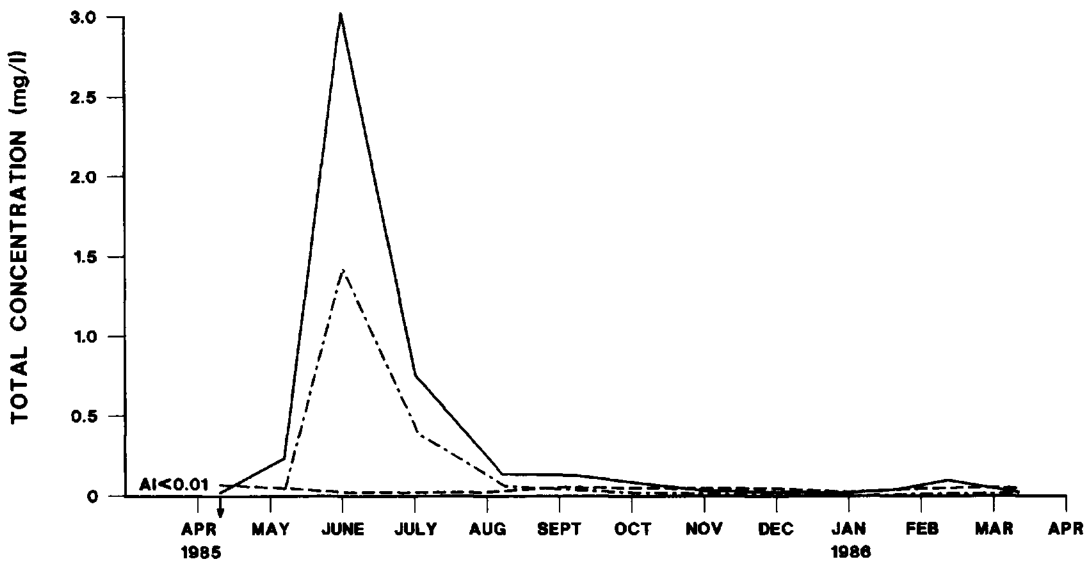
ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
29/10/86
KLAP:[205057]860601002.CHT

UPPER STATION



LOWER STATION



LEGEND

- TOTAL IRON (solid line)
- TOTAL ALUMINUM (dash-dot line)
- TOTAL BARIUM (dashed line)
- ↓ Less than analytical detection limit

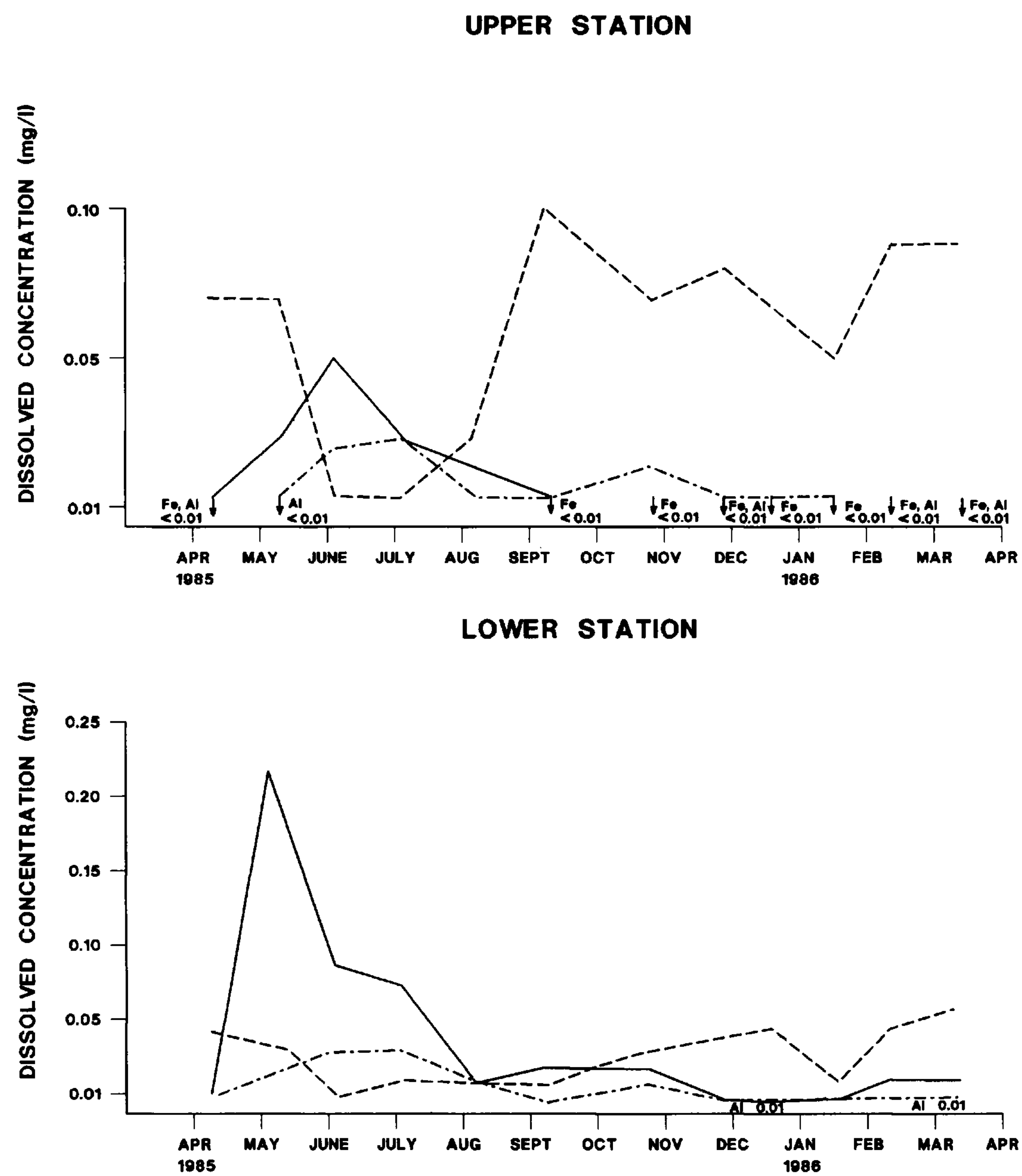
FIGURE 3-5

MOUNT KLAPPAN ANTHRACITE PROJECT

TOTAL IRON, ALUMINUM AND BARIUM CONCENTRATIONS LITTLE KLAPPAN RIVER, 1985-86

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
30/10/86
KLAP:[205057]860601003.CHT



LEGEND

- ———— DISSOLVED IRON
- -·-·-·-· DISSOLVED ALUMINUM
- -------- DISSOLVED BARIUM
- ↓ Less than analytical detection limit

FIGURE 3-6

MOUNT KLAPPAN ANTHRACITE PROJECT

DISSOLVED IRON, ALUMINUM AND BARIUM CONCENTRATIONS LITTLE KLAPPAN RIVER, 1985-86

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
02/11/86
KLAP:[205057]860601004.CHT

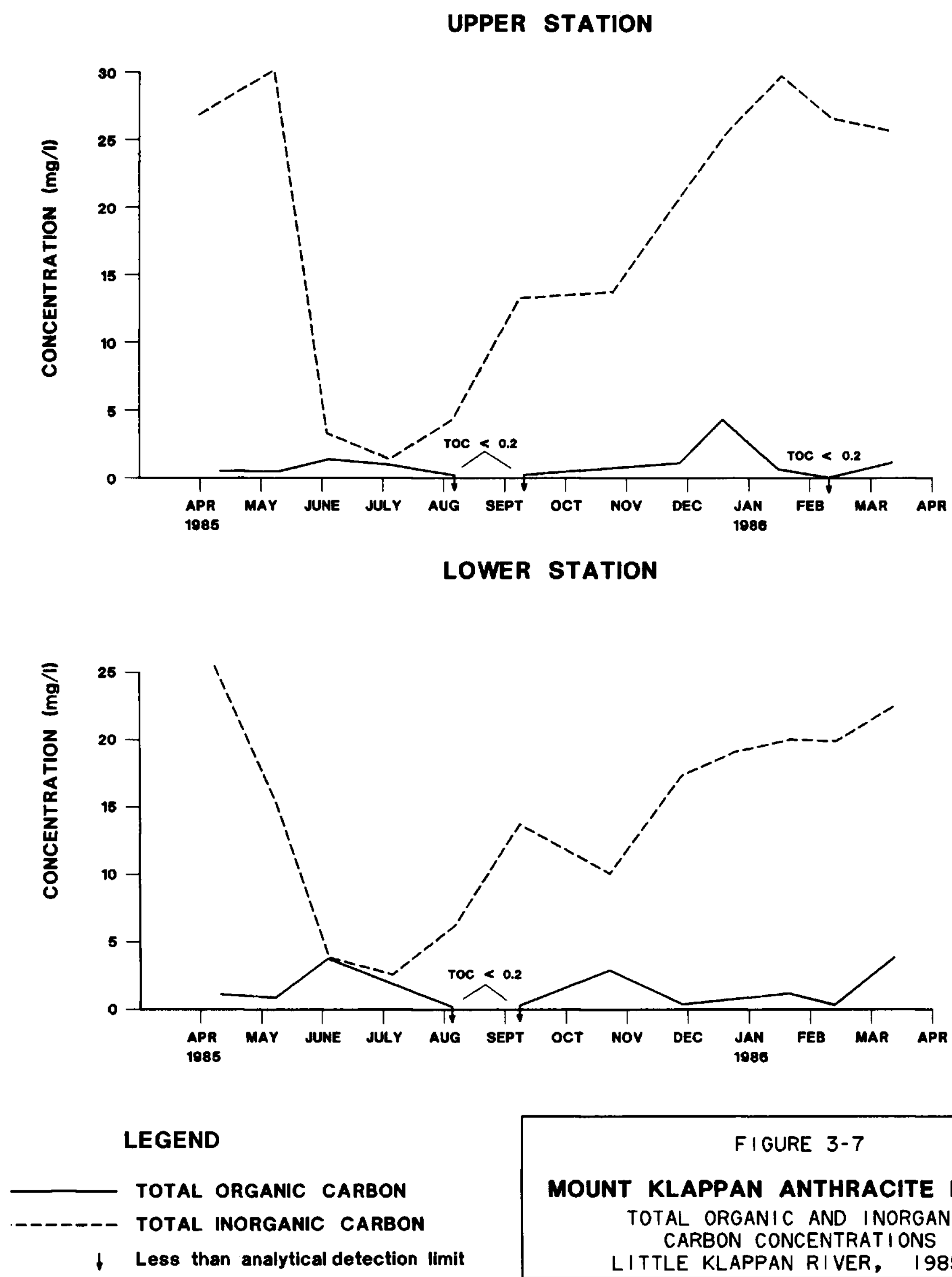


FIGURE 3-7

MOUNT KLAPPAN ANTHRACITE PROJECT

TOTAL ORGANIC AND INORGANIC CARBON CONCENTRATIONS LITTLE KLAPPAN RIVER, 1985-86

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
02/11/86
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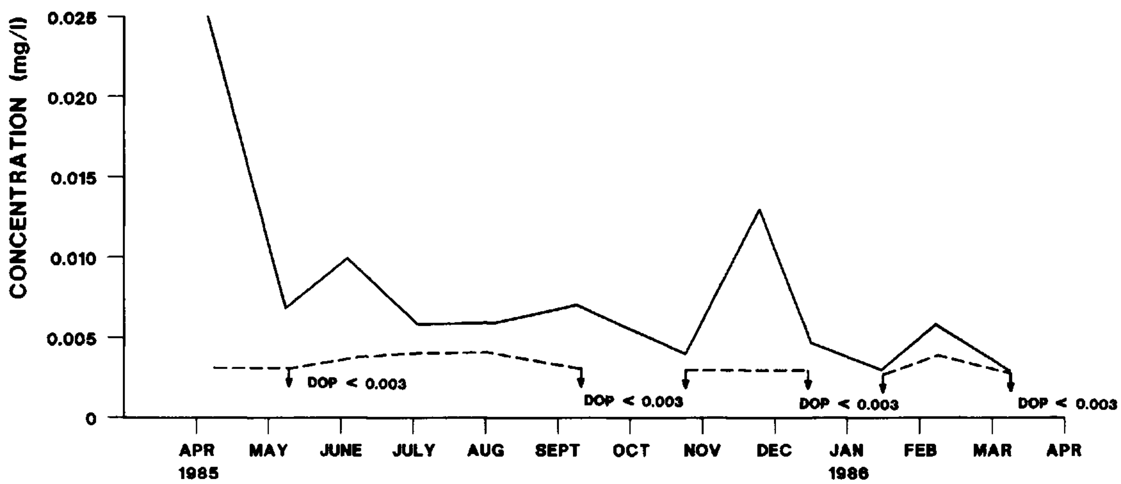
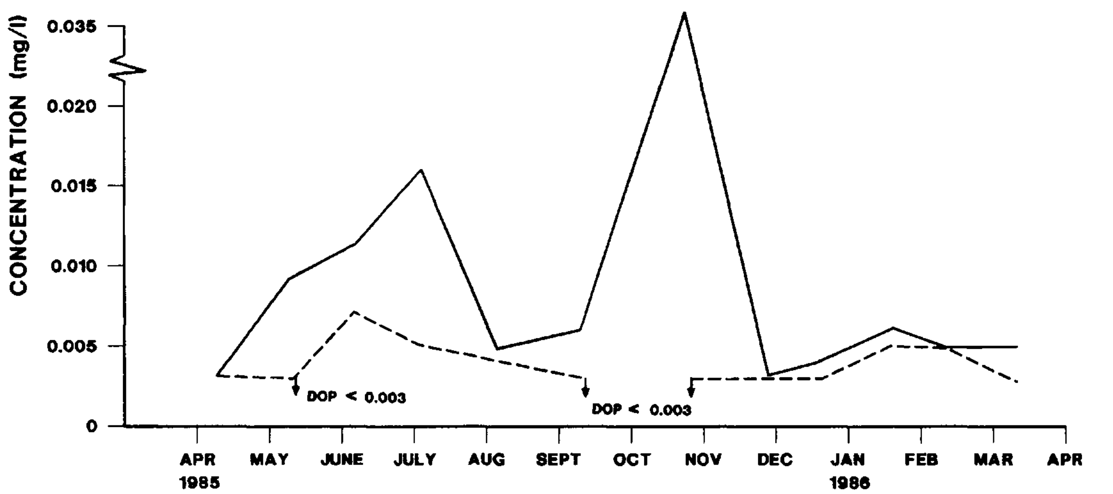
UPPER STATION



LOWER STATION



LEGEND

———— TOTAL DISSOLVED PHOSPHORUS

- - - - - - - DISSOLVED ORTHO PHOSPHORUS

↓ Less than analytical detection limit

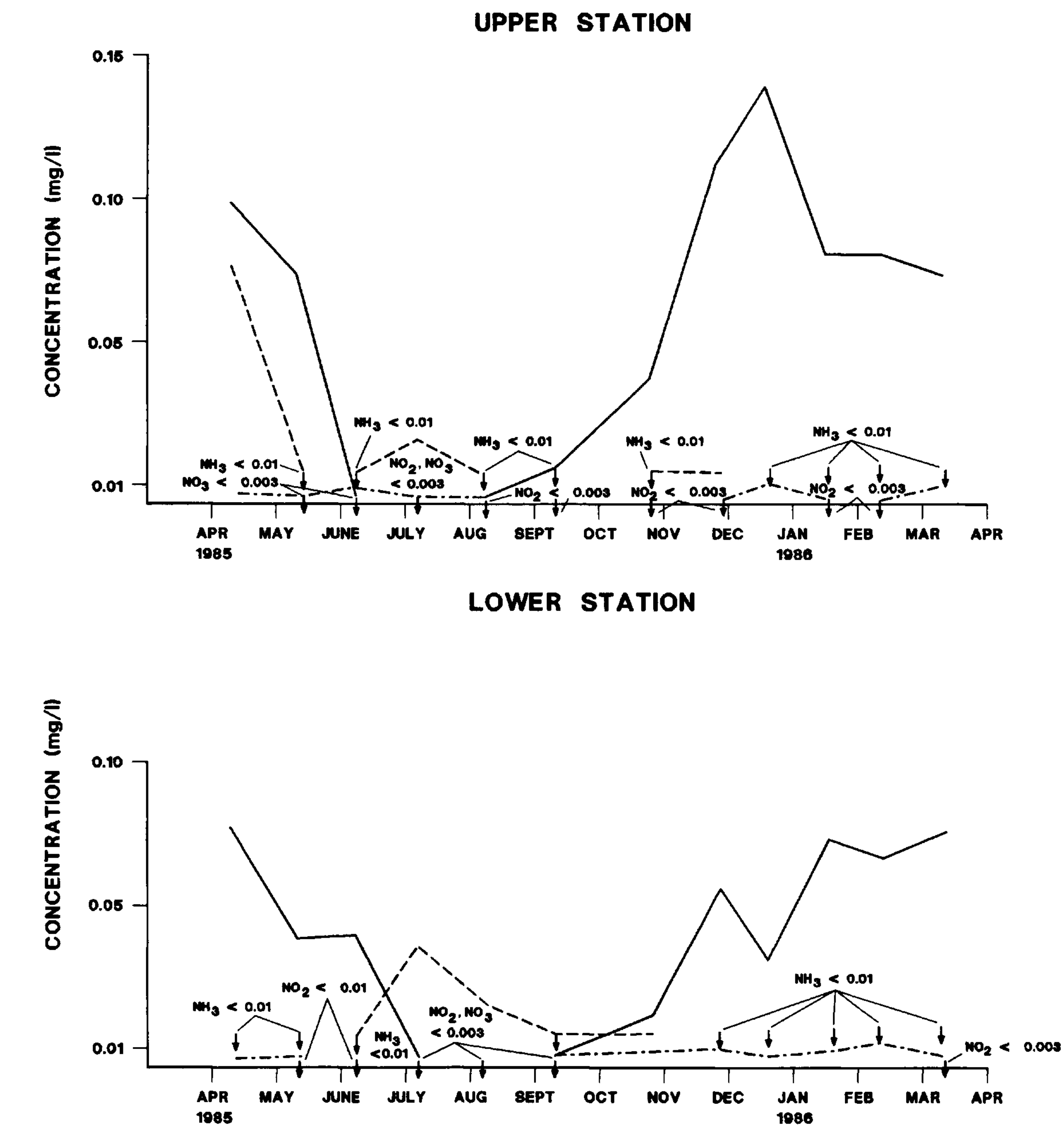
FIGURE 3-8

MOUNT KLAPPAN ANTHRACITE PROJECT

DISSOLVED PHOSPHORUS AND ORTHO PHOSPHORUS CONCENTRATIONS LITTLE KLAPPAN RIVER, 1985-86

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
02/11/86
KLAP:[205057]86060I006.CHT



LEGEND

- NITRATE
- AMMONIA
- NITRITE
- Less than analytical detection limit

FIGURE 3-9

MOUNT KLAPPAN ANTHRACITE PROJECT

NITRATE, NITRITE AND AMMONIA-NITROGEN CONCENTRATIONS LITTLE KLAPPAN RIVER, 1985-86

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
02/11/86
KLAP:[205057]860601007.CHT

correlation except for dissolved aluminum. Reasons for the discrepancy in these results may be due to the different analytical methods used by the two laboratories. Apart from the discrepancy with aluminum, the inter-laboratory comparison lends confidence with respect to quality control.

The TSS and turbidity survey was conducted during freshet at all sampling sites on a weekly basis between June 4 and July 4, 1985 to give background information on these parameters prior to mine development. The results of samples taken at the beginning of June and July are included in Appendix A while the weekly sampling results for the intervening period are summarized in Table 3-3. Peak TSS concentrations were generally found to occur on June 18, at which time values ranged from a low of 15.2 mg/l at Didene Creek to a high of 626 mg/l at lower Hobbit Creek. Three other sites had high TSS values on June 18, Upper Hobbit Creek (382 mg/l), Upper Spatsizi River (528 mg/l) and Fox Creek (361 mg/l). The peak TSS concentration in Didene Creek did not occur until July 3, at which time the maximum value of 24.0 mg/l was recorded. Turbidity followed a similar trend, as anticipated.

2.5.2 Surface Water Nitrogen/Phosphorous Ratios

An additional aspect of the Mount Klappan surface water quality study was an investigation of N:P ratios in attached algae at the watercourses under observation. The ratios which result from comparing the total nitrogen (TN) to total phosphorus (TP) content of attached algae can be used to indicate whether the aquatic system is nitrogen or phosphorus limited, or if the system is co-limited. Since nitrogen-based explosives will be used at the mine, potential effects of nitrate addition to the streams under study are important from a planning perspective. The addition of a limiting nutrient to an aquatic system can cause an increase in algae productivity along with associated changes in water quality. Important water uses which may be affected by increased nitrogen concentration include drinking water use, fisheries, recreation/aesthetics and industrial water use (Pommen 1983).

The range of normally encountered N:P ratios for algal tissues from freshwater is 5:1 to 10:1 (Nordin 1982). Ratios below this range are characteristic of nitrogen limitation while those above this range indicate phosphorus limitation. Only two of the N:P ratios from the August, 1986 survey were within the "normal" range (upper Hobbit Creek and lower Little Klappan) (Table 3-4). The upper Little Klappan station exhibited a phosphorus limitation (14.5:1), while the remaining four stations all exhibited nitrogen limitation.

Only two N:P ratios from the August, 1985 survey fell into the "normal" range (upper Hobbit Creek and Fox Creek) (Table 3.4). The upper Little Klappan River site showed a phosphorus limitation (22.2:1). The remaining five sites exhibited N:P ratios between 2.05:1 and 3.8:1, indicating nitrogen limitation. During the September, 1985 survey, possible nitrogen limitation was indicated at two sampling stations (lower Spatsizi River and lower Hobbit Creek; N:P of 3.4:1 and 4.1:1 respectively (Table 3-4). The upper Hobbit Creek and upper Spatsizi River sites suggest possible phosphorus limitation (N:P of 10.7:1 and 11.1:1, respectively). The N:P ratios of attached algae at the four remaining sites (upper and lower Little Klappan River, Fox Creek and Didene Creek) during September fell into the "normal" range.

Three of the present sampling locations were also sampled in August 1984 for algal tissue N:P content (Table 3-4). The upper Spatsizi River sample fell into the "normal" range (5.97:1), while the sample from Didene Creek was below the "normal" range (4.06:1) and the ratio from the upper Little Klappan River site was above the "normal" range (15.4:1).

The interpretation of N:P ratio analyses in attached algae samples at the Mount Klappan licence area is far from definitive (Table 3-9). Whereas some sampling stations exhibited consistency between sampling periods (e.g. the lower Spatsizi River and lower Hobbit Creek stations indicated nitrogen limitation in August 1985 and 1986 and September 1985) shifts between limiting factors are also apparent between sampling periods (e.g. lower Little Klappan River station was nitrogen limiting in August, 1985 and co-

TABLE 3-9

SUMMARY OF TRENDS IN ATTACHED ALGAL NUTRIENT LIMITATIONS, MOUNT KLAPPAN LICENCE AREA, 1984, 1985 AND 1986

Nitrogen Limitation (N:P < 5:1)		Co-limitation (N:P 5-10:1)		Phosphorus Limitation (N:P > 10:1)
		Upper Little Klappan River Sep/85	←	Upper Little Klappan River Aug/84/85/86
Lower Little Klappan River Aug/85	→	Lower Little Klappan River Sep/85, Aug/86		
		Fox Creek Aug & Sep/85		
Didene Creek Aug/84/85/86	→	Didene Creek Sep/85		
Upper Spatsizi River Aug/85, Aug/86	—	Upper Spatsizi River Aug/84	→	Upper Spatsizi River Sep/85
Lower Spatsizi River Aug & Sep/85, Aug/86				
		Upper Hobbit Creek Aug/85, Aug/86	→	Upper Hobbit Creek Sep/85
Lower Hobbit Creek Aug & Sep/85, Aug/86				

limiting in September 1985, and August, 1986; the Upper Spatsizi River was nitrogen limiting in August 1985 and 1986, co-limiting in August 1984, and phosphorus limiting in September 1985). In the Little Klappan River drainage, the headwaters appears to be co-limiting or phosphorus limiting, while the downstream station appears to be nitrogen limiting or co-limiting. In the Didene Creek drainage, the headwater region (i.e. Fox Creek) appears to be both nitrogen and phosphorus limiting while at the creek mouth, the trend is from nitrogen limitation in August to a co-limiting system in September.

It is suspected that several other factors also play important roles in determining algal productivity at the licence area, notably the short growing season (mid-July through September) and the relatively cold water temperatures (the maximum water temperature recorded in running waters at the licence area from 1984 to 1986 was 13^{0}C, at Fox Creek on August 6, 1985). This relatively poor environment for algal growth was evident during 1984, 1985 and 1986 investigations, as attached algae were extremely difficult to locate, and algal samples which were collected often contained substantial quantities of sediment which had settled on the algae. Additionally, this technique does not account for species specific differences in nitrogen and phosphorus ratios within attached algae. Thus comparisons between stations where different species may be growing, or between sampling dates where the species composition or relative abundance within the community may have changed could lead to inappropriate conclusions.

A guideline to prevent eutrophication has been developed by the United States Environmental Protection Agency (1973). This criterion suggests that to control eutrophication, levels of inorganic nitrogen (nitrate-nitrogen plus nitrite-nitrogen plus ammonia-nitrogen) should not exceed 1.0 mg/l in free-flowing waters at the beginning of the growing season. Levels of inorganic nitrogen et the downstream station on the Little Klappan River in mid-June, 1986 and early July, 1985 were in the range of 0.04 mg/l; those in Fox Creek were in the range of 0.036 mg/l in mid-June, 1986, and 0.054 mg/l in early July, 1985; and, in Didene Creek inorganic nitrogen concentrations were in the range of 0.013 mg/l in mid-June, 1986 and 0.04 mg/l in early July, 1985. Clearly, the streams of the Mount Klappan licence area are well below the EPA criterion of 1.0 mg/l.

Another means of evaluating possible nitrogen or phosphorus limitation in an aquatic system is to consider the ratios of these elements in creek waters. Nordin (1982) concludes that when supply ratios of N:P (nitrate plus ammonia: total dissolved phosphorus) are in the 8-10:1 range both nitrogen and phosphorus are limiting, while ratios of less than 5-6:1 indicate nitrogen limitation, and ratios of greater than 12:1 indicate phosphorus limitation. The 1985 and 1986 water quality information indicate the N:P supply ratios fall well below a ratio of 5:1, suggesting nitrogen limitation at all sites during growing seasons (Table 3-10).

Algal growth, or chlorophyll a values, may be used to monitor changes in nitrogen or phosphorus availability in streams (Nordin 1982). Results from samples collected in August, 1986 indicate very low standing crops of algae at all stations (Table 3-5) when compared to the results of studies from a variety of habitats (Stockner and Shortreed 1976). Continued monitoring of chlorophyll a may be useful in detecting changes in phosphorus and especially nitrogen availability since the water within the Mount Klappan licence area appears to be largely nitrogen limiting to algal growth.

2.6 CONCLUSIONS

The 1985 and 1986 Mount Klappan water quality studies provide pre-development baseline data regarding seasonal trends in the water chemistry of the licence area. The water quality was found to be good, and no limitations to mine development were apparent. Nine metals were found, on occasion, to naturally exceed the criteria established by the Ministry of Environment. Available information suggests that algal growth in the Little Klappan River may be nitrogen-limited during at least part of the growing season.

TABLE 3-10

NITROGEN: PHOSPHORUS RATIOS[a] IN WATER SAMPLES COLLECTED AT THE MOUNT KLAPPAN LICENCE AREA, AUGUST-SEPTEMBER, 1985-1986

	August, 1985			September, 1985			August, 1986		
	NO_3/NH_3	TDP	N:p[b]	NO_3/NH_3	TDP	N:p[b]	NO_3/NH_3	TDP	N:p[b]
Spatsizi River upstream station	0.005/<0.01	0.008	1.9	<0.003/<0.01	0.020	0.65	<0.003/<0.01	0.015	0.87
Spatsizi River downstream station	0.003/<0.01	0.005	2.6	<0.003/<0.01	0.004	3.3	<0.003/<0.01	0.011	1.18
Hobbit Creek upstream station	0.003/<0.01	0.010	1.3	<0.003/<0.01	<0.003	<4.3	<0.003/<0.01	0.014	0.93
Hobbit Creek downstream station	<0.003/<0.01	0.003	4.3	<0.003/<0.01	0.005	2.6	0.012/<0.01	0.014	1.57
Fox Creek	<0.003/<0.01	0.004	3.3	<0.003/<0.01	0.009	1.4	<0.003/<0.01	0.014	0.93
Didene Creek	<0.003/<0.01	0.003	4.3	<0.003/<0.01	0.005	2.6	<0.003/<0.01	0.004	3.25
Little Klappan River upstream station	0.003/<0.01	0.006	2.2	0.011/<0.01	0.007	3.0	<0.003/<0.01	0.022	0.59
Little Klappan River downstream station	<0.003/ 0.02	0.005	4.6	<0.003/<0.01	0.006	2.2	<0.003/<0.01	0.021	0.62

[a] Nitrate (NO_3) and Ammonia (NH_3): Total Dissolved Phosphorus (TDP).

[b] Ratios taken as worst case, i.e., less than values taken as a concentration at the detection limit. Actual N:P ratios will be lower than those indicated.

3.0 SURFACE WATER HYDROLOGY

3.1 STUDY OBJECTIVES

The objectives of the surface water hydrology study were to:

- provide baseline data regarding hydrologic conditions and flow;
- permit prediction of hydrologic impacts of the proposed development;
- permit development of mitigations for such impacts.

3.2 METHODS

During conduct of the surface water quality investigation in 1984, 1985 and 1986, watercourse discharges were determined at all sampling stations on creeks and rivers. Staff gauges were installed from June to November of 1985 at all sites, with subsequent survey to bench marks during the August field work. Staff gauge installation was done according to the approach suggested by the Inland Waters Directorate of Environment Canada (1976). Locations of staff gauges are illustrated in Figure 3-1. Staff gauge readings were taken during water quality surveys, at which times discharges were measured, as well as on an opportunistic basis during the conduct of other environmental studies at the licence area. Almost daily readings were taken between early June and early August at the lower Little Klappan River, Fox Creek, and both upper and lower Hobbit Creek stations.

Surface water discharges were determined using the methods outlined by the Inland Water Directorate (1981). A Marsh-McBirney Model 201 Electromagnetic water velocity meter was used for velocity determinations at approximately 25 verticals on a transect across the river or creek. At each measurement point, velocity was determined at 0.2 and 0.8 m of depth when ice cover was present or if open-water depth exceeded 0.75 m. Averages of the two readings were used as the velocity for that vertical. For open water sites where depth was less than 0.75 m, the velocity reading was taken at 0.6 of depth.

In 1986, a continuous water-level recorder and gauge (Leupold and Stevens Type A, model 71 with float and beaded chain within a pressure treated plywood stilling well) were installed on the Little Klappan River. The recorder, located on the left downstream bank adjacent to the Mount Klappan air strip (Figure 3-10), was in operation from June 15 to September 26, 1986.

3.3 DATA PRESENTATION

Staff gauge readings and discharge measurements taken during 1985 and 1986 are summarized in Table 3-11 and 3-12. Mean daily discharges for the Little Klappan River derived from the continuous water level recorder are shown in Table 3-13. Representative hydrographs, from the upper Spatsizi River and the lower Little Klappan River stations are shown in Figures 3-11 and 3-12.

3.4 DISCUSSION

3.4.1 Mount Klappan Licence Area

Within the Mount Klappan licence area, minimum flows during 1985 and 1986 were measured during late winter (February to April) at all sampling stations (Table 3-11 and 3-12). Maximum recorded flows in 1986 occurred in June at all stations. Maximum flows in 1985, as determined from staff gauge readings, occurred slightly earlier. Maximum flows in the smaller tributaries (e.g., Hobbit Creek, June 18) occurred earlier than the major watercourses.

Low flows at the various stations ranged from 0.0008 m^3/s (February, 1986) at upper Hobbit Creek to 0.514 m^3/s (March, 1986) at the downstream Spatsizi River station while high flows (at the same stations) were 0.955 m^3/s (June, 1986) and 28.963 m^3/s (September, 1986) respectively.

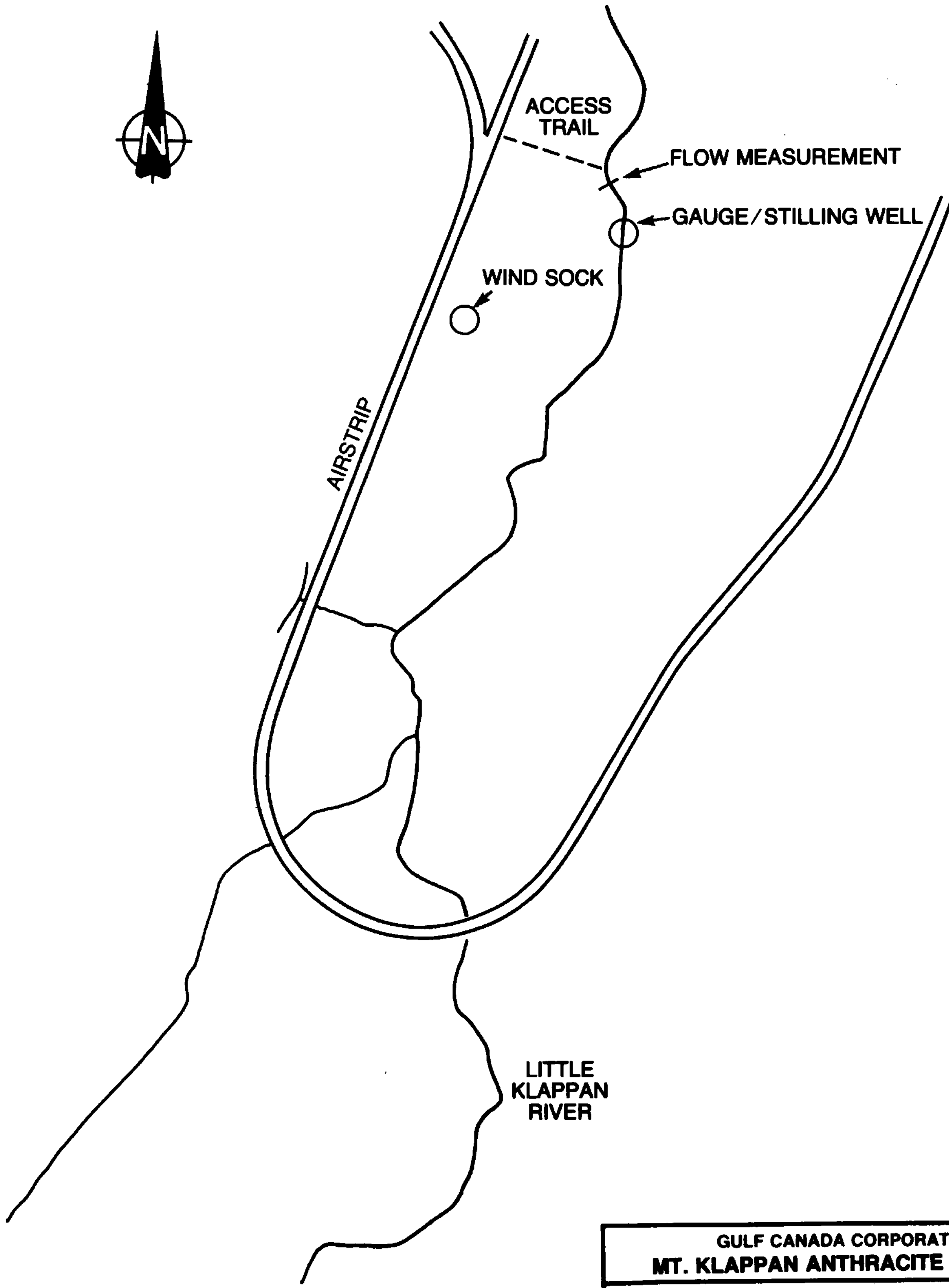


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FIGURE 3-10

LOCATION MAP
WATER LEVEL RECORDING GAUGE

ENVIRONMENTAL MANAGEMENT ASSOCIATES

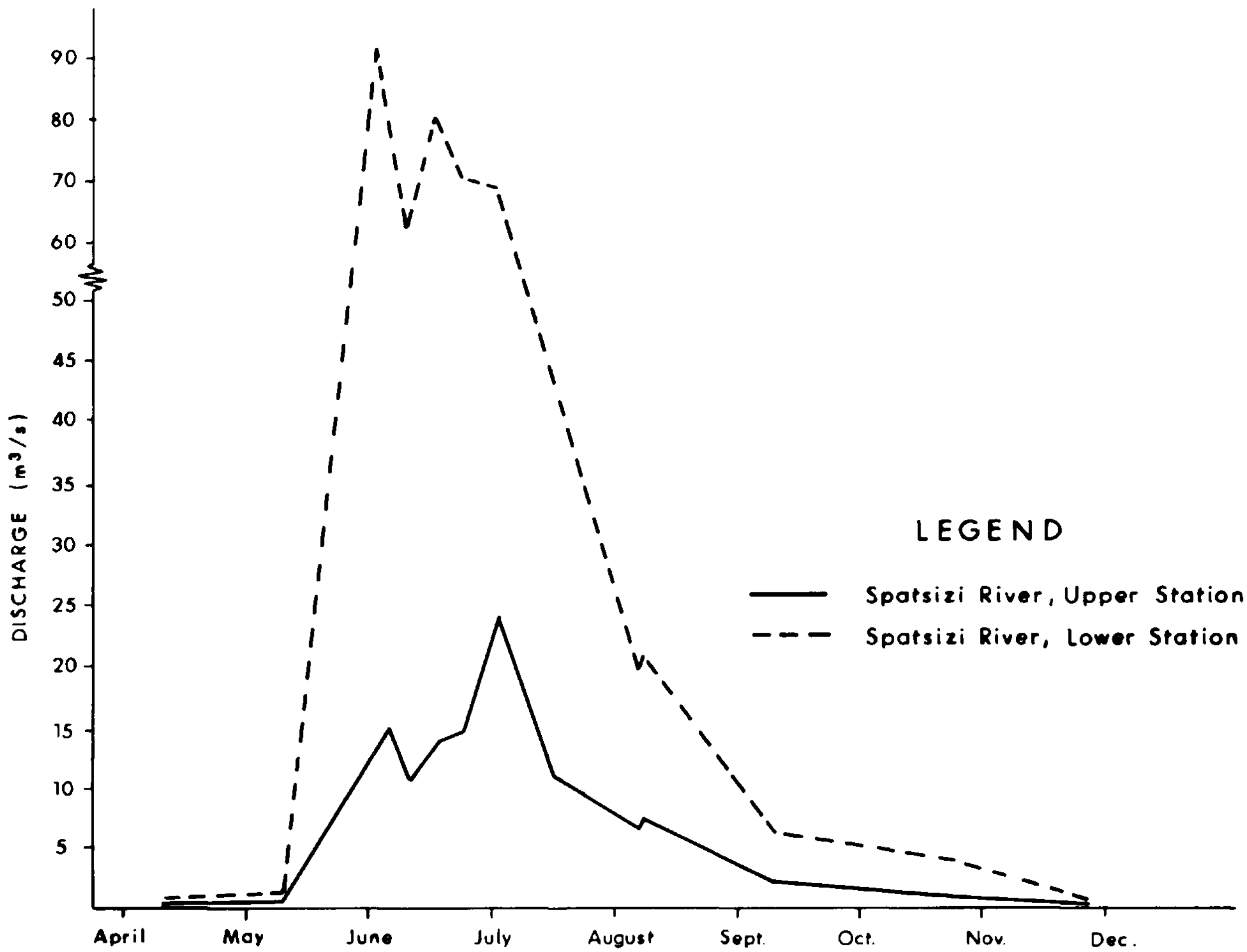

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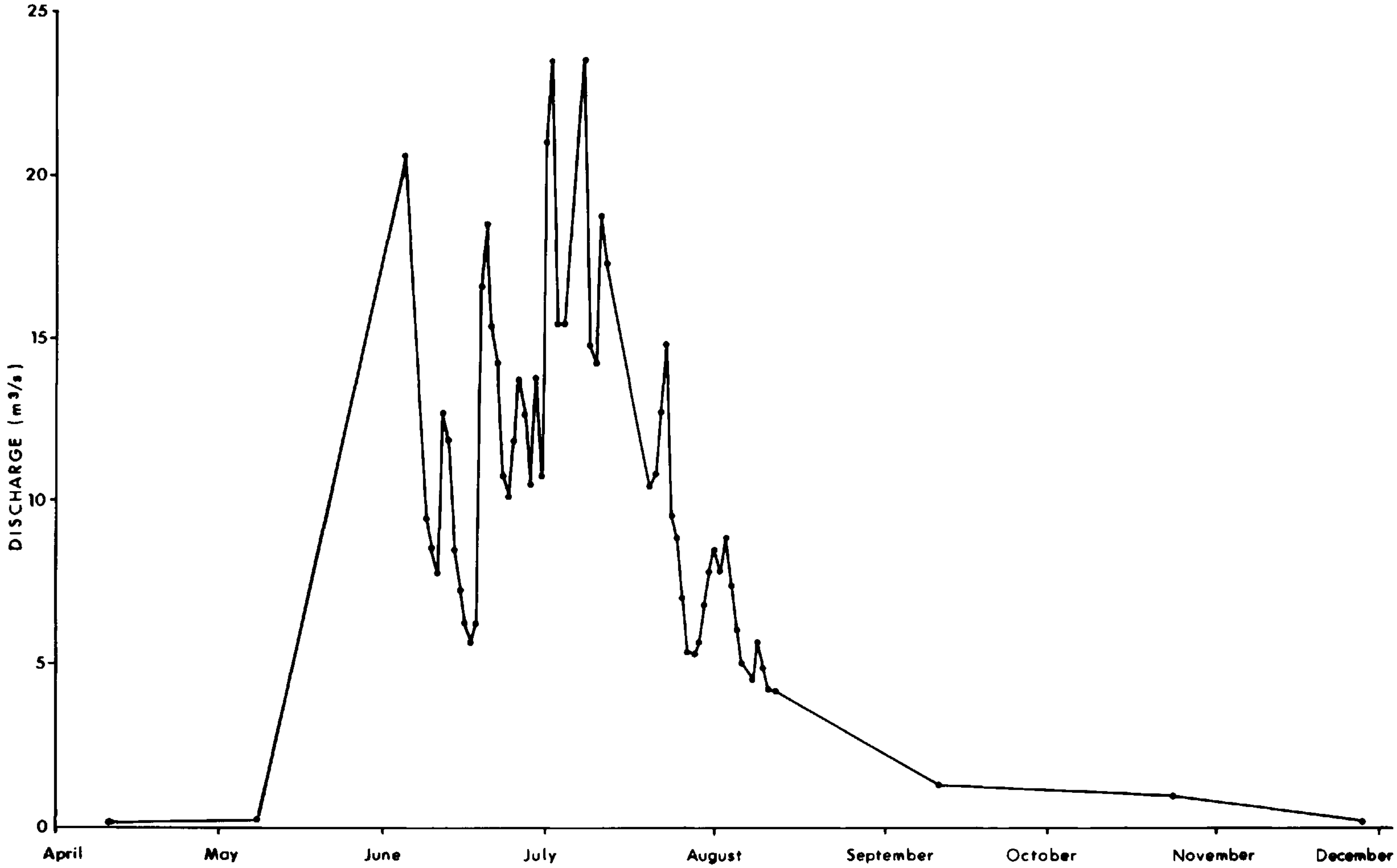
FIGURE 3-11

SPATSIZI RIVER HYDROGRAPH APRIL TO NOVEMBER, 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES



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MT. KLAPPAN ANTHRACITE PROJECT

FIGURE 3-12

HYDROGRAPH OF THE LITTLE KLAPPAN RIVER, LOWER STATION, APRIL - NOVEMBER, 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

TABLE 3-11

STAFF GAUGE READINGS AND ASSOCIATED SURFACE WATER DISCHARGES FROM THE MOUNT KLAPPAN LICENCE AREA, 1985-1986

	1985																
	Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec
	SC[a]	Q[b]	SG	Q	SG	Q	SG	Q	SG	Q	SG	Q	SG	Q	SG	Q	Q
Little Klappan River upstream station	N/A	0.029	N/A	0.023	-	2.50	0.46	3.878	0.38	1.736	0.20	0.403	(0.24)[c]	0.167	0.09	0.036	0.061
Little Klappan River downstream station	N/A	0.112	N/A	0.193	0.78	20.423	0.70	16.633	0.42	3.753	0.25	1.223	0.21	0.890	0.10	0.168	0.163
Fox Creek	N/A	0.057	N/A	0.031	0.39	4.264	0.36	2.380	0.23	0.565	0.14	0.117	0.12	0.135	0.01	0.033	0.027
Didene Creek	N/A	0.020	N/A	0.110	0.54	13.571	0.47	9.417	0.18	1.222	0.10	0.479	0.11	0.459	0.01	0.059	0.062
Spatsizi River upstream station	N/A	0.252	N/A	0.429	0.44	14.930	0.57	21.108	0.29	5.805	0.15	2.236	0.11	1.204	0.01	0.272	0.367
Spatsizi River downstream station	N/A	0.644	N/A	1.305	1.04	90.604	0.94	66.591	0.52	17.660	0.29	6.603	0.22	3.881	0.01	0.813	1.197
Hobbit Creek upstream station	N/A	0.007	N/A	0.010	0.44	1.060	0.35	0.822	0.12	0.116	0.04	0.043	0.03	0.010	0.01	0.009	0.006
Hobbit Creek downstream station	N/A	0.008	N/A	0.129	0.35	0.976	0.29	0.643	0.17	0.117	0.07	0.042	0.07	0.032	(0.18)[c]	0.042	0.003

continued . . .

Table 3-11 (continued)

	1986					
	Jan	Feb	Mar	Jun	Aug	Sep
	Q	Q	Q	Q	Q	Q
Little Klappan River upstream station	0.061	0.014	0.003	2.247	1.36	1.707
Little Klappan River downstream station	0.086	0.057	0.089	15.24	3.983	3.818
Fox Creek	0.047	0.021	0.004	2.742	0.431	0.532
Didene Creek	0.044	0.010	0.022	8.299	0.967	4.068
Spatsizi River upstream station	0.267	0.184	0.232	15.578	7.202	4.894
Spatsizi River downstream station	0.711	0.572	0.514	68.52	16.641	28.963
Hobbit Creek upstream tation	0.005	0.0008	0.002	0.955	0.120	0.165
Hobbit Creek downstream station	0.009	0.0015	-[c]	1.002	0.134	0.152

[a] SG - staff gauge reading (m); staff gauges installed from June to November, 1985 only.
[b] Q - discharge (m^3/s).
[c] staff gauge reading inaccurate or unavailable due to downstream ice-jam creating abnormally high water level reading.

TABLE 3-12

STAFF GAUGE READINGS AND FLOWS FROM THE STAGE-DISCHARGE CURVES,
MOUNT KLAPPAN LICENCE AREA, JUNE 8 - AUGUST 11, 1985

	Upper Little Klappan River		Lower Little Klappan River		Fox Creek		Didene Creek		Upper Spatsizi River		Lower Spatsizi River		Upper Hobbit Creek		Lower Hobbit Creek	
	SG[a]	Q[b]	SG	Q	SG	Q	SG	Q	SG	Q	SG	Q	SG	Q	SG	Q
June 8	-	-	0.58	9.50	0.33	1.85	-	-	-	-	-	-	0.29	0.54	0.225	0.22
June 9	-	-	0.55	8.50	0.30	1.34	-	-	-	-	-	-	0.26	0.47	0.21	0.18
June 10	-	-	0.53	7.75	0.30	1.34	-	-	-	-	-	-	0.25	0.44	0.20	0.17
June 11	-	-	0.65	12.70	0.35	2.30	0.46	9.50	0.385	11.00	0.91	67.50	0.35	0.75	0.32	0.73
June 12	-	-	0.63	11.80	0.33	1.85	-	-	-	-	-	-	0.29	0.54	0.23	0.24
June 13	-	-	0.55	8.50	0.275	1.00	-	-	-	-	-	-	0.27	0.49	0.20	0.17
June 14	-	-	0.51	7.20	0.25	0.75	-	-	-	-	-	-	0.24	0.42	0.18	0.13
June 15	-	-	0.48	6.20	0.26	0.84	-	-	-	-	-	-	0.23	0.40	0.17	0.12
June 16	-	-	0.46	5.60	0.25	0.75	-	-	-	-	-	-	0.24	0.42	0.17	0.12
June 17	-	-	0.48	6.70	0.26	0.84	-	-	-	-	-	-	0.29	0.54	0.23	0.23
June 18	-	-	0.72	16.50	0.41	5.05	0.47	9.90	0.435	14.00	1.01	80.25	0.46	1.23	0.46	-[c]
June 19	-	-	0.75	18.50	0.405	4.80	-	-	-	-	-	-	0.36	0.81	0.36	-[c]
June 20	-	-	0.70	15.40	0.38	3.25	-	-	-	-	-	-	0.35	0.75	0.355	-[c]
June 21	-	-	0.68	14.25	0.36	2.55	-	-	-	-	-	-	0.30	0.57	0.27	0.37
June 22	-	-	0.61	10.75	0.32	1.65	-	-	-	-	-	-	0.27	0.49	0.23	0.24
June 23	-	-	0.59	10.10	0.31	1.48	-	-	-	-	-	-	0.27	0.49	0.23	0.24
June 24	-	-	0.63	11.80	0.35	2.30	-	-	-	-	-	-	0.29	0.54	0.26	0.34
June 25	-	-	0.67	13.75	0.36	2.55	0.44	8.70	0.45	15.00	0.96	73.75	0.31	0.60	0.28	0.42
June 26	-	-	0.65	12.70	0.37	2.90	-	-	-	-	-	-	0.31	0.60	0.28	0.42
June 27	-	-	0.60	10.40	0.33	1.85	-	-	-	-	-	-	0.27	0.49	0.24	0.26
June 28	-	-	0.57	13.75	0.30	1.34	-	-	-	-	-	-	0.24	0.42	0.20	0.17
June 29	-	-	0.61	10.75	0.36	2.55	-	-	-	-	-	-	0.28	0.52	0.24	0.26
June 30	-	-	0.78	21.00	0.44	-[c]	-	-	-	-	-	-	0.41	1.02	0.42	-[c]
July 1	-	-	0.80	23.50	0.39	3.70	-	-	-	-	-	-	0.40	0.97	0.42	-[c]
July 2	-	-	0.70	15.40	0.35	2.30	-	-	-	-	-	-	0.28	0.52	0.29	0.47
July 3	-	-	0.70	15.40	-	-	0.47	9.90	0.57	22.25	0.94	71.25	-	-	-	-
July 4	0.46	3.65	-	-	0.36	2.55	-	-	-	-	-	-	0.37	0.84	-	-

continued . . .

Table 3-12 (continued)

	Upper Little Klappan River		Lower Little Klappan River		Fox Creek		Didene Creek		Upper Spatsizi River		Lower Spatsizi River		Upper Hobbit Creek		Lower Hobbit Creek	
	SG[a]	Q[b]	SG	Q	SG	Q	SG	Q	SG	Q	SG	Q	SG	Q	SG	Q
July 7	-	-	0.80	23.50	0.39	3.70	-	-	-	-	-	-	0.31	0.60	0.39	-[c]
July 8	-	-	0.69	14.75	0.38	3.25	-	-	-	-	-	-	0.29	0.54	0.35	1.18
July 9	-	-	0.68	14.25	0.35	2.30	-	-	-	-	-	-	0.28	0.52	0.34	1.04
July 10	-	-	0.76	18.75	0.39	3.70	-	-	-	-	-	-	0.35	0.75	0.43	-[c]
July 11	-	-	0.73	17.25	0.35	2.30	-	-	-	-	-	-	0.28	0.52	0.37	-[c]
July 16	-	-	-	-	0.27	0.95	-	-	0.385	11.00	-	-	-	-	-	-
July 19	-	-	0.60	10.40	0.32	1.65	-	-	-	-	-	-	0.34	0.71	0.42	-[c]
July 20	-	-	0.61	10.75	0.28	1.05	-	-	-	-	-	-	0.24	0.42	0.31	0.62
July 21	-	-	0.65	12.70	0.35	2.30	-	-	-	-	-	-	0.255	0.44	0.33	0.89
July 22	-	-	0.59	14.75	0.26	0.84	-	-	-	-	-	-	0.20	0.33	0.25	0.29
July 23	-	-	0.58	9.50	0.34	2.05	-	-	-	-	-	-	0.225	0.37	0.33	0.89
July 24	-	-	0.56	8.80	0.29	1.20	-	-	-	-	-	-	0.19	0.30	0.24	0.26
July 25	-	-	0.505	7.0	0.265	0.88	-	-	-	-	-	-	0.17	0.26	0.22	0.22
July 26	-	-	0.455	5.35	0.24	0.66	-	-	-	-	-	-	0.145	0.20	0.20	0.17
July 27	-	-	0.45	5.25	0.23	0.51	-	-	-	-	-	-	0.15	0.21	0.19	0.15
July 28	-	-	0.46	5.60	0.24	0.66	-	-	-	-	-	-	0.145	0.20	0.20	0.17
July 29	-	-	0.50	6.80	0.25	0.75	-	-	-	-	-	-	0.155	0.21	0.21	0.18
July 30	-	-	0.53	7.75	0.27	0.95	-	-	-	-	-	-	0.17	0.26	0.23	0.24
July 31	-	-	0.55	8.50	0.27	0.95	-	-	-	-	-	-	0.18	0.28	0.24	0.26
Aug 1	-	-	0.53	7.75	0.26	0.84	-	-	-	-	-	-	0.16	0.24	0.22	0.22
Aug 2	-	-	0.56	8.80	0.27	0.95	-	-	-	-	-	-	0.175	0.26	0.24	0.26
Aug 3	-	-	0.52	7.40	0.26	0.84	-	-	-	-	-	-	0.17	0.26	0.23	0.24
Aug 4	-	-	0.47	6.00	0.24	0.66	-	-	-	-	-	-	0.145	0.20	0.21	0.18
Aug 5	-	-	0.44	5.0	0.23	0.51	-	-	-	-	-	-	0.13	0.17	0.17	0.12
Aug 6	0.375	1.73	-	-	0.23	0.51	0.18	1.30	0.29	6.75	0.515[d]	20.00	-	-	-	-
Aug 7	0.355	1.51	0.42	4.50	0.225	0.48	0.20	0.31	0.31	7.40	0.535	22.00	0.12	0.15	0.195	0.16
Aug 8	-	-	0.46	5.60	0.235	0.54	-	-	-	-	-	-	0.11	0.13	0.185	0.14
Aug 9	-	-	0.43	4.80	0.24	0.66	-	-	-	-	-	-	0.12	0.15	0.215	0.20
Aug 10	-	-	0.41	4.20	0.23	0.51	-	-	-	-	-	-	0.11	0.13	0.19	0.15
Aug 11	-	-	0.41	4.20	0.22	0.45	-	-	-	-	-	-	0.10	0.11	0.18	0.13

[a]SG - Staff Gauge readings (m).

[b]Q - Flow taken from stage-discharge curve (m^3/s).

[c]Staff Gauge reading too far off stage-discharge curve to give an accurate flow.

[d]Staff Gauge reset.

TABLE 3-13

LITTLE KLAPPAN RIVER NEAR MINE SITE
1986
MEAN DAILY DISCHARGE
(m^3/s)

Day	June	July	August		September	
1		12.568	4.031		1.949	
2		10.915	4.619		1.643	1.631
3		7.386	4.378		0.934	0.750
4		6.789	4.300		0.754	0.510
5		8.156	2.798		0.721	0.468
6		9.115	3.702		0.668	0.398
7		9.518	3.260		0.631	0.349
8		9.030	2.397		0.583	0.288
9		8.789	2.212		0.981	0.813
10		8.550	2.513		1.359	1.304
11		7.922	3.016		1.061	0.921
12		7.614	2.396		0.826	0.606
13		7.084	3.597		0.620	0.336
14	11.600	11.600	1.999	2.004[a]	0.549	0.245
15	16.785	12.400	1.051	0.907	0.504	0.189
16	15.109	9.601	0.934	0.750	0.470	0.149
17	12.968	7.999	1.207	1.113	0.446	0.121
18	11.398	7.386	0.952	0.775	0.428	0.103
19	10.915	7.461	0.709	0.451	0.428	0.103
20	10.1076	7.461	0.636	0.356	0.425	0.100
21	9.030	6.789	0.601	0.311	0.420	0.095
22	9.354	7.085	0.606	0.306	2.653	2.652
23	9.936	5.655	1.072	0.935	6.606	
24	7.386	4.378	1.643	1.631	4.681	
25	5.453	3.810	1.372	1.320	3.546	
26	6.211	3.756	1.160	1.052		
27	9.114	4.995	1.372	1.320		
28	11.105	3.756	1.412	1.369		
29	11.202	3.597	1.736	1.731		
30	11.600	3.864	1.219	1.129		
31		3.702	1.093	0.964		

[a] Lower stage/discharge curve.

3.4.2 Little Klappan River Watershed

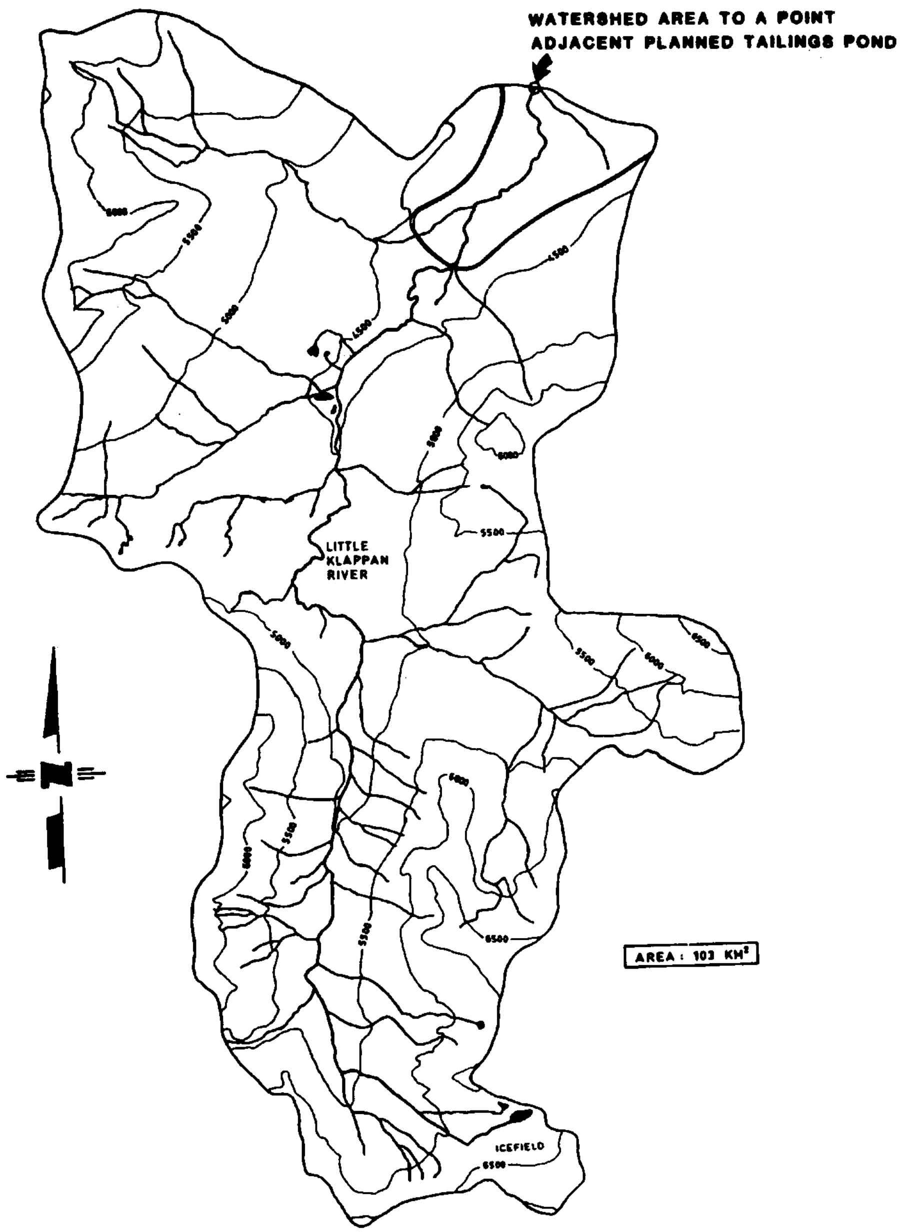
3.4.2.1 Introduction

The watershed of the Klappan River is located in a climatologic transition from maritime Pacific to dry interior continental. The isohyet map prepared by B.C. Hydro and Power Authority (B.C. Hydro 1981) indicates that the average annual precipitation over the Klappan Basin is approximately 550 mm and over the upper Little Klappan approximately 650 mm. A previous report suggested the rain equivalent total precipitation should range between 300 and 500 mm based on the Didene meteorologic station records. The mean annual runoff of the Klappan River near the confluence with the Stikine River (WSC gauge 08CC001) is 634 mm, measured over 20 years. The upper Klappan and Little Klappan watersheds include a proliferation of icefields which contribute to runoff over and above the contribution of annual precipitation. In recent years the contributions of icefield melt may have been reduced in the upper Little Klappan where an icefield noted in the maps dated 1967 has almost disappeared.

The Little Klappan River watershed (Figure 3-1), discharges to the Klappan River and then ultimately to the Stikine River. The drainage area of the watershed of the upper Little Klappan River downstream to the approximate location of the tailings pond (Figure 3-13) and the approximate location of the continuous flow recorder (Figure 3-10) is 103 km^2, ranging from an elevation of 1270 m to 2070 m. The mean elevation is 1600 m. There is the vestige of a small icefield at the head of the Little Klappan River. The length and slope of the basin are shown in Figure 3-14.

3.4.2.2 Hydrologic and Meteorologic Data

The most useful and significant hydrologic data used for this study was that available from the WSC gauge 08CC001, Klappan River at the Stikine River. The record is complete for over 20 years and the flows contain the tributary inflows of the Little Klappan River. Other regional gauges such as the Spatsizi River near the mouth (WSC gauge 08CA001) and the upper



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MT. KLAPPAN ANTHRACITE PROJECT

FIGURE 3-13

LITTLE KLAPPAN RIVER DRAINAGE BASIN

SCALE 1:75,000

ENVIRONMENTAL MANAGEMENT ASSOCIATES

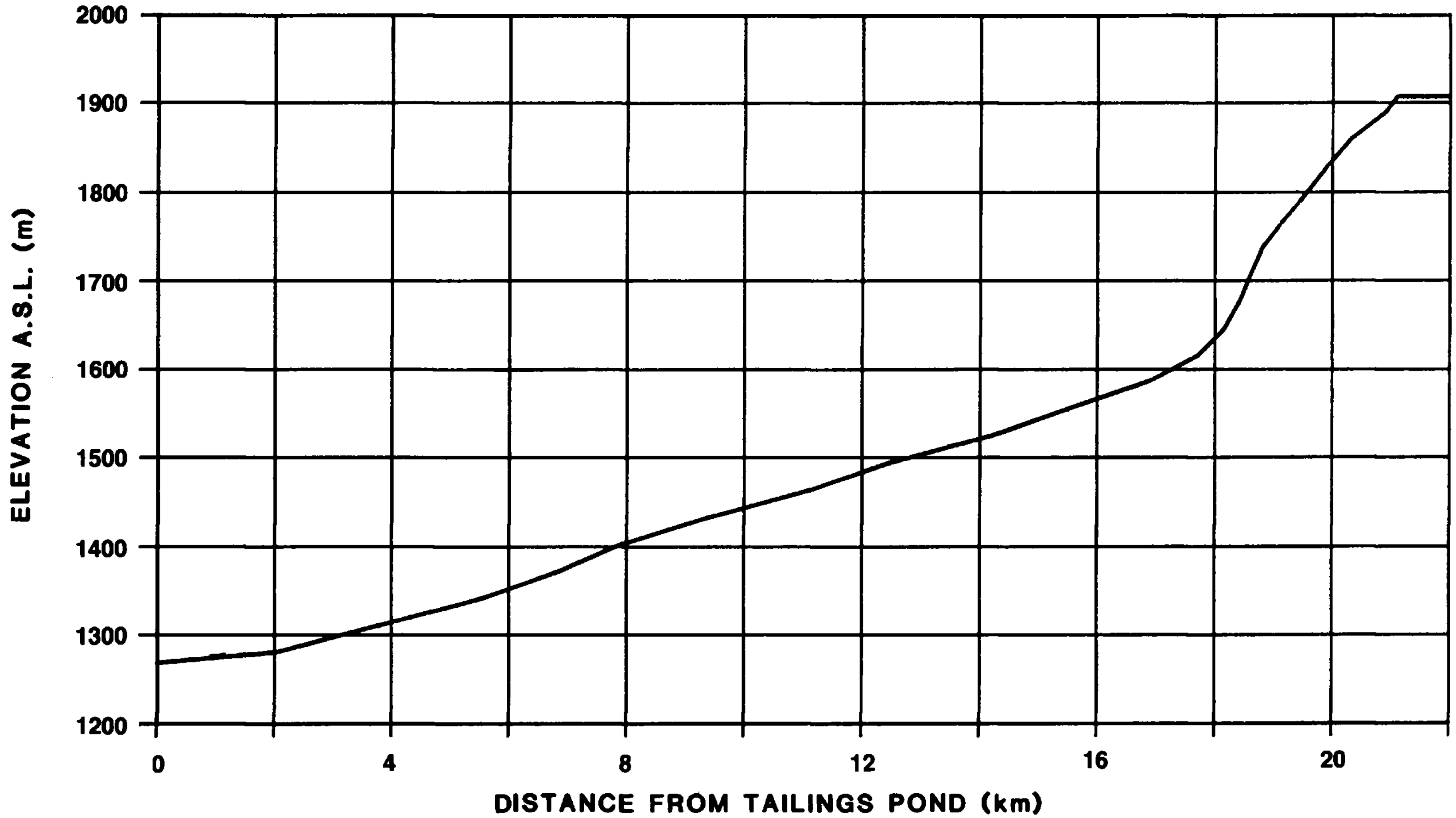

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FIGURE 3-14

LONGITUDINAL PROFILE, LITTLE KLAPPAN RIVER

ENVIRONMENTAL MANAGEMENT ASSOCIATES

Stikine River below Spatsizi River (WSC gauge 08CA002) have only 4 complete years of record and their drainage areas are slightly less and greater respectively than the Klappan gauge. The flow data collected for their study in 1984 and 1985 was useful for comparison with regional estimates.

The precipitation data base for the upper Little Klappan watershed is short and at apparent variance with that predicted by B.C. Hydro and the unit runoff over the Klappan Basin. However, the Didene station located on the valley floor will produce values far below the precipitation occurring at higher elevations. A rough estimate of precipitation at various elevations can be made by assuming a linear increase with increased elevation. B.C. Hydro (1981) used an increase of 25 mm per 100 m of elevation above 850 m. Using an average annual precipitation (based on 3.5 years of data) of 343 mm at the Didene station (MOE 1984), the average annual precipitation of the upper Little Klappan occurs at higher elevations and is estimated at 430 mm.

The upper Stikine station has a mean annual precipitation of 552 mm (MOE 1984) which would produce an estimated corresponding value of 590 mm for the subject basin. When evaporation and transpiration are considered, runoff based on either value would produce unit runoffs well below the basin average. This analysis suggests precipitation on the Klappan above the confluence with the Little Klappan basin is considerably higher than the existing data support, or alternatively the 3.5 years of data are not representative of the long term mean annual precipitation.

3.4.2.3 Mean Annual Runoff

The mean annual runoff of the Little Klappan River basin can be expected to range from 600 to 700 mm. In 1985 the runoff on this basin between April and November (95% of annual runoff) is estimated at 580 mm, and therefore 1985 appeared to be a below average year. However, based on the June and July flows at the Klappan WSC gauge, 1985 was 14 percent above average.

The Spatsizi River near the mouth (WSC gauge 08CA001) had a mean annual runoff of 540 mm over the period of 1981 to 1984. The mean annual runoff of the Klappan over the corresponding period was 642 mm. Since the estimated mean annual precipitation is equal on both basins it is reasonable to suggest that 100 mm of runoff or 15 percent of the total runoff on the Klappan is icefield melt. The Spatsizi River has few icefields.

Mean annual runoff based on 530 mm of precipitation runoff of the Klappan River would produce a corresponding value of 630 mm of runoff on the upper Little Klappan. Icefield melt will add little runoff over the subject watershed and result in an average annual runoff of 650 mm. This would correspond to an average annual flow of 2.1 m^3/s at a point in the watershed adjacent to the planned location of the tailings pond.

3.4.2.4 Maximum and Minimum Annual Runoff

Based on the relatively long-term record of the Klappan River near its confluence with the Stikine River, the annual runoff can be expected to vary from 81 percent to 123 percent of the mean. The maximum and minimum annual runoff for the much smaller and therefore more variable flow watershed at the mine site would be approximately 70 percent and 130 percent respectively.

3.4.2.5 Mean Monthly Flow Distribution

The distribution of the flow between the months will correspond somewhat to the distribution displayed by the flows of the Klappan River near the Stikine River. Winter flows would tend to be relatively lower because of the higher elevation of the watershed at the mine site and summer flows would be marginally higher due to increased unit runoff. The approximate distribution of mean monthly flows at the mine site would therefore be:

Month	Percent of Annual Flow
January	<1.0
February	<1.0
March	<1.0
April	<1.0
May	4
June	32
July	31
August	16
September	9
October	3
November	2
December	<1.0

3.4.2.6 Flood Flows

A regional flood study was completed to determine design flood flow for the project area. The study utilized Water Survey of Canada (WSC) gauge data from the surrounding regional stations plus seasonal gauge data collected by Gulf Canada consultants. Data from the following WSC stations was included in the analysis.

Station Number	Station Name	Drainage Area (km2)	Mean Annual Runoff (mm)	Mean Annual Daily Flood (L/s/km2)	Years of Data For Flood Calculation
08CE001	Stikine R. at Telegraph Creek	29,300	430	81	32
08CB001	Stikine R. above Grand Canyon	18,800	490	91	27
08CC001	Klappan R. above confluence with Stikine River	3,550	630	113	24
08EE008	Goathorn R. near Telkwa	132	420	112	25
08EE012	Simpson Ck. at the mouth	13.2	610	179	16
08CA001	Spatsizi R. near the mouth	3,400	540	115	5
08CA002	Stikine R. below Spatsizi R.	7,690	520	112	5
08CB002	Tanzilla R. near Telegraph Creek	1,600	350	78	8
86CG003	Iskut R. at outlet of Kinaskan L.	1,250	420	52	21
08CG004	Iskut R. above Snippaker Creek	7,230	1,200	192	18
08CG005	More Ck. near the mouth	844	1,800	320	12
08CG006	Forrest Kerr above 460m contour	311	2,700	510	14

Although 12 regional stations are listed in the above table, only 5 were ultimately useful in developing design flood information for the project area. The drainage catchments of the first three stations listed include the project area drainages but all three have drainage areas in excess of 3 000 km^2. These stations alone may therefore not provide suitable information about flood flows in the small (1-100 km^2) catchments which are typical in the project area.

The nearest suitable gauged small catchments were determined to be those of Goathorn River near Telkwa and Simpson Creek at the mouth (Smithers). Although these catchments are nearly 300 km southeast of the project site they were judged to be hydrologically similar to those at the site. They are located approximately the same distance from the Pacific marine influence as the project study area and they also cover similar elevation ranges. As well, the mean annual runoff and mean annual daily flood rates compare favourably with the recorded values at the Stikine and Klappan gauge sites.

The remaining seven stations were selected for inclusion in the table on the basis of geographic proximity to the project, however, examination of the catchment physiography and recorded data indicates that these stations either provide no additional information, or provide data which is not representative of the site.

Log normal and Gumbel (Chow, 1964) extrapolations of the peak instantaneous and peak daily unit flows for the useful stations were then performed in order to predict 10-year and 200-year return period flood flows. Good agreement between the two methods was achieved. The extrapolated unit flows were plotted against drainage area on logarithmic paper. However, before drawing design curves on the basis of this information, the hydrometric data from the site was also analyzed and plotted with the regional data.

The recorded peak flows for the site data are tabulated below together with the corresponding flow for Klappan River near the Stikine.

Station Name	Drainage Area (km2)	Recorded Peak Unit Flow (L/s/km2)	Date
Upper Hobbit Creek	5.7	216	June 18, 1985
Fox Creek	26	194	June 18, 1985
Lower Little Klappan River	146	162	July 1 & 7, 1985
Klappan R. above confluence with Stikine	3550	137	July 6, 1985

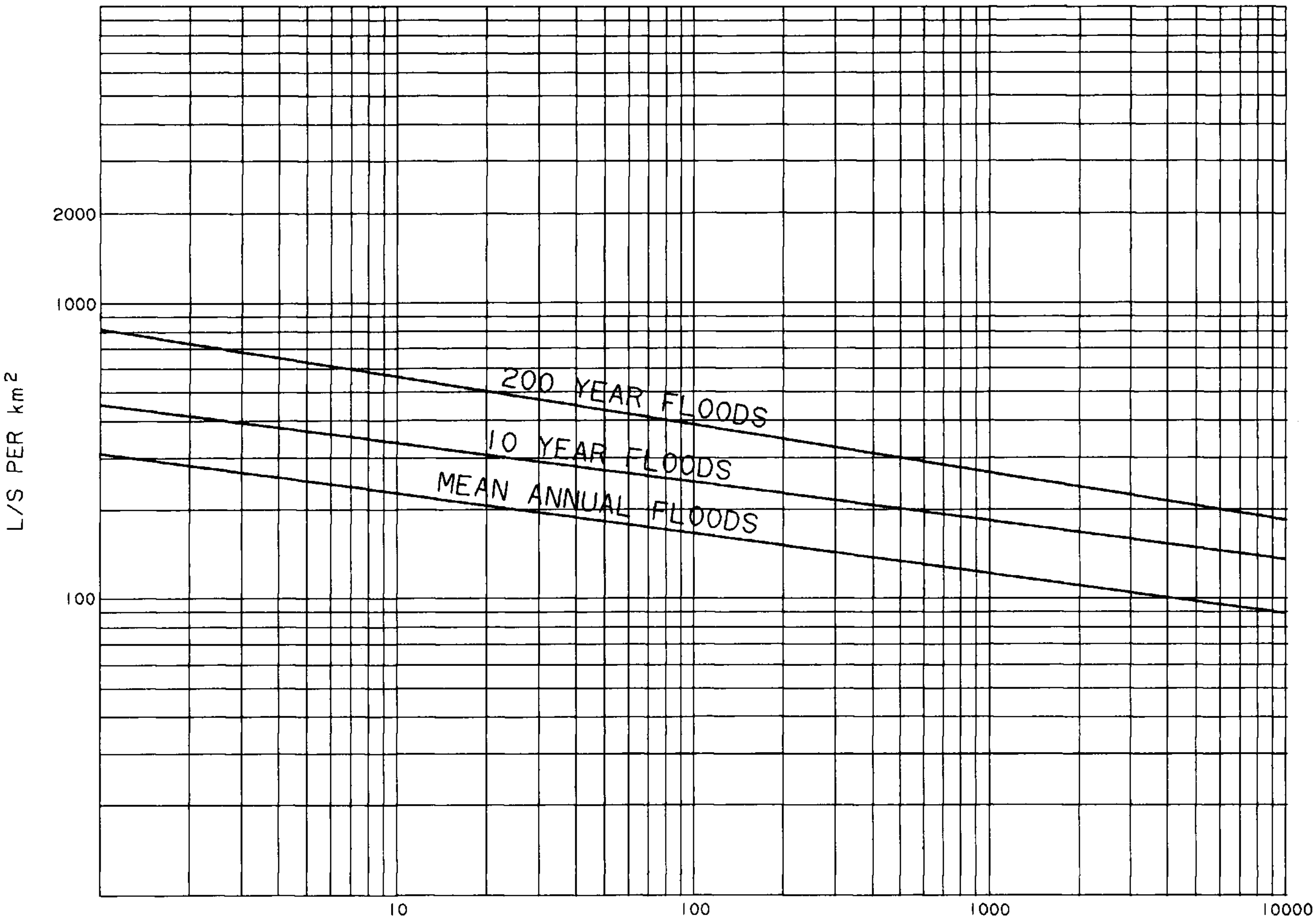
Based on the regional frequency analysis the 1985 peak flows have return periods between 2 and 5 years.

The return period for the Klappan River peak daily flow during 1985 was approximately 9 years. Therefore, assuming a similar flood magnitude at both the Klappan and project creeks, the design curves generated by the WSC data appear to be conservative. The above site data is, however, only corroborative at best and it will only become confirmatory when several more years of peak data are available.

The design curves finally selected for peak instantaneous and peak daily runoff are shown in Figures 3-15 and 3-16. The curves indicate flood flows from undisturbed lands. They must be adjusted to represent flows from surfaced areas, rock disposal areas and pits by using the design factors indicated on the figures. These factors have been selected through engineering judgement based on experience with similar coal mining developments in B.C.

3.4.2.7 Low Flows

The low flow regime was determined principally from the flow data of the Klappan River near the Stikine. Drainage area of the Klappan River was transpesed to the Little Klappan drainage at the mine site using an area



NOTE:
CURVES APPLY TO UNDISTURBED AREAS.
FOR DISTURBED AREAS MULTIPLY VALUE OBTAINED FROM CURVE BY THE FOLLOWING FACTORS:

COARSE ROCK DUMPS	- 1.0
ROADS & OTHER SURFACED AREAS	- 2.0
BARE ROCK SURFACE WITH NO DEPRESSION STORAGE	- 3.0

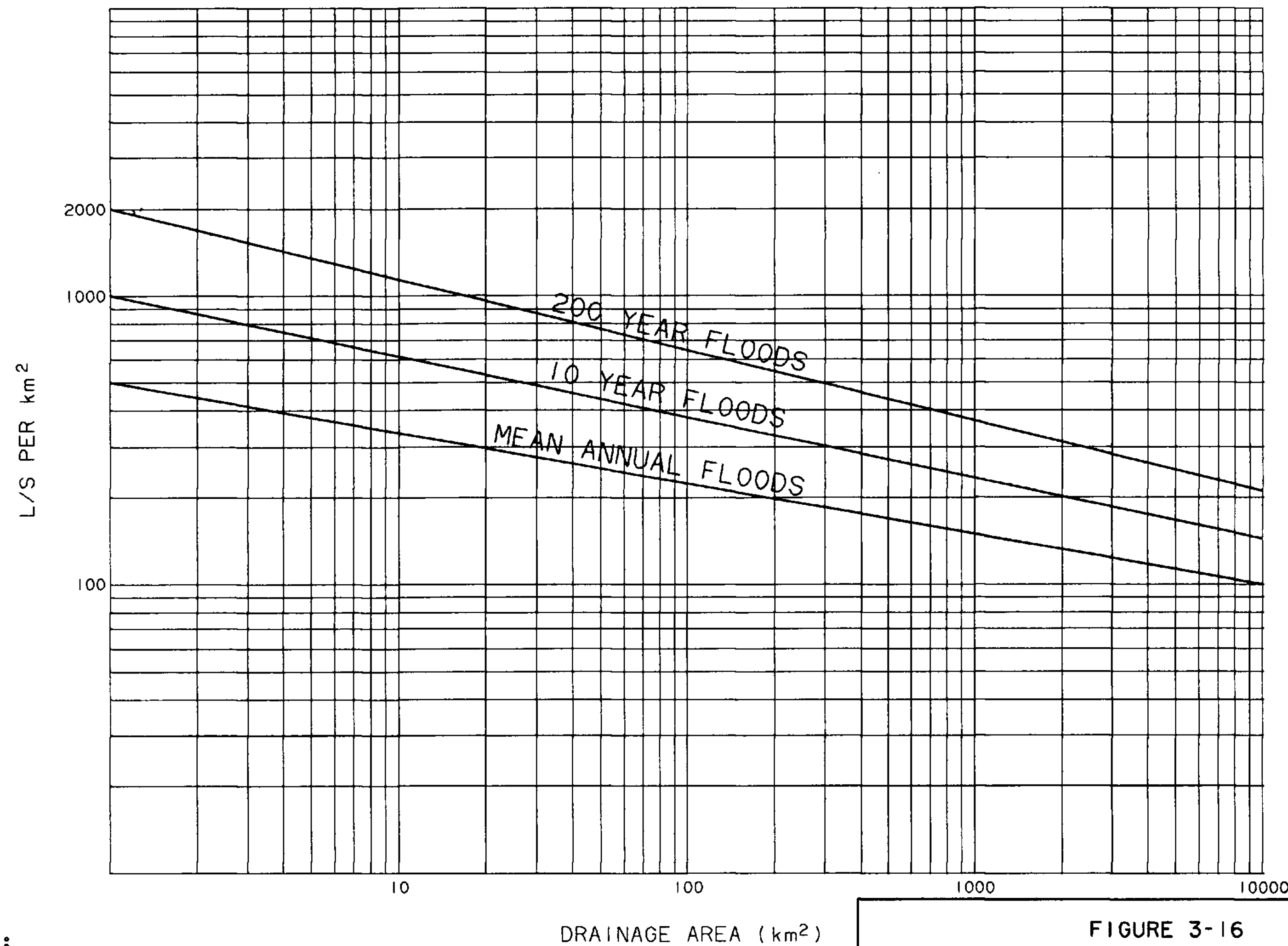
FIGURE 3-15

MOUNT KLAPPAN ANTHRACITE PROJECT

PEAK DAILY UNIT RUNOFF

KER, PRIESTMAN & ASSOCIATES LTD.

GULF CANADA CORPORATION
06/01/87
KLAP:[205057]860601049.LOC



NOTE:
CURVES APPLY TO UNDISTURBED AREAS.
FOR DISTURBED AREAS MULTIPLY VALUE OBTAINED FROM CURVE BY THE FOLLOWING FACTORS:

COARSE ROCK DUMPS	- 1.0
ROADS & OTHER SURFACED AREAS	- 2.0
BARE ROCK SURFACE WITH NO DEPRESSION STORAGE	- 3.0

FIGURE 3-16

MOUNT KLAPPAN ANTHRACITE PROJECT

PEAK INSTANTANEOUS UNIT RUNOFF

KER, PRIESTMAN & ASSOCIATES LTD.

GULF CANADA CORPORATION
06/01/87
KLAP:[205057]860601050.LOC

ratio to the 1.25 power. The variability of flows about the mean (5, 10 and 20-year return periods) was calculated using a variability index suggested by Lane and Lei (1949). The variability values were also checked against the unit hydrograph approach developed by Snyder (Chow 1964) and the spot measurements made in 1984 and 1985 at the minesite and were found to be consistent. The results of these analyses are presented below:

		Return Period (years)		
	Mean	5	10	20
Annual Minimum Daily Discharge (L/s/km2)	0.84	0.61	0.50	0.42
Annual Minimum 7-Day Discharge (L/s/km2)	0.97	0.63	0.51	0.43
Annual Minimum Monthly Discharge (L/s/km2)	1.03	0.70	0.58	0.45

3.4.2.8 Gauge Flows at the Mine Site, Summer 1986

The mean daily discharges of the Little Klappan River at the proposed location of the tailings pond (Figure 3-13) from June 15 to September 25 were determined from the chart record provided by the continuous water level recorder (Figure 3-10).

The mean daily flows and hydrograph for the summer of 1986 resulting from the recorded stage and stage-discharge relationship are provided on Table 3-13 and Figure 3-17 respectively. The two lines on the hydrograph at low flows are the envelope of probable discharges.

3.4.2.9 Characterization of 1986 Summer Flows

The recorded flows of the Klappan River near the Stikine were used to estimate flows at the mine site and preliminary mean daily flows, from June

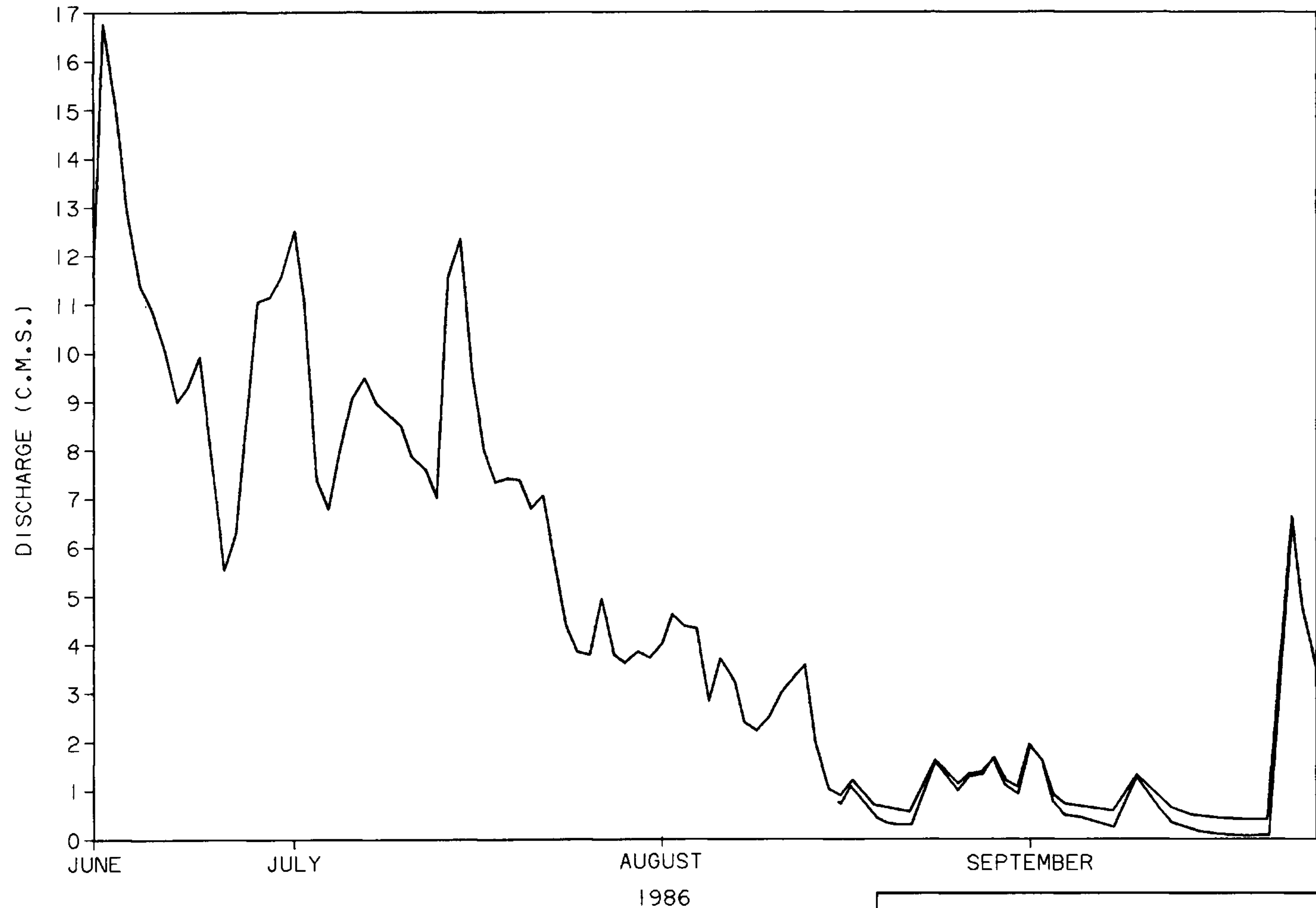


FIGURE 3-17

MOUNT KLAPPAN ANTHRACITE PROJECT

MEAN DAILY DISCHARGE,
LITTLE KLAPPAN RIVER, 1986.

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
30/12/86
KLAP:[205057]860601046.LOC

15 to July 15, 1986, were obtained from Water Survey of Canada (Table 3-14). The flows from July 15 to September 25 were not available at the time of writing this report.

Characterization of the flows at the mine site can be made on the basis of: mean low for the period (June 15 to July 14); and peak flow during the period.

The peak flow during this period usually is the maximum annual daily discharge and is based on the observer's recollection that the flow at the mine site on June 15 was the peak flow in 1986, to the end of September. The recorded peak flows and the estimated peak at the mine site based on the techniques explained previously are:

Peak Flows (m^3/s)

Klappan River near the Stikine River	Little Klappan River at Mine Site	
	Measured	Estimated
318	16.8	18.7

The similarity of the estimated and recorded flows of the Little Klappan River confirms the technique and suggests that the peak flow estimates in the section on annual maximum daily discharge are reasonable.

The mean annual flow of the Klappan River near the Stikine River during the period June 15 to July 14 is approximately 240 m^3/s. The mean flow for this period, in 1986, was 230.6 m^3/s (Table 3-14) or 96 percent of normal. The flow in the Little Klappan River for the corresponding period was 9.75 m^3/s. The estimated runoff for this period, based on June and July representing 31 and 32 percent respectively of the mean annual flow, is 7.1 m^3/s. The recorded value is 37 percent greater than estimated but the

TABLE 3-14

FLOW RATES
KLAPPAN RIVER NEAR STIKINE RIVER
(STATION 08CC001)

Date	m^3/s	Date	m^3/s
June 15	225	July 1	300
June 16	255	July 2	318[a]max
June 17	243	July 3	252
June 18	224	July 4	198
June 19	219	July 5	211
June 20	200	July 6	254
June 21	191	July 7	277
June 22	181	July 8	282
June 23	199	July 9	260
June 24	180	July 10	267
June 25	147	July 11	258
June 26	130	July 12	250
June 27	161	July 13	227
June 28	225	July 14	221
June 29	276		---
June 30	286	Mean	230.6

[a] Flow measured at $75.3 m^3/s$ - 28 August

comparison method is tenuous. The best statement that can be made regarding the recorded mean flow of 9.75 m^3/s is that it represents close to a median or expected mean value for that period.

4.0 GROUNDWATER

4.1 STUDY OBJECTIVES

The objectives of the groundwater study were to provide baseline groundwater data for the mine development area to:

- allow satisfactory pre-development documentation of groundwater quality and hydrology;
- permit the prediction of impacts, of the proposed development;
- facilitate engineering design to overcome these impacts.

4.2 METHODS

In late 1986 a geotechnical program was undertaken to test the building foundation areas, waste disposal area and the mine area. Forty standpipes and piezometers were installed in the mine infrastructure area and 14 standpipes and piezometer installations were made in the mine area.

The piezometers were used to measure groundwater pressure conditions existing in the boreholes. The piezometers installed by various workers during the 1984, 1985 and 1986 field seasons are monitored periodically. The most recent set of readings was taken in September, 1986.

Infiltration tests were conducted on 11 piezometers across the mine area to evaluate ground permeability. In addition, water samples were obtained from the drill holes, following the general procedure outlined in Section 2.1. Two thermister strings were also installed to supplement the three thermister strings installed in previous programs (1984 and 1985).

4.3 RESULTS AND DISCUSSION

4.3.1 Water Quality

Three groundwater samples, from DDH 86008, 86018 AND 86019, were obtained from the proposed pit area in September 1986. Samples showed high pH, specific conductance, alkalinity, and anomalous concentrations of dissolved aluminum, as well as slightly elevated dissolved copper and other metals (Table 3-15). It is suspected that the samples may have been contaminated by drilling mud. Because of the lateness of the season, it was not possible to obtain new samples. However, Gulf is committed to a seasonal sampling of tbe groundwaters of the proposed mine and infrastructuro areas.

4.3.2 Hydrology

A summary of the groundwater hydrology is presented here under the headings of the mine and various infrastructure areas. For a more complete treatment of the groundwater hydrology of these areas, see Volume II, Parts III and V.

4.3.2.1 Pit Area

Piezometric levels vary from depths of -15 to -60 m near the crest of Lost Ridge to artesian conditions in the southeast area of the proposed pit. Permeability appears to be greater parallel to bedding than across bedding. Average permeabilities range from 10^{-3} to 10^{-6} cm/sec. Faults and folds tend to 'compartmentalize' groundwater conditions. In general, the structural character of the pit area tends to act like a dish-shaped configuration which contains groundwater.

4.3.2.2 Waste Disposal Area

Piezometers (both standpipe and pneumatic) have been installed in five 1985 holes and two 1986 holes. A total of 10 instruments have been installed.

The 1986 results suggest near surface piezometric elevations for a variety of locations and at different depths. The 1985 holes show decreased pressures, possibly due to different climatic conditions this year compared to last year.

TABLE 3-15

GROUNDWATER MONITORING RESULT
(SEPTEMBER 1986)

		DDH 86018	DDH 86019	DDH 86008
Calcium	(mg/L)	9.6	12.8	43.8
Magnesium	(mg/L)	6.0	7.6	0.6
Sodium	(mg/L)	253.	80.	252.
Potassium	(mg/L)	1.52	21.	3.87
Chloride	(mg/L)	0.6	1.8	-0.1
Sulphate	(mg/L)	12.8	61.5	2.0
PP Alkalinity as Caco3	(mg/L)	43.0	-0.5	694.
Total Akalinity as Caco3	(mg/L)	623.	194.	809.
pH	(units)	0.88	8.03	12.4
Carbonate	(mg/L)	51.6	-0.5	136.
Hydroxide	(mg/L)	655.	237.	197.
Total Hardness as Caco3	(mg/L)	48.7	63.3	111.8
Fluoride	(mg/L)	0.44	0.22	0.19
Specific conductance	(umhos/cm)	1,140.	486.	2,780.
Total Inorganic Carbon	(mg/L)	89.0	37.0	10.0
Total Organic Carbon	(mg/L)	4.5	9.6	7.8
Total Ammonia Nitrogen	(mg/L)	0.60	0.44	9.80
Total Kjeldahl Nitrogen	(mg/L)	1.60	1.86	12.0
Nitrite Nitrogen as N	(mg/L)	0.004	0.013	0.009
Nitrate Nitrogen as N	(mg/L)	0.061	0.45	0.159
Ortho Phosphorous as P	(mg/L)	0.012	0.010	0.010
Total Phosphorous as P	(mg/L)	0.098	0.047	0.020
Total Filtrable Residue	(mg/L)	670.	290.	600.
Non Filtrable Residue	(mg/L)	10,300.	348.	868.
Aluminum	(mg/L)	0.43	3.10	93.5
Barium	(mg/L)	0.11	0.03	0.08
Cadmium	(mg/L)	-0.0002	0.0006	-0.0002
Chromium	(mg/L)	0.061	0.002	0.007
Copper	(mg/L)	0.003	0.038	0.010
Iron	(mg/L)	0.12	0.006	0.08
Lead	(mg/L)	-0.002	0.004	0.016
Manganese	(mg/L)	0.036	0.020	-0.004
Mercury	(mg/L)	-0.00005	-0.00005	0.00010
Nickel	(mg/L)	0.001	0.002	0.007
Selenium	(mg/L)	0.0006	0.0002	0.0003
Silver	(mg/L)	-0.001	-0.001	-0.001
Zinc	(mg/L)	0.009	0.011	0.009

Note - metals are dissolved
- minus (-) sign denotes "less than"

In general, the upper part of the waste disposal area is located within a recharge area, while the lower part of the waste disposal area is in a discharge area. In some areas, low permeability glacial till confines water in bedrock, at least for those years of high groundwater conditions. In other areas of rock outcrops, poorly defined seepage may occur. At higher elevations on Lost Ridge, surficial groundwater tables within colluvial materials may be perched on bedrock, while the bedrock groundwater conditions may be similar to those in the mine.

4.3.2.3 Plant Area

The depths to water indicated in piezometers varies widely from about 7.8 m below ground surface to about 3.6 m above ground surface (artesian). Only two 1986 test holes encountered water during the drilling process of which one continued to yield water after completion of the borehole. The other eleven test holes drilled in the vicinity of the proposed plant in 1986 encountered no groundwater inflows.

In general, groundwater seepage occurs in the near surface softened soils and organic soils. Most of the seepage appears to be within the upper portion of the till unit in materials disturbed by frost action and within surficial organic materials. In general, for piezometers located at depth in the glacial till, higher groundwater pressures seem to correlate with proximity of the piezometer to the bedrock surface.

4.3.2.4 Mine Office and Dry Area

Test hole drilling encountered groundwater seepage at 1.5 to 1.8 m depth except in the test hole located on the bog which encountered groundwater at the ground surface.

4.3.2.5 Tailings and Coarse Refuse Area

Piezometric levels range from about 1.5 m below ground surface to 4.5 m above ground surface (artesian) in the vicinity of the proposed tailings dam.

In general, higher piezometric water pressures exist in the till soils in the vicinity of the proposed tailings dam as compared to in the vicinity of the coarse refuse area. Higb piezometric pressure is consistent with water recharge into interlayered granular materials within the till at higher levels in the basin.

In general, shallow depths to groundwater are indicated across the area. Previous sandy zones in the till at the proposed tailings dam area produced some water during the drilling of some test holes. The presence of artesian water in the drill holes is consistent with a fairly pervious stratum located at depth connected to a recharge source at higher elevation.

The groundwater levels in the vicinity of the coarse refuse area vary from about 0.8 to 6.5 m below ground surface. In general, the groundwater levels in the surficial soils are about 1 or 2 m below ground surface. Piezometers located in glacial tills indicate water pressures well below ground surface.

4.3.2.6 Freshwater Dam

Drill holes located on the floodplain beside the Little Klappan River generally encountered groundwater inflow at about 1 m depth.

However, in all cases but one, a solid auger drilling method was used to advance the hole to refusal. The test hole which penetrated the deepest sands and gravels was advanced with a solid auger drilling method. Although there was some water in the hole during drilling, the hole stood satisfactorily to allow sampling at a 6.5 m depth.

Advancing an open hole below the water table in sands and gravels suggests that the gravels would yield nominal amounts of water in pumping tests. Furthermore, there is no clear evidence in the field investigations to date that significant open worked gravels exist within the sands and gravels of the Little Klappan River.

Drilling on the abutments of the proposed dam was carried out using a solid auger drilling method. No groundwater inflows were encountered.

5.0 IMPACTS AND MITIGATION

5.1 OBJECTIVES

The objectives of this section are to:

- identify and/or predict the potential impacts of the proposed mine development on the aquatic environment;
- quantify these impacts, where possible;
- assess the ramifications and significance of these impacts as they may affect the environment and/or the development;
- develop and present design or operating mitigations for the proposed development which may reduce or eliminate the negative impacts.

Many of the aquatic impacts and mitigations are dealt with in terms of design implications in Volume II. Where possible, reference will be made to the appropriate sections rather than repeating the information here.

5.2 SURFACE WATER QUALITY IMPACTS AND MITIGATION

The criteria established for the project by the Waste Management Branch of the B.C. Ministry of the Environment (Table 3-8) meet the most sensitive use requirements for published water quality criteria (i.e., protection of aquatic life, drinking water standards, irrigation use, etc.).

The existing water quality of the upper Little Klappan River, and indeed the licence area generally may be categorized as good. Surface waters are slightly alkaline and typically soft to moderately hard. Nutrient levels are relatively low as are the general levels of total and dissolved metals although three -iron, aluminum and copper- were present in relatively high background concentrations, particularly iron and aluminum during freshet. Of these, only copper was present at levels near the criterion established by the Ministry of Environment. No component in the surface water quality was identified which would hinder development of an anthracite mine on the

Mount Klappan licence area.

Generally, impacts on water quality by the proposed mine development could occur through the introduction of suspended solids and/or changes in water chemistry. These changes could in turn either positively or negatively affect productivity, stream biota, or the acceptability of the water for human consumption. Impacts resulting from the introduction of suspended sediments will be limited by the implementation of the surface water management plan discussed in Volume II, Part 6. Impacts resulting from changes in water chemistry will be limited by (a) the Ministry of Environment objectives for effluent discharge and (b) limited chemical alteration of water resulting from anthracite processing.

It is anticipated that there should be no difficulty in meeting the effluent guidelines of the Ministry of Environment. The Hobbit-Broatch Test Pit and Wash Plant Settling Pond and Tailings water chemistry results, discussed in more detail below, support this contention.

5.2.1 Suspended Solids

All effluent, including surface drainage from the development area will be passed through settling ponds to reduce suspended solids to the Pollution Control objective of 25-75 mg/l. The water management facilities for attaining this goal are fully described in Volume II, Part Six. Any deleterious effects of increases in suspended solids on stream biota in the Little Klappan River and downstream systems will thus be minimized and negligible.

5.2.2 Water Chemistry

During pre-mine development, two opportunities occurred to experimentally monitor changes in water quality which might occur as a result of mine development; the Hobbit-Broatch test pit (with the nearby Hobbit Creek); and the pilot plant settling and tailings ponds.

5.2.2.1 Water Quality Investigations of Hobbit-Broatch Test Pit and Hobbit Creek 1985-1986

Introduction

The Hobbit Broatch Test Pit located on the upslope side of the B.C. Rail grade, in close proximity to Hobbit Creek (Figure 3-1) was formed when a trial cargo of anthracite was removed from the site during the winter of 1984/ 85. A pond formed in the pit during freshet in 1985, fed partly by a small spring located in the southwest corner. Water quality was monitored to ensure that no discharges from the pit would occur that would exceed Ministry of Environment effluent objectives.

Methods

To monitor Hobbit Creek to determine if this test pit was affecting the quality of the creek water, two stations were established on the creek, one upstream and one downstream of the pit. The stations were sampled monthly from the initiation of the water quality sampling program in April 1985 to March 1986 and in June, August and September of 1986. Sampling in Hobbit-Broatch Pit commenced in August, 1985 and also continued to September, 1986. The parameters examined, and the methods employed for sampling and analyses are identical to those described in Section 2.3, Part III of this volume.

Data Presentation

The water quality data at the upstream control and the downstream station on Hobbit Creek and of the ponded water in the Hobbit-Broatch Test Pit is summarized in Appendix B.

Discussion

There were no unexpected differences in the water quality of the upstream and downstream stations at Hobbit Creek during the monitoring programs conducted in 1985 and 1986. In general, there was a slight increase in most parameters such as conductivity, total alkalinity, anion and cation concentrations, TSS and turbidity at the lower station as would be expected with the increase in drainage area at the downstream station during freshet.

Dissolved metal concentrations and nutrients were generally comparable at the two stations. In summary, there was no detected change in water quality in Hobbit Creek as a result of the test pit adjacent to the creek. This result is not unexpected, however, as there is no direct drainage from the pit area to Hobbit Creek.

Initial samples of the ponded water in Hobbit-Broatch Pit had elevated concentrations of most parameters examined, as would be anticipated with a recently disturbed area. As the seasons progressed, concentrations declined. The pH of pit waters appears to have decreased slightly from 1985 to 1986, but all values continued to be basic. Sulphate values were slightly higher than those of running waters adjacent to the pit (i.e., Hobbit Creek stations), until the summer of 1986 at which time pit waters had sulphate concentrations which were significantly higher than the adjacent creek. These elevated sulphate values are likely the result of mineral oxidation from the exposed anthracite and waste rock. The sulphate ion is readily soluble and as water in the pit is ponded, one would expect an increase in this parameter. The nitrate/nitrite concentrations in pit water exhibited a trend consistent with the comparable parameters in Hobbit Creek. Initial phosphorus values were generally higher than those of Hobbit Creek, but these values decreased over the sampling period, and declined to concentrations near those of adjacent running waters. Inorganic carbon concentrations were approximately the same as those of Hobbit Creek except during freshet when TIC values declined due to the dilution factor in the creek; however, as anticipated, organic carbon values were higher in the pit than in creek waters.

A trend to decreased concentrations over time was also generally observed with the dissolved metals. The two exceptions are manganese and barium, which had values in the range of <0.004 to 0.049 mg/l and 0.012 to 0.20

mg/l, respectively. These metal concentrations may be associated with the spring water which enters the pond from the southwest corner of the pit.

All characteristics of the Hobbit-Broatch Test Pit waters were well within the objectives for final effluent which would be discharged to fresh waters (MOE 1979).

5.2.2.2 Wash Plant Settling and Tailings Pond Water Quality

A temporary wash plant was constructed at the Gulf Mount Klappan licence area during the late summer of 1985. The plant was designed to utilize recycled tailings pond supernatant to minimize water requirements for the washing process. A settling pond was also constructed adjacent to the wash plant site, to collect surface runoff from the plant facility. As a condition of Approval Number NE-0205 for operation of the facility, a sampling and monitoring program was specified by the Waste Management Branch of the Ministry of Environment.

Four sample locations were specified for the program; the upper and lower stations on the Little Klappan River (i.e., the stations used for the collection of baseline data for the Mount Klappan licence area); the tailings pond supernatant; and, the settling pond supernatant. Sampling of the tailings and settling ponds was to be conducted monthly, presumably while the plant was in operation. The parameters to be measured as a condition of the permit were: TSS, pH, nitrate/nitrite as nitrogen and the dissolved forms of the metals aluminum, copper, cadmium, chromium, iron, lead and zinc. Prior to any release from the ponds and after shutdown of the wash plant, toxicity of the supernatant in the ponds was to be determined by an LT50 bioassay. The permit further stipulated that the upper and lower stations on the Little Klappan River should be sampled when the supernatant from the tailings pond was released to the intermittent creek and ultimately to the Little Klappan River.

Methods

The settling and tailings ponds were sampled from September, 1985 through to September of 1986. Wash plant operations ceased on December 13, 1985. However, sampling was continued on a monthly basis through to March, 1986, as well as in June, August and September of 1986.

The initial design for the settling pond specified piping of settling pond supernatant from the tailings pond for recycling within the wash plant. Technical problems prevented this disposal method for settling pond supernatant. A channel was therefore constructed from the settling pond to the adjacent intermittent creek. One additional sampling station was added during June 1985 at the point where this discharge was entering the adjacent muskeg drainage.

The methods employed during this aspect of the surface water investigations at the Mount Klappan licence area in 1985 are identical to those previously described in Section 2.3, of this Part, with the following exceptions. LT50 bioassays were conducted from December/85 through September/86 on both tailings pond and settling pond supernatants according to the guidelines specified in "Laboratory Procedures for Measuring Acute Lethal Toxicity of Liquid Effluents to Fish," Waste Management Branch, November, 1982.

As the program progressed it appeared that these supernatants were becoming more toxic to fish but the reason could not be determined on the basis of the analytical data. In August 1986 the analytical program specified in the permit was expanded to include the full list of parameters analyzed at other locations on the licence area. In addition, the concentration of phenolic compounds was determined at these stations (as well as all other monitoring stations on the licence area), and a hydrocarbon scan was carried out on samples from the three stations at the wash plant site. The hydrocarbon scan employs gas chromatography followed by carbon concentrations of individual carbon species within the sample. The detection limit for this analysis is 0.01 mg/l per species.

Data Presentation

The results of water quality analyses at the tailings pond, settling pond and settling pond drainage ditch are summarized in Appendix B. The LT50 bioassay results are presented in Table 3-16 while the results of the hydrocarbon scan are summarized in Table 3-17.

Discussion of Tailings Pond Data

Sampling over the 12 month period indicated an initial slight decline in pH to values still within the "neutral" range (i.e., from 7.5 to 6.5). The pH recovered to its original value approximately eight months after the cessation of wash-plant operation. The decrease in pH is likely due to absorption of carbon dioxide from the air, oxidation of sulphide minerals and hydrolysis of the ferric (Fe^{+++})ion. This pH change is considered to be inconsequential.

Nitrate/nitrite concentrations ranged from 0.018 to less than 0.003 mg/l. The nitrate/nitrite concentrations in the lower Little Klappan River were less than those of the tailings pond supernatant in September (<0.003 mg/l), but much higher throughout the remainder of the monitoring period. Concern regarding inorganic nitrogen in the tailings pond relates to use of nitrogen-based explosives during mining, which generally did not occur during the trial cargo operations. The measured concentrations were considerably lower than the effluent objective of 10 mg/l.

Of the dissolved metals examined during the monitoring program, cadmium was below the detection level. Very low concentrations of lead (generally <0.002 mg/l), copper (<0.001 mg/l to 0.004 mg/l), chromium (<0.001 to 0.004 mg/l) and aluminum (<0.01 to 0.04 mg/l) were found during the monitoring program. These values are comparable to the Little Klappan River background conditions. Dissolved zinc values were erratic in the tailings pond during the 12-month period, and were slightly higher than the concentrations of these parameters in the Little Klappan River during the comparable time period, but were always less than the effluent objective of 0.2 mg/l.

TABLE 3-16

LT50 BIOASSAY RESULTS[a]

Sample Location	December, 1985			January 1986			February, 1986			March, 1986			June, 1986			August 1986[b]		
	pH	DO	% Survival	pH	DO	% Survival	pH	DO	% Survival	pH	DO	% Survival	pH	DO	% Survival	pH	DO	% Survival
Tailings Pond	6.56	9.0	100	7.41	8.2	70	7.33	10.0	60	7.02	9.3	100			50	7.77	7.8	100
Settling Pond	7.38	9.1	90	8.01	8.4	100	7.68	9.8	100	7.54	9.2	90			60	7.87	7.9	100

[a] 100% concentration, 96-hour test, N=10 fish (*Salmo gairdneri*).
[b] Bioassays conducted in duplicate.

TABLE 3-17

RESULTS OF HYDROCARBON SCAN, TAILINGS AND SETTLING POND SAMPLES, AUGUST, 1986[a]

Carbon Species	Component	Settling Pond	Tailings Pond
C_6	Hexanes	-[b]	-
C_7	Heptanes	Trace[c]	-
C_8	Octanes	0.02	0.02
C_9	Nonanes	0.05	0.04
C_{10}	Decanes	0.04	0.07
C_{11}	Undecanes	-	-
C_{12}	Dodecanes	Trace	0.02
C_{13}	Tridecanes	-	0.01
C_{14}	Tetradecanes	-	-
C_{15}	Pentadecanes	-	-
C_{16}	Hexadecanes	-	-
C_{17}	Heptadecanes	-	0.02
C_{18}	Octadecanes	-	0.09
C_{19}	Nonadecanes	-	0.07
C_{20}	Eicosanes	-	0.07
C_{21}	Heneicosanes	-	-
C_{22}	Docosanes	-	-
C_{23}	Tricosanes	-	-
C_{24}	Tetracosanes	-	-
C_{25}	Pentacosanes	-	-

[a] Results presented as mg/l.

[b] - denotes concentrations less than 0.01 mg/l.

[c] Trace denotes concentrations at detection limit (0.01 mg/l)

Dissolved iron exhibited a high initial value (0.38 mg/l), but subsequently subsided to concentrations which approximate background levels in the river. In all instances, dissolved metal concentrations were a fraction of the objectives for final effluent discharges. The only metal which may be leaching from coal particles in the tailings pond is zinc; the maximum concentration recorded was 0.022 mg/l on August 6, 1986, which does not present any concerns for a tailings facility as the most rigorous effluent objective for dissolved zinc is 0.2 mg/l.

Discussion of Settling Pond Data

Samples from the wash plant settling pond and the pond/site drainage ditch revealed some interesting results. The pH of these waters approximated those of the Little Klappan River, when the drainage was active. During the winter months (December through March) there was no discharge from the settling pond. With no inflow, the quantity of water in the pond was very small. In late winter, only a few centimeters of water could be located in the pond, under approximately one metre of ice. Under these conditions, the pH of the pond waters did decline slightly to 6.90 in March . However, the pH quickly returned to 7.4-7.5 once the water began to flow. No particular significance is attached to this minor pH change. The TSS concentrations exceeded effluent objectives in September, October and November, due to traffic at the wash-plant site during this time period. Proper design of sediment basins in the full-scale operation will eliminate concern over the quality of the effluents.

Nitrate/nitrite values were initially higher in the settling pond drainage (0.021 to 0.32 mg/l range in October and November) than in the tailings pond (0.004 and 0.009 mg/l, respectively), but were within the range noted for the Little Klappan River during this time period. The concentration of these nutrients had dropped to very low levels by February. Dissolved cadmium, copper, chromium, lead, and aluminum concentrations were all low and generally comparable to those of the tailings pond and well within the Licence requirements.

Several elements did exhibit abnormal concentrations in the settling pond or settling pond drainage. The concentration of dissolved iron was uncharacteristically high in the settling pond in August, 1986, at which time a concentration of 0.25 mg/l was noted. However, this does not exceed the most rigorous MOE objective for effluents, which is 0.3 mg/l. An elevated dissolved iron concentration was noted in the settling pond drainage in June, 1986, when a value of 0.51 mg/l was recorded. The dissolved iron in the settling pond was low on that date (0.03 mg/l); therefore, the source of this iron must have been drainage along the ditch from the wash plant, or the upslope area which drains along the road margin.

Dissolved zinc concentrations were initially high within the settling pond (0.47 mg/l), but subsequently dropped to values much closer to those recorded for the tailings pond effluent. Dissolved zinc values increased in June and August at the settling pond (0.16 and 0.12 mg/l, respectively), as well as in the settling pond outflow in August (0.11 mg/l). It appears that dissolved zinc concentrations increased in the vicinity of the wash plant, probably in response to the stockpiling and handling of crushed coal, in a manner similar to that of the tailings pond effluent. The dissolved zinc values were, however, approximately one-half of the most rigorous objective for the mining industry (0.2 mg/l) in British Columbia (MOE 1979).

Dissolved manganese concentrations, measured as a part of the expanded August 1986 analytical program, in the settling pond supernatant measured 0.16 mg/l. This exceeds the Ministry of Environment effluent objective of 0.1 mg/l. These concentrations would not pose a threat to the aquatic resources of the Mount Klappan are. The objective is established on the basis of drinking water standards.

The second constituent of the settling pond effluent which was found at levels higher than anticipated was phenol which was present at a concentration of 0.007 mg/l. As previously discussed, this concentration is well below the guideline for the protection of the aquatic resource (0.2 mg/l).

Similarly the hydrocarbon scan (Table 3-17) did not result in the identification of any potentially toxic materials in the effluent.

The expanded analysis identified no component that either exceeded effluent objectives or was there in high enough concentrations to account for the mortality. No fish died in the August bioassay, confirming the relatively good quality of both the settling and tailings pond supernatants.

Efforts were also directed to checking the analytical component of the bioassay. No controls were run for any of the bioassays other than for August 1986 when duplicate samples were tested. No comment can be made on analytical procedures and the health and vitality of fish stocks. The cause of the mortality in the bioassay experiments remains unknown but does not appear to be related to settling and tailings pond water quality.

LT 50 Bioassay

In light of the analytical results, no mortality would be expected in a bioassay test of tailings and settling pond supernatant. Mortality did occur but in a highly variable and unpredictable manner. The LT 50 bioassay results are summarized in Table 3-16. Comparisons with the analytical data can suggest no causal relationship between mortality and any specific parameter.

Additional steps were taken to attempt to identify the cause of the mortality in the LT 50 bioassays.

1. Sulphate concentrations were analyzed beginning February 1986.

2. Analytical program expanded in August 1986 to be equivalent to that for other stations in the surface water quality program.

3. The concentration of phenolic compounds was measured in August 1986.

4. A hydrocarbon scan was conducted in August 1986 on both settling and tailings pond supernatants.

The purpose of the latter test was to check for the presence of any toxic hydrocarbon-based materials.

5.2.2.3 Acid Generation

The potential for acid generation by the anthracite and waste rock has been discussed in Volume II Part Six. The data shows that there is an abundance of acid neutralizing rocks in the mining waste. Only 8 of 104 samples showed a positive acid production potential. These potentially acid-producing strata occur infrequently within the mining sequence and are primarily siltstones and claystones.

Consequently, because acid generation appears to be extremely unlikely to occur, the water quality impacts will be negligible. Minor oxidation of sulphate will occur, however, and result in slightly elevated sulphate, total dissolved solids and conductivity of pit and runoff waters. These increases cannot easily be quantified, but are expected to be small and are not associated with aquatic toxicity.

5.2.2.4 Nitrogen Contamination from Explosives

The background levels of inorganic nitrogen (nitrate/nitrite plus ammonia) in the upper Little Klappan River (Table 3-18), are lower than the water quality criteria set by the MOE for the Mount Klappan Licence area.

However, nitrogen will be added to the effluent waters of the mine from the residue of explosives. The expected levels of explosives-N in the Little Klappan River are shown in Table 3-18. When explosives-N and background-N are summed, the inorganic nitrogen levels will not likely exceed the MOE water quality criteria (Table 3-8). For the purpose of these calculations, it has been assumed that the nitrogen is present as nitrate (94%), nitrite (1%) and ammonia (5%).

TABLE 3-18

EXPECTED NITROGEN CONCENTRATIONS IN THE LITTLE KLAPPAN RIVER

	Existing (mg/l)[1]	Expected Increase (mg/l)[2]	Water Quality Criteria (mg/l)[3]
NO_3 - N	<0.003 - 0.138	0.14	0.30
NO_2 - N	<0.003 - 0.009	0.002	0.02
NH_3 - N	<0.01 - 0.40[5]	0.008[5]	0.016[4]

1. See Tables 3-2 and 3-3.
2. See Table 6-6 of Volume II, Part VI; assumed split 94% NO_3 - N, 1% NO_2 - N, 5% NH_3 -N.
3. From Table 3-13.
4. Un-ionized (max).
5. Less than 2% of this NH_3-N will be un-ionized at the prevailing pH and temperature.

The addition of inorganic nitrogen to the upper Little Klappan River may increase its productivity although there is some suggestion (Appendix A) that at least in late-summer (1985) the upper Little Klappan is phosphorus or phosphorus-nitrogen co-limited. However, the resulting inorganic nitrogen levels of the Little Klappan River and downstream waters would still be far below the 1.0 mg/l suggested for the beginning of the growing season by the United States Environmental Protection Agency (1973) to control eutrophication.

5.2.2.5 Conclusions

The results of the experimental monitoring program on the Hobbit-Broatch test pit and Hobbit Creek and the wash plant settling and tailings ponds, the acid generation studies, and the discussion of nitrogen contamination from explosives, indicate that few problems are anticipated in meeting the final effluent objectives.

5.3 SURFACE WATER HYDROLOGY IMPACTS AND MITIGATION

The clearing of vegetation and removal of soils on the site will decrease the water holding ability of the site, increase the rate of runoff and intensify storm peaks. Such runoff will be capable of carrying sediments and causing erosion. Key sources of potential impacts include the issues discussed below.

5.3.1 Erosion and Siltation

An increase in silt loads is the most obvious and, potentially, one of the more adverse effects of mine development. Increased siltation may enter watercourses as a result of:

- open pit mine operations
- clearing and grubbing
- cut and fill operations for road construction
- grading and ditching activities

The severity of the effects on aquatic life caused by the introduction of silt to the watercourse will vary considerably with the timing, location and quantity of silt released.

5.3.2 Groundwater Removal

Based on piezometric data, limited pumping will be required in the pits early in the project and these waters will also be diverted through the settling pond system. Drains and relief wells may be installed to maintain disposal area and highwall stability. Groundwater which seeps into disturbed areas such as the pit may be contaminated by suspended solids which will require removal prior to discharge. All mine surface drainage goes to sedimentation traps if necessary.

5.3.3 Mitigation Methods

Sediment Control During Operation

Increases in suspended sediment concentrations in mine runoff will be controlled by collection of runoff by ditching to sediment ponds. In most cases these could consist of two ponds, a smaller pond for trapping coarser sediment and a larger pond for settling the majority of the fine material. The outflow from the final ponds could be discharged to either the Little Klappan River or Fox Creek. The ponds will be monitored and should the effluent fail to meet objectives, the systems would be upgraded to improve the effluent quality.

The long-term sediment control measures are described in detail in Part Six of Volume II, which contains the Water Management Plan for the Lost-Fox Mine.

Protection of Adjacent Areas

Waterbodies and areas adjacent to a construction site will be protected from sediment deposition. This will be accomplished by preserving a well-vegetated buffer strip around the lower perimeter of the land disturbance, or sediment basins, or by a combination of such measures.

Vegetated buffer strips will be used alone only where runoff in sheet flow is expected. Buffer strips will be at least 30 m in width, where practical.

Stabilization of Disturbed Areas

Soil stabilization refers to measures which protect soil from the erosive forces of raindrop impact and flowing water. Applicable practices include vegetative establishment, and the early application of gravel base. Selected soil stabilization measures will be appropriate for the time of year, site conditions and estimated duration of use.

Cut and Fill Slopes

Cut and fill slopes will be designed and constructed in a manner which will minimize erosien. Consideration will be given to the length and steepness of the slope, the soil type, upslope drainage area, groundwater conditions and other applicable factors. Slopes which are found to be eroding excessively within 1 year of construction will be provided with additional slope stabilizing measures where practical

The following guidelines will aid in developing an adequate design:

- Roughened soil surfaces are generally preferred to smooth surfaces on slopes.

- Diversions will be constructed at the top of long steep slopes which have significant drainage areas above the slope.

- Wherever a slope face crosses a water seepage plane which endangers the stability of the slope, adequate drainage or other protection will be provided, where practical.

Stabilization of Waterways and Outlets

All channels will be designed and constructed to withstand the expected velocity of flow from the design runoff without erosion. Stabilization adequate to prevent erosion will also be provided at the outlets of all pipes and paved channels.

Drainage

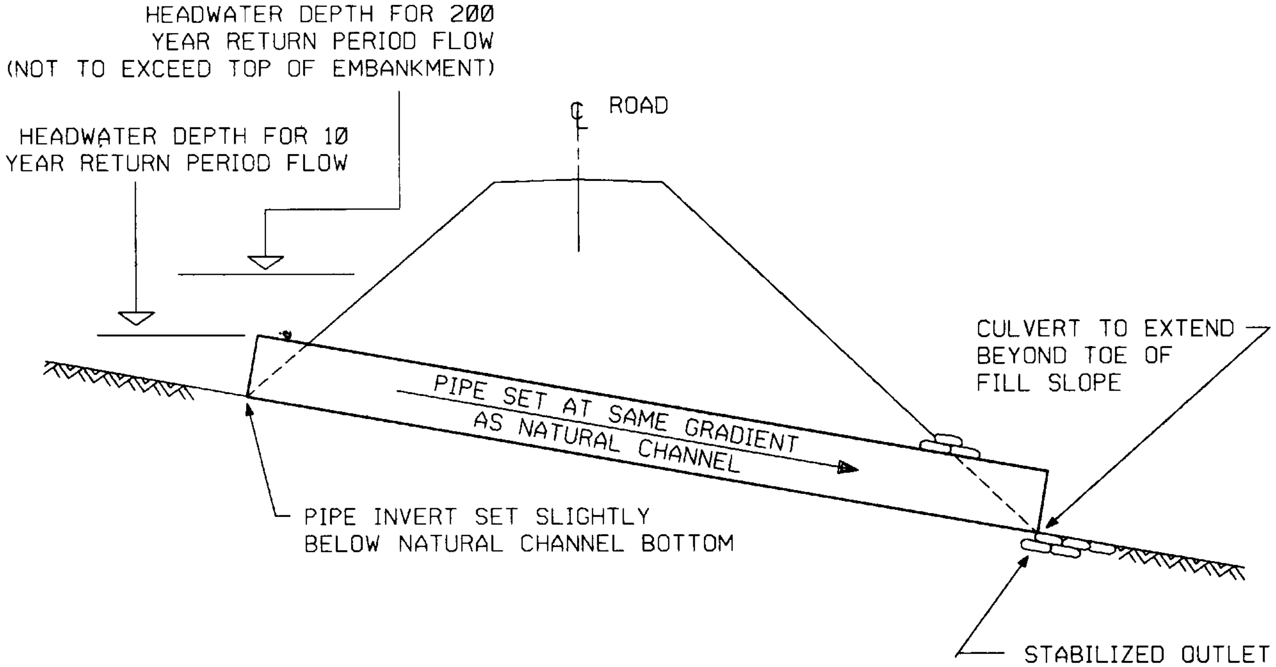
Culverts will be provided at watercourses and natural draws and to convey lateral drainage at intervals from the uphill side of the road to the downhill side, on long uniform grades. The interval will not be greater than 300 m. Minimum 800 mm diameter culverts will be used and they will extend beyond the toe of the fill slope. A typical culvert installation is shown in Figure 3-18.

Sufficient capacity to allow for blockage, freezing, ease of cleaning and flood flows will be achieved by maintaining the 800 mm minimum diameter requirement and by sizing larger culverts according to the design flood curves criteria covered in Section 3.4.2.6.

Normally culverts will be sized to accommodate the 10-year peak instantaneous flood when flowing just full. As well, the maximum culvert headwater depth during the 200-year flood will not exceed the top of the embankment.

Stream Crossings

Construction vehicles will not enter watercourses unless it is unavoidable. Where in-channel work is necessary, precautions will be taken to stabilize the work area during construction to minimize erosion. The channel (including bed and banks) will always be restabilized immediately after in-channel work is completed.



NOTES

1) THIS CULVERT INSTALLATION DETAIL IS APPLICABLE AT LOCATIONS WHERE FISH PASSAGE IS NOT REQUIRED.
INSTALLATIONS OF CULVERTS REQUIRING FISH PASSAGE WILL BE IN ACCORDANCE WITH FISH AND WILDLIFE BRANCH REQUIREMENTS.

2) MINIMUM CULVERT DIAMETER = 800mm.

FIGURE 3-18

MOUNT KLAPPAN ANTHRACITE PROJECT

TYPICAL CULVERT INSTALLATION
PROFILE

KER, PRIESTMAN & ASSOCIATES LTD.

GULF CANADA CORPORATION
06/01/87
KLAP:[205057]86060105I.LOC

Where a watercourse must be crossed by construction vehicles regularly during construction, a stream crossing will be provided.

Borrow Pits

Borrow pits will be located such that they do not adversely affect nearby watercourses. Borrow material will be obtained from upland sites which are no closer than 30 m from any active river channel unless there is no alternative to the use of streambed or floodplain material.

If a stream does not support or have the potential to support fish populations, then permission may be requested from the Ministry of Environment to excavate streambed or floodplain material.

In areas where waste or soil will be stockpiled, the same 30 m setback will apply. Waste piles will be as deep and compact as possible to minimize exposed surface. Waste areas will be stabilized to prevent wind and water erosion as and when practical during the life of the operation.

Revegetation

This section refers to revegetation of areas which are disturbed during construction, such as cut and fill slopes, and does not cover general reclamation resulting from pit operations.

A permanent vegetative cover will be established on denuded areas not otherwise permanently stabilized by other methods such as aggregate topping. Permanent vegetation will not be considered established until a ground cover is achieved which is mature enough to control soil erosion satisfactorily and to survive severe weather conditions.

The need for erosion control structures and attendant maintenance will be reduced by erosion prevention through revegetation. In addition to its soil stabilization effects, revegetation also increases the aesthetic quality of the site considerably.

5.3.4 Conclusions

The surface water hydrology studies provide baseline data for the development area and the licence area in general. These data have been utilized in project design, particularly with respect to the surface water management plan. No factor in surface water hydrology has been identified which would preclude development of an anthracite mine on the Mount Klappan licence area or which would create unmanageable impacts.

The water management and reclamation plans outlined in Part Six of Volume II will control suspended solids in area water courses such that the Pollution Control objective of 25-75 mg/l will be met.

Various suggested mitigative measures are included throughout this document. However, it should be noted that mitigative measures will be based on observation, experience and common sense. For example, if the control ditches discussed will disturb more ground and cause more erosion than is happening initially then it is not a good decision to make the ditches. Generally the undisturbed ground cover is the most effective erosion control.

5.4 FISHERIES IMPACTS AND MITIGATIONS

5.4.1 Introduction

The fisheries resources of the project area were identified and adequately described in the Stage I submission. No further inventory was required as the data were sufficient for the assessment of impacts in the Stage II submission.

The Stage 1 review comments focussed on the assessment of the potential impacts on the fish resources from sedimentation, acid generation, interrupted fish passage and increased sport fishing.

The Little Klappan River, Fox Creek, Didene Creek, and the Spatsizi River are the water courses with the potential to be impacted as a result of construction and/or operational activities. Didene Creek and Fox Creek have no identified fish resources in the reaches adjacent to the project. A five to ten metre high waterfall one kilometre upstream of where the Didene joins the Spatsizi River limits upstream fish distribution. Arctic grayling, Dolly Varden, burbot and Longnose sucker have been sampled in the upper Spatsizi River but their numbers were found to be small.

The Little Klappan River contains Dolly Varden and mountain whitefish, but apparently in limited numbers. The reach of the river upstream of the B.C. Railway Grade crossing, with its fast runs and rapids, is characterized as marginal habitat for overwintering, spawning and feeding. The lower adjacent reaches of the Little Klappan River are characterized as good fish habitat but fast runs here probably also limit populations.

5.4.2 Impact Assessment

Sedimentation

Instream activities and construction and mining activities will contribute to the sedimentation of water courses. In most streams, including those adjacent to the mining development, sedimentation is a natural phenomenon, and, depending on timing, concentration and duration, sediment introductions may have few detrimental effects. Most aquatic organisms have the ability to tolerate long term siltation when concentrations are low and to tolerate short term exposure to high sediment loads. Periods of high rainfall and spring runoff are characterized by high sediment loads.

Sedimentation of Didene Creek, the Spatsizi River and the Little Klappan River may result from surface disturbance during construction and mining operations. Sedimentation will be limited by the development, early in the construction phase and prior to surface stripping, of a series of collector and drainage ditches and sedimentation ponds. The sediment ponds provide for controlled decant of sediment-free surface water. The water management facilities are described in detail in Volume II, Part Six.

Some sediment will be released to Didene Creek and the Little Klappan River during the construction of the surface drainage system. The impact on the fish resources will be negligible and short term, even in the Spatsizi River which could receive some sedimentation from the inflow of Didene Creek. The Spatsizi River is normally a turbid river during the open water season.

Sedimentation will result also from instream construction activities on the Little Klappan River. The construction of the water reservoir dam or the infiltration water galleries will result in the release of sediments into the Little Klappan. These sediment releases, while potentially of high concentration, will be short term and limited to the construction period. Because of the self-scouring action of this generally high energy system, and the ability of aquatic organisms to recover rapidly from the effects of sediment introductions, no long term effects from sedimentation are anticipated. The impact on the fisheries resource of the Little Klappan River will be negligible.

Acid Mine Drainage

The issue of acid mine drainage is discussed in Volume II - Part Six. The conclusion of that discussion is that there will be no acid mine drainage from either the waste disposal area or the coarse refuse area. There will be no impacts on fish resources from acid mine drainage.

Interrupted Fish Passage

The only interruption of fish passage will occur on the Little Klappan River from the construction of the water reservoir dam.

The upper reach of the Little Klappan River, which would be isolated from the remainder of the river by the construction of the dam, provides only marginal habitat for overwintering, spawning and feeding. The loss of this section of the river is not expected to impact significantly the fish resources in the remainder of the Little Klappan River where habitat is considered to be from good to very good. The impact on the fish resources of the Little Klappan River from the dam are expected to be negligible.

Increased Sport Fishing

The fish resources of both the Spatsizi and Little Klappan Rivers have the potential to be impacted by increased sport fishing activities. The upgraded access to the area and the increased number of people in the area are both factors.

The impact will be limited somewhat by the accessibility of fishable rivers. The majority of on-site workers will net have vehicles on-site because of their dependence on the bus commute system. However, management of impacts on fish from sports fishing can only be obtained through effective regulatory control.

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APPENDIX A

SURFACE WATER QUALITY ANALYSIS

MOUNT KLAPPAN LICENCE AREA

Appendix A **Page**

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
UPSTREAM STATION, LITTLE KLAPPAN RIVER

Parameter	1984 Winter Apr.	Spring June	Summer August	Fall October
Discharge (m3/s)	-	2.9	1.6	0.4
Temperature (°C)	-	1.0	11.0	0.0
Dissolved Oxygen	-	-	-	-
ph (units)	-	7.4	7.8	7.9
Conductivity (umhos/cm)	-	50	121	147
Total Alkalinity	-	47.5	53.0	64.0
Calcium - Total	-	-	-	-
Magnesium - Total	-	-	-	-
Sulphate - Total	-	2.2	5.8	7.1
Fluoride - Total	-	-	-	-
Total Hardness	-	21.2	50.0	58.0
TSS	-	131.0	5.2	0.4
TDS	-	-	-	-
Turbidity (NTU)	-	3.0	6.2	0.6
Nitrate as N	-	0.041	0.010	0.008
Nitrite as N	-	0.003	0.004	<0.003
NH3 - N	-	<0.01	<0.01	<0.01
Total Dissolved Phosphorus	-	0.018	0.010	0.004
Dissolved Ortho Phosphorus	-	0.12	<0.003	0.003
Total Organic Carbon	-	-	-	1.1
Total Inorganic Carbon	-	-	-	16.5
Cadmium - Total	-	<0.0002	<0.0002.	<0.0002
Cadmium - Dissolved	-	<0.0002	<0.0002	<0.0002
Copper - Total	-	0.014	0.001	0.001
Copper - Dissolved	-	<0.001	<0.001	<0.001
Iron - Total	-	5.22	0.04	0.05
Iron - Dissolved	-	0.07	0.03	0.03
Chromium - Total	-	0.014	2.23b	0.004
Chromium - Dissolved	-	<0.001	0.63b	0.001
Manganese - Total	-	0.279	0.006	<0.004
Manganese - Dissolved	-	0.013	<0.004	<0.004
Zinc - Total	-	0.024	0.061	0.003
Zinc - Dissolved	-	0.002	<0.001	0.003
Aluminium - Total	-	2.50	0.11	0.04
Aluminium - Dissolved	-	0.02	0.02	0.01
Lead - Total	-	0.002	0.005	<0.001
Lead - Dissolved	-	<0.001	0.002	<0.001
Barium - Total	-	0.10	0.10	0.03
Barium - Dissolved	-	0.03	0.09	0.03
Nickel - Total	-	0.019	0.005	0.001
Nickel - Dissolved	-	0.02	<0.001	<0.001
Mercury - Total	-	<0.00010	<0.00010	<0.00010
Phenols	-	-	0.002	0.002

[a]Values in mg/l unless otherwise indicated.
[b]Sample contamination suspected.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
UPSTREAM STATION, LITTLE KLAPPAN RIVER

	1985										
			June 5								
Parameter[a]	Apr. 9	May 8	Rep 1	Rep 2	Rep 3	July 4	Aug. 6	Sept. 10	Oct. 23	Nov. 27	Dec. 17
Discharge (m3/s)	0.029	0.023	2.50			3.878	1.736	0.403	0.167	0.036	0.61
Temperature (°C)	0	0.5	0			1.0	8	8.5	0	0	0.0
Dissolved Oxygen											13.0
ph (units)	7.85	7.9	6.8			7.7	8.2	8.45	8.5	8.3	7.76
Conductivity (umhos/cm)	141	260	33			27	70	160	175	210	250
Total Alkalinity	129	139	14.9			24.9	40	77.5	92.8	110.0	123.0
Calcium - Total	22.5	22.0	3.9	4.0	4.0	3.1	6.2	13.6	17.0	17.2	24.2
Magnesium - Total	14.2	14.0	3.0	3.0	3.0	1.7	3.3	7.5	10.2	12.2	16.7
Sulphate - Total	13.0	12.5	3.6	3.2	3.4	1.0	2.7	6.6	8.9	10.8	13.8
Fluoride											
Total Hardness	115	113	22.1	22.3	22.3	14.7	29.1	64.8	64.4	93.2	129.7
TSS	2.4	2.0	22.0	19.0	26.0	8.8	5.2	2.9	1.0	12.0	1.3
TDS											
Turbidity (NTU)	0.80	0.6	16.0	13.0	11.5	7.3	9.6	1.6	2.6	3.9	0.32
Nitrate as N	0.100	0.76	<0.003	<0.003	<0.003	<0.003	0.003	0.11	0.041	0.123	0.138
Nitrite as N	0.004	<0.003	0.006	0.004	0.004	<0.003	<0.003	<0.003	<0.003	0.003	0.007
NH3 - N	0.08	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.01	<0.01
Total Dissolved Phosphorus	0.025	0.007	0.010	0.010	0.010	0.006	0.006	0.007	0.004	0.013	0.005
Dissolved Ortho Phosphorus	0.003	<0.003	0.005	0.003	0.003	0.004	0.004	<0.003	<0.003	0.003	<0.003
Total Organic Carbon	0.04	0.6	1.3	1.2	1.3	1.0	<0.2	<0.2	0.8	1.1	4.4
Total Inorganic Carbon	27.0	30.0	3.5	3.5	3.5	1.5	4.5	13.5	14.0	21.5	23.6
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Copper - Total	0.001	<0.001	0.003	0.003	0.005	0.002	<0.001	0.002	<0.001	0.006	0.001
Copper - Dissolved	0.001	0.001	0.001	0.001	0.001	<0.001	<0.001	0.002	<0.001	0.002	0.001
Iron - Total	0.10	0.03	1.68	1.08	3.21	0.48	0.02	0.11	0.02	0.10	0.01
Iron - Dissolved	<0.01	0.03	0.051	0.054	0.049	0.03	0.02	<0.01	<0.01	<0.01	<0.01
Chromium - Total	<0.001	<0.001	0.001	0.004	0.003	0.003	<0.001	<0.001	<0.001	0.003	0.002
Chromium - Dissolved	0.17	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Manganese - Total	0.046	0.008	0.046	0.042	0.85	0.14	<0.004	<0.004	<0.004	0.004	<0.004
Manganese - Dissolved	0.008	<0.004	0.002	0.003	0.003	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Zinc - Total	0.005	0.005	0.007	0.018	0.008	0.004	0.007	0.005	0.001	0.057	0.006
Zinc - Dissolved	0.005	0.004	0.005	0.008	0.005	0.003	0.005	0.004	<0.001	0.028	0.006
Aluminium - Total	0.01	0.02	0.90	0.52	1.45	0.32	0.01	0.03	0.03	0.05	0.01
Aluminium - Dissolved	<0.01	<0.01	0.30	0.03	0.02	0.03	0.01	<0.01	0.02	<0.01	0.01
Lead - Total	<0.001	0.002	0.002	0.002	<0.001	0.003	<0.002	0.003	<0.002	<0.002	0.002
Lead - Dissolved	<0.001	0.001	<0.001	<0.001	<0.001	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Barium - Total	0.09	0.07	0.02	0.02	0.03	0.02	0.03	0.11	0.07	0.08	0.07
Barium - Dissolved	0.07	0.07	0.01	0.01	0.01	0.01	0.03	0.10	0.07	0.08	0.07
Nickel - Total	<0.001	0.001	0.006	0.11	0.012	0.006	0.004	<0.001	<0.001	0.006	0.002
Nickel - Dissolved	<0.001	0.001	0.001	0.001	0.001	0.001	0.002	<0/001	<0.001	<0.001	0.002
Mercury - Total	0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00005	<0.00005	<0.00005	<0.00005	0.00005	<0.00005
Phenols											

[a]Values in mg/l unless indicated otherwise.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
UPSTREAM STATION, LITTLE KLAPPAN RIVER

Parameter	1986					
	Jan 15	Feb 10	Mar 10	Jun 17	Aug 5	Sep 23
Discharge (m3/s)	0.061	0.014	0.003	2.247	1.362	1.707
Temperature (°C)	0.0	0.0	0.05	2.0	11.0	4.5
Dissolved Oxygen	8.1	8.0	22.3	8.8	6.4	6.6
ph (units)	8.3	7.9	7.90	7.9	7.85	7.2
Conductivity (umhos/cm)	257	249	270	42	72	109
Total Alkalinity	128.4	126.4	129.9	17.5	32.6	51.8
Calcium - Total	23.7	24.1	24.8	3.40	6.8	
Magnesium - Total	17.6	14.3	15.1	2.05	4.0	
Sulphate - Total	14.5	12.1	11.9	1.3	2.7	
Fluoride						
Total Hardness	131.6	119.1	124.0	16.9	33.4	
TSS	1.3	1.6	<0.4	23	7.5	
TDS						
Turbidity (NTU)	0.3	0.3	0.28	18	12.0	
Nitrate as N	0.084	0.084	0.077	0.074	<0.003	
Nitrite as N	<0.003	<0.003	0.007	<0.003	<0.003	
NH3 - N	<0.01	<0.01	<0.01	0.04	<0.01	
Total Dissolved Phosphorus	0.003	0.006	0.003	0.022	0.022	
Dissolved Ortho Phosphorus	<0.003	0.004	<0.003	0.004	0.003	
Total Organic Carbon	0.8	<0.2	1.2	1.2	<0.2	
Total Inorganic Carbon	30.0	27.0	26.0	3.5	8.0	
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Copper - Total	0.003	0.007	0.005	0.003	0.003	
Copper - Dissolved	0.002	0.003	0.004	0.001	<0.001	
Iron - Total	0.03	0.08	0.01	1.04	1.12	
Iron - Dissolved	<0.01	<0.01	<0.01	0.04	0.02	
Chromium - Total	<0.001	0.003	0.003	0.004	0.002	
Chromium - Dissolved	<0.001	<0.001	0.002	<0.001	<0.001	
Manganese - Total	<0.004	<0.004	<0.004	0.032	0.024	
Manganese - Dissolved	<0.004	<0.004	<0.004	<0.004	0.004	
Zinc - Total	0.010	0.014	0.005	<0.001	0.011	
Zinc - Dissolved	0.006	0.005	0.005	<0.001	0.006	
Aluminium - Total	0.02	0.02	<0.01	0.52	0.71	
Aluminium - Dissolved	0.01	<0.011	<0.01	0.02	<0.01	
Lead - Total	0.003	0.003	<0.002	<0.002	0.005	
Lead - Dissolved	<0.002	0.003	<0.002	<0.002	0.002	
Barium - Total	0.08	0.09	0.09	0.04	0.12	
Barium - Dissolved	0.05	0.09	0.09	0.03	0.03	
Nickel - Total	0.001	0.001	0.003	0.002	0.004	
Nickel - Dissolved	0.001	<0.001	<0.001	0.01	<0.001	
Mercury - Total	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Phenols					<0.001	

[a]Values in mg/l unless otherwise indicated.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
DOWNSTREAM STATION, LITTLE KLAPPAN RIVER

	1984			
Parameter	Winter Apr.	Spring June	Summer August	Fall October
Discharge (m3/s)	0.7	36.3	16.0	8.1
Temperature (°C)	1.0	7.5	10.0	2.0
Dissolved Oxygen				
ph (units)	7.2	7.4	7.8	7.7
Conductivity (umhos/cm)	315	92	140	167
Total Alkalinity	166	38.0	-	65.0
Calcium - Total				
Magnesium - Total				
Sulphate - Total	44.2	10.0	20.8	23.5
Fluoride - Total	0.07	-	-	-
Total Hardness	156	36	76	70
TSS	3.2	38.0	9.2	1.6
TDS	205	-	-	-
Turbidity (NTU)	0.6	14.0	5.4	1.2
Nitrate as N	0.037	0.0.26	0.009	0.005
Nitrite as N	0.009	0.004	0.004	0.005
NH3 - N	0.01	<0.01	<0.01	<0.01
Total Dissolved Phosphorus	0.006	0.018	0.092	0.004
Dissolved Ortho Phosphorus	<0.003	0.007	<0.003	0.004
Total Organic Carbon	-	2.1	-	3.9
Total Inorganic Carbon	-	6.5	-	14.0
Cadmium - Total	<0.0005	<0.0002	<0.0002	<0.0002
Cadmium - Dissolved	-	<0.0002	<0.0002	<0.0002
Copper - Total	<0.001	0.003	0.001	0.002
Copper - Dissolved	-	<0.001	<0.001	0.002
Iron - Total	0.12	0.77	0.06	0.11
Iron - Dissolved	0.03	0.11	0.02	0.07
Chromium - Total	<0.001	0.013	0.075	0.003
Chromium - Dissolved	-	0.001	0.062	0.002
Manganese - Total	0.009	0.040	0.004	0.006
Manganese - Dissolved	-	0.013	<0.004	<0.004
Zinc - Total	0.001	0.016	0.003	0.002
Zinc - Dissolved	-	0.003	0.003	0.002
Aluminium - Total	0.02	0.90	1.08	0.06
Aluminium - Dissolved	-	0.04	0.04	0.02
Lead - Total	<0.001	0.004	0.002	0.002
Lead - Dissolved	-	<0.001	<0.001	<0.001
Barium - Total	0.04	0.04	0.05	0.02
Barium - Dissolved	-	0.02	0.05	0.02
Nickel - Total	<0.001	0.005	0.005	0.001
Nickel - Dissolved	-	0.003	0.002	0.001
Mercury - Total	<0.00005	0.00064	0.00023	<0.00010
Phenols	0.16	-	0.001	0.002

[a]Values in mg/l unless otherwise indicated.
[b]Sample contamination suspected.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
DOWNSTREAM STATION, LITTLE KLAPPAN RIVER

	1985										
			June 4								
Parameter[a]	Apr. 10	May 7	Rep 1	Rep 2	Rep 3	July 3	Aug. 5	Sept. 10	Oct. 23	Nov. 27	Dec. 18
Discharge (m3/s)	0.112	0.193	20.423			16.633	3.753c	1.223	0.890	0.168	0.163
Temperature (°C)	1.0	1.0	1.0			8.0	7.0	9.0	0.0	0.0	0.0
Dissolved Oxygen											13.2
ph (units)	7.19	7.7	7.1			7.6	7.95	8.3	8.0	8.3	7.40
Conductivity (umhos/cm)	267	215	40			55	96	158	151	230	226
Total Alkalinity	109	87.7	14.5			20.6	35	64.0	60.0	83.3	87.0
Calcium - Total	24.4	17.2	4.1	4.0	4.0	4.8	7.0	14.0	12.8	19.6	21.3
Magnesium - Total	15.5	11.9	3.2	3.2	3.2	2.9	4.8	9.4	9.0	13.1	13.5
Sulphate - Total	31.0	24.0	3.2	3.2	3.1	6.0	11.5	16.7	17.0	26.1	28.6
Fluoride											
Total Hardness	125	92	23.4	23.2	23.2	23.9	37.3	73.7	69.0	102.9	106.8
TSS	<0.4	3.6	8.0	11.0	13.0	14.0	1.2	0.5	1.0	1.0	1.3
TDS											
Turbidity (NTU)	0.53	2.3	26.5	25.0	27.0	17.0	3.75	3.7	2.3	1.1	0.66
Nitrate as N	0.078	0.042	0.005	0.004	0.004	<0.003	<0.003	<0.003	0.016	0.058	0.035
Nitrite as N	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	0.005	0.004
NH3 - N	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.02	<0.01	0.01	<0.01	<0.01
Total Dissolved Phosphorus	0.003	0.009	0.012	0.012	0.013	0.016	0.005	0.006	0.036	0.003	0.004
Dissolved Ortho Phosphorus	0.003	<0.003	0.006	0.005	0.007	0.005	0.004	<0.003	<0.003	0.003	0.003
Total Organic Carbon	1.0	0.8	3.6	3.8	3.6	2.0	<0.2	<0.2	2.8	0.4	0.8
Total Inorganic Carbon	25.0	15.5	3.5	4.5	3.5	2.5	6.0	13.5	10.0	17.0	19.1
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Copper - Total	0.001	0.001	0.006	0.006	0.006	0.003	0.001	0.003	0.001	0.002	0.003
Copper - Dissolved	0.001	<0.001	0.001	0.003	0.002	<0.001	<0.001	0.002	0.001	0.002	0.003
Iron - Total	0.02	0.26	3.03	2.98	3.14	0.76	0.16	0.15	0.04	0.03	0.03
Iron - Dissolved	0.01	0.22	0.099	0.093	0.094	0.08	0.02	0.03	0.03	0.01	0.01
Chromium - Total	<0.001	<0.001	0.004	0.003	0.003	0.003	<0.001	<0.001	0.002	0.001	<0.001
Chromium - Dissolved	<0.001	<0.001	<0.001	0.003	0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001
Manganese - Total	<0.004	0.011	0.061	0.063	0.65	0.017	<0.004	.006	0.004	0.009	0.010
Manganese - Dissolved	<0.004	0.005	0.004	0.004	0.004	<0.004	<0.004	<0.004	<0.004	0.009	0.010
Zinc - Total	0.005	0.004	0.005	0.008	0.039	0.003	0.005	0.010	0.002	0.003	0.008
Zinc - Dissolved	0.005	0.003	0.005	0.108	0.004	0.002	0.001	0.010	0.001	0.003	0.007
Aluminium - Total	<0.01	0.04	1.32	1.33	1.67	0.41	0.07	0.04	0.04	<0.01	0.02
Aluminium - Dissolved	<0.01	0.03	0.04	0.04	0.04	0.04	0.02	0.01	0.02	<0.01	0.01
Lead - Total	<0.001	0.003	0.002	0.002	0.003	0.002	<0.002	0.007	<0.002	<0.002	<0.002
Lead - Dissolved	<0.001	0.001	<0.001	0.002	<0.001	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Barium - Total	0.06	0.05	0.02	0.03	0.03	0.02	0.03	0.08	0.04	0.05	0.04
Barium - Dissolved	0.05	0.04	0.01	0.01	0.01	0.02	0.02	0.02	0.04	0.05	0.05
Nickel - Total	<0.001	0.001	0.009	0.15	0.011	0.003	0.005	<0.001	<0.001	0.006	<0.001
Nickel - Dissolved	<0.001	0.001	0.001	0.002	0.001	<0.001	0.005	<0/001	<0.001	<0.001	<0.001
Mercury - Total	0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00005	<0.00005	<0.00005	<0.00005	0.00005	<0.00005
Phenols											

[a]Values in mg/l unless indicated otherwise.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
DOWNSTREAM STATION, LITTLE KLAPPAN RIVER

Parameter	Jan 18 1986	Feb 11	Mar 10	Jun 15	Aug 5	Sep 24
Discharge (m3/s)	0.086	0.057	0.089	15.24	3.983	3.818
Temperature (°C)	0.0	0.0	0.05	5.0	9.0	7.0
Dissolved Oxygen	11.1	10.4	11.3	10.3	7.2	7.8
ph (units)	8.15	8.0	7.10	6.8	7.4	7.9
Conductivity (umhos/cm)	265	240	260	42	80	105
Total Alkalinity	100.1	95.6	97.0	16.6	31.0	40.4
Calcium - Total	23.1	24.2	23.4	3.40	7.6	
Magnesium - Total	15.5	15.9	16.9	2.05	5.1	
Sulphate - Total	30.5	32.2	31.0	1.3	8.6	
Fluoride						
Total Hardness	121.5	125.9	128	16.9	40.0	
TSS	0.6	<0.4	1.3	23	3.0	
TDS						
Turbidity (NTU)	0.4	1.2	0.34	18	6.0	
Nitrate as N	0.073	0.068	0.076	0.074	<0.003	
Nitrite as N	0.006	0.008	<0.003	<0.003	<0.003	
NH3 - N	<0.01	<0.01	0.01	0.04	<0.01	
Total Dissolved Phosphorus	0.006	0.005	0.005	0.022	0.021	
Dissolved Ortho Phosphorus	0.005	0.005	0.003	0.004	0.003	
Total Organic Carbon	1.2	0.3	4.0	1.2	<0.2	
Total Inorganic Carbon	20.0	20.0	22.5	3.5	6.5	
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Copper - Total	0.003	0.006	0.005	0.003	0.002	
Copper - Dissolved	0.003	0.004	0.004	0.001	<0.001	
Iron - Total	0.03	0.09	0.03	1.04	0.32	
Iron - Dissolved	0.01	0.02	0.02	0.04	0.01	
Chromium - Total	<0.001	0.004	0.004	0.004	0.004	
Chromium - Dissolved	<0.001	0.003	0.002	<0.001	<0.001	
Manganese - Total	0.004	0.005	0.007	0.032	0.009	
Manganese - Dissolved	0.004	0.004	<0.004	0.004	<0.004	
Zinc - Total	0.004	0.007	0.005	<0.001	0.010	
Zinc - Dissolved	0.004	0.006	0.005	<0.001	0.007	
Aluminium - Total	0.01	0.02	0.02	0.52	0.23	
Aluminium - Dissolved	0.01	<0.01	0.01	0.02	0.01	
Lead - Total	0.005	0.003	0.002	<0.002	0.004	
Lead - Dissolved	<0.002	0.003	<0.002	<0.002	0.002	
Barium - Total	0.03	0.06	0.06	0.04	0.11	
Barium - Dissolved	0.02	0.05	0.06	0.03	0.02	
Nickel - Total	0.010	<0.001	0.002	0.002	0.002	
Nickel - Dissolved	0.005	<0.001	<0.001	0.001	<0.001	
Mercury - Total	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Phenols					<0.001	

[a]Values in mg/l unless otherwise indicated.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
FOX CREEK

Parameter[a]	1985 Apr 10	May 7	June 5 Rep 1	June 5 Rep 2	June 5 Rep 3	July 4	Aug. 6	Sept. 10	Oct. 23	Nov. 29	Dec. 19
Discharge (m3/s)	0.056	0.031	4.264			2.380	0.565	0.117	0.135	0.033	0.027
Temperature (°C)	0	0	1			1.5	13	6	0	0	0.0
Dissolved Oxygen											11.7
ph (units)	7.61	8.1	7.6			7.6	8.2	8.45	8.6	8.3	8.10
Conductivity (umhos/cm)	398	330	46			54	210	294	290	350	368
Total Alkalinity	196	166	19.2			34.3	95	132.1	133.9	202.9	184.0
Calcium - Total	27.1	22.0	7.3	7.3	7.2	5.0	12.7	20.6	19.2	18.1	27.0
Magnesium - Total	29.2	22.8	5.2	5.1	5.2	4.8	13.1	21.2	20.6	23.3	25.8
Sulphate - Total	25.8	20.4	2.5	2.5	3.0	3.6	11.0	17.9	16.7	21.1	23.0
Fluoride											
Total Hardness	188	149	39.7	39.2	39.4	32.3	85.7	138.7	132.8	141.1	173.6
TSS	6.4	2.4	98.0	94.0	101.0	50.8	<1.0	4.4	1.0	14.0	<0.4
TDS											
Turbidity (NTU)	8.33	1.2	58.0	60.0	63.0	36.0	5.8	1.4	1.3	0.73	0.2
Nitrate as N	0.087	0.052	0.014	0.013	0.010	0.004	<0.003	<0.003	0.030	0.047	0.066
Nitrite as N	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	0.003	0.008	0.006
NH3 - N	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	0.04
Total Dissolved Phosphorus	0.005	0.007	0.023	0.021	0.022	0.022	0.004	0.009	0.013	0.006	0.007
Dissolved Ortho Phosphorus	0.003	<0.003	0.008	0.007	0.010	0.020	0.003	<0.003	<0.003	<0.003	<0.003
Total Organic Carbon	1.3	1.0	2.6	2.9	2.6	1.4	1.0	1.7	2.0	0.4	0.6
Total Inorganic Carbon	48.0	34.5	10.0	10.0	9.0	6.5	18.0	29.0	27.0	42.0	43.0
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Copper - Total	0.001	0.001	0.010	0.010	0.010	0.002	<0.001	0.002	0.001	0.003	0.003
Copper - Dissolved	0.001	0.001	0.001	0.002	0.001	0.001	<0.001	<0.001	0.001	0.002	0.001
Iron - Total	0.05	0.21	5.89	5.61	6.66	2.03	0.06	0.06	0.01	0.07	0.02
Iron - Dissolved	0.02	0.12	0.179	0.137	0.122	0.05	<0.01	<0.03	0.01	<0.01	<0.01
Chromium - Total	<0.001	<0.001	0.003	0.003	0.006	0.003	<0.001	<0.001	<0.001	0.002	0.001
Chromium - Dissolved	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
Manganese - Total	0.012	0.078	0.137	0.153	0.155	0.63	0.007	<0.004	<0.004	0.004	<0.004
Manganese - Dissolved	0.046	0.078	0.011	0.007	0.008	<0.004	0.006	<0.004	<0.004	<0.004	<0.004
Zinc - Total	0.12	0.004	0.013	0.005	0.020	0.004	0.010	0.008	0.001	0.006	0.047
Zinc - Dissolved	0.009	0.004	0.005	0.005	0.004	0.003	0.005	0.003	0.001	0.002	0.031
Aluminium - Total	0.01	0.01	1.28	1.43	1.28	0.58	0.05	0.04	0.03	0.01	0.02
Aluminium - Dissolved	<0.012	<0.01	0.04	0.03	0.03	0.02	0.01	<0.01	0.02	0.01	<0.01
Lead - Total	0.002	<0.001	0.003	0.004	0.002	0.003	<0.002	0.003	<0.002	<0.002	<0.002
Lead - Dissolved	0.002	<0.001	0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002
Barium - Total	0.008	0.07	0.05	0.06	0.05	0.04	0.06	0.11	0.07	0.00	0.08
Barium - Dissolved	0.07	0.06	0.01	0.02	0.02	0.02	0.06	0.11	0.07	0.08	0.08
Nickel - Total	<0.001	0.002	0.014	0.014	0.014	0.005	0.016	<0.001	<0.001	0.007	0.001
Nickel - Dissolved	<0.001	<0.001	0.002	0.002	0.001	0.001	0.003	<0.001	<0.001	<0.001	<0.001
Mercury - Total	0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Phenols											

[a]Values in mg/l unless indicated otherwise.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
FOX CREEK

Parameter	1986 Jan 15	Feb 12	Mar 12	Jun 16	Aug 5	Sep 25
Discharge (m3/s)	0.047	0.021	0.004	2.742	0.431	0.532
Temperature (°C)	0.0	0.0	0.5	5.0	14.5	3.0
Dissolved Oxygen	9,8	10.4	11.4	10.0	7.6	9.0
ph (units)	8.6	8.3	7.70	7.3	8.2	7.3
Conductivity (umhos/cm)	249	370.0	458	47	198	190
Total Alkalinity	190.5	200.1	229.5	23.8	92.4	84.0
Calcium - Total	26.0	29.8	28.4	3.54	14.0	
Magnesium - Total	26.2	28.5	29.7	23.62	14.6	
Sulphate - Total	22.6	23.6	22.8	2.9	10.5	
Fluoride						
Total Hardness	172.8	191.7	193	23.7	95.1	
TSS	<0.4	0.7	<0.4	74	2.5	
TDS						
Turbidity (NTU)	0.3	0.3	0.33	80	2.7	
Nitrate as N	0.071	0.073	0.081	0.036	<0.003	
Nitrite as N	0.005	0.007	0.004	<0.003	<0.003	
NH3 - N	<0.01	<0.01	0.01	<0.01	<0.01	
Total Dissolved Phosphorus	0.008	0.008	0.012	0.021	0.014	
Dissolved Ortho Phosphorus	<0.006	0.005	0.003	0.010	<0.003	
Total Organic Carbon	1.8	0.8	2.6	2.2	<0.2	
Total Inorganic Carbon	46.5	47.0	48.0	5.5	21.0	
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Copper - Total	0.005	0.005	0.004	0.007	0.001	
Copper - Dissolved	0.004	0.003	0.004	0.002	0.001	
Iron - Total	0.02	0.13	0.01	1.91	1.14	
Iron - Dissolved	0.01	<0.01	0.01	0.09	<0.01	
Chromium - Total	<0.001	<0.001	0.001	0.002	0.004	
Chromium - Dissolved	<0.001	<0.001	0.001	0.002	0.002	
Manganese - Total	<0.004	<0.004	<0.004	0.067	0.005	
Manganese - Dissolved	<0.004	<0.004	<0.004	0.004	<0.004	
Zinc - Total	0.015	0.008	0.003	0.012	0.008	
Zinc - Dissolved	0.010	0.005	0.002	<0.001	0.006	
Aluminium - Total	0.02	0.02	0.02	0.67	0.03	
Aluminium - Dissolved	0.01	<0.01	<0.01	0.04	0.01	
Lead - Total	0.005	0.005	0.002	0.024	0.003	
Lead - Dissolved	0.002	0.002	<0.002	<0.002	0.002	
Barium - Total	0.05	0.15	0.09	0.08	0.15	
Barium - Dissolved	0.05	0.10	0.09	0.01	0.06	
Nickel - Total	0.002	<0.001	<0.001	0.010	0.002	
Nickel - Dissolved	0.001	<0.001	<0.001	<0.001	<0.001	
Mercury - Total	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Phenols					<0.002	

[a]Values in mg/l unless otherwise indicated.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
DIDENE CREEK

Parameter	1984 Winter Apr.	Spring June	Summer August	Fall October
Discharge (m3/s)	0.1	4.9	5.5	3.1
Temperature (°C)	1.0	8.0	6.0	2.5
Dissolved Oxygen				
ph (units)	7.7	7.2	7.2	7.1
Conductivity (umhos/cm)	260	47	-	88
Total Alkalinity	108.0	19.0	70.0	37.0
Calcium - Total				
Magnesium - Total				
Sulphate - Total	21.8	3.9	4.6	6.6
Fluoride - Total	0.11	-	-	-
Total Hardness	117.0	21.6	51.0	33.0
TSS	0.8	28.4	4.8	2.8
TDS	155	-	-	-
Turbidity (NTU)	0.4	14.0	4.6	2.2
Nitrate as N	0.52	0.009	0.006	0.004
Nitrite as N	0.11	0.003	0.005	0.003
NH3 - N	<0.01	<0.01	<0.01	0.01
Total Dissolved Phosphorus	0.004	0.020	0.008	0.007
Dissolved Ortho Phosphorus	<0.003	0.018	0.003	0.006
Total Organic Carbon	-	-	-	7.4
Total Inorganic Carbon	-	-	-	8.5
Cadmium - Total	<0.0005	<0.0002	<0.0002	<0.0002
Cadmium - Dissolved	-	<0.0002	<0.0002	<0.0002
Copper - Total	<0.001	0.003	0.007	0.002
Copper - Dissolved	-	0.001	<0.001	0.002
Iron - Total	0.04	0.91	0.04	0.21
Iron - Dissolved	0.02	0.14	0.03	0.09
Chromium - Total	<0.001	0.008	0.041	0.002
Chromium - Dissolved	-	0.005	0.031	0.001
Manganese - Total	<0.004	0.040	0.005	<0.004
Manganese - Dissolved	-	0.016	<0.004	<0.004
Zinc - Total	<0.001	0.015	0.009	0.001
Zinc - Dissolved	-	0.115	<0.001	<0.001
Aluminium - Total	0.01	0.53	0.19	0.10
Aluminium - Dissolved	-	0.04	0.05	0.04
Lead - Total	<0.001	0.002	0.002	<0.001
Lead - Dissolved	-	<0.001	<0.001	<0.001
Barium - Total	0.04	0.03	0.05	0.02
Barium - Dissolved	-	0.02	0.05	0.01
Nickel - Total	<0.001	0.009	0.006	0.006
Nickel - Dissolved	-	0.003	0.003	0.005
Mercury - Total	<0.00005	0.00063	0.00051	<0.00010
Phenols	0.004	-	0.001	0.002

[a]Values in mg/l unless otherwise indicated.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
DIDENE CREEK

Parameter[a]	1985										
			June 5								
	Apr. 10	May 7	Rep 1	Rep 2	Rep 3	July 3	Aug. 6	Sept. 10	Oct. 23	Nov. 27	Dec. 18
Discharge (m3/s)	0.019	0.010	13.571			9.417	1.222	0.479	0.439	0.059	0.062
Temperature (°C)	0	0	3			1.05	9	6	0	0	0.0
Dissolved Oxygen											14.0
ph (units)	7.52	8.1	7.2			7.8	8.2	8.25	7.8	8.1	7.56
Conductivity (umhos/cm)	273	190	34			57	138	170	60	210	219
Total Alkalinity	124	78.5	16.1			31.4	40	74.3	69	102.8	107.0
Calcium - Total	20.7	11.7	3.9	3.9	3.9	4.6	8.8	13.1	12.2	14.2	19.8
Magnesium - Total	16.7	10.5	2.3	2.3	2.3	3.4	8.2	11.4	10.3	14.0	16.0
Sulphate - Total	23.0	10.4	1.5	1.3	1.3	4.1	11.0	13.6	13.0	16.9	23.7
Fluoride											
Total Hardness	121	72.5	19.2	19.2	19.2	25.5	55.8	79.6	72.9	93.1	115.3
TSS	<0.0004	2.8	17.0	14.0	15.0	24.0	1.2	1.2	1.0	7.6	1.3
TDS											
Turbidity (NTU)	0.44	3.1	36.0	38.0	40.5	20.0	1.85	1.6	1.3	4.7	0.6
Nitrate as N	0.080	0.028	0.007	0.007	0.007	<0.003	<0.003	<0.003	0.010	0.055	0.028
Nitrite as N	<0.003	<0.003	0.008	0.009	0.010	<0.003	<0.003	<0.003	0.004	0.011	0.006
NH3 - N	<0.01	<0.01	0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Total Dissolved Phosphorus	0.003	0.014	0.008	0.010	0.006	0.015	0.003	0.005	0.010	0.006	0.008
Dissolved Ortho Phosphorus	0.003	<0.003	0.005	0.005	0.005	0.007	0.003	<0.003	<0.003	<0.003	<0.003
Total Organic Carbon	0.80	2.2	4.3	4.6	4.2	2.8	0.9	1.6	3.0	0.8	1.1
Total Inorganic Carbon	27.5	28.0	4.0	3.5	3.5	4.0	11.0	14.0	12.5	20.0	22.7
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Copper - Total	0.002	0.001	0.006	0.007	0.006	0.003	<0.001	0.003	0.001	0.004	0.002
Copper - Dissolved	0.002	0.001	0.001	0.001	0.001	0.002	<0.001	<0.001	0.001	0.002	0.001
Iron - Total	0.01	0.25	3.62	4.00	3.93	0.86	0.12	0.13	0.03	0.07	0.02
Iron - Dissolved	0.01	0.24	0.145	0.143	0.163	0.07	0.01	0.05	0.01	0.01	<0.01
Chromium - Total	<0.001	<0.001	0.004	0.006	0.005	0.002	<0.001	<0.001	0.003	0.001	<0.001
Chromium - Dissolved	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese - Total	<0.004	0.007	0.088	0.093	0.091	0.026	0.006	<0.004	<0.004	<0.004	<0.004
Manganese - Dissolved	<0.004	<0.004	0.006	0.007	0.009	<0.004	<0.004	<0.004	<0.004	<0.004	0.24
Zinc - Total	0.009	0.004	0.011	0.009	0.007	0.011	0.012	0.012	0.001	0.008	0.010
Zinc - Dissolved	0.009	0.004	0.005	0.004	0.004	0.006	0.006	0.008	0.001	0.005	0.005
Aluminium - Total	0.02	0.02	1.08	1.14	1.12	0.37	0.02	0.07	0.01	<0.01	0.04
Aluminium - Dissolved	0.01	0.02	0.03	0.03	0.04	0.04	<0.01	<0.01	0.01	<0.01	0.01
Lead - Total	0.002	<0.001	0.003	0.002	0.002	0.003	<0.002	0.004	<0.002	<0.002	0.002
Lead - Dissolved	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.002	<0.002	0.002
Barium - Total	0.05	0.04	0.04	0.04	0.03	0.03	0.04	0.07	0.03	0.05	0.04
Barium - Dissolved	0.05	0.04	0.01	0.01	0.01	0.02	0.04	0.06	0.03	0.05	0.02
Nickel - Total	<0.001	0.002	0.009	0.10	0.009	0.005	0.006	0.002	<0.001	0.006	0.002
Nickel - Dissolved	<0.001	0.002	0.002	0.001	0.001	0.001	0.003	0.001	<0.001	0.002	0.001
Mercury - Total	0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00005	<0.00005	<0.00006	<0.00005	0.00005	<0.00005
Phenols											

[a]Values in mg/l unless indicated otherwise.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
DIDENE CREEK

Parameter	1986					
	Jan 16	Feb 10	Mar 10	Jun 18	Aug 5	Sep 23
Discharge (m3/s)	0.044	0.010	0.022	8.299	0.967	4.068
Temperature (°C)	0.0	0.0	0.05	6.0	13.0	6.0
Dissolved Oxygen	9.4	10.2	11.9	9.1	7.2	7.0
ph (units)	8.35	8.0	7.95	7.1	8.1	7.2
Conductivity (umhos/cm)	254	183	248	44	136	102
Total Alkalinity	102.9	108.5	110.6	20.9	58.6	39.8
Calcium - Total	19.3	23.1	19.2	3.85	11.1	
Magnesium - Total	16.8	18.9	16.2	3.06	9.7	
Sulphate - Total	23.2	23.4	23.0	3.3	9.6	
Fluoride						
Total Hardness	117.4	135.5	115	22.2	67.7	
TSS	1.3	0.8	2.2	8.6	0.5	
TDS						
Turbidity (NTU)	0.3	0.8	0.3	8.2	1.8	
Nitrate as N	0.065	0.066	0.066	0.013	<0.003	
Nitrite as N	0.005	0.008	0.009	<0.003	<0.003	
NH3 - N	<0.01	<0.01	0.04	<0.01	<0.01	
Total Dissolved Phosphorus	0.006	0.006	0.015	0.008	0.004	
Dissolved Ortho Phosphorus	0.005	0.004	0.003	0.007	<0.003	
Total Organic Carbon	1.2	1.0	3.6	4.3	0.5	
Total Inorganic Carbon	23.0	22.5	24.5	3.5	13.5	
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Copper - Total	0.004	0.005	0.005	0.007	0.002	
Copper - Dissolved	0.003	0.004	0.004	0.004	0.001	
Iron - Total	0.04	0.04	0.01	0.55	0.08	
Iron - Dissolved	<0.01	<0.01	<0.01	0.07	0.01	
Chromium - Total	<0.001	<0.001	<0.001	0.002	0.003	
Chromium - Dissolved	<0.001	<0.001	<0.001	<0.001	0.001	
Manganese - Total	<0.004	<0.004	<0.004	<0.004	<0.004	
Manganese - Dissolved	<0.004	<0.004	<0.004	<0.004	<0.004	
Zinc - Total	0.011	0.012	0.004	0.007	0.098	
Zinc - Dissolved	0.009	0.008	0.003	0.005	0.052	
Aluminium - Total	0.02	0.03	0.02	0.21	0.02	
Aluminium - Dissolved	0.01	0.01	0.01	0.03	0.01	
Lead - Total	0.004	0.004	<0.002	<0.002	0.002	
Lead - Dissolved	<0.002	0.002	<0.002	<0.002	0.002	
Barium - Total	0.03	0.13	0.05	0.10	0.12	
Barium - Dissolved	0.03	0.06	0.05	0.10	0.03	
Nickel - Total	0.001	<0.001	0.001	0.005	0.002	
Nickel - Dissolved	0.001	<0.001	0.001	0.002	<0.001	
Mercury - Total	<0.00005	<0.00005	<0.00005	<0.00005	<0.0005	
Phenols					<0.002	

[a]Values in mg/l unless otherwise indicated.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
UPSTREAM STATION, SPATSIZI RIVER

Parameter[a]	1984 Winter Apr.	Spring June	Summer August	Fall October
Discharge (m3/s)	0.3	14.1	10.4	5.5
Temperature (°C)	1.0	6.0	9.0	2.0
Dissolved Oxygen	-	-	-	-
ph (units)	8.3	7.4	7.6	7.5
Conductivity (umhos/cm)	204	78	97	118
Total Alkalinity	96.0	19.0	50.0	53.0
Calcium - Total	-	-	-	-
Magnesium - Total	-	-	-	-
Sulphate - Total	7.8	3.7	5.3	5.3
Fluoride - Total	0.09	-	-	-
Total Hardness	91.8	29.1	45.0	45.0
TSS	1.2	64.4	65.0	5.2
TDS	130	-	-	-
Turbidity (NTU)	1.0	22.0	28.0	3.4
Nitrate as N	0.064	0.017	0.006	0.005
Nitrite as N	0.010	0.003	0.006	0.005
NH3 - N	<0.01	<0.01	<0.01	<0.01
Total Dissolved Phosphorus	0.005	0.018	0.008	0.008
Dissolved Ortho Phosphorus	<0.003	0.012	0.004	0.006
Total Organic Carbon	-	-	-	2.8
Total Inorganic Carbon	-	-	-	13.5
Cadmium - Total	<0.0005	<0.0002	<0.0002	<0.0002
Cadmium - Dissolved	-	<0.0002	<0.0002	<0.0002
Copper - Total	<0.001	0.005	0.005	0.002
Copper - Dissolved	-	0.001	<0.001	0.001
Iron - Total	0.21	1.31	0.05	0.40
Iron - Dissolved	0.03	0.12	0.05	0.05
Chromium - Total	<0.001	0.013	0.52b	0.003
Chromium - Dissolved	-	<0.001	0.33b	0.002
Manganese - Total	0.026	0.074	0.030	<0.004
Manganese - Dissolved	-	0.018	<0.004	<0.004
Zinc - Total	0.001	0.018	0.005	0.003
Zinc - Dissolved	-	<0.001	<0.001	0.003
Aluminium - Total	0.01	1.68	0.27	0.22
Aluminium - Dissolved	-	0.05	0.06	0.02
Lead - Total	<0.001	0.002	0.003	<0.001
Lead - Dissolved	-	0.002	<0.001	<0.001
Barium - Total	0.07	0.07	0.11	0.03
Barium - Dissolved	-	0.04	0.07	0.03
Nickel - Total	<0.001	0.006	0.010	0.003
Nickel - Dissolved	-	0.002	0.001	0.003
Mercury - Total	<0.0005	0.00036	0.00044	<0.00010
Phenols	0.031	-	0.001	0.002

[a]Values in mg/l unless otherwise indicated.
[b]Sample contamination suspected.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
UPSTREAM STATION, SPATSIZI RIVER

Parameter[a]	1985										
			June 5								
	Apr. 10	May 8	Rep 1	Rep 2	Rep 3	July 3	Aug. 6	Sept. 9	Oct. 22	Nov. 28	Dec. 17
Discharge (m3/s)	0.252b	0.429	14.93b			21.108	5.805	2.236	1.204	0.272	0.367
Temperature (°C)	0	1	1			2	9	8	0	0	0.0
Dissolved Oxygen											12.0
ph (units)	7.35	8.1	7.2			8.0	8.25	8.2	8.6	8.5	7.24
Conductivity (umhos/cm)	208	145	72			74	84	105	134	180	178
Total Alkalinity	104	101	32.1			35.4	40	49.9	65.3	109.1	83.4
Calcium - Total	19.02	16.7	4.7	4.8	4.8	6.5	7.3	10.6	12.8	17.3	16.2
Magnesium - Total	10.7	9.9	4.8	4.8	4.8	4.1	3.9	5.6	7.3	9.8	9.2
Sulphate - Total	7.6	6.6	3.9	3.8	3.4	2.9	3.4	4.6	5.7	5.4	6.9
Fluoride											
Total Hardness	92.0	82.5	31.5	31.8	31.8	33.1	34.3	49.5	62.0	83.5	78.3
TSS	<0.4	3.2	16.0	10.0	14.0	65.2	6.4	3.5	16.0	5.0	3.5
TDS											
Turbidity (NTU)	1.08	3.1	32.5	31.5	35.0	38.0	9.9	5.8	3.1	0.97	1.8
Nitrate as N	0.069	0.049	0.008	0.009	0.009	0.006	0.005	<0.003	0.038	0.064	0.046
Nitrite as N	<0.003	<0.003	<0.003	0.005	0.005	<0.003	<0.003	<0.003	0.003	0.005	<0.003
NH3 - N	<0.01	<0.01	<0.01	0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	0.01
Total Dissolved Phosphorus	<0.003	0.006	0.011	0.011	0.013	0.028	0.008	0.020	0.006	0.026	0.007
Dissolved Ortho Phosphorus	<0.003	<0.003	0.005	0.006	0.007	0.005	0.003	<0.003	<0.003	<0.003	0.003
Total Organic Carbon	1.1	1.2	2.9	2.8	2.9	1.0	<0.2	<0.2	1.0	0.2	0.4
Total Inorganic Carbon	23.5	20.5	7.0	7.0	7.0	5.0	6.5	10.0	13.0	18.0	19.1
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Copper - Total	0.001	0.001	0.011	0.011	0.011	0.004	0.001	0.002	0.001	0.004	0.004
Copper - Dissolved	0.001	<0.001	0.001	0.001	0.001	<0.001	0.001	0.002	0.001	0.003	0.004
Iron - Total	0.12	0.37	5.29	5.39	4.97	2.33	0.78	0.05	0.02	0.13	0.09
Iron - Dissolved	0.05	0.25	0.173	0.145	0.095	0.05	0.03	0.02	0.01	0.03	0.04
Chromium - Total	<0.001	0.001	0.005	0.007	0.005	0.005	<0.001	0.013	0.001	0.003	0.002
Chromium - Dissolved	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.002
Manganese - Total	0.022	0.039	0.131	0.135	0.122	0.07	0.018	0.013	0.009	0.012	0.009
Manganese - Dissolved	0.018	0.014	0.017	0.014	0.013	0.006	0.005	0.010	0.005	0.011	0.008
Zinc - Total	0.011	0.035	0.012	0.013	0.022	0.005	0.004	0.017	<0.001	0.007	0.015
Zinc - Dissolved	0.011	0.003	0.004	0.005	0.004	0.004	0.003	0.005	<0.001	0.002	0.012
Aluminium - Total	0.01	0.04	1.97	1.91	4.50	0.90	0.38	0.21	0.05	0.02	0.08
Aluminium - Dissolved	0.01	0.02	0.07	0.05	0.03	0.03	0.01	0.01	0.03	0.01	0.04
Lead - Total	0.013	0.002	0.002	0.002	0.003	0.003	<0.002	0.007	<0.002	<0.002	0.003
Lead - Dissolved	0.006	0.001	<0.001	<0.001	<0.001	0.003	<0.002	<0.002	<0.002	<0.002	<0.002
Barium - Total	0.07	0.07	0.07	0.09	0.09	0.07	0.06	0.14	0.05	0.07	0.04
Barium - Dissolved	0.07	0.06	0.03	0.03	0.03	0.03	0.04	0.12	0.05	0.05	0.04
Nickel - Total	<0.001	<0.001	0.014	0.28	0.015	0.006	0.010	0.003	<0.001	0.007	0.001
Nickel - Dissolved	<0.001	<0.001	0.001	0.001	0.001	0.002	0.002	0.001	<0.001	<0.001	0.001
Mercury - Total	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00005	<0.00005	<0.00005	<0.00005	0.00005	<0.00005
Phenols											

[a]Values in mg/l unless indicated otherwise.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
UPSTREAM STATION, SPATSIZI RIVER

Parameter	Jan 16	Feb 10	1986 Mar 10	Jun 17	Aug 5	Sep 24
Discharge (m3/s)	0.267	0.184	0.232	15.578	7.202	4.894
Temperature (°C)	0.0	0.0	0.5	5.0	10.0	5.0
Dissolved Oxygen	9.2	9.8	12.4	8.1	8.2	8.8
ph (units)	7.90	7.9	7.70	7.5	8.0	7.4
Conductivity (umhos/cm)	208	143	140	73	65	98
Total Alkalinity	94.1	109.4	95.4	36.6	43.6	46.4
Calcium - Total	19.5	21.9	17.7	6.49	7.9	
Magnesium - Total	10.7	11.7	10.1	4.81	4.1	
Sulphate - Total	8.0	8.5	7.6	2.9	3.1	
Fluoride						
Total Hardness	93.2	102.9	85.8	36.0	36.6	
TSS	<0.4	0.9	2.0	52	8.0	
TDS						
Turbidity (NTU)	1.2	1.2	1.84	50	14.0	
Nitrate as N	0.075	0.074	0.073	0.015	<0.003	
Nitrite as N	0.007	0.006	0.009	0.003	<0.003	
NH3 - N	<0.01	<0.01	0.02	0.01	<0.01	
Total Dissolved Phosphorus	0.005	0.007	0.007	0.026	0.015	
Dissolved Ortho Phosphorus	0.005	0.004	0.003	0.004	0.003	
Total Organic Carbon	0.8	0.6	1.0	2.7	<0.2	
Total Inorganic Carbon	20.0	21.0	19.5	6.5	7.0	
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Copper - Total	0.012	0.007	0.005	0.022	0.002	
Copper - Dissolved	0.004	0.005	0.004	0.004	0.001	
Iron - Total	0.13	0.22	0.24	2.41	0.065	
Iron - Dissolved	0.04	0.05	0.06	0.07	0.03	
Chromium - Total	<0.001	0.003	0.004	0.003	0.003	
Chromium - Dissolved	<0.001	0.001	0.003	0.003	<0.001	
Manganese - Total	0.019	0.032	0.040	0.063	0.014	
Manganese - Dissolved	0.009	0.029	<0.004	0.007	<0.004	
Zinc - Total	0.072	0.008	0.005	<0.001	0.005	
Zinc - Dissolved	0.010	0.006	0.005	<0.001	0.003	
Aluminium - Total	0.08	0.04	0.08	0.33	0.45	
Aluminium - Dissolved	<0.01	<0.01	0.01	0.03	<0.01	
Lead - Total	<0.002	<0.002	<0.002	0.009	0.005	
Lead - Dissolved	<0.002	<0.002	<0.002	<0.002	0.002	
Barium - Total	0.08	0.08	0.08	0.14	0.10	
Barium - Dissolved	0.06	0.08	0.08	0.07	0.03	
Nickel - Total	<0.001	<0.001	<0.001	0.029	0.003	
Nickel - Dissolved	<0.001	<0.001	<0.001	0.001	<0.001	
Mercury - Total	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Phenols					<0.001	

[a]Values in mg/l unless otherwise indicated.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
DOWNSTREAM STATION, SPATSIZI RIVER

Parameter	1984 Winter Apr.	Spring June	Summer August	Fall October
Discharge (m3/s)	0.06	51.9	26.4	21.1
Temperature (°C)	1.0	9.0	12.0	2.0
Dissolved Oxygen				
ph (units)	8.0	7.2	7.7	7.1
Conductivity (umhos/cm)	195	59	101	102
Total Alkalinity	92.0	28.5	98.0	49.0
Calcium - Total				
Magnesium - Total				
Sulphate - Total	14.1	4.4	7.2	6.6
Fluoride - Total	0.18	-	-	-
Total Hardness	96.2	26.1	50.0	37.5
TSS	4.4	54.0	7.2	4.0
TDS	135	-	-	-
Turbidity (NTU)	0.8	24.0	6.4	3.2
Nitrate as N	0.047	0.017	0.007	0.004
Nitrite as N	0.010	0.003	0.004	0.004
NH3 - N	0.02	<0.01	<0.01	<0.01
Total Dissolved Phosphorus	0.004	0.017	0.009	0.006
Dissolved Ortho Phosphorus	<0.003	0.012	0.003	0.004
Total Organic Carbon	-	2.5	-	4.5
Total Inorganic Carbon	-	4.5	-	10.5
Cadmium - Total	<0.0005	0.001	<0.0002	<0.0002
Cadmium - Dissolved	-	0.0008	<0.0002	<0.0002
Copper - Total	<0.001	0.006	0.002	0.002
Copper - Dissolved	-	<0.001	<0.001	0.001
Iron - Total	0.08	1.42	0.05	0.29
Iron - Dissolved	0.06	0.16	<0.01	0.07
Chromium - Total	<0.001	0.015	4.82b	0.003
Chromium - Dissolved	-	<0.001	1.11b	0.002
Manganese - Total	0.009	0.062	0.009	0.009
Manganese - Dissolved	-	0.020	<0.004	<0.004
Zinc - Total	0.013	0.013	0.010	0.002
Zinc - Dissolved	-	0.003	0.001	<0.001
Aluminium - Total	0.02	1.34	0.03	0.16
Aluminium - Dissolved	-	0.06	0.03	0.03
Lead - Total	<0.002	0.002	<0.001	<0.002
Lead - Dissolved	-	0.002	<0.001	<0.001
Barium - Total	0.03	0.05	0.05	0.02
Barium - Dissolved	-	0.02	0.05	0.02
Nickel - Total	<0.001	0.006	0.006	0.002
Nickel - Dissolved	-	0.002	0.001	0.001
Mercury - Total	<0.00005	0.00048	0.00018	<0.00010
Phenols	<0.001	-	0.001	0.002

[a]Values in mg/l unless otherwise indicated.
[b]Sample contamination suspected.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
DOWNSTREAM STATION, SPATSIZI RIVER

	1985										
			June 3								
Parameter[a]	Apr. 11	May 8	Rep 1	Rep 2	Rep 3	July 3	Aug. 6	Sept. 10	Oct. 23	Nov. 28	Dec. 18
Discharge (m3/s)	0.644	1.305	90.604			66.591	17.660c	6.603	3.881	0.813	1.197
Temperature (°C)	0.5	0	4.5			6.0	6.0	6	0	0	0.0
Dissolved Oxygen											13.1
ph (units)	7.12	7.7	7.6			7.8	8.0	8.1	7.7	8.0	7.32
Conductivity (umhos/cm)	212	145	45			60	95	133	66	190	188
Total Alkalinity	102	92.6	20.6			35.5	40	59.4	65.3	92.6	82.0
Calcium - Total	23.4	18.3	5.9	6.0	5.9	6.9	9.4	13.1	14.2	20.4	22.3
Magnesium - Total	10.1	8.6	2.6	2.5	2.6	2.5	4.0	5.7	7.2	9.3	9.2
Sulphate - Total	13.1	9.6	3.3	3.2	3.3	3.8	6.5	10.5	10.0	6.7	13.5
Fluoride											
Total Hardness	100	81	25.5	25.3	25.5	27.5	40.0	56.2	65.1	89.2	93.6
TSS	<0.4	0.4	22.0	24.0	19.0	14.4	2.0	1.2	2.0	3.6	<0.4
TDS											
Turbidity (NTd)	0.76	1.9	33.0	31.5	34.0	21.0	4.6	4.1	1.1	4.07	0.56
Nitrate as N	0.069	0.031	0.006	0.006	0.006	0.004	0.003	<0.003	0.017	0.067	0.048
Nitrite as N	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	<0.003	<0.003	0.004	0.008	0.003
NH3 - N	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	0.02
Total Dissolved Phosphorus	<0.003	0.006	0.012	0.011	0.013	0.020	0.005	0.004	0.006	0.003	0.016
Dissolved Ortho Phosphorus	<0.003	<0.003	0.007	0.006	0.006	0.005	0.003	<0.003	<0.003	<0.003	0.004
Total Organic Carbon	1.2	1.2	5.0	5.0	5.0	2.2	1.0	1.4	2.0	0.5	0.8
Total Inorganic Carbon	22.0	18.5	35.0	5.0	5.0	4.0	8.0	12.5	12.0	18.5	18.1
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Copper - Total	0.001	0.002	0.007	0.009	0.009	0.003	0.002	0.002	0.001	0.003	0.004
Copper - Dissolved	0.001	0.001	0.004	0.002	0.003	<0.001	<0.001	0.001	0.001	0.001	0.003
Iron - Total	0.19	0.25	4.13	5.56	5.88	1.99	0.38	0.33	0.02	0.06	0.11
Iron - Dissolved	0.03	0.019	0.119	0.130	0.120	0.07	0.02	0.07	<0.01	0.01	<0.01
Chromium - Total	<0.001	0.015	0.032	0.004	0.009	0.003	<0.001	0.002	0.003	0.005	0.002
Chromium - Dissolved	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	0.001	<0.001	0.003	<0.001
Manganese - Total	0.019	0.016	0.096	0.134	1.39	0.056	0.015	0.034	<0.004	0.006	0.010
Manganese - Dissolved	0.016	<0.004	0.010	0.011	0.010	0.004	0.006	0.011	<0.004	<0.004	0.009
Zinc - Total	0.006	0.006	0.013	0.033	0.020	0.008	0.132	0.006	<0.001	0.004	0.018
Zinc - Dissolved	0.005	0.001	0.013	0.005	0.006	0.007	0.107	0.006	<0.001	0.002	0.012
Aluminium - Total	0.01	0.04	1.63	5.30	2.50	1.00	0.16	0.08	0.01	0.01	0.06
Aluminium - Dissolved	0.01	0.02	0.05	0.06	0.05	0.04	0.01	0.01	0.01	<0.01	0.02
Lead - Total	0.002	0.003	0.008	0.008	0.005	0.003	<0.002	0.007	<0.002	<0.002	<0.002
Lead - Dissolved	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Barium - Total	0.05	0.05	0.03	0.03	0.04	0.03	0.03	0.06	0.04	0.06	0.03
Barium - Dissolved	0.05	0.05	0.02	0.02	0.02	0.02	0.03	0.06	0.04	0.05	0.03
Nickel - Total	<0.001	0.005	0.011	0.10	0.013	0.006	0.005	<0.001	<0.001	0.004	<0.001
Nickel - Dissolved	<0.001	0.001	0.001	0.001	0.001	0.002	0.003	<0.001	<0.001	<0.001	<0.001
Mercury - Total	0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00005	<0.00005	<0.00005	<0.00005	0.00005	<0.00005
Phenols											

[a]Values in mg/l unless indicated otherwise.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MOUNT KLAPPAN LICENCE AREA
DOWNSTREAM STATION, SPATSIZI RIVER

Parameter	1986 Jan 16	Feb 11	Mar 11	Jun 18	Aug 5	Sep 24
Discharge (m3/s)	0.711	0.572	0.514	68.52	16.643	28.96
Temperature (°C)	0.0	0.0	0.5	5.0	9.0	5.0
Dissolved Oxygen	11.2	11.4	13.5	8.2	8.6	8.8
ph (units)	7.85	7.7	7.40	7.3	7.7	7.4
Conductivity (umhos/cm)	200	185	205	48	88	98
Total Alkalinity	84.1	88.5	89.0	21.9	38.0	46.3
Calcium - Total	21.8	23.5	22.2	6.05	10.2	
Magnesium - Total	9.78	9.9	10.1	2.50	5.0	
Sulphate - Total	13.9	13.4	13.5	3.4	5.5	
Fluoride						
Total Hardness	94.7	99.4	97.0	25.4	46.1	
TSS	1.3	1.1	<0.4	14	4.5	
TDS						
Turbidity (NTU)	0.43	1.2	0.46	16	4.2	
Nitrate as N	0.065	0.061	0.062	0.102	<0.003	
Nitrite as N	0.005	0.005	0.010	<0.003	<0.003	
NH3 - N	<0.01	<0.01	0.01	<0.01	<0.01	
Total Dissolved Phosphorus	0.005	0.004	0.005	0.015	0.011	
Dissolved Ortho Phosphorus	0.005	0.003	0.003	0.006	0.003	
Total Organic Carbon	0.8	0.3	2.5	3.2	<0.2	
Total Inorganic Carbon	19.0	20.0	19	3.5	9.0	
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Copper - Total	0.004	0.006	0.005	0.003	0.001	
Copper - Dissolved	0.002	0.004	0.003	0.003	0.001	
Iron - Total	0.06	0.13	0.09	1.06	0.02	
Iron - Dissolved	0.02	0.02	0.03	0.06	0.01	
Chromium - Total	<0.001	0.002	0.004	0.004	0.001	
Chromium - Dissolved	<0.001	0.002	0.003	<0.001	<0.001	
Manganese - Total	0.015	0.029	0.027	0.024	0.005	
Manganese - Dissolved	0.012	0.026	<0.004	0.004	0.005	
Zinc - Total	0.008	0.011	0.006	<0.001	0.004	
Zinc - Dissolved	0.008	0.005	0.004	<0.001	0.004	
Aluminium - Total	0.04	0.03	0.01	0.54	0.03	
Aluminium - Dissolved	0.01	<0.01	0.01	0.03	0.03	
Lead - Total	<0.002	<0.002	<0.002	<0.002	0.004	
Lead - Dissolved	<0.002	<0.002	<0.002	<0.002	0.003	
Barium - Total	0.05	0.11	0.06	0.11	0.11	
Barium - Dissolved	0.04	0.06	0.05	0.10	0.03	
Nickel - Total	0.001	<0.001	<0.001	0.004	<0.001	
Nickel - Dissolved	0.001	<0.001	<0.001	0.003	<0.001	
Mercury - Total	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Phenols					<0.001	

[a]Values in mg/l unless otherwise indicated.

APPENDIX B

SURFACE WATER QUALITY ANALYSIS, TRIAL CARGO OPERATIONS

MOUNT KLAPPAN LICENCE AREA

Appendix B **Page**

RESULTS OF SURFACE WATER QUALITY ANALYSES
UPSTREAM STATION, HOBBIT CREEK

Parameter[a]	1985										
			June 4								
	Apr. 11	May 8	Rep 1	Rep 2	Rep 3	July 2	Aug. 5	Sept. 9	Oct. 22	Nov. 26	Dec. 16
Discharge (m^3/s)	0.007	0.010	1.06			0.822	0.183	0.043	0.010	0.009	0.006
Temperature (°C)	0	1	1			8	6	6	0	0	0.0
Dissolved Oxygen											11.1
ph (units)	7.75	7.7	7.1			7.7	8.4	8.6	8.3	8.4	8.02
Conductivity (umhos/cm)	400	250	35			63	168	240	241	290	322
Total Alkalinity	214	171	14.9			30.6	70	116.3	135.0	154.0	172
Calcium - Total	26.0	18.6	4.3	4.3	4.5	4.5	10.2	17.2	16.2	16.5	23.7
Magnesium - Total	28.6	16.7	4.3	4.5	4.4	4.1	10.9	18.7	17.9	21.4	24.8
Sulphate - Total	14.4	11.1	2.3	2.3	2.1	2.4	6.0	11.8	9.6	11.5	13.4
Total Hardness	183	115	28.4	28.4	29.4	28.1	70.4	119.9	114.1	129.3	161.3
TSS	0.8	0.8	4.0	7.0	8.0	20.0	2.4	0.4	3.0	9.0	0.6
Turbidity (NTU)	1.50	1.9	26.0	21.0	23.0	14.0	2.2	0.6	1.7	16.7	0.48
Nitrate as N	0.108	0.096	0.005	0.005	0.006	<0.003	<0.003	<0.003	0.033	0.073	0.040
Nitrite as N	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	0.006	0.005
NH3 - N	<0.01	<0.01	<0.01	0.03	<0.01	0.05	<0.01	<0.01	0.03	<0.01	<0.01
Total Dissolved Phosphorus	0.004	0.007	0.008	0.008	0.007	0.010	0.010	<0.003	0.004	0.006	0.006
Dissolved Ortho Phosphorus	0.003	<0.003	0.007	0.008	0.007	0.006	0.003	<0.003	<0.003	<0.003	0.003
Total Organic Carbon	1.5	1.4	4.9	4.6	5.0	2.2	1.0	0.2	2.0	0.4	0.6
Total Inorganic Carbon	48.5	37.5	6.5	6.5	6.0	5.0	15.0	25.0	24.0	39.0	38.0
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	-
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Copper - Total	0.001	0.001	0.005	0.005	0.005	0.002	<0.001	0.003	<0.001	0.004	-
Copper - Dissolved	0.001	0.001	0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	0.002	0.003
Iron - Total	0.06	0.07	2.53	2.43	2.52	0.91	0.17	0.04	0.14	0.09	-
Iron - Dissolved	0.01	0.07	0.096	0.108	0.099	0.07	<0.01	0.03	0.10	<0.01	<0.01
Chromium - Total	0.003	0.003	0.004	0.002	0.003	<0.001	<0.001	0.006	0.003	0.004	-
Chromium - Dissolved	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese - Total	0.005	<0.004	0.057	0.058	0.59	0.028	0.008	<0.004	<0.004	<0.004	-
Manganese - Dissolved	<0.004	<0.004	<0.004	0.004	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.012
Zinc - Total	0.004	0.007	0.007	0.011	0.011	0.009	0.017	0.012	0.001	0.006	-
Zinc - Dissolved	0.004	0.003	0.012	0.008	0.011	0.001	0.007	0.005	<0.001	0.002	0.009
Aluminium - Total	0.02	0.02	0.69	0.67	0.63	0.32	0.04	<0.01	0.01	0.02	-
Aluminium - Dissolved	0.01	0.01	0.03	0.03	0.03	0.03	0.01	<0.01	0.01	0.01	0.01
Lead - Total	<0.001	<0.001	0.003	0.003	0.002	0.003	<0.002	0.003	<0.002	<0.002	-
Lead - Dissolved	<0.001	<0.001	0.002	0.002	0.002	0.001	<0.002	<0.002	<0.002	<0.002	0.002
Barium - Total	0.09	0.07	0.04	0.03	0.03	0.03	0.06	0.13	0.07	0.12	-
Barium - Dissolved	0.09	0.07	0.02	0.02	0.02	0.02	0.05	0.13	0.07	0.08	0.05
Nickel - Total	<0.001	<0.001	0.008	0.007	0.008	0.005	0.007	<0.001	<0.001	0.008	-
Nickel - Dissolved	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.004	<0.001	<0.001	<0.001	<0.001
Mercury - Total	0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00005	<0.00005	<0.00005	<0.00005	0.00005	<0.00005
Phenols											

[a]Values in mg/l unless indicated otherwise.

RESULTS OF SURFACE WATER QUALITY ANALYSES
UPSTREAM STATION, HOBBIT CREEK

Parameter	1986 Jan 15	Feb 10	Mar 10	Jun 17	Aug 5	Sep 24
Discharge (m3/s)	0.005	0.008	0.002	0.955	0.120	0.165
Temperature (°C)	0.0	0.0	0.5	2.5	5.0	5.5
Dissolved Oxygen	10.9	10.4	12.0	10.1	9.6	7.9
ph (units)	8.20	8.0	8.15	8.1	7.6	7.9
Conductivity (umhos/cm)	390	349.5	380	40	129	155
Total Alkalinity	169.1	181.1	191.4	20.0	79.4	74.5
Calcium - Total	21.8	23.3	23.8	3.16	11.1	
Magnesium - Total	24.7	26.2	26.2	3.11	12.1	
Sulphate - Total	13.1	12.9	12.8	2.4	5.9	
Total Hardness	156.1	166.0	167.0	20.7	77.5	
TSS	<0.4	0.7	<0.4	15	2.5	
Turbidity (NTU)	0.4	1.2	0.32	18	1.6	
Nitrate as N	0.077	0.081	0.079	0.148	<0.003	
Nitrite as N	0.006	0.004	0.012	<0.003	<0.003	
NH3 - N	<0.01	<0.01	0.01	<0.01	<0.01	
Total Dissolved Phosphorus	0.016	0.009	0.006	0.020	0.014	
Dissolved Ortho Phosphorus	0.006	0.005	0.003	0.007	0.003	
Total Organic Carbon	1.5	0.2	2.5	3.5	<0.2	
Total Inorganic Carbon	41.5	42.0	40.0	4.0	17.5	
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Copper - Total	0.003	0.006	0.005	0.003	0.002	
Copper - Dissolved	0.003	0.004	0.003	0.002	<0.001	
Iron - Total	0.02	0.16	0.01	0.72	0.12	
Iron - Dissolved	<0.01	<0.01	<0.01	0.06	<0.01	
Chromium - Total	0.001	0.003	0.006	0.002	<0.001	
Chromium - Dissolved	0.001	<0.001	0.005	0.002	<0.001	
Manganese - Total	<0.004	<0.004	<0.004	0.029	0.009	
Manganese - Dissolved	<0.004	<0.004	<0.004	<0.004	<0.004	
Zinc - Total	0.012	0.006	0.005	<0.001	0.009	
Zinc - Dissolved	0.010	0.004	0.004	<0.001	0.006	
Aluminium - Total	0.02	0.05	<0.01	0.27	0.04	
Aluminium - Dissolved	0.01	<0.01	<0.01	0.02	<0.01	
Lead - Total	0.003	0.002	<0.002	0.005	0.005	
Lead - Dissolved	0.003	<0.002	<0.002	<0.002	0.002	
Barium - Total	0.05	0.15	0.10	0.10	0.16	
Barium - Dissolved	0.05	0.10	0.010	0.08	0.05	
Nickel - Total	0.002	<0.001	<0.001	0.003	0.002	
Nickel - Dissolved	0.002	<0.001	<0.001	0.002	0.001	
Mercury - Total	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Phenols					<0.001	

[a]Values in mg/l unless otherwise indicated.

RESULTS OF SURFACE WATER QUALITY ANALYSES, DOWNSTREAM STATION, HOBBIT CREEK

Parameter[a]	1985										
			June 4								
	Apr. 12	May 8	Rep 1	Rep 2	Rep 3	July 2	Aug. 5	Sept. 9	Oct. 22	Nov. 26	Dec. 17
Discharge (m3/s)	0.008	0.129	0.976			0.643	0.154c	0.042	0.032	0.042	0.003
Temperature (°C)	0	0	1			9	7	7	0	0	0.0
Dissolved Oxygen											12.6
ph (units)	7.83	8.1	7.0			8.0	8.4	8.4	8.65	8.4	8.04
Conductivity (umhos/cm)	410	360	41			67	169	242	258	310	280
Total Alkalinity	215	187	18.2			34.6	70	119.3	127.9	163.6	178.0
Calcium - Total	26.4	22.4	4.4	4.7	4.6	4.9	10.7	17.2	16.9	17.7	25.1
Magnesium - Total	30.0	25.0	4.7	4.8	4.7	4.5	10.8	20.7	18.8	23.0	26.4
Sulphate - Total	23.0	20.8	2.3	2.4	2.5	2.4	6.7	9.4	11.6	12.7	17.7
Total Hardness	190	159	30.3	31.5	30.8	30.8	71.2	128.	119.6	138.9	171.4
TSS	1.0	4.0	24.0	25.0	33.0	33.6	<1.0	1.8	1.0	9.3	0.7
Turbidity (NTU)	1.40	7.9	41.5	43.0	42.0	12.0	1.65	0.6	0.8	0.97	0.36
Nitrate as N	0.095	0.091	0.007	0.006	0.006	<0.003	<0.003	<0.003	0.028	0.059	0.035
Nitrite as N	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	0.006	0.004
NH3 - N	<0.01	<0.01	<0.01	0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Total Dissolved Phosphorus	<0.003	0.005	0.009	0.010	0.010	0.011	0.003	0.005	0.004	0.005	0.005
Dissolved Ortho Phosphorus	<0.003	<0.003	0.007	0.007	0.008	0.007	<0.003	<0.003	<0.003	<0.003	0.003
Total Organic Carbon	10.0	1.0	5.1	3.7	4.3	2.0	0.8	<0.2	2.0	0.6	1.9
Total Inorganic Carbon	54.0	39.0	7.0	7.0	7.0	5.0	16.0	21.0	24.5	37.0	39.0
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Copper - Total	0.001	0.001	0.009	0.009	0.008	0.003	<0.001	0.002	0.001	0.004	0.004
Copper - Dissolved	0.001	0.001	0.001	0.001	0.001	<0.001	<0.001	0.002	<0.001	0.002	0.004
Iron - Total	0.03	0.17	5.25	4.56	5.18	0.95	0.01	0.22	0.01	0.06	0.01
Iron - Dissolved	<0.01	0.03	0.125	0.125	0.124	0.08	0.01	0.03	<0.01	<0.01	0.01
Chromium - Total	0.006	<0.001	0.004	0.002	0.004	0.001	<0.001	0.004	<0.001	0.004	<0.001
Chromium - Dissolved	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese - Total	0.004	<0.004	0.120	0.114	0.128	0.023	<0.004	0.012	0.004	0.004	<0.004
Manganese - Dissolved	<0.004	<0.004	0.006	0.006	0.005	<0.004	<0.004	0.005	<0.004	<0.004	<0.004
Zinc - Total	0.007	0.009	0.035	0.012	0.027	0.004	0.017	0.017	<0.001	0.008	0.011
Zinc - Dissolved	0.007	0.008	0.007	0.007	0.005	0.002	0.005	0.003	<0.001	0.005	0.008
Aluminium - Total	0.01	0.03	1.20	0.94	1.42	0.21	0.01	0.04	0.02	0.01	0.02
Aluminium - Dissolved	0.01	0.01	0.03	0.03	0.03	0.03	<0.01	0.01	0.02	<0.01	0.02
Lead - Total	<0.001	0.002	0.004	0.004	0.004	0.002	<0.002	0.004	<0.002	0.002	0.002
Lead - Dissolved	<0.001	0.001	0.002	0.001	0.001	0.001	<0.002	<0.002	<0.002	0.002	<0.002
Barium - Total	0.07	0.08	0.05	0.05	0.06	0.03	0.05	0.14	0.07	0.06	0.08
Barium - Dissolved	0.07	0.08	0.02	0.02	0.02	0.03	0.06	0.13	0.07	0.07	0.08
Nickel - Total	<0.001	0.002	0.010	0.1012	0.015	0.005	0.007	<0.001	<0.001	0.007	0.001
Nickel - Dissolved	<0.001	0.001	<0.001	0.001	0.001	<0.001	0.007	<0.001	<0.001	0.001	0.001
Mercury - Total	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00005	<0.00006	<0.00006	<0.00005	0.00005	<0.00005
Phenols											

[a]Values in mg/l unless indicated otherwise.

RESULTS OF SURFACE WATER QUALITY ANALYSES
DOWNSTREAM STATION, HOBBIT CREEK

Parameter	1986 Jan 15	Feb 10	Mar 10	Jun 78	Aug 5	Sep 24
Discharge (m3/s)	0.009	0.0015	0.002	1.002	0.134	0.152
Temperature (°C)	0.0	0.0	0.5	3.0	7.0	5.0
Dissolved Oxygen	10.9	10.6	11.2	7.1	9.2	7.2
ph (units)	8.15	7.9	8.0	7.9	7.8	7.9
Conductivity (umhos/cm)	371	402	425	44	135	153
Total Alkalinity	179.4	190.4	208.4	21.9	80.0	74.4
Calcium - Total	24.3	28.8	27.1	3.35	11.8	
Magnesium - Total	27.1	32.7	32.6	3.39	12.3	
Sulphate - Total	18.5	29.5	25.5	1.7	6.1	
Total Hardness	172.2	206.5	202	22.3	80.1	
TSS	0.6	<0.4	<0.4	29	1.5	
Turbidity (NTU)	0.24	0.3	0.20	28	2.3	
Nitrate as N	0.080	0.114	0.100	0.034	0.012	
Nitrite as N	0.003	0.004	0.010	<0.003	<0.003	
NH3 - N	<0.01	0.01	0.01	<0.01	<0.01	
Total Dissolved Phosphorus	0.018	0.008	0.005	0.018	0.014	
Dissolved Ortho Phosphorus	0.005	0.003	0.003	0.007	<0.003	
Total Organic Carbon	1.4	1.0	1.4	11.6	<0.2	
Total Inorganic Carbon	43.0	45.0	45.0	4.0	18.5	
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Copper - Total	0.003	0.007	0.005	0.006	0.001	
Copper - Dissolved	0.003	0.004	0.001	0.002	<0.001	
Iron - Total	<0.03	0.07	0.02	1.20	0.02	
Iron - Dissolved	<0.01	<0.01	<0.01	0.07	<0.01	
Chromium - Total	<0.001	<0.001	0.004	0.004	0.002	
Chromium - Dissolved	<0.001	<0.001	0.002	<0.001	<0.001	
Manganese - Total	<0.004	<0.004	<0.004	0.044	0.005	
Manganese - Dissolved	<0.004	<0.004	<0.004	0.006	<0.004	
Zinc - Total	0.010	0.008	0.006	0.016	0.006	
Zinc - Dissolved	0.006	0.008	0.006	0.004	0.004	
Aluminium - Total	0.01	0.03	0.01	0.28	0.05	
Aluminium - Dissolved	0.01	<0.01	0.01	0.02	<0.01	
Lead - Total	0.002	<0.002	0.002	<0.002	0.003	
Lead - Dissolved	0.002	<0.002	0.002	<0.002	0.003	
Barium - Total	0.05	0.10	0.10	0.06	0.14	
Barium - Dissolved	0.05	0.10	0.10	0.06	0.05	
Nickel - Total	0.001	0.002	0.002	0.004	0.002	
Nickel - Dissolved	0.001	0.001	0.002	<0.001	0.001	
Mercury - Total	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Phenols					<0.001	

[a] Values in mg/l unless otherwise indicated.

RESULTS OF SURFACE WATER QUALITY ANALYSES
HOBBIT BROATCH PIT

Parameter[a]	1985					1986					
	Aug. 5	Sept. 10	Oct. 22	Nov. 27	Dec. 16	Jan.15	Feb. 10	Mar. 10	June 17	Aug. 4	Sept. 24
Temperature (°C)	14	9	0	0	0.0	0.0	0.0	0.5	11.0	14.5	8.0
Dissolved Oxygen					10.2	10.2	7.8	5.5	7.6	7.6	7.6
ph (units)	8.7	8.45	8.9	8.5	7.85	7.85	7.75	7.98	8.2	7.6	8.15
Conductivity (umhos/cm)	270	251	290	280	310	310	300	310	328	385	380
Total Alkalinity	110	107.4	141.5	131.5	144	144	153.7	141.8	80.6	135.8	111.8
Calcium - Total	17.0	17.9	19.9	16.5	23.4	23.4	22.3	21.9	25.7	27.3	
Magnesium - Total	13.4	14.5	17.5	17.0	18.5	18.5	18.4	18.5	22.7	23.4	
Sulphate - Total	23.6	22.0	22.0	21.6	28.4	28.4	28.4	27.8	78.5	80.0	
Total Hardness	97.7	104.4	121.7	111.2	134.6	134.6	131.4	131.0	157.6	164.5	
TSS	72.0	26.0	21.0	5.3	12.0	12.0	0.8	5.5	48	3.0	
Turbidity (NTU)	95.06	146.3	26.0	46.7	34.0	34.0	0.6	8.2	60	7.4	
Nitrate as N	0.009	<0.003	0.016	0.040	0.003	0.003	0.030	0.073	0.040	<0.003	
Nitrite as N	<0.003	0.004	0.008	0.007	<0.003	<0.003	0.008	0.008	0.005	<0.003	
NH3 - N	0.040	.01	0.12	<0.01	0.06	0.06	0.04	0.05	0.02	<0.01	
Total Dissolved Phosphorus	0.048	0.030	0.008	0.007	0.023	0.023	0.008	0.015	0.035	0.013	
Dissolved Ortho Phosphorus	0.028	0.026	0.004	0.004	0.015	0.015	0.007	0.006	0.019	0.004	
Total Organic Carbon	4.7	3.5	3.8	5.0	4.9	4.9	4.2	5.8	4.0	2.0	
Total Inorganic Carbon	21.5	21.5	32.5	32.0	29.6	29.6	29.0	31.0	17.0	21.0	
Cadmium - Total	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Cadmium - Dissolved	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Copper - Total	0.009	0.019	0.002	0.008	0.005	0.005	0.008	0.006	<0.012	0.003	
Copper - Dissolved	0.005	0.004	0.002	0.001	0.005	0.005	0.004	0.002	0.010	0.002	
Iron - Total	4.79	8.40	0.01	2.26	1.41	1.41	0.027	0.22	3.07	0.21	
Iron - Dissolved	0.18	0.032	<0.01	0.04	0.07	0.07	0.02	0.01	0.03	<0.01	
Chromium - Total	<0.001	0.025	<0.001	0.007	0.002	0.002	0.001	0.003	0.003	<0.001	
Chromium - Dissolved	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.001	0.001	<0.001	
Manganese - Total	0.090	0.101	0.019	0.044	0.032	0.015	0.019	0.017	0.094	0.012	
Manganese - Dissolved	0.037	0.014	0.017	0.035	0.017	0.0125	0.014	<0.004	0.049	0.007	
Zinc - Total	0.020	0.034	0.002	0.017	0.024	0.012	0.013	0.024	0.016	0.006	
Zinc - Dissolved	0.018	0.008	0.002	0.008	0.016	0.009	0.010	0.023	<0.001	0.006	
Aluminium - Total	1.44	7.9	0.18	0.84	0.35	0.11	0.08	0.02	0.83	0.06	
Aluminium - Dissolved	0.02	0.13	0.02	<0.01	0.02	0.02	<0.01	<0.01	0.01	<0.01	
Lead - Total	<0.002	0.010	<0.002	0.003	0.006	0.004	<0.002	0.002	<0.002	0.004	
Lead - Dissolved	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	<0.002	<0.002	<0.002	0.003	
Barium - Total	0.22	0.84	0.23	0.21	0.21	0.12	0.21	0.20	<0.002	0.016	
Barium - Dissolved	0.18	0.02	0.19	0.18	0.19	0.12	0.20	0.20	0.20	0.12	
Nickel - Total	0.020	0.065	0.002	0.009	0.007	0.003	0.006	0.008	0.018	0.007	
Nickel - Dissolved	0.019	0.003	0.002	0.003	0.005	0.003	0.003	<0.003	0.019	<0.006	
Mercury - Total	0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00005	
Phenols										0.001	

[a]Values in mg/l unless indicated otherwise.

RESULTS OF SURFACE WATER QUALITY ANALYSES, MT. KLAPPAN PROPERTY, TAILINGS POND, 1985-86

Parameter[a]	1985 Sep 10	1985 Oct 22	1985 Nov 26	1985 Dec 17	1986 Jan 15	1986 Feb 12	1986 Mar 12	1986 Jun 17	1986 Aug 6	1986 Sep 24	Effluent Objectives[b]
Temperature (°C)	5	0	0	0	0	0	0		16.0	8.0	
pH (units)	7.7	6.4	6.5	6.86	7.0	6.7	6.5		7.5	7.8	6.5-8.5
Conductivity (umhos/cm)									360	380	
Total Alkalinity									35.8	39.0	
Calcium - Total									13.0		
Magnesium - Total									34.0		
Sulphate - Total						281	310	125	144		
Total Hardness									172.4		
TSS	1200.0	20.0	16.0	1.3	<0.4	<0.4	1.3	6.0	7.0		25
Turbidity (NTU)									9.8		
Nitrate as N									0.011		
Nitrite as N									<0.003		
Nitrate/Nitrite as N	0.008	0.004	0.009	0.018	0.007	<0.003	<0.003	0.008			10.0
NH_3-N									0.04		1.0
Total Dissolved Phosphorus									0.020		
Dissolved Ortho Phosphorus									0.004		2.0
Total Organic Carbon									<0.2		
Total Inorganic Carbon									8.0		
Cadmium - Total									<0.0002		
Cadmium - Dissolved	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002		0.01
Copper - Total									0.001		
Copper - Dissolved	0.001	0.001	0.001	0.003	0.003	0.003	0.004	0.002	<0.001		0.05
Iron - Total									0.35		
Iron - Dissolved	0.38	<0.01	0.07	<0.01	<0.01	<0.01	<0.01	0.03	<0.01		0.3
Chromium - Total									0.003		
Chromium- Dissolved	<0.001	0.001	<0.001	<0.001	0.004	0.001	0.003	<0.001	0.002		0.05
Manganese - Total									0.078		
Manganese - Dissolved									0.077		0.1
Zinc - Total									0.022		
Zinc - Dissolved	0.012	0.002	0.006	0.008	0.010	0.010	0.009	0.009	0.022		0.2
Aluminum - Total									0.10		
Aluminum - Dissolved	0.04	0.02	0.01	<0.01	<0.01	0.01	0.03	<0.01	<0.01		0.5
Lead - Total									0.003		
Lead - Dissolved	<0.002	<0.002	<0.002	<0.002	0.002	0.003	<0.002	<0.002	<0.002		0.05
Barium - Total									0.13		
Barium - Dissolved									0.03		
Nickel - Total									0.002		
Nickel - Dissolved									<0.001		
Mercury - Total									<0.00005		Nil
Phenols									0.001		

[a] Values in mg/l unless indicated otherwise.
[b] Most rigorous objectives for the discharge of final effluents to fresh waters (MOE 1979).

RESULTS OF SURFACE WATER QUALITY ANALYSES, MT. KLAPPAN PROPERTY, SETTLING POND, 1985-86

Parameter[a]	1985 Sep 10	1985 Oct 22	1985 Nov 29	1985 Dec 19	1986 Jan 15	1986 Feb 12	1986 Mar 12	1986 Jun 17	1986 Aug 6	1986 Sep 24	Effluent Objectives[b]
Temperature (°C)	3	0	0	0	0	0	0.5		14.5	8.0	
pH (units)	7.5	7.3	7.9	7.67	7.0	6.95	6.90		7.4	7.48	6.5-8.5
Conductivity (umhos/cm)									730	570	
Total Alkalinity									138.6	87.9	
Calcium - Total									28.6		
Magnesium - Total									44.0		
Sulphate - Total						170	180	144	155		
Total Hardness									252.6		
TSS	205.0	60.0	173.0	16.0	2.6	2.0	11.0	7.7	3.5		25
Turbidity (NTU)									8.0		
Nitrate as N									<0.003		
Nitrite as N									<0.003		
Nitrate/Nitrite as N	0.008	0.025	0.021	0.062	0.015	<0.003	<0.003	0.004			10.0
NH_3-N									0.02		1.0
Total Dissolved Phosphorus									0.033		
Dissolved Ortho Phosphorus									0.011		2.0
Total Organic Carbon									12.5		
Total Inorganic Carbon									21.0		
Cadmium - Total									<0.0002		
Cadmium - Dissolved	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002		0.01
Copper - Total									0.004		
Copper - Dissolved	0.001	0.001	0.002	0.003	0.008	0.003	0.005	0.004	0.002		0.05
Iron - Total									0.50		
Iron - Dissolved	0.18	0.04	0.06	<0.01	0.02	<0.01	0.01	0.03	0.25		0.3
Chromium - Total									0.004		
Chromium- Dissolved	0.001	0.001	0.005	<0.001	0.006	0.001	<0.001	<0.001	<0.001		0.05
Manganese - Total									0.16		
Manganese - Dissolved									0.16		0.1
Zinc - Total									0.12		
Zinc - Dissolved	0.47	0.002	0.008	0.019	0.017	0.046	0.052	0.16	0.12		0.2
Aluminum - Total									0.10		
Aluminum - Dissolved	0.04	0.01	<0.01	0.02	0.09	<0.01	0.01	0.01	0.04		0.5
Lead - Total									0.002		
Lead - Dissolved	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002		0.05
Barium - Total									0.14		
Barium - Dissolved									0.05		
Nickel - Total									0.009		
Nickel - Dissolved									0.004		
Mercury - Total									<0.00005		Nil
Phenols									0.007		

[a] Values in mg/l unless indicated otherwise.
[b] Most rigorous objectives for the discharge of find effluents to fresh waters (MOE 1979).

RESULTS OF SURFACE WATER QUALITY ANALYSES, MT. KLAPPAN PROPERTY, SETTLING POND OUTFLOW, 1985-86

Parameter[a]	1985 Oct 22	1985 Nov 27	1985 Dec 19[b]	1986 Jan 15[b]	1986 Feb 12[b]	1986 Mar 12[b]	1986 Jun 17	1986 Aug 6	1986 Sep 24	Effluent Objectives[c]
Temperature (°C)	0	0						14.0	7.0	
pH (units)	8.0	7.6						7.6	7.6	6.5-8.5
Conductivity (umhos/cm)								500	300	
Total Alkalinity								92.5	64.4	
Calcium - Total								34.1		
Magnesium - Total								59.0		
Sulphate - Total							45.5	209.0		
Total Hardness								328.1		
TSS	493.0	110.0					20.0	0.5		25
Turbidity (NTU)								0.7		
Nitrate as N								<0.003		
Nitrite as N								<0.003		
Nitrate/Nitrite as N	0.020	0.032					0.009			10.0
NH_3-N								<0.01		1.0
Total Dissolved Phosphorus								0.021		
Dissolved Ortho Phosphorus								0.005		2.0
Total Organic Carbon								1.7		
Total Inorganic Carbon								23.0		
Cadmium - Total								<0.0002		
Cadmium - Dissolved	<0.0002	<0.0002					<0.0002	<0.0002		0.01
Copper - Total								0.002		
Copper - Dissolved	0.002	0.001					0.006	<0.001		0.05
Iron - Total								0.07		
Iron - Dissolved	0.016	0.05					0.51	<0.01		0.3
Chromium - Total								0.001		
Chromium- Dissolved	0.002	0.005					<0.001	<0.001		0.05
Manganese - Total								0.15		
Manganese - Dissolved								0.14		0.1
Zinc - Total								0.11		
Zinc - Dissolved	0.002	0.015					0.066	0.11		0.2
Aluminum - Total								0.01		
Aluminum - Dissolved	0.03	0.02					0.06	0.01		0.5
Lead - Total								0.002		
Lead - Dissolved	<0.002	<0.002					<0.002	0.002		0.05
Barium - Total								0.12		
Barium - Dissolved								0.05		
Nickel - Total								0.004		
Nickel - Dissolved								0.002		
Mercury - Total								<0.00005		Nil
Phenols								0.002		

[a] Values in mg/l unless indicated otherwise.
[b] No water in drainage.
[c] Most rigorous objectives for the discharge of final effluents to fresh waters (MOE 1979).

PART FOUR - TERRESTRIAL ENVIRONMENT

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PART FOUR - TERRESTRIAL ENVIRONMENT

1.0 SURFICIAL GEOLOGY AND SOILS

1.1 INTRODUCTION

In the Stage I studies for the Mount Klappan Coal Project, 42 soil profile descriptions were recorded and information on the area soils, surficial materials and vegetation was presented. In response to government review comments on the Stage I soil studies, further surveys were done and more soil profiles were described during the summer of 1986.

The main objectives were to provide a soil map of the minesite area, including the proposed pit, waste dump, plant, reservoir, tailings pond and camp areas, and to comment on the potential use of soils in reclamation.

Investigation of surficial geology units and groundwater flow regimes was also undertaken in 1986 through a rotary drilling and backhoe testpit program. The objectives of this study were to evaluate foundation conditions and comment on the expected stability of various minesite components.

Soil studies commenced with a review of existing information on the area geology, soils and vegetation (Clement and Vold 1985; Pojar 1986; Pojar et al. 1983; Young and Alley 1978). Black and white, 1:30 000 scale aerial photographs were examined and pretyped. The study area was traversed on foot and soil profiles were examined. Seventeen new profile descriptions were recorded. Field-truthed aerial photos were used to produce a 1:50 000 scale map from an NTS topographic base map. Some bulked soil samples were collected and analysed in the laboratory.

Surficial materials were initially identified through airphoto interpretation. This was followed by field reconnaissance work which included surface mapping, logging of rotary (track-mounted, center sample air rotary drill)

drill holes and backhoe test pits and subsequent laboratory analysis of drill core and soil samples from shelby tube, standard penetration and grab samples.

Permafrost conditions were evaluated through installation and monitoring of five thermistor strings and observations documented during the Trial Cargo mining operation.

1.2 SURFICIAL GEOLOGY

The major surficial geology units in the area include silt and clay tills, slopewash or glacial outwash deposits including silty sands and some gravels, and fen or bog organic-rich deposits.

The clay or silt till deposit is the most widespread surficial deposit in the area. A bulk sample of glacial till usually contains more coarse grain sizes than fine grain sizes. Clay or silt usually predominate in the fines fraction of the soil grains less than #10 sieve size (less than 2 mm) which distinguishes the clay and silt till. The plasticity ranges from medium (clay till) to low plastic. Some cobbles and boulders are also present. The material is typically stiff to hard with water contents of 10% or below except in the near surface frost zone where water contents up to 15 to 20% occur. Till depths may exceed 15 metres in the waste rock disposal area. Till depths range widely in the plant area from a few metres to greater than 15 metres. In the tailings area, depths are typically 10 to 13 metres.

Some till-like deposits are predominantly sandy. Most of these deposits were encountered in the tailings area and may represent, in part, slopewash or water sorted tills.

Outwash or slopewash granular deposits include silty sand or silty sands and gravels and occur sporadically along the north side of Lost Ridge. Airphoto analysis suggests that at the end of glaciation there was abundant surface runoff down the north side of the ridge toward the Little Klappan

River, which left behind sporadic and discontinuous deposits. Some of these deposits may also be minor morainal deposits which have since been eroded. The deposits tend to be shallow, but have been found to depths of 3-6 metres in some test pits and drill holes.

Colluvium (gravity transported debris) and talus (scree) are found on the upper reaches of Lost Ridge, particularly on the north side and, to a lesser degree, below some of the hogbacks. These deposits are formed by rock fall, creek and slopewash. The deposits may range from bouldery scree to silty materials containing some gravel where weak bedrock has weathered and broken down. The deposits are typically not more than 5 to 10 metres deep, and are frequently much shallower.

Fen and bog deposits (muskeg) discontinuously overlie glacial till in many of the lower areas of the ridge and in the valley, including the plant site/tailings pond area. The deposits are typically shallow (often less than 0.5 to 1.0 metres deep) but local pockets may reach 4 metres deep. These deposits are not continuous, but tend to form in low, poorly drained pockets on the bedrock surface or in the glacial till. Peat encountered in these deposits ranges from amorphous to fibrous.

In general, the glacial till deposits may be overlain by fen or bog deposits or by the slopewash/glacial outwash deposits. The colluvial deposits are frequently underlain by bedrock, although these deposits may overrun onto the glacial till. Other more recent stream gravels and sands occur along the valley bottom of the Little Klappan River as well as along small side streams draining the Lost Ridge area.

Seasonal frost may penetrate up to 3 metres in the Klappan area, and normally thaws each year. A "warm" permafrost condition (minimum temperatures are -0.23^{o}C) exists only in the crest area of Lost Ridge and extends to a depth of about 30-40 metres.

1.3 DESCRIPTION OF EXISTING SOILS

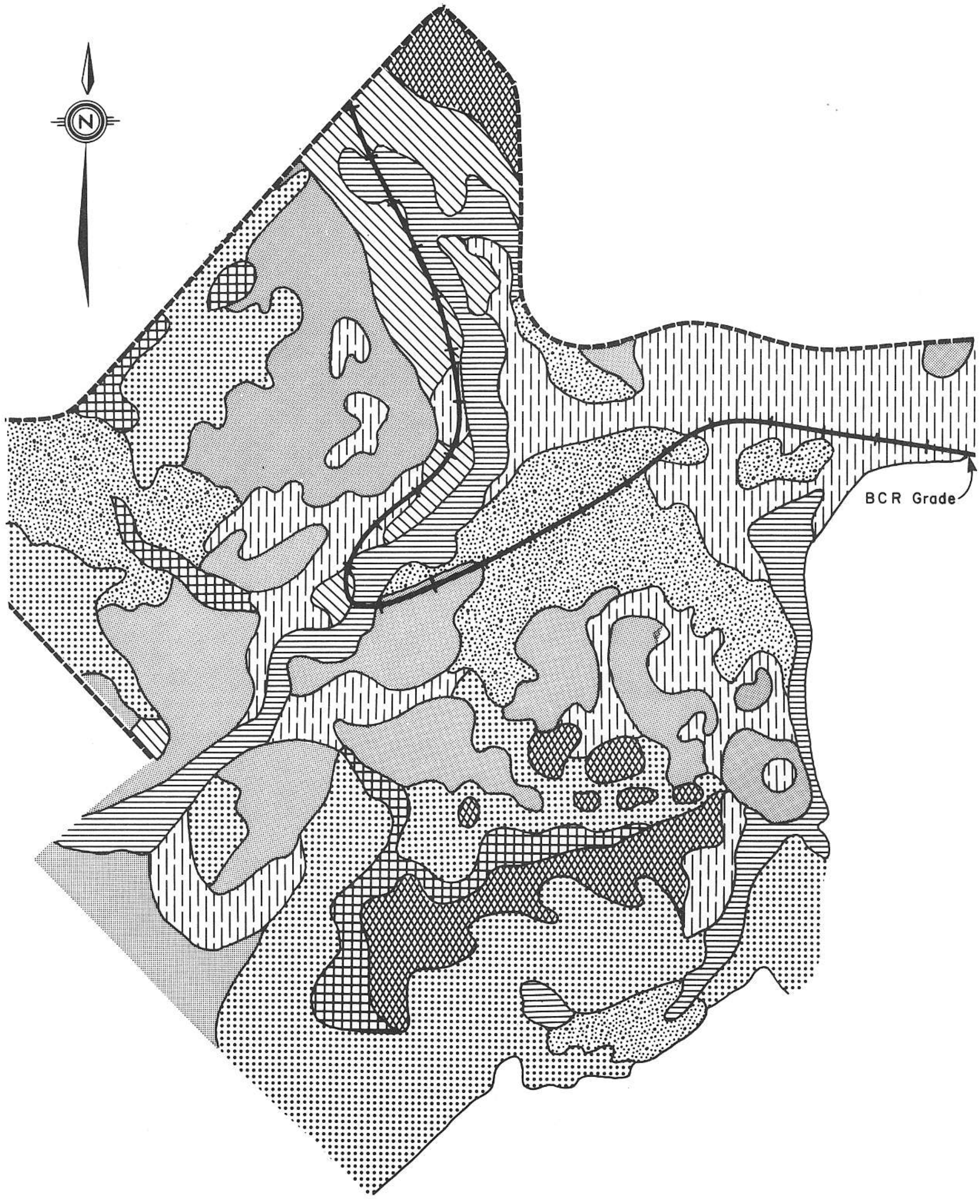
The 1:50 000 scale soil map is shown in Figure 4-1 and the map legend is given in Figure 4-1A. Terminology and abbreviations used follow CSSC (1978) and Klinka et al (1981). However names are related to local topographic features. Some laboratory data from bulked soil samples are presented in Table 4-1.

Eight soil map units are defined and shown in Figure 4-1. The map units represent seven soil associations. The Klappan Association is shown in two classifications (representing predominantly deeper and predominantly shallower surficial materials) on the soil map. The "Steep-Rocky" Land map unit does not, strictly speaking, represent a soil association so much as an area consisting largely of non-soil.

Ridgetop soils are mainly well drained, coarse textured, shallow Regosols and Brunisols occurring in the Alpine Tundra zone. Regosols predominate in areas that have been subject to more recent solifluction. Gleyed subgroups occur in imperfectly drained areas. These soils dominate along the crest of Lost Ridge and are generally less than 1.0 metre in depth.

Lost Ridge soils are derived from predominantly deep colluvium. Solifluction and mixing ("turbation") by animals such as Hoary Marmots (**Marmota caligata**) are important in influencing soil characteristics, particularly at higher elevations. Soils here are Regosols and Brunisols as well; however, Clement and Vold (1985) and Vold (1986) note that Humo-Ferric Podzols may occur especially in the Subalpine Spruce-Willow-Birch zone. The few bulk samples analyzed in this study do not meet the chemical or color criteria (see CSSC 1978) for a podzolic B. horizon. Lost Ridge soils are found mainly on the gentler sloping south side of Lost Ridge and can be more than 1.0 metre deep in some areas.

Didene soils consist of mainly thin layers of predominantly mesic organic materials overlying medium to fine textured morainal or, occasionally, glaciofluvial materials in the subalpine (Spruce-Willow-Birch zone). Common



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MT. KLAPPAN ANTHRACITE PROJECT

FIGURE 4-1

SOILS MAP
MOUNT KLAPPAN MINESITE AREA

NORECOL ENVIRONMENTAL CONSULTANTS LTD.

MAP UNIT NAME	GENETIC MATERIALS	% COURSE FRAGMENTS	TEXTURE	DRAINAGE	MAIN SOIL SUBGROUPS	MINOR SOIL SUBGROUPS	COMMENTS
RIDGETOP	MORAINAL (INCLUDING SOLIFLUCTED MATERIALS)	10 TO 50	SANDY LOAMY	WELL	ORTHIC REGOSOL ORTHIC HUMIC REGOSOL ORTHIC DYSTRIC BRUNISOL ORTHIC SOMBRIC BRUNISOL	GLEYED SOMBRIC BRUNISOL GLEYED REGOSOL	LITHIC PHASES COMMON. DEPTH OFTEN 0.3 TO 1 m. AREAS OF IMPERFECT DRAINAGE HAVE GLEYED SOIL SUBGROUPS. SLOPES GENERALLY 10 TO 30%.
LOST RIDGE	COLLUVIUM	20 TO 80	SANDY LOAMY TO LOAMY	MODERATELY WELL TO POOR	ORTHO SOMBRIC BRUNISOL ORTHO DYSTRIC BRUNISOL ORTHO REGOSOLS CUMULIC REGOSOLS GLEYED SOMBRIC BRUNISOL	GLEYED HUMIC REGOSOL GLEYED REGOSOL	TURBIC PHASES AND SOLIFLUCTED PHASES ARE COMMON. MATERIALS OFTEN > 1 m DEEP. SLOPES GENERALLY > 30%.
STEEP-ROCKY LAND	BEDROCK, TALUS AND COLLUVIUM	80 TO 100	SANDY LOAMY	VERY RAPID TO RAPID	NON-SOIL	ORTHIC REGOSOL (LITHIC PHASES)	SLOPES GENERALLY > 60%.
DIDENE	ORGANIC VENEERS OVERLYING MORAINAL	0	CLAY LOAM	POOR TO VERY POOR	TERRIC MESISOL REGO GLEYSOL	TYPIC MESISOL	
KLAPPAN	MORAINAL	20 TO 60	SANDY LOAMY & LOAMY	WELL TO MODERATELY WELL	ORTHIC DYSTRIC BRUNISOL	GLEYED REGOSOL REGO HUMIC GLEYSOL REGO GLEYSOL (PEATY PHASES) GLEYED ORTHIC REGOSOLS	DEPTH OF MATERIALS VARIABLE; MAINLY < 1 m AT HIGHER ELEVATIONS AND > 1 m AT LOWER ELEVATIONS.
AIRSTRIP	FLUVIAL	10 TO 50	SANDY LOAMY (SANDY, SILTY CLAY LOAM, LOAM)	MODERATELY WELL	ORTHIC SOMBRIC BRUNISOL ORTHIC DYSTRIC BRUNISOL ORTHIC REGOSOL	GLEYED SOMBRIC BRUNISOL GLEYED DYSTRIC BRUNISOL	
BUTLER	GLACIOFLUVIAL	40 TO 80		RAPID TO WELL	ORTHO DYSTRIC BRUNISOL	ORTHIC SOMBRIC BRUNISOLS	ICE CONTACT DEPOSITS; OFTEN < 1 m DEEP AND OVERLYING MORAINAL MATERIAL.

FIGURE 4-1A

MOUNT KLAPPAN ANTHRACITE PROJECT

SOILS MAP LEGEND
MOUNT KLAPPAN MINE SITE

GULF CANADA CORPORATION

GULF CANADA CORPORATION
08/12/86
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TABLE 4-1

ANALYSIS OF SOIL SAMPLES

Sample	PH[a]	% Sand	% Fines	Total N%[b]	Available Nutrients[c]			
					P	K	Ca	Mg
Lost Ridge								
Ah	4.7	9.6	79.7	0.41	1	43	2150	900
Bm	5.1	28.7	65.2	0.14	<1	17	700	250
C	5.7	-	-	-	-	-	-	-
Waste Disposal Area	7.4	63.0	2.8	0.30	4	58	550	850

a. Determined in calcium chloride.

b. N (nitrogen) determined colorimetrically on sulfuric acid digest using a modified micro Kjedahl procedure.

c. P (phosphorus) by Bray extract.
K (potassium), Ca (calcium) and Mg (magnesium) by ammonium acetate method at PH = 7.0.

soils subgroups are Teric Mesisols and Rego Gleysols; small pockets of deeper organic materials are associated with Typic Mesisols.

Klappan soils include mainly well to moderately well drained, medium to coarse textured Dystric Brunisols developed from morainal materials; gleysolic and gleyed regosolic soils occur in imperfectly drained depressions. Surficial materials are generally deep at lower elevations but are often less than one metre deep at higher elevations. The proposed plant site will be in an area dominated by Klappan soils.

Airstrip soils are mainly moderately well drained, loamy to coarse loamy textured Brunisols and Regosols developed from fluvial parent materials along creeks and rivers, such as the Little Klappan in the subalpine zone. Butler soils are mainly rapidly to well drained Brunisols developed from coarse-loamy textured ice-contact (glaciofluvial) materials.

Laboratory analyses of surface soil horizons on Lost Ridge indicate that they tend to be slightly acidic and are sometimes high in organic matter. Nutrient values are relatively high for calcium and magnesium but rather low for nitrogen and phosphorus. Potassium values are quite limited as well. A bulk sample of sandier soil taken from the waste rock disposal area was found to be mildly alkaline. Nutrient levels were similar to the Lost Ridge soils except calcium levels were lower.

1.4 IMPACTS AND MITIGATION

The chemical properties of the soils in the alpine areas where mine development will cause their removal, suggest that they could be suitable for stockpiling and later use in reclamation of the area. Fertilization would be required because of the low levels of nitrogen and phosphorus. The shallowness of most of the Ridgetop and Lost Ridge soils however probably precludes the technical feasibility of stockpiling.

One of the main benefits of conserving and using topsoil for reclamation would be to improve substrate physical properties such as water retention.

Even so, loamy materials would not be stable in this environment except on the gentlest slopes. In general, stockpiling does not appear justified for mine site reclamation.

Similar arguments apply to low elevation areas in the study area. Some benefits may be realized from stockpiling and respreading surface organic and mineral soil. However, fertilization would still be required to establish vegetation. Poor substrate physical properties, resulting from surface crusting and compaction or because of naturally high density, typical of Klappan and Didene subsoils, can be less expensively ameliorated by mechanical site preparation. Extensive high cost materials handling does not appear to be justified considering the end land use of the area as habitat for prey species such as marmots, ground squirrels and ptarmigan.

Experience has shown that surface preparation and re-vegetation of the waste disposal area will result in habitat quite suitable for feeding and shelter of these species.

2.0 VEGETATION

2.1 COMMUNITY CLASSIFICATION

The vegetation of the mine development area has been classified and discussed in detail in Volume III of the Stage I application. The vegetation associations identified as occurring in the mine area are:

Cowparsnip-Horsetail Type
Horsetail Type
Horsetail-Cinquefoil-Fescue Type
Spruce-Fescue-Juniper Type
Cinquefoil-Fescue Type
Fescue Type
Cinquefoil-Fescue-Dwarf Willow Type
Cinquefoil-Fescue-Saxifrage Type
Festuca-Juniper-Saxifrage Type
Aspen Type
Riverbar Type

Detailed distribution mapping of these vegetation associations was also provided in the Stage I report.

Comments resulting from the Mine Development Steering Committee review of the Stage I suggested that special survey methods should be employed to identify any rare plant species which are native to the project site. Such a survey has been conducted and is reported in this section. Locations of rare plant communities are also identified to determine whether they will be affected by proposed project developments.

In general, it was found that a number of species classified as rare are found in the Mount Klappan area. It was also noted that these species are relatively common in the area and tend to be classified as rare because the region is considered to be near the limit of the geographical distribution of these species. Based on the dispersion of these plants throughout the area, no rare species population would be endangered by the project.

It was also noted in the Stage I review comments that impacts on vegetation from dust and power plant air emissions should be addressed.

Lichen species tend to be the plant types most sensitive to air emissions, particularly sulphur dioxide. The detailed assessment of ambient SO_2 levels and sulphur deposition rates presented in Part Two of this volume is used here to show that lichen communities are unlikely to be affected by the predicted power plant emissions. Details of this impact analysis are incorporated here as are the results of re-vegetation trials conducted as part of the reclamation planning process.

2.2 RARE VASCULAR PLANTS

Standard methods for the assessment of rare plant species in British Columbia have not been developed. The methods employed in this report were developed following discussions with personnel in the Ministry of Environment and at the British Columbia Provincial Museum. Field visits for the purposes of finding and documenting rare plant species were undertaken in mid-July and at the end of August 1986. The late spring visit focussed on the assessment of drier sites while the late summer visit concentrated on wetter sites. During both visits representitive traverses of the areas to be impacted during development of the mine were conducted. Unique habitats encountered along the traverses were studied in detail and plant species which were of limited distribution were collected. Traverses of areas outside of the areas to be impacted were also made to broaden the number of unique habitats visited. Collected plants were pressed and dried for positive identification. The plants collected during the course of this study will be donated to the herbarium of the British Columbia Provincial Museum.

Plant specimens were identified using the keys provided in Hitchcock and Cronquist (1973), Hulten (1968) and Ceska (1976) for the sedges. Nomenclature follows that of Taylor and MacBryde (1977).

Plant species occurring in the Mount Klappan project area are listed in Table 4-2. An indication of their rareness as defined by Straley et al (1985) is included with the list. Rare plants are described by Straley et al (1985) as falling into one of the following classes:

R1 - plant taxa that are represented by a single or few known populations, usually with only a few individuals in the populations.

R2 - plant taxa that have few to several populations but usually with a relatively large number of individuals in each population.

R3 - plant taxa that have no distinct geographical range or distribution, usually scattered in the province, in isolated populations consisting of small numbers of plants.

R4 - plant taxa that are restricted in their general distribution in the province and often represent the northern or southern limits of more commonly distributed plants. The populations often consist of numerous individuals but with a narrow geographical range.

Table 4-2

VASCULAR PLANTS OF THE MOUNT KLAPPAN PROJECT AREA

ASPLENIACEAE

Gymnocarpium dryopteris (L.) Newm.

EQUISETACEAE

Equisetum arvense L.
E. scirpoides Michx.
E. sylvaticum L.
E. variegatum Schleich.

LYCOPODIACEAE

Hyperzia selgo (L.) Bernh. ex Schrank & Martius
Lycopodium alpinum L.
L. annotinum L.
L. clavatum L.
L. complanatum L.

SELAGINELLACEAE

Selaginella selaginoides (L.) Link

CUPRESSACEAE

Juniperus communis L.

PINACEAE

Abies lasiocarpa (Hook.) Nutt.
Picea engelmannii Parry ex Engelm.
P. glauca (Moench) Voss
Pinus contorta Dougl. ex Loud.

APIACEAE

Heracleum spondylium L.
Osmorhiza purpurea (Coult. & Rose) Suksd.

ASTERACEAE

Achillea millefolium L.
Agoseris aurantiaca (Hook.) Greene
A. glauca (Pursh) Raf.
Antennaria alpina (L.) Gaert.
A. microphylla Rydb.
Arnica cordifolia Hook.
A. mollis Hook.
Artemisia arctica Less.
A. campestris L. ssp. borealis (Pall.) Hall & Clements

Table 4-2 Cont'd

VASCULAR PLANTS OF THE MOUNT KLAPPAN PROJECT AREA

Aster alpinus L. ssp. Vierhapperi Onno
A. conspicuus Lindley
Crepis nana Richards.
Erigeron acris L.
E. humilis Graham
E. peregrinus (Pursh) Greene
Hieracium gracile Hook.
Petasites frigidus (L.) Franch.
Senecio lugens Richards.
S. pauciflorus Pursh
S. triangularis Hook.
Solidago canadensis L.
S. multiradiata Ait.
Taraxacum ceratophorum (Ledeb.) DC.
T. lyratum (Ledeb.) DC.

BETULACEAE

Betula glandulosa Michx.

BORAGINACEAE

Mertensia paniculata (Ait.) G. Don
Myosotis asiatica (Vestergren) Schischkin & Sergevskaja)

BRASSICACEAE

Arabis drummondii Gray
A. holboellii Hornem.
Cardomine oligosperma Nutt. var. kamtschatica (Regel) Detl.
Draba cana Rydb.
R1 D. lonchocarpa Rydb. var. thompsonii (C.L. Hitchc.) Rollins
R3 D. longipes Raup
D. nivalis Liljebl.

CAMPANULACEAE

Campanula lasiocarpa Cham.
R4 C. uniflora L.

CAPRIFOLIACEAE

Linnaea borealis L.

Viburnum edule Michx.) Raf.

Table 4-2 Cont'd

VASCULAR PLANTS OF THE
MOUNT KLAPPAN PROJECT AREA

CARYOPHYLLACEAE

Cerastium arvense L.
C. beeringianum Cham. & Schlecht.
Melandrium apetalum (L.) Fenzl
Minuartia rubella (Wahlenb.) Hiern
Sagina aaginoides (L.) Karst.

Silene acaulis (L.) Jacq.
Stellaria calycantha (Ledeb.) DC.
S. longipes Goldie

CORNACEAE

Cornus canadensis L.

CRASSULACEAE

Sedum oreganum Nutt.

ELEAGNACEAE

Shepherdia canadensis (L.) Nutt.

EMPETRACEAE

Empetrum nigrum L.

ERICACEAE

Arctostaphylos alpina (L.) Spreng.
A. rubra (Rehder & Wilson) Fern.
A. uva-ursi (L.) Spreng.
Cassiope mertensiana (Bong.) G. Don
C. tetragona (L.) D. Don
Kalmia microphylla (Hook.) Heller
Phyllodoce empetriformis (Sm.) D. Don
Vaccinium membranaceum Dougl. ex Hook.
V. ovalifolium Sm. in Rees
V. scoparium Leiberg
V. vitis-idaea L.

FABACEAE

R4 Astragalus robbinsii (Oakes) Gray
Lupinus arcticus Wats
R1 Oxytropis campestris (L.) DC. var. jordalii (Pors.) Walsh
R4 O. nigrescens (Pall.) Fisch. ssp. bryophila (Greene) Hult.

Table 4-2 Cont'd

VASCULAR PLANTS OF THE MOUNT KLAPPAN PROJECT AREA

FUMARIACEAE

Corydalis pauciflora (Steph.) Pers.

GENTIANACEAE

Gentiana glauca Pall.
Gentianella propinqua (Richards.) Gillett

GERAMIACEAE

Geranium viscosissimum Fisher & Meyer

GROSSULARIACEAE

Ribes hudsonianum Richards
R. lacustre (Pers.) Poir.

MENYANTHACEAE

Menyanthes trifoliata L.

ONAGRACEAE

Epilobium alpinum L. var. alpinum
E. alpinum L. var. lactiflorum (Hausskn.) Hitchc
E. angustifolium L.
E. latifolium L.

PAPAVERACEAE

R1 Papaver macounii Greene

PARNASSIACEAE

Parnassia fimbriata Koenig
P. kotzebuei Cham. in spreng.
P. palustris L.

POLEMONIACEAE

Polemonium caeruleum L.

POLYGONACEAE

Bistorta vivipara (L.) Gray
Oxyria digyna (L.) Hill

Table 4-2 Cont'd

VASCULAR PLANTS OF THE MOUNT KLAPPAN PROJECT AREA

Rumex alpestris Michx.

PORTULACACEAE

Claytonia sarmentosa C.A. Meyer

PRIMULACEAE

Androsace septentrionalis L.
Tirentalis europaea L. ssp. *arctica* (Fisch. ex Hook.) Hulten

PYROLACEAE

Moneses uniflora (L.) Gray
Orthilia secunda (L.) House
Pyrola asarifolia Michx.

RANUNCULACEAE

Aconitum delphinifolium DC.
Actaea rubra (Ait.) Willd
Anemone multifida Poir. in Lam.
A. parviflora Michx.
A. richardsonii Hook.
Aquilegia formosa Fisch. in DC.
Caltha leptosepala DC
Delphinium glaucum Wats.
Ranunculus escholtzii Schlecht.
R. occidentalis Nutt. in Torr. & Gray
R3 *R. pygmaeus* Wahlenb.
Thalictrum alpinum L.
T. occidentale Gray

ROSACEAE

Dryas integrifolia Vahl
Fragaria virginiana Duchesne
Luetkea pectinata (Pursh) Kuntze
Potentilla diversifolia Lehm.
P. fruticosa L.
R3 *P. hyparctica* Malte
P. uniflora Ledeb.
Rubus acaulis Michx.
R. pedatus Sm.
Sanguisorba sitchensis C. A. Meyer
Sibbaldia procumbens L.

Table 4-2 Cont'd

VASCULAR PLANTS OF THE MOUNT KLAPPAN PROJECT AREA

RUBIACEAE

Galium boreale L.
G. trifidum L.

SALICACEAE

Populus tremuloides Michx.
Salix alaxensis (Andress.) Cov.
S. arctica Pall.
S. barclayi Andress.
S. barratiana Hook.
S. commutata Bebb
S. drummondiana Barratt in Hook.
S. glauca L.
S. myrtillifolia Andress.
S. nivalis L.
S. pedicellaris Pursh
S. polaris Wahlenb.
S. reticulata L.
S. stolonifera Cov.

SAXIFRAGACEAE

Leptarrhena pyrolifolia (D. Don) DC.
Mitella nuda L.
M. pentandra Hook.
Saxifraga adscendens L.
S. caespitosa L.
S. cernua L.
R2 S. flagellaris Sternb. & Willd. in Sternb.
S. lyallii Engl.
S. nivalis L.
S. occidentalis Wats.
S. punctata L.
S. tricuspidata Rottboll
Tiarella unifoliata Hook.

SCROPHULARIACEAE

R3 Castilleja occidentalis Torr.
R4 C. raupii Pennell
C. unalaschensis (Cham. & Schlecht.) Malte
Pedicularis labradorica Wirsing
P. sudetica Willd.
Rhinanthus minor L.
Veronica wormskjoldii Roemer & Schult.

Table 4-2 Cont'd

VASCULAR PLANTS OF THE MOUNT KLAPPAN PROJECT AREA

VALERIANACEAE

Valeriana dioica L.

VIOLACEAE

Viola adunca Sm. in Rees

CYPERACEAE

Carex albonigra Mack.
C. aquatilis Wahlenb.
C. atrosquama Mack.
C. brunnescens (Pers.) Poir.
C. disperma Dewey
C. gynocrates Wormskj.
R2 C. heleonastes L.f.
C. lachenalii Schkuhr
C. leptalea Wahlenb.
C. macloviana D'Urv.
C. macrochaeta C.A. Meyer
C. media R. Br.
C. microptera Mack.
C. nardina E. Fries
C. nigricans C.A. Meyer
C. paupercula Michx.
C. phaeocephala Piper
C. physocarpa Presl
C. pluriflora Hult.
C. podocarpa R. Br.
C. scirpoidea Michx.
C. stenochlaena (Holm) Mack.
R4 C. supina Willd.
C. vaginata Tausch
Eriophorum angustifolium Honck.
E. vaginatum L.
Kobresia myosuroides (Vill.) Fiori & Paoletti
Scirpus cespitosus L.

JUNCACEAE

Juncus drummondii E. Meyer
J. mertensianus Bond.
Luzula parviflora (Ehrh.) Desv.
L. spicata (L.) DC.

Table 4-2 Cont'd

VASCULAR PLANTS OF THE MOUNT KLAPPAN PROJECT AREA

LILIACEAE

- *Fritillaria camschatcensis* (L.) Ker-Gawler
- *Streptopus amplexifolius* (L.) DC.
- *Veratrum eschscholtzii* Gray

ORCHIDACEAE

- *Listera cordata* (L.) R.Br. in Ait.
- *Platanthera dilatata* (Pursh) Lindl. ex Beck
- *P. saccata* (Greene) Hult.
- *Spiranthes romanzoffiana* Cham.

POACEAE

- *Agrostis aequivalvis* Trin.
- *A. scabra* Willd.
- *Agropyron violoaceum* (Hornem.) Lange
- *Bromus pumpellianus* Scribn.
- *B. vulgaris* (Hook.) Shear
- *Calamagrostis canadensis* (Michx.) Beauv.
- *Danthonia intermedia* Vasey
- *Elymus glaucus* Buckl.
- *Festuca altiaca* Trin.
- *F. brachyphylla* Schult.
- *Hierochloe alpina* (Swartz) Roem. & Schult.
- *H. oderata* (L.) Beauv.
- *Poa arctica* R. Br.
- *P. alpina* L.
- *P. pratensis* L.
- *Trisetum spicatum* (L.) Richter
- *Vahlodea atropurpurea* (Wahlenb.) E. Fries ex Hartm.

Rare plants and their rarity classifications found in the Mount Klappan study are summarized below. All of these species occur in locations unaffected by project developments and the loss of rare populations will not occur.

R4 Astragalus robbinsii (Oakes) Gray
R4 Campanula uniflora L.
R2 Carex heleonastes L.F.
R4 Carex supina Willd.
R3 Castilleja occidentalis Torr.
R4 C. raupii Pennell
R1 Draba lonchocarpa Rydb. var. thompsonii (C.L. Hitchc.) Rollins
R3 D. longipes Rapu
R1 Oxytropis campestris (L.) DC. var. jordalii (Pors.) Walsh
R4 Oxytropis nigrescens (Pall.) Fisch. ssp. bryophila (Greene) Hult.
R1 Papaver macounii Greene
R3 Potentilla hyparctica Malte
R3 Ranunculus pygmaeus Wahlenb.
R2 Saxifraga flagellaris Sternb. & Willd. in Sternb.

Astragalus robbinsii is generally restricted to southern and western British Columbia. It is found in the Mount Klappan area on drier sites and talus at relativey low elevation. Campanula uniflora is found at high elevations in the project area. The normal range of this plant is considerably further north. It occurs on most of the alpine ridges in the project area, including Lost Ridge where the mine will be located. It is likely that the inclusion of this species in the list of rare plants reflects the lack of extensive botanical investigation in northern British Columbia. Carex heleonastes and Carex supina are circumboreal species which reach the southern limit of their range in northern British Colmbia. Castilleja occidentalis is generally distributed in the eastern part of the province, in the Rocky Mountains, while C. raupii is generally a more northern species. Both of these species occur in high subalpine meadows in the Mount Klappan area. Draba lonchocarpa occurs rarely throughout the province while D. longipes is generally a more northern species. Oxytropis campestris is a northern species which enters British Columbia in the northwestern part of the province. Oxytropis nigrescens occurs sporadically throughout the northern part of the province. Papaver macounii is widespread in Alaska and only rarely comes into the province. It is found on the high peaks of the study area with some regularity. Potentialla hyparctica is a plant of northern distribution, which is found in scattered locations throughout British Columbia. In the project area it is found on drier alpine ridges and screes. The small Ranunculus pygmaeus is found scattered throughout northern North America. Saxifraga flagellaris occurs at high elevations on open rocky ridges in the project area. It occurs in northern British Columbia as part of the southern limits of its circumboreal distribution. The locations of these species in the project area are given in Table 4-3.

All of the rare species found in the Mount Klappan project area, with the exception of Astragalus robbinsii, Castilleja occidentalis, Castilleja raupii and Carex eleonastes also occur in the Gladys Lake Ecological Reserve (Pojar 1986). Carex supina was found in a study of the vegetation of the Stikine and Iskut drainages conducted for B.C. Hydro (Techman, 1980). It is likely that with further botanical examination of the northern part of the province, many of the species listed as rare now would be excluded from a rare species list.

The impact of the mining operations on the rare species identified as occurring in the area will be limited to the loss of a few individuals. There will not be the loss of a population. There are other locations where these species occur, unaffected by the mining development.

2.3 AIR EMISSION EFFECTS ON VEGETATION

Detailed analysis of air emissions associated with operation of a refuse anthracite-fired power plant at Mount Klappan is presented in Part Two of this volume on Atmospheric Environment. That section also provides the results of air emission dispersion modelling studies used to estimate concentrations of pollutants in the area surrounding the power plant.

TABLE 4-3

LOCATIONS OF RARE PLANTS IN THE MOUNT KLAPPAN AREA

Species	Locations (s)
Astragalus robbinsii	- 57 deg. 15 min. N 128 deg. 45 min. W - 57 deg. 13 min. N 128 deg. 51 min. W - 57 deg. 19 min. N 128 deg. 57 min. W
Campanula uniflora	- Lost Fox Mine Area (57 deg. 14 min. N 128 deg. 54 min. W)
Carex heleonastes	- 57 deg. 07 min. N 128 deg. 38 min. W
Carex supina	- Lost Fox Mine Area
Castilleja occidentalis	- 57 deg. 19 min. N 128 deg. 57 min. W
Castilleja raupii	- Lost Fox Mine Area
Draba lonchocarpa	- Lost Fox Mine Area - Knooph Hill (57 deg. 14 min. N 128 deg. 50 min. W)
Draba longipes	- Lost Fox Mine Area
Oxytropis campestris	- Lost Fox Mine Area
Oxytropis nigrescens	- Knooph Hill
Papaver macounii	- Knooph Hill
Potentilla hyparctica	- Lost Fox Mine Area
Ranunculus pygmaeus	- Lost Fox Mine Area
Saxifraga flagellaris	- Knooph Hill

As noted in the Stage I review comments, one of the questions regarding a power plant at the site is the potential for loss of lichen in the area since these plant types are known to be quite sensitive to air pollution. It has also been suggested that lichen may form an important part of the winter range diet for caribou. Based on the dispersion modelling work described in Part Two of this volume, it is predicted that ambient air quality conditioos will be such that the impact to the lichon vegetation from power plant air emissions will be negligible.

The primary air emission constituents of concern with respect to lichen and other plants are nitrogen oxides and sulphur dioxide. Each is discussed in the following subsections.

2.3.1 Effects of Sulphur Emissions on Vascular Plants

Sulphur is an essential plant nutrient which is required in substantial amount for a variety of plant structures and functions (Loman et al, 1972). Consequently, at very low concentrations, fumigations with industrial sulphur dioxide may have neutral or even beneficial effects on plants, especially those growing in sulphur deficient soils. However, if sulphur dioxide is taken up rapidly at rates in excess of the plants requirements, it may cause injury to a variety of metabolic and structural components of the cell (Daines 1968, Treshow 1970, Malhotra 1976 and 1977). The degree of injury depends upon the concentration and length of exposure of the plant to sulphur dioxide, climatic conditions and the sensitivities of exposed species. Levels affecting species groups are shown in Table 4-4.

Vascular plants are generally less sensitive than lichens and mosses to sulphur dioxide fumigations. Native tree species are injured by minimum average one hour concentrations ranging from approximately 0.41 ppm for larch to 0.87 ppm for white spruce (Dreisinger and McGovern, 1971).

Minimum concentrations ranging from 0.13 ppm (trembling aspen) to 0.50 ppm (white spruce) are reported to cause injury after eight hours of exposure. Linzon (1972) rates the sensitivity of other common species as intermediate

Table 4-4

THRESHOLD CONCENTRATIONS OF SULPHUR DIOXIDE (ppm)
CAUSING INJURY TO VASCULAR PLANTS
(DREISINGER AND MCGOVERN 1970)

	1 Hour	8 Hour
TREES		
Trembling Aspen	.42	.13
Jack Pine	.52	.20
White Birch	.46	.21
Larch	.41	.26
Balsam Poplar	.82	.26
White Spruce	.87	.50
SHRUBS AND HERBS		
Bracken Fern	.45	.21
Willow	.41	.30
Alder	.46	.21
Timothy	.66	.21
Barley	.63	.12
Red Clover	.70	.14
Raspberry	.74	.39

Note: Predicted maximum one-hour concentration resulting from Mount Klappan power plant emissions is 0.03 ppm.

for balsam fir and Engelmann spruce; and tolerant for lodgepole pine (similar to white spruce).

Few data are available on concentrations and durations of exposure which will injure native shrubs and herbs. However, concentrations which will cause injury to a variety of agricultural and forest species range from 0.6 to 1.3 ppm when exposed for one hour and from 0.15 to 0.40 ppm when exposed for eight hours (Dreisinger and McGovern, 1970). Dreisinger (1967) concludes that sulphur dioxide concentrations of 0.95, 0.55, 0.35 and 0.25 ppm for one, two, four and eight hour duration respectively may cause acute injury to a variety of vascular plants. Table 4-4 provides estimates of injurious concentrations for a variety of vascular plants.

The long-term effects of low levels of sulphur dioxide emissions on eastern white pine wero noted by Linzon (1971) in the Sudbury area. He found tree death and reductions in radial growth over a 10-year period where the mean annual concentration of sulphur dioxide was 0.017 ppm. Negative effects were slight further from the emission source where mean annual concentrations of sulphur dioxide averaged 0.008 ppm.

Near Whitecourt, Alberta, preliminary studies by Hocking (1975) found no effects on tree growth from gas plant sulphur dioxide emissions. However, Winner and Bewley (1978) indicated that emissions of 71 tonnes per day of sulphur dioxide from two plants near Fox Creek Alberta have reduced forest undergrowth vegetation within three kilometres or more of the source. For comparison, the Mount Klappan power plant is expected to produce 0.6 tonnes per day of sulphur dioxide.

The effects of sulphur dioxide emissions from two large gas processing plants (Ram River and Strachan) in the foothills west of Rocky Mountain House, Alberta which together emit approximately 140 tonnes per day of sulphur dioxide, were studied by Addison et al (1984) for a 10 year period and concluded that gaseous emissions have had little or no measureable effects on trees in the area. A more recent study of the Strachan plant (Intera Environmental Consultants Ltd., 1983) confirmed that there was no observable effect on trees due to gaseous emissions.

In the vicinity of the two oil sands processing plants north of Fort McMurray, Alberta which together emit approximately 485 tonnes per day of sulphur dioxide, Addison (1982) reported that long-term measurements representing a 14 year period of vascular plant community change, soil nutrient change, and tree growth could not be related to pollution deposition. Some plant responses such as germination of jack pine appeared to be influenced, but the magnitude of response was not great enough to be significant.

2.3.2 Effects of Sulphur Emissions on Lichens

The air dispersion modelling for the Mount Klappan power plant emissions has indicated that maximum 1-hour ground level concentrations of SO_2 will be about 0.03 ppm and that the area affected by maximum annual average concentrations will experience levels of about 0.003 ppm. These values are used to evaluate the substantial volume of literature which exists on the susceptibility of lichen to air pollution, specifically to SO_2.

Lichens have been recognized as indicators of air pollution in the past, but have only become important in biological monitoring during the past twenty years when their role in progressively more sophisticated environmental protection and management has been realised. Reviews of the history of lichen studies in air pollution monitoring are contained in LeBlanc and Rao (1950) Ferry et al (1973) and Anderson and Treshow (1984). These texts give extensive documentation of the negative effects of SO_2 on lichens. The nature of impacts vary from (i) progressive and complete elimination of lichen species in an affected area; (ii) reduced overall distribution of lichens; (iii) reduced reproductive capability; (iv) morphological (anatomical) or metabolic damage.

Although different lichen species may have different susceptibilities to SO_2 damage, SO_2 is generally considered to be the greatest pollutant threat to lichens and it has been the focus of studies ever since the initial work by Skye (1958), LeBlanc and Rao (1966) and Schonbeck (1969).

As a group, lichens are more susceptible to sulphur dioxide injury than vascular plants and they generally disappear from highly polluted areas. This is partly explained by the fact that lichens have no waxy cuticle or outer layer to protect them from environmental hazards or reduce water loss, nor have they any openings through which gases pass (Anderson and Treshow 1984). Their entire surface is exposed to diffusion of chemicals in the air or in the substrate. Such chemicals may then accumulate in the tissues, and any to which the tissues are not adapted can prove harmful when concentrations reach excessive levels. As well, lichens have no deciduous parts or root systems through which toxic substances can be shed or removed.

The literature is not clear on whether lichens are affected by continuous ambient low levels of SO_2 in the atmosphere or if they are affected by the relatively high concentrations that occur in polluted areas from time to time. (Anderson and Treshow 1984). Which ever is the case, lichens seem to disappear from "polluted" areas.

Those regions with high humidity and rain fall, which afford luxuriant lichen growth are also those which are most likely to show evidence of SO_2 effects. (Hawksworth 1973; Sundstrom and Hallgren 1973). The location of the lichens in a microhabitat sense is also important. Lichens growing on trees or branches (Harris 1972; LeBlanc **et al** 1972) may be more susceptible than lichens growing on other substrates or on the ground. This may be caused by several factors such as their exposure to the wind, the inherent pH of the bark which may have a lower buffering capacity than other media. The timing of the SO_2 concentration in relation to the metabolic and reproductive activity of the lichen may also be significant. (Gilbert 1965, 1970; Robitalille **et al** 1977; Laundon 1967; Brodo 1966).

In selecting species for assessing the effects of SO_2, four useful ecological descriptions therefore frequently occur in the literature. These are as follows:

"terricolous" - growing on soil
"saxicolous" - growing on bare rock
"corticolous" - growing on the bark of trees
"epiphytic" - growing on plants

In literature describing the food habitats of caribou, lichens are frequently given only two ecological descriptions: arboreal or terrestrial. In this report, "terrestrial" is used as an equivalent to "terricolous" or "saxicolous"; "arboreal" is equivalent to "corticolous" or "epiphytic". It is clearly important to assess such ecological factors in determining the relevance of lichens as bio-indicators of pollution, and may reveal that lichens are not the best index (Nash 1976).

Linzon (1978) describes the growth forms of lichens (fruticosependulous or stalked; foliose - leaf-like; and crustoso - adhering closely to the substrate) and suggests that sensitivity to SO_2 declines as the crustose form is approached, while corticolous (including primarily fruticose and foliose species) are more sensitive to SO_2 than terricolous or saxicolous species.

2.3.2.1. Critical SO_2 Concentrations

Hawksworth and Rose (1970) indicated that all epiphytic lichens were absent at mean annual SO_2 levels of .068 ppm. When levels exceeded .024ppm lichens were severely depleted, and effects in terms of abundance and vigour were measurable at concentrations as low as .012ppm.

Lichens suffer increasing injury as long-term average concentrations rise above 0.01 ppm and almost never grow where long-term average values exceed 0.21 ppm (Case, 1973). LeBlanc and Rao (1973) concluded that long-term average sulphur dioxide concentrations during the growing season of greater than 0.03 ppm cause acute injury to lichens in the Sudbury, Ontario area and further (LeBlanc and Rao, 1975) concluded that mean annual concentrations of sulphur dioxide as low as 0.01 ppm may injure sensitive species of such genera as Usnea, Lobaria, Ramalina and Cladonia. Mosses may be equally sensitive (Gilbert, 1968; Loman et al 1972) although fewer data are available. Table 4-5 summarizes the SO_2 levels observed to effect lichens.

Because data are presented in Table 4-5 in terms of long-term averages, it is difficult to access the influence or impact of short-term high concentrations or fumigations. Thus, there remains the question of whether or not the lichens are responding to long-term low levels of sulphur dioxide or to relatively infrequent high concentrations which occur during fumigations caused by air stagnation or other atmospheric effects.

The results of laboratory studies using controlled atmospheres containing known amounts of sulphur dioxide have lead Nash (1973) to suggest that lichens appear to be no more sensitive to direct sulphur dioxide fumigations than higher plants. He found that injury occurs after a 12 hour fumigation of 0.5 ppm on average for 8 species tested.

Most studies of lichens reported above have largely been conducted in zones more temperate than northwestern British Columbia. Indeed relatively few studies of the effects of SO_2 or other pollutants on lichens have been conducted in northern Canada or ecologically-similar regions of Europe or the U.S.S.R. This section will provide an overview of studies in Canada undertaken in the environments that provide climatically and botanically comparable situations to the Spatsizi area.

Most of the Canadian studies in the boreal forest of sub-artic regions have examined the effects of SO_2 on corticolous (epiphytic) lichens. However, Tomassini et al. (1976) suggest that saxiolous species (e.g., Stereocaulon paschale, Umbilicaria spp.) accumulate larger quantities of sulphur than terricolous species. They state that the Peltigeraceae show higher concentrations of elements, and may be better at absorbing substrate elements. In particular; species (e.g., Cladina spp.) which show above average levels of elements (including sulphur) should be more sensitive monitors of change.

In the vicinity of the Ram River and Strachan gas plants where daily sulphur dioxide emissions average about 140 tonnes, Addison et al (1984)

Table 4-5

MEAN ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE (ppm) CAUSING INJURY TO LICHENS

Injury	LeBlanc (1969)	Gilbert (1970)	Hawksworth & Rose (1970)
None	0.01	0.015	0.01
Chronic (3-12 species present)	0.01 - 0.03	0.017 - 0.022	0.01 - 0.02
Acute (only 2 species present)	0.03	0.047	0.02 - 0.06
No Lichens	0.03	0.65	0.06

Note: Predicted maximum mean annual concentration at Mount Klappan is 0.003 ppm.
British Columbia Pollution Control Objective for mean annual concentration is 0.01 ppm.

and Marsh (1982, 1984) found that the data covering a 10 year period of operation on lichen community responses to sulphur dioxide was too inconclusive to make any definitive statement. For example, arboreal lichen species Bryoria and Cetraria did not show any differences between sites with higher deposition rates of sulphur and those with lower deposition rates. This was unexpected, since Bryoria has been demonstrated to be a sensitive species (Skorepa and Vitt, 1976) and has been reported to be more sensitive to sulphur dioxide than either Hypogymnia or Cetraria (Hawksworth, 1973).

In contrast, at higher levels of sulphur emissions (485 tonnes per day) near the oil sand plants north of Fort McMurray over a 14 year period, declines in lichen and moss communities have been reported by several authors (Loman, 1978; Addison and Puckett, 1980; Krouse and Case, 1981; and Case, 1982). The least luxurient lichen condition was related to areas of high sulphur deposition, and elevated levels of sulphur and other heavy metals in the tissue (Dabbs, 1985). Addison (1982) stated that demonstration of plant response to deposited pollutants was difficult. While he found that some plant responses such as lichen health and vigor, pollutant content in tissues, and lichen community composition appeared to be influenced, the magnitude was very small.

2.3.2.2 Predicted Concentrations at Mount Klappan

A plume dispersion modelling study has been undertaken by Gulf in order to predict the area that might be affected by emissions from the power plant at Mount Klappan. (See Part Two - Atmospheric Environment). The model used is the "SSAQ-Turbulence Method." This predicts that average annual ground level concentrations of SO_2 will be greatest west-northwest of the power plant. Lower concentrations will occur to the southeast, southwest and northeast.

Total sulphur dioxide emissions from the power plant are anticipated to be about 0.6 tonnes per day. Maximum ground level concentrations under worst case conditions are predicted to be 0.03 ppm for 1 hour. The highest average annual concentration is predicted to be 0.003 ppm. Each of these concentrations is well below the British Columbia Level A Ambient Air Control Objectives of 0.17 ppm (1 hour) and 0.01 ppm (annual). Details of annual concentrations are shown in Table 4.6 in order of greatest concentration. The area of highest annual concentration at 0.003 parts per million is about 3 km northwest of the plant in steep rocky terrain.

In the three areas of lower concentration, only one incorporates a small portion of the Spatsizi Wilderness Park, and is the lowest area of concentration calculated. The 0.0004 ppm zone for average annual ground level SO_2 concentration extends approximately 3.0 km into the Park, and includes an area of approximately five km^2 within its boundaries, between Butler Creek in the west and the Spatsizi River in the east. All available information indicates that no effect on lichen would be expected in this or any area of the Park.

The vegetation types that occur within the plume areas are predominantly spruce and fir forests with arboreal lichens and a moss dominated understory. At higher elevations, alpine tundra vegetation is gradually replaced by rock outcrops. Characteristic species include dwarf willow, herbs, grasses, mosses and lichens. The short and long-term effect of sulphur dioxide on the vegetation of the mine area is expected to be negligible based on the literature which suggests that effects are not observable below annual concentrations of about 0.01 ppm. The zone of highest annual concentration will be well below this level at 0.003 ppm and this area is steep and rocky with little vegetation. All other areas will have even lower sulphur dioxide concentrations and in most cases, at or below detectable limits. The low level of emissions and dispersion patterns suggest also that no impact on lichens or vascular plants will occur in the Spatsizi Plateau Wilderness Park east of the power plant.

2.3.3 Effects of Sulphur Emissions on Soil Chemistry

Sulphur dioxide emissions can also affect vegetation in two ways through soils: 1) they can add nutrient sulphur and 2) they can contribute to soil

TABLE 4-6

MAXIMUM AVERAGE ANNUAL SO_2 CONCENTRATIONS AT GROUND LEVEL
AS PREDICTED
FOR THE POWER PLANT PLUME BY THE SSAQ TURBULENCE METHOD MODEL

Direction From Power Plant	Area Descriptor	ppm	Distance From Power Plant (km)	Altitude(m) ASL
1. WNW	North side of "Nass Pass", outside and moving away from the Park	0.0029	3.0	1575
2. SE	Eastern Slopes of Lost Ridge, outside the Park	0.0011	2.0	1445
3. SW	Little Klappan River headwaters, outside and moving away from the Park.	0.0007	7.0	1495
4. NE	North side of Didene Creek valley, inside the Park	0.0004	4.0	1450

acidity. Nutrient addition is beneficial in terms of plant growth particularly in forested areas where soils are commonly deficient in plant available sulphur. The stimulation in plant growth resulting from sulphur addition can, however, reduce selenium concentration in forage plants. As well, increased soil acidity, can be beneficial or detrimental depending upon the initial reaction (pH) of the soil. In the case of forested soils, which are commonly acidic in the surface layer, addition of sufficient sulphur to depress soil pH could reduce availability of nutrients for plant growth.

Sulphur gas emissions can enter the soil system by direct soil absorption, impaction of sulphur particles on vegetation and the ground surface, and by precipitation. Both direct soil absorption and impaction of sulphur are termed "dry deposition". This is distinguished from precipitation related deposition which is called "wet deposition". Controversy exists in the literature over which of these soil sulphur addition mechanisms is most important, their relative importance often being site specific. Regardless of the mode of deposition, the most important consideration is the effect (beneficial or detrimental) of the added sulphur on the soil and plant growth. Prediction of this effect is possible through knowledge of soil type and chemical properties of the receiving soil.

Limited information is available for the project area dealing with the chemical properties of soils, particularly with respect to their susceptibility to acidification. However, based on the regional bedrock geology (Holland, 1976) and soil survey information of the project area it is possible to assess relative susceptibility of the surficial soils to acidification. This information coupled with predicted sulphur deposition rates in the project area allows some preliminary conclusion to be made regarding effects of sulphur gas emissions on soils in the project area.

The majority of soils within the area of highest predicted sulphur deposition, to the northeast of the emission source, are sandy textured Dystric Brunisols (Klappan and Lost Ridge Association) and Organic Mesisols (Didene Association). Dystric Brunisols generally occur on parent materials of low base status and the surface horizon of this soil is characteristically acid in reaction (pH less than 5.5). Due to this relatively low pH (low base saturation) and low cation exchange capacity, caused by the moderately coarse texture and high coarse fragments content, it is likely that the buffering capacity of this soil type is relatively low.

Fluvial soils of the Airstrip Association also occur within and proximate to the area of highest predicted sulphur deposition. Like the Klappan Association, these Brunisolic soils have a sandy texture and high coarse fragments content. Due to the presence of an organic rich surface horizon however, they would tend to have a higher cation exchange capacity and buffering capacity than the Klappan Association.

Penney (1977) and Beaton et al (1974) estimate that the addition of between 500 and 1400 kg/ha of sulphur will lower soil pH by about one unit on cultivated mineral soil. The predicted maximum sulphur deposition associated with the Mount Klappan power plant is 5.5 kg/ha/per year. This maximum deposition rate would occur in only a very limited area within about 1000 metres of the power plant. Even over the 20 year project life, the possible effect would be to eventually lower the pH by less than two-tenths of a unit if all of the sulphur deposited over the 20 years remains in place and unchanged. However, through chemical weathering and physical leaching, e significant portion of the sulphates resident in the soils can be expected to convert to organic forms and/or be washed out by precipitation and drainage. It should also be noted that for 7 to 10 months each year, the deposition will actually be on snow rather than directly on soil. It should be expected that a substantial portion of this deposition would be carried away with the spring thaw runoff. As such, the impact of added sulphur in lowering soil pH is likely to be very minor where the maximum deposition occurs and negligible where the deposition rates are lower even in the longer term.

Organic soils of the Didene Association also occur in the area of highest deposition. These soils have very high cation exchange capacities and would therefore be highly buffered and resistant to acidification by added sulphur. These soils have the ability to reduce added sulphur to unavailable organic forms and to gaseous sulphur which can be lost by volatilization. Therefore, the organic soils may be capable of storing or transforming added sulphur without being significantly acidified. On these soils, the effect on soil pH is anticipated to be negligible as well.

2.3.4 Effects of Nitrogen Oxides on Vegetation

The role of nitrogen oxides (mainly nitrogen oxide and nitrogen dioxide) as potential damaging agents to plants has been discussed by Manning and Feder (1980) and Linzon (1985). They have indicated that nitrogen oxides, although precursors to acid rain and ozone, are not generally considered to cause injury to plants outside the laboratory.

Long-term controlled laboratory experiments have showed that a variety of agricultural plants are injured by levels of nitrogen dioxide ranging from 0.13 to 0.6 ppm over periods from 10 to 240 days (Taylor and Eaton 1966, and Thompson **et al** 1970). In short-term controlled experiments Heck (1964) found that nitrogen dioxide concentration as low as 1.0 ppm for several hours caused acute injury to sensitive plants.

Experimental laboratory work has shown that low levels of nitrogen dioxide (0.10 ppm) in combination with sulphur dioxide (0.10 ppm) injured five agriculture plant species in a 4 hour exposure period (Tingey **et al** 1971). These effects were synergistic in that neither 2 ppm of nitrogen dioxide or 0.5 ppm of sulphur dioxide alone injured the same plant species.

Maximum annual ground level concentrations of nitrogen oxides from the power plant are predicted to be 0.005 ppm which is far below the British Columbia Level A guideline of 0.04 ppm. Nitrogen dioxide concentrations will follow the same dispersion pattern as predicted for sulphur dioxide in that the highest annual concentration will occur some 3 km northwest of the plant on steep rocky terrain.

The short- and long-term effects of nitrogen oxides are difficult to relate with effects cited in literature due to different species and different growing conditions. However, since the level af nitrogen oxides from the power plant are considerably lower than those shown to cause injury in laboratory experiments there is not expected to be any effect on the vegetation of the Spatsizi area. The impact will be negligible.

The possibility of the nitrogen oxide emissions contributing to the local formation of ozone is unlikely. This is not only due to the low amount of nitrogen oxide, but also due to the lack of suitable atmospheric conditions for the formation of ozone (i.e. warm temperature, high light, low humidity, little or no precipitation and low wind speeds).

While both nitrogen oxides and sulphur dioxide will be present, the amounts will be too low to cause any synergistic effects on the vegetation.

2.4 POTENTIAL IMPACTS

The impact of the project on the vegetational communities in the area of the mine development will be negligible. The community associations affected occur widely throughout the area and vegetation lost as the result of direct disturbance of the land is a very small proportion of the total vegetation of this type available in the area. Reclamation of disturbed areas through revegetation, as discussed in the next section, will assist the re-establishment of vegetational communities in the long-term.

There will be no impact on the vegetation from coal dust. Dusting of vegetation, either from coal mining and preparation activities or from traffic activity along unpaved roads, is a widely occurring phenomenom. There is no evidence that vegetation is affected.

The potential negative impact of air emissions from the thermal generating plant on vegetation has been shown by modelling studies to be negligible.

The SO_2 emissions, which cause the greatest concern, are expected to be well below levels considered toxic to both vascular and non-vascular plants. Sulphur deposition on soils will have negligible effects on soil acidity.

2.5 RECLAMATION TRIALS

Revegetation of the project area will be one of the objectives of the reclamation plan and will constitute the principal form of mitigation of effects on vegetation. Successful test plot reclamation trials have been conducted at the Mount Klappan project site in anticipation of mine development. These test plots, which were initiated in 1984 with a series of single species trials at both high and low elevation sites, were continued in 1985 by testing species mixes at both high and low elevations.

Operational reclamation work was conducted in the early fall of 1985 with mixed seeding on the pilot plant tailings dam. In late summer of 1986, a reclamation program was carried out at the test pit in the Hobbit-Broatch area and in the pilot plant site area. The methods employed in the establishment of the trials and operational reclamation are outlined in more detail in Part Six of Volume II. Results from these reclamation efforts as well as the test plots are presented here.

Information gained in the previous and present reclamation trials and operational reclamation work will be useful in the development of sound reclamation techniques. Adverse climatic conditions will be the limiting factor in the reclamation of mining disturbances. Long winters and generally cold weather limits growth of plants in the area, especially at higher elevations. The growth of plants is, however, enhanced by the long daylight hours in summer afforded by the northern location.

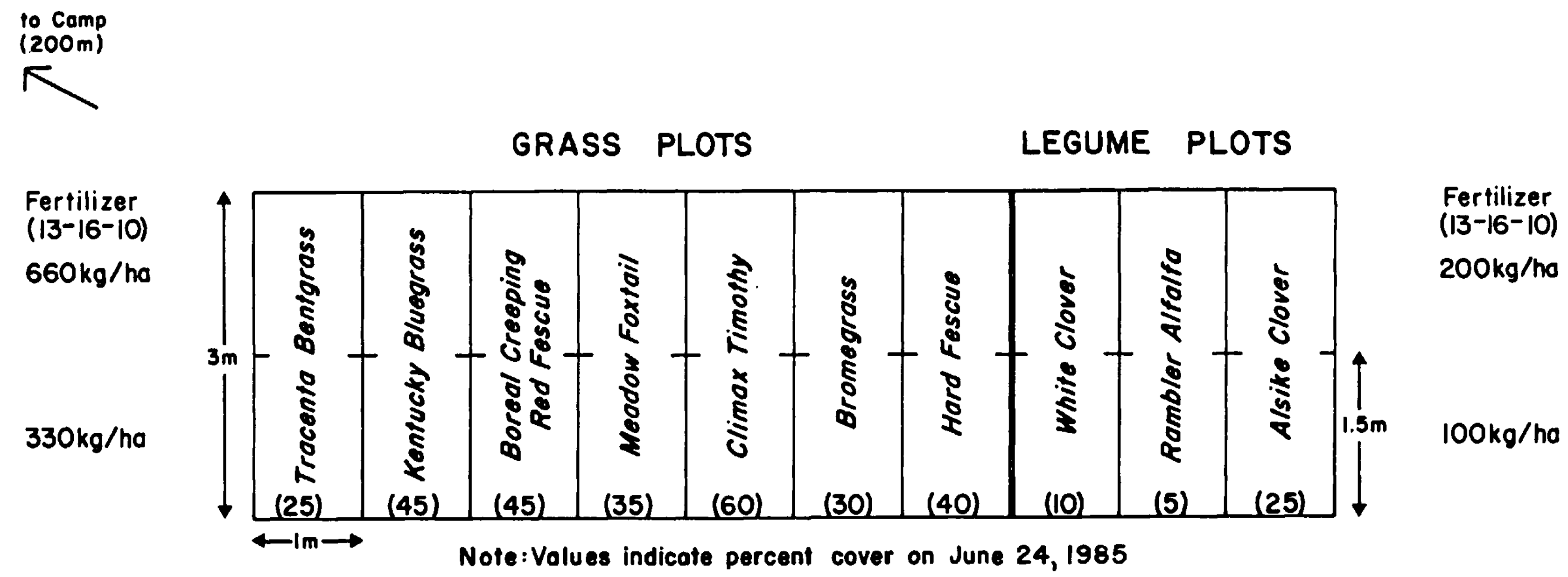
Reclamation at the mine site will seek to control erosion and develop productive ecosystems for the lands disturbed by mining. Present land use in the general area is as wildlife habitat. The first step in the reclamation of the site will be the establishment of an erosien controlling cover of grasses and legumes. Reclamation trials initiated in 1984 were developed to determine those plant species which could perform this initial function. Subsequent trials have had the additional objeotive of revegetating disturbed sites.

2.5.1 1984 Single Species Trials

Single species trials were established at high and low elevations on July 12th and 13th, 1984. Seven grasses and three legumes were seeded at each site. The plots were treated with two different levels of inorganic fertilizer. Full details of the methods used in establishing the single species trials and initial results are given in Gulf's Mount Klappan Anthracite Project Stage I Submission, Section 2.3 Terrestrial Environment.

All of the species seedad at both the high and low elevation sites had germinated and showed signs of growth by August 15 1984. Over-wintering survival, especially at the high elevation site, however, was predicted to be critical to the effective establishment of vegetation. The plots were visited again en June 24th, 1985 and good growth was apparent with most of the species at the low elevation plots. Figure 4-2 indicates the experimental design and success rates for the species tested. Unfortunately, most of the high elevation plots had been destroyed by road construction. Only one portion of the Climax Timothy plot remained. This species hed a total cover of 25 percent on June 24th, 1985.

The growth of many of the single species was considered good by the end of the 1985 growing season. There was some evidence of nutrient deficiency at that time. An addition of 300 kg/ha of 13-16-10 fertilizer was made to the low elevation plot on September 3rd, 1985. Timothy had the best cover of the seeded grasses, while alsike clover was the best legume. The bentgrass had good germination and early growth, however severe winter kill was noted in the spring of 1985. Snow clearing operations during the winter of 1985/86 destroyed these plots but sufficient information on the germination and early growth of the seeded species was gained so that species mixes could be formulated which had a reasonable chance of success.



Plot Elevation : 1300m ASL
Substrate : Glacial Till
Seeding Rate : 100kg/ha
Fertilizing Rate : As shown

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MT. KLAPPAN ANTHRACITE PROJECT

FIGURE 4-2

EXPERIMENTAL LAYOUT AND RESULTS OF LOWER ELEVATION TEST PLOTS

SCALE 1 cm = 0.66 m

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2.5.2 1985 Species Mix Trials

Species mix trials were established during the week of June 19 - 25, 1985. In addition to the primary objective of testing the performance of two mixes of grasses and legumes, the trials were established on sites which had been disturbed by exploration and associated activities thus performing some useful reclamation of disturbed sites. The testing of species mixes at this time was deemed prudent as mixes of grasses and legumes will be used in the actual reclamation of the proposed mine rather than single species.

In many cases, a properly designed and balanced seed mix can result in better cover of established vegetation than single species. This is due in part to the synergistic effects of the grasses and legumes as well as the ability of a mix of species to establish more fully on the range of microhabitats normally encountered in an actual reclamation situation.

Two seed mixes were developed for the mine site area. The mixes are designated as low and high elevation to correspond with the anticipated areas to be disturbed. Table 4-7 gives the species composition of the mixes. The mixes were developed with both bunch and sod forming grasses to fully utilize the niches available in the reclamation environment. Both mixes contained at least 40 percent legumes by species composition. The high legume content will help to ensure that the seeded stands are self maintaining relative to nitrogen. Nitrogen is commonly the limiting nutrient in reclamation situations. The seed mixes were composed of Canada Number 1 seed as the high quality seed was felt to be cost-effective in the reclamation context. The seed mixes were balanced by the weight of the seeds, the purity of Number 1 seed and the germination capacity of the seed. As a result,the established stand should be balanced with regard to species, and not dominated by species with a lower seed weight.

Three low elevation and three high elevation sites were selected for the trials. The sites were selected to represent the range of conditions expected in the mining operation; thus, the sites differed with respect to moisture regime and substrate composition. Table 4-8 presents the edaphic

TABLE 4-7

RECLAMATION TRIAL SPECIES MIXES

Species	Percent by Species Composition	Percent by Weight
High Elevation Mix		
Boreal Creeping Red Fescue	20	23.4
Durar Hard Fescue	20	24.7
Meadow Foxtail	10	9.8
Climax Timothy	10	5.6
Aurora Alsike clover	25	23.9
White Clover	15	12.6
Low Elevation Mix		
Boreal Creeping Red Fescue	15	9.9
Bromegrass	10	32.6
Meadown Foxtail	10	5.5
Climax Timothy	10	3.2
Reubens Canada Bluegrass	10	1.9
Aurora Alsike clover	20	10.8
White Clover	5	2.4
Rambler Alfalfa	20	33.7

TABLE 4-8

EDAPHIC FEATURES OF THE 1985 TEST SITES

Location	Substrate	Moisture Regime
Low Elevation Sites		
Camp Drain Field	Glacial till	Mesic/moist
Core Storage Road	Glacial till	Mesic
Hobbit-Broatch	Till/coaly shale	Mesic/dry
High Elevation Sites		
SW Ridge of Lost Fox	Weathered rock	Dry
Lost Fox Basin	Weathered rock/soil	Mesic/dry
Lost Fox Basin	Organic/mineral soil	Moist

features of the trial sites.

The trials were established by dry broadcasting the seed and fertilizer onto the selected sites. No site preparation was conducted prior to seeding as the sites were sufficiently rough to create micro-sites for seed germination and seeding establishment. The seed was spread at a rate of 100 kg/ha. A balanced fertilizer, 13-16-10 was applied at the time of seeding at a rate of 300 kg/ha to supply plant nutrients during the establishment and early growth of the stand. No tending of the trial sites was conducted during the growing season as it is expected that there will be no tending during actual reclamation of mine areas.

The trial sites were visited on September 3rd, 1985 to assess the germination and early growth of the stands. Some growth was evident at all of the sites although the sites with greater moisture available to the young plants showed better growth. This was expected due to the very dry summer. At the low elevation sites, there was good growth at both the Core Storage Road site and the Camp Drain Field site. Unfavourable thermal regimes resulting from the dark colour of the substrate in the Hobbit-Broatch Pit site is thought to be responsible for the relatively poor growth at this site. In general, on the more moist sites there was a good development of the seeded legumes as well as the grasses, while at the drier sites, the legumes were virtually absent.

Growth at the 1985 high and low elevation sites showed the same general pattern. Those sites with the greatest moisture availability showed the greatest growth. All of the high elevation sites had boen somewhat disturbed by exploration activity since establishment.

The mixed seed trial sites were visited on July 15, 1986 and good growth was apparent at all sites. Again, the dark colour of the Hobbit-Broatch site had limited growth on the south face. At the high elevation sites, the fescues, meadow foxtail, and in moister locations, the clovers showed good growth. None of the plants at higher elevations were flowering except a few timothy plants in sheltered locations. This is probably due to the shorter, cooler growing season at high elevations. At the lower elevation sites, many of the grasses were flowering as were the clovers.

By September, 1986, growth of the seeded species was doing very well. At the high elevation sites, plant colour was good and the plants were well established. Legume content at the drier high elevation sites was low. At the low elevation sites, growth on the moist and mesic substrates was excellent with a cover of about 60 percent. Most of the species were flowering. Growth on the dark coloured substrate at the Hobbit Broatch site was limited.

All of the grasses and legumes used in the trials are perennials and the initial year of growth is primarily one of establishment while the second and subsequent years growth are characterized by mature growth and flowering of the plants. Some requirements of further fertilizer applications are anticipated as the substrates are characteristically low in nutrients. The application of fertilizer at the time of establishment was kept relatively low as heavy applications of fertilizer during the early growth of grass and legume stands tends to foster the growth of the grasses at the expense of the legumes. Careful assessments of the stand vigor will be required to determine the extent to which further fertilizer is required.

2.5.3 Operational Reclamation Programs

Development of a large anthracite bulk sampling program in 1985 resulted in the need for a tailings pond to retain the fine anthracite and rejects from the washplant. A tailings pond was constructed in the summer of 1985 adjacent to the washplant. The tailings pond dykes are constructed of compacted local till. Although this is good engineering material for such a facility there is a potential for significant erosion on the downstream face of the dykes from heavy rains and spring run-off. Concern over potential for such erosion led to the development of the 1985 operational reclamation program.

The 1985 operational reclamation program consisted of seeding and fertilizing the downstream faces of the tailings pond dykes. A total of 2.5 ha of disturbed ground was seeded and fertilized during the period of August 31st to September 4th, 1985. In addition to accomplishing reclamation work, the program will serve as a test of the effectiveness of fall seeding in the Mount Klappan area. The low elevation seed mix developed for the spring trial was used. Seed was spread at a rate of 100 kg/ha using hand-held cyclone seeders. Fertilizer was spread at a rate of 300 kg/ha at the time of seeding. Again, cyclone seeders were used. No site preparation was conducted as the construction of the dykes had resulted in bulldozer cleat marks over the entire face of the dykes. These are excellent sites for seed germination and plant growth. The "cat-track" phenomenon is well known in reclamation.

By July 1986, growth was beginning to appear on the tailings pond dyke. In September, growth at the site was considered reasonable but excessive compaction on portions of the dyke appeared to have restricted growth although there was good growth in many of the microsites created by bulldozer cleats.

Also, in September 1986, an operational hydroseeding program was conducted on the regraded Hobbit-Broatch test pit area and the water line area. Slopes in the pit had been graded to conform with the local topography and a drainage channel was created to direct run-off water to the pond area. The pond will remain as a sediment trap through the initial years of vegetation establishment.

An effort was made to spread soil materials over as much of the pit area as possible. The pit and water line areas were seeded with the low-elevation seed mix at a rate of 100 kg/ha. Fertilizer was applied at a rate of 300 kg/ha. Mulch was applied with the seed and fertilizer at an average rate of 600 kg/ha in the Hobbit-Broatch area. Mulch was applied at a rate of about 1200 kg/ha on the darker coloured portions of the area in an effort to reduce the heat generated by the sun striking this dark material. It is expected that once the vegetatien becomes established, the dark colour will have little effect on the plants. A total of 12 hectares was seeded in the two areas and assessments of the progress of these tests will be made in 1987.

The degree of success experienced to date with test plots assures the long term reclamation of disturbed areas.

3.0 WILDLIFE

3.1 WILDLIFE STUDY APPROACH

In the Biophysical Environment report, Volume III of the Stage I submission, Gulf reviewed the wildlife data available for the area and the 1984 wildlife studies on the property were described. The analysis concluded that the expected impacts of the Mount Klappan project would be minimal. The project site was not found to be an area of intense use or habitation by any of the species common to the region. However, because the migration patterns associated with caribou and the extended range of grizzly bear, it was noted that the project could potentially affect these animals during particular times of their life cycles. Detailed study of the movements and activities of these two species over the past two years however has revealed that the project represents no unique habitat to either and project developments are unlikely to interfere with them.

In the Stage I submission, Gulf committed to provide a detailed study of these two species as part of the Stage II assessment of the project. This study would, as stated in the Stage I submission, "Focus on migration, calving, and rutting activities of caribou, and denning and foraging activities of grizzly bears. The study will be organized so that information can be simultaneously gathered on other sensitive species (specifically, mountain goats, moose and Golden Eagles), and further observations of other wildlife can be made. The purpose of the study will be to generate an accurate information base from which to assess impacts of the Lost-Fox mine development, justify any measures recommended to mitigate impacts, and provide the foundation for the monitoring program."

In its comments on the Stage I the government agreed that caribou and grizzly bear are the two species of greatest concern. They encouraged continued close liason between Gulf and the Spatsizi Association for Biological Research. The Government review indicated that the potential impacts of disturbance on wildlife should be addressed in the Stage II report and that Gulf's proposed studies of habitat composition and use in areas of disturbance and non-disturbance would be a "vital component" of these efforts to determine impacts.

The Stage II wildlife survey program commenced in April, 1985 and continued until October of that year. The wildlife habitat investigations were carried out in July of 1985.

3.1.1 Location of Study

The field program included a ground based survey within the licence area and an aerial survey which included not only the licence area but also the immediately adjacent peaks and drainages within a 10-15 km radius of the licence area (Figure 4-3). In addition, major valleys (e.g., Nass River and Skeena River) leading from the licence area were surveyed in a less rigorous fashion during flights to and from the licence area. The Kluayetz Creek/Fire Flats area is a recognized area of caribou activity (Bergerud and Butler 1978; Hatler 1983); surveys of this area were conducted regularly in order that the results could give perspective on the licence area.

As the study progressed, liaison with the Spatsizi Association for Biological Research (SABR) was maintained in order to obtain relevant information from ongoing radio-tracking studies of caribou.

3.1.2 Objectives of Study

3.1.2.1 Wildlife Surveys

Because caribou and grizzly bears were identified as the two critical species with respect to mine development, the 1985 Stage II studies were focussed on these two species. Additional information on other species was also collected whenever they were encountered and the information is included in this report.

The information collected for caribou focussed on winter range, migration, calving, summer distribution, and rutting. The study focus for grizzly bears was on denning and foraging habits.

3.1.2.2 Habitat Investigations

In addition to the collection of base line data, the habitat studies included a site specific examination of those areas, termed "development areas" which would be alienated from wildlife use by the Lost-Fox mine and its associated infrastructure.

To determine whether or not any of these development areas had a unique value to wildlife the utilization of each area by wildlife was compared to the utilization by wildlife of a comparable habitat area which would not be disturbed by mine development. This area was designated the "control area". The method of selection is described in more detail in Section 3.3 Habitat Analysis.

Greater utilization by wildlife of a development area compared to its control area would imply unique characteristics for the development area; equal utilization of both areas would indicate the development area was not unique whereas lesser utilization of the development area would imply a lesser value to wildlife than that of the control area.

3.2 WILDLIFE SURVEYS

3.2.1 Methods

In 1984, a series of helicopter aerial surveys was undertaken, involving visits to the licence area at critical times for wildlife. These surveys provided initial baseline data with which to define a preliminary list of key issues. In order to provide more detailed information on these items, the 1985 program involved more intensive aerial surveys at the same critical time periods but excluding the winter months, supplemented by additional ground and aerial surveys as necessary to confirm or deny the existence of site-specific concerns relating to the Lost-Fox minesite development areas.

Since wildlife movements into or through the planned mine activity area take place erratically, the presence of a groundbased observer during summer months facilitated collection of data at the detailed level required. This was particularly relevant to caribou. The observer also collected information on and investigated sightings reported by others at the exploration camp. In addition to the licence area, aerial surveys concentrated on the Kluayetz Creek drainage, which is recognized as a key wildlife area (Bergerud and Butler 1978). The objective was to obtain comparative information which would give perspective on the licence area.

Surveys were undertaken as follows:

Dates	Primary Focus
April 16 - 18	Grizzly bear denning emergence aerial survey.
April 29 - May 1	Grizzly bear denning emergence aerial survey.
May 27 - June 1	Spring caribou migration and calving aerial survey.
June 8 - July 9	On-site observer.
July 10 - 20	Caribou post-calving aerial survey.
July 21 - August 6	On-site observer.
August 7 - 11	Summer grizzly bear foraging areas aerial survey.
September 16 - 20	Fall grizzly bear foraging areas aerial survey.
October 9 - 14	Caribou rut aerial survey.

A mid-November aerial survey for grizzly bear denning was planned but was not completed due to bad weather. For all the aerial surveys, at least two biologists were present.

Data recorded included the following: species, numbers, group size and composition, sex and age class (where distinguishable), location, habitat occupied, elevation above sea level using the helicopter's altimeter, and general behaviour. When possible, Hatler's (1983) approach to classifying caribou into age and sex categories was utilized. The category of "subadult" was added where caribou were observed with body sizes indicating either yearlings or small adults carrying antlers that did not aid in classification. Habitat types occupied were also recorded. For the purposes of distribution analysis, observations of wildlife are mapped and tabulated in this report according to licence area divisions established by Gulf during exploration activities (Figure 4-3).

Ground surveys were accomplished primarily by driving along the British Columbia Railway (BCR) grade, and took place between June 4 and August 12, 1985. Marker stakes were positioned along the grade at one-kilometre intervals between Conglomerate Creek (tributary to the Little Klappan River) and Hobbit Creek (tributary to the Spatsizi River) and were calculated from a truck odometer at other locations. The markers were numbered to coincide with distances from Highway 37 along the BCR grade. Thus, Conglomerate Creek was near the km 100 marker and Hobbit Creek near the km 127 marker. Locations of wildlife observed relative to the grade could thus be established.

The BCR grade was driven daily in early morning and evening when observations of wildlife were most likely to be made, and frequently during midday when human activities along the grade were more intense. The section between Conglomerate Creek and Hobbit Creek and the trail leading down the south bank of Hobbit Creek to the Spatsizi River were always driven. When it became passable to vehicular traffic, the grade beyond Hobbit Creek was occasionally driven as far as the Garner Creek airstrip on the Skeena River.

When wildlife was observed, time of day, sex, age, and group size of the animals were noted, as well as their distance from the grade and behaviour. Behaviour of wildlife in the presence of the survey vehicle and other disturbances was also noted. Unless an animal remained stationary (i.e. bedded), it was observed continuously until out of sight. If tracks of

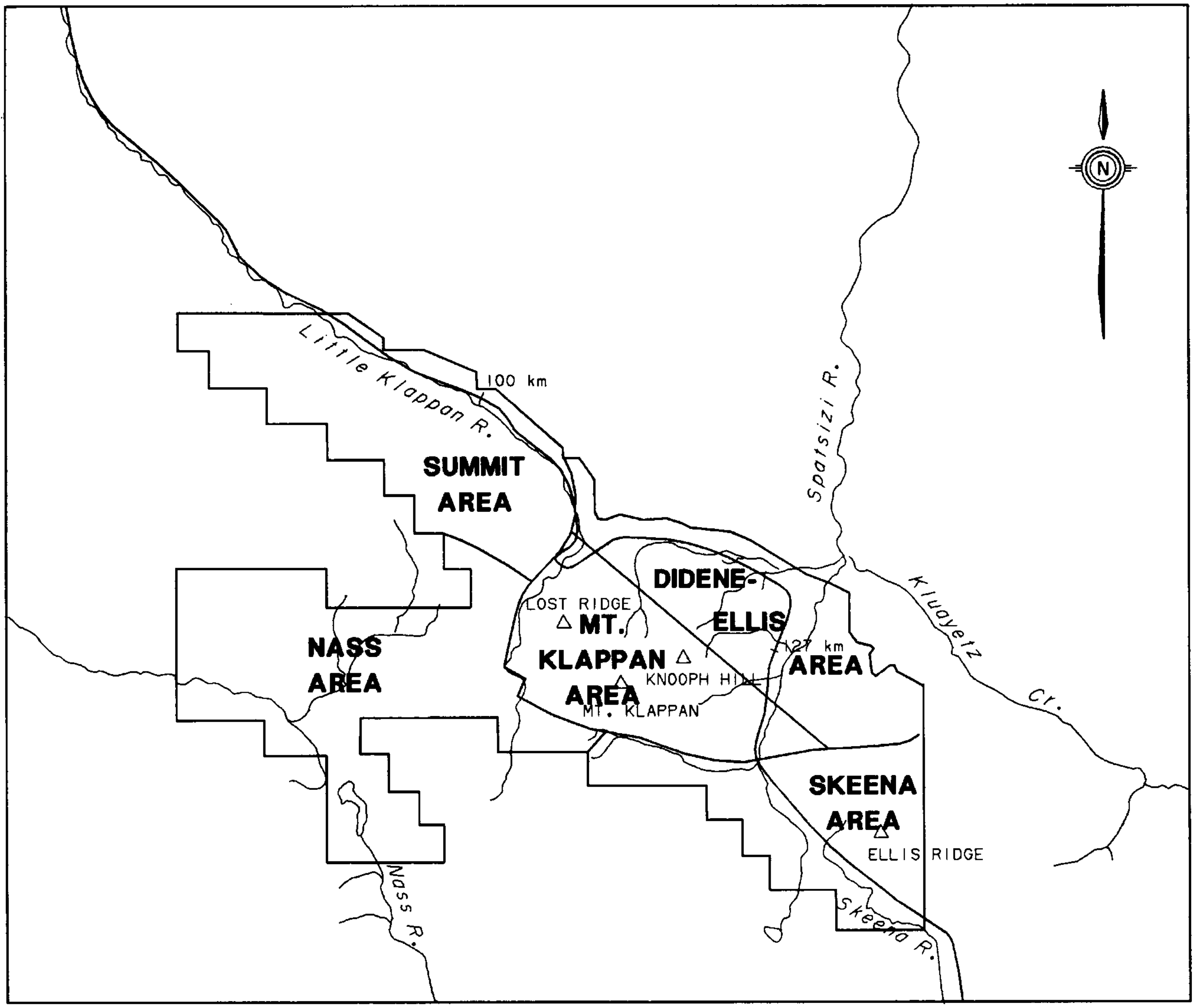

FIGURE 4-3

MOUNT KLAPPAN ANTHRACITE PROJECT

AREA SUB-DIVISIONS
USED IN WILDLIFE DISTRIBUTION ANALYSIS

ENVIRONMENTAL MANAGEMENT ASSOCIATES

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ungulates or bears were encountered, direction of travel, track age, and estimated number of animals were noted. Bear tracks were measured if clear prints were available. All data were subsequently plotted on 1:50 000-scale topographic maps.

Personnel at the exploration camp were asked to report any wildlife observations to the wildlife study team. The wildlife study was advertised in the exploration camp, and reports were subsequently received from a variety of sources ranging from helicopter pilots to field geologists and heavy vehicle operators.

3.2.2 Caribou

The results of 1985 surveys are given in Tables 4-9 to 4-15 and the distribution of observations is mapped in Figures 4-4 to 4-8. Figure 4-8 shows the routes along which caribou were tracked by helicopter, the locations of mineral licks, and locations of trails which indicate regular, or perhaps annual, use by caribou. Figure 4-9 gives fine detail on the distribution of caribou observed from the ground in the vicinity of the BCR grade.

3.2.2.1 Seasonal Distribution

The Stage I submission indicated that the licence area has no capability for caribou winter range owing to excessive snow depths. Hatler's (1985) findings strongly support this contention, as Figure 4-10 (taken from Hatler 1985) shows. Nearly all of the February and March locations of radio-collared caribou are along the Stikine River valley or the lower Klappan River at least 60-70 km distant from the proposed site of mining activities. No wintering caribou were observed on the licence area.

On the April 16 and 29 surveys, no caribou were observed nor was evidence (tracks) of their presence observed on either the licence area or in the Kluayetz Creek/Spatsizi River area.

TABLE 4-9

AERIAL SURVEYS FOR CARIBOU: RESULTS FROM THE SPRING MIGRATION AND CALVING PERIOD, MAY 20 - JUNE 15, 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Location
May 30											2M,1F	1189	Kluayetz Cr.
											1F	1189	Kluayetz Cr.
May 31											2M,1F	1219	Kluayetz Cr.
											1F,1Y	1250	Kluayetz Cr.
											2F	1798	Spatsizi R. trib.
June 1											1M	1280	Didene Cr.
June 2											1F,1J	2042	Tahtsedle Cr.
											1F	1707	L. Klappan R.
											1F	1981	Above Spatsizi R.
June 3											1F,1J*	2042	Tahtsedle Cr.
											1F,2Y	1189	Spatsizi R.
June 4											1F,1J*	2042	Tahtsedle Cr.
											1F,1Y	2042	Above Spatsizi R.
											10F,1Y	1189	Kluayetz Cr.
											2F	1219	Kluayetz Cr.
											1M,1F	1219	Kluayetz Cr.
											2M,3F	1189	Kluayetz Cr.
											2M	1189	Kluayetz Cr.
													Didene Cr.
													Spatsizi R.
June 5											1F,1J*	2042	Tahtsedle Cr.
											1Y	1219	Spatsizi R.
											1F1J	1753	Above Spatsizi R.
											1F,1J	2012	Above Spatsizi R.
											2F	1250	Spatsizi R.
June 6											1F,1J*	2042	Tahtsedle Cr.
											2F,1J	1707	Above Spatsizi R.
											1F,1J	1737	Above Spatsizi R.
											1F,1J	2042	Above Spatsizi R.
June 7											1F,1J*	2042	Tahtsedle Cr.
June 11			2M	1341									

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult; U - unclassified; * - Repeat observation.

TABLE 4-10

AERIAL SURVEYS FOR CARIBOU: RESULTS FROM THE POST-CALVING PERIOD
JUNE 16 - JULY 16, 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Location
June 18			1M,3A	1189							1M,3A	1067	Spatsizi R.
June 25			1F	1433							3F	1097	Spatsizi R.
July 3											2M	1219	Spatsizi R.
											1M,1F	1219	Spatsizi R.
July 12											2M	2103	Above Conglomerate Cr.
July 15							4M1F	1555			1M,2F	1981	Above Spatsizi R.
							5M	1555			2M,9F,3J	1951	Above Spatsizi R.
											5F,5J	1768	Above Spatsizi R.
											5M	1737	Above Buckinghorse L.
											14M	1280	Kluayetz Cr.
											59U,5M, 5J	1311	Fire Flats
											1M	1280	Didene Cr.
											1F,1J	1890	near Summit
											1M,6F,4J	1829	Klappan R. trib.
											1F,1J	1707	L. Klappan R.
July 16	2F	1676	1F,1J	1798			2M	1859	2F	1280			
	1F	1615	7F,2J	1829					2F	1402			
	3M,5F,2S	1646											

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult;
U - unclassified.

TABLE 4-11

AERIAL SURVEYS FOR CARIBOU: RESULTS FROM THE MID-SUMMER PERIOD, JULY 17-SEPTEMBER 18, 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Location
August 9			2Y	1280			2M	1554			2F	1250	Kluayetz Cr.
			2Y	1219			3S	1402			4M	1219	Kluayetz Cr.
			1F,1J	1311							1F	1219	Fire Flats
			2M,2F,4S	1311							3F,1J	1798	Above Spatsizi R.
			1Y	1311							1F,2S	1676	Didene Cr. trib.
			1M,4U	1311							2M,1F,1Y	1585	Tsetia Cr.
			4U	1341							2F,1J	1585	Conglomerate Cr.
											3F,2J	1615	Butler Cr.
September 18	2F,1J	1768									1M,11F,	1615	Klappan R.
											2J,2Y,2S		L. Klappan R.
											1M,2J,	1707	L. Klappan R. trib.
											1S,9U		
											6F,1J,1S	1707	above Buckinghorse L.
											1M	1859	above Buckinghorse L.

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult; U - unclassified.

TABLE 4-12

AERIAL SURVEYS FOR CARIBOU: RESULTS FROM THE FALL DISTRIBUTION AND RUT PERIOD, SEPTEMBER 19 - OCTOBER 15, 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Location
October 11					2M,1F,1Y	1829					8M,1J, 5Y,19U	1768	Klappan R. L. Klappan R.

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); s - Subadult; a - Adult; U - unclassified.

TABLE 4-13

GROUND SURVEYS AND REPORTED OBSERVATIONS OF CARIBOU: RESULTS FROM THE SPRING MIGRATION AND CALVING PERIOD, MAY 20 - JUNE 15, 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
June 4*			2F	1341									km 112
June 6*			1U	1341									km 118
June 7*					1M	1341							km 99
June 9			1S	1280									km 125
June 10*			2F, 1Y	1280									km 117
June 10*			2M	1341									km 123
June 11*			1F	1250									km 114 Met. Stn.
June 11*			1M	1250									km 114 Met. Stn.
June 11											2M	1371	km 120 Slope N. of camp
June 12	1M	1311											km 109
June 12*			6A, 1Y	1341									Spatsizi R.
June 12*			4A	1341									Spatsizi R.
June 13			1F	1280									km 123.3
June 14*			2Y	1280									km 124 on grade
June 15			4M	1311									km 115.1

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult; U - unclassified.

* reported observation

TABLE 4-14

GROUND SURVEYS AND REPORTED OBSERVATIONS OF CARIBOU: RESULTS FROM THE POST-CALVING PERIOD, JUNE 16 - JULY 16, 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
June 16			1M,1S	1311									km 118.9
June 16			1S	1341									km 124.8
June 16			2M,1F,1S	1311									Off Hobbit Tr.
June 17*			1M,1F	1341									km 124
June 18			2M	1250									km 106.5
June 18			4M,1S	1341									km 125.6
June 19*					1M,1F	1250							km 102 Gravel Pit
June 20*					2M,4U	1250							km 102 Gravel Pit
June 20			1S	1250									km 125
June 21			1M,2S	1250									km 107.5
June 21			1S	1280									km 115
June 21			2M	1311									km 120
June 21			1F,1Y	1402									km 126
June 21*			2M	1311									km 120 N. of camp
June 22					2M,1F	1219							km 101
June 22			3F,1Y	1341									km 114 Met. Stn.
June 23					2M	1341							km 102
June 23			1M	1341									km 120.5
June 23					1M	1311							km 102.5
June 23					1M,1F	1311							km 102.5
June 23*			1U	1311									km 105
June 23*	3F	1280											Tahtsedle Cr.
June 23*			3F	1402									Spatsizi R.
June 24*			1M,2Y	1250									km 124
June 24			1F	1341									km 114 Met. Stn.
June 24					2M	1371							km 102
June 24					3M	1371							km 103

Continued ....

Table 4-14
Continued

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
June 25			2M	1311									km 106.5
June 25			2F	1341									km 125.8
June 26			2M	1219									km 125 Near Spatsizi R.
June 26*			2M,1F	1250									km 110
June 27*			2F	1219									km 128
June 27			2M	1189									Off Hobbit Tr.
June 28			1F	1371									km 115.3
June 28			1F,1Y	1371									km 114 Met. Stn.
June 28			2M	1341									km 106
June 28			1M,1F,2Y	1371									km 126
June 28			2M	1189									km 126 Near Spatsizi R.
June 28*			1M,2F	1493									Knooph Hill
June 28*			1F	1463									Knooph Hill
June 28*			4Y	1250									km 107
June 28*					5U	1341							km 115
June 28*	2M,1F	1676											Lost Ridge
June 29*			1M	1341									km 114 Met. Stn.
June 29*			1U	1371									Old BCR Camp
June 29*					1F	1219							km 103 on grade
June 29			1M,2Y	1341									km 125.3
June 29			2Y	1341									km 113.5
June 29			1F,3Y	1250									km 110
June 29			2F	1311									km 120.2
June 29					1M	1280							km 106
June 29					3M	1341							km 102
June 30					2M,1F	1280							km 104
June 30			4F	1341									km 116
June 30			1F	1311									km 121
June 30*	2Y	1524											Lost Fox Basin

Continued ....

Table 4-14
Concluded

Date	LICENCE AREA: MT. KLAPPAN Age/Sex	MT. KLAPPAN Elev(m)	DIDENE-ELLIS Age/Sex	DIDENE-ELLIS Elev(m)	SUMMIT Age/Sex	SUMMIT Elev(m)	NASS Age/Sex	NASS Elev(m)	SKEENA Age/Sex	SKEENA Elev(m)	OFF LICENCE AREA Age/Sex	OFF LICENCE AREA Elev(m)	LOCATION
July 1*			2M	1280									km 108
July 2*			2U	1341									km 106
July 2			2F	1341									km 121.7
July 2			1M, 1F	1341									km 118.7
July 3*			5F	1341									km 118
July 3*			2F, 1Y	1341									km 118
July 4*	1M	1646											Mt. Klappan
July 4*	1F	1646											Mt. Klappan
July 6*			9U	1311									km 114 Met. Stn.
July 6			1M, 1S	1280									km 107
July 8			1S	1341									km 117.8
July 8*			1F	1341									km 114 Met. Stn.
July 8*					1F	1311							km 102 Near Gravel Pit
July 8*	5U	1646											Mt. Klappan
July 9*			1M	1341									km 117
July 9											2F, 1J	1981	km 102 In Park
July 10			1F	1371									km 116.4
July 11*											11U, 4J	1829	In Park
July 12*			2M	1341									km 120.7 Crossed Grade
July 12*											10U	1829	In Park
July 12*											5U	1829	Near Butler Cr.
July 12			3M, 2F, 2Y	1311									km 117.6
July 12					1F, 1J	1341							km 106.4
July 13*			2U	1341									Near Summit Strip
July 13*			3U	1341									Didene Cr. Valley
July 16*			1Y	1341									km 114

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult;
U - unclassified.

* reported observation

TABLE 4-15

GROUND SURVEYS AND REPORTED OBSERVATIONS OF CARIBOU: RESULTS FROM PART OF THE MID-SUMMER PERIOD, JULY 17 - AUGUST 11, 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
July 19*	1M	1341											km 111
July 19*							3M,2F,1J	1707					above Nass Pass
July 22											1A	1981	km 103 In Park
July 22											2U	1798	km 100 In Park
July 22											5J,11U	1829	km 101 In Park
July 23*			7U	1341									km 118
July 23*	1U	1676											Lost Fox
July 23*							1M,1F	1493					Nass Pass
July 23-24			1M	1341									km 120.3
July 23-25			3M,3Y,1S	1341									km 116
July 25*									1M	1250			km 140
July 26*	2M,1S	1676											Lost Ridge
July 26*							4M,1S	1493					Upper L. Klappan R.
July 26			1S	1341									km 117.4
July 29			1M	1341									km 120.3
July 30*			1M	1341									km 113
July 30			1F,1Y	1311									km 114 Met. Stn.
July 31			1M	1341									km 118
July 31			1F	1341									km 116.2
August 1	1F	1707											Lost Fox Access Rd.
August 1*	6U	1676											Mt. Klappan
August 2*			1M	1341									km 119
August 2			1M	1341									km 120.8
August 2			1S	1341									km 114.5
August 2			2M,2F 1Y,2S	1341									km 116
August 2											1M,8F	1676	km 115 In Park
August 2											1M	1676	km 118.5 In Park

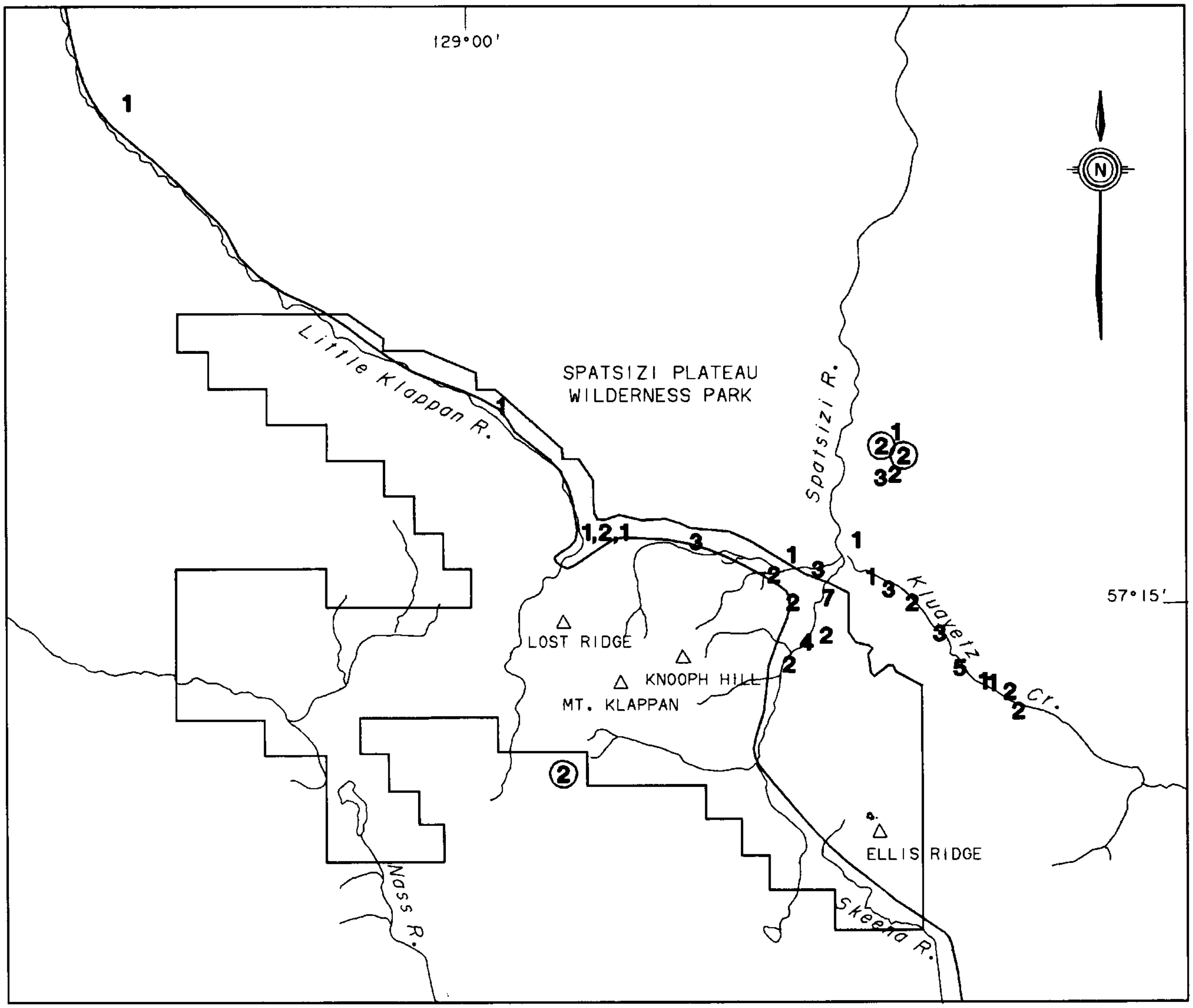
Continued ....

Table 4-15
Concluded

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
August 3	1F,1S	1341											km 115
August 3	3M	1341											km 116
August 3											1F,1Y,1J	1676	km 102 In Park
August 3			2M	1311									km 120
August 3*	1M,1F	1676											Mt. Klappan
August 4*	1M,3F	1737											Mt. Klappan
August 4*	5U	1676											Mt. Klappan
August 5*	3M	1341											km 112 On grade
August 5*	1M,3F	1646											Lost Fox Basin
August 5											1M	1676	km 122 In Park
August 5											1M,3F, 1Y,3J	1951	km 100 In Park
August 6*	5U	1676											Mt. Klappan
August 7*	6U	1707											Lost Ridge
August 7*	5U	1676											Mt. Klappan
August 8											1M,4F,1J	1554	km 116 In Park
August 8											2M,9F,4J	1585	km 103 In Park
August 8											1S,3F,2Y	1585	km 101 In Park
August 8	1F,1J	1554											Mt. Klappan
August 8	1M	1311											km 121.2 Didene Cr.
August 9			1M	1311									km 114
August 9											1M,13U, 2J	1829	km 116 In Park
August 11											2M,4F, 4J,3U	1646	km 116 In Park
August 11			1F,4S	1311									km 118
August 11			1M	1311									km 125
August 11			1M	1311									km 117.7

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult; U - unclassified.

* reported observation



0 2 4 6 km

3 NUMBER OF ANIMALS SITED

② BIRTHSITE WITH MULTIPLE OBSERVATIONS

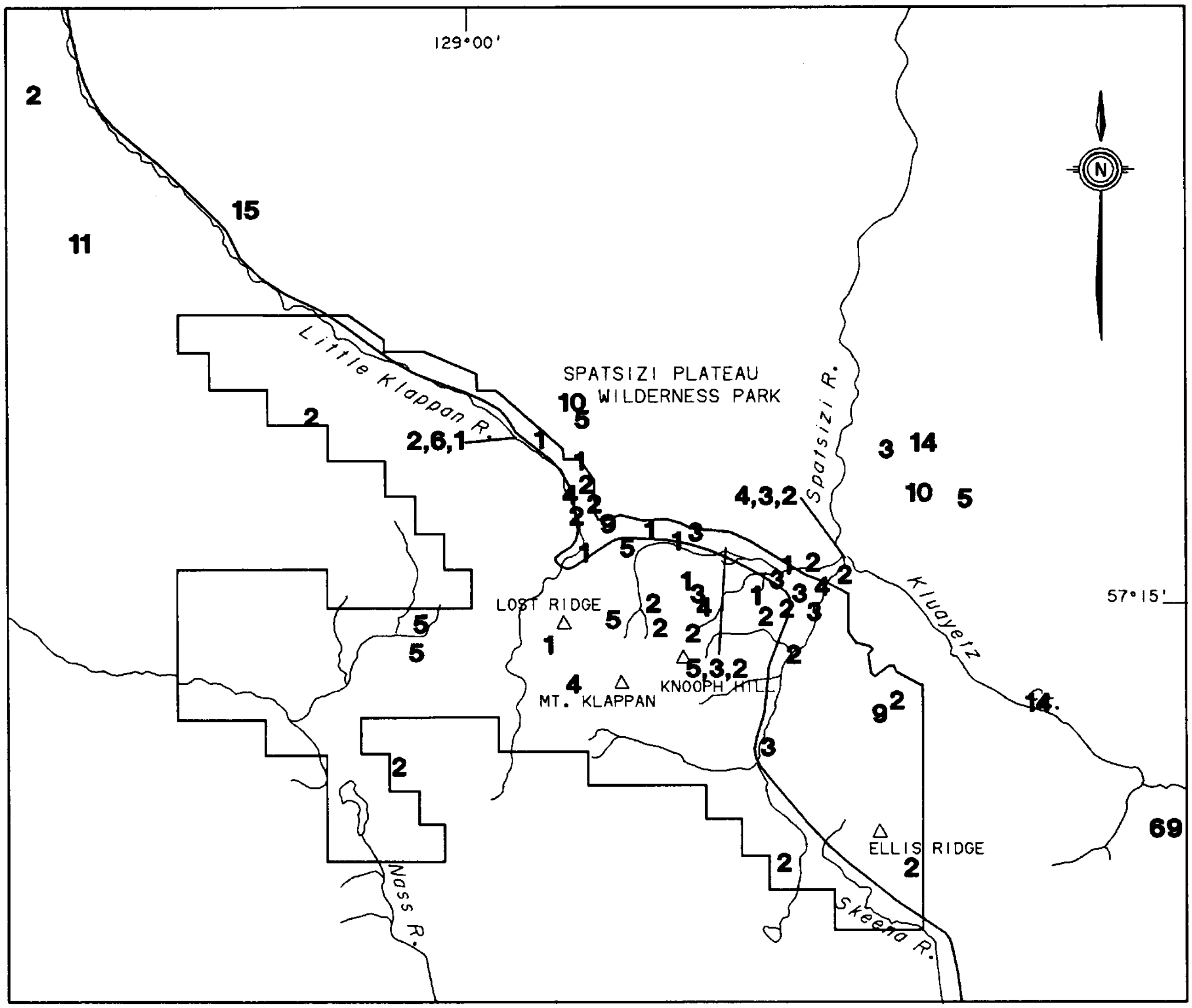
FIGURE 4-4

MOUNT KLAPPAN ANTHRACITE PROJECT

DISTRIBUTION OF CARIBOU OBSERVATIONS DURING THE SPRING MIGRATION AND CALVING PERIOD, MAY 20 - JUNE 15, 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
08/12/86
KLAP:[205057]860601025.LOC



0 2 4 6 km

3 NUMBER OF ANIMALS SITED

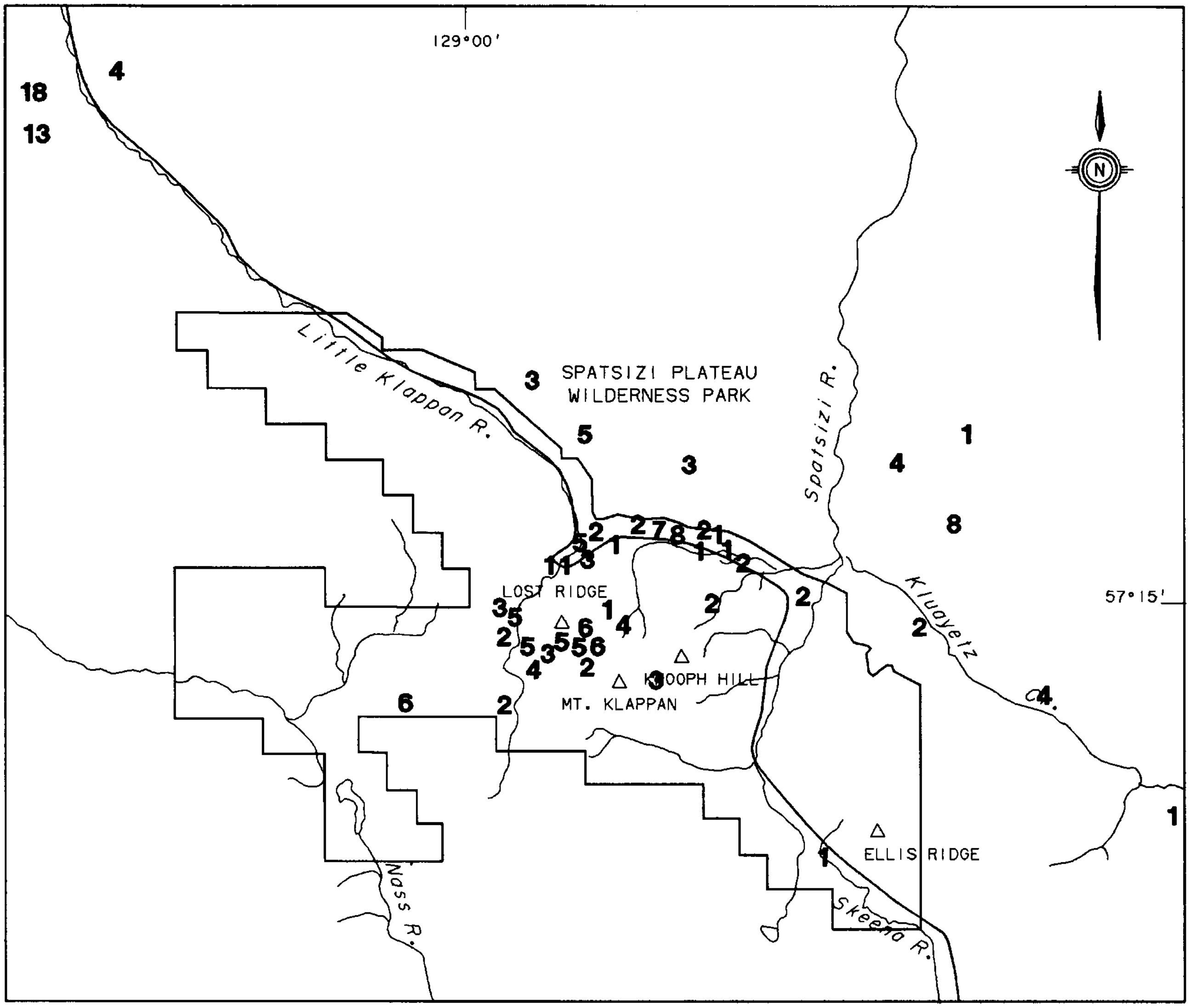
FIGURE 4-5

MOUNT KLAPPAN ANTHRACITE PROJECT

DISTRIBUTION OF CARIBOU OBSERVATIONS
DURING THE POST-CALVING PERIOD,
JUNE 16 - JULY 17, 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
08/12/86
KLAP:[205057]860601020.LOC



0 2 4 6 km

3 NUMBER OF ANIMALS SITED

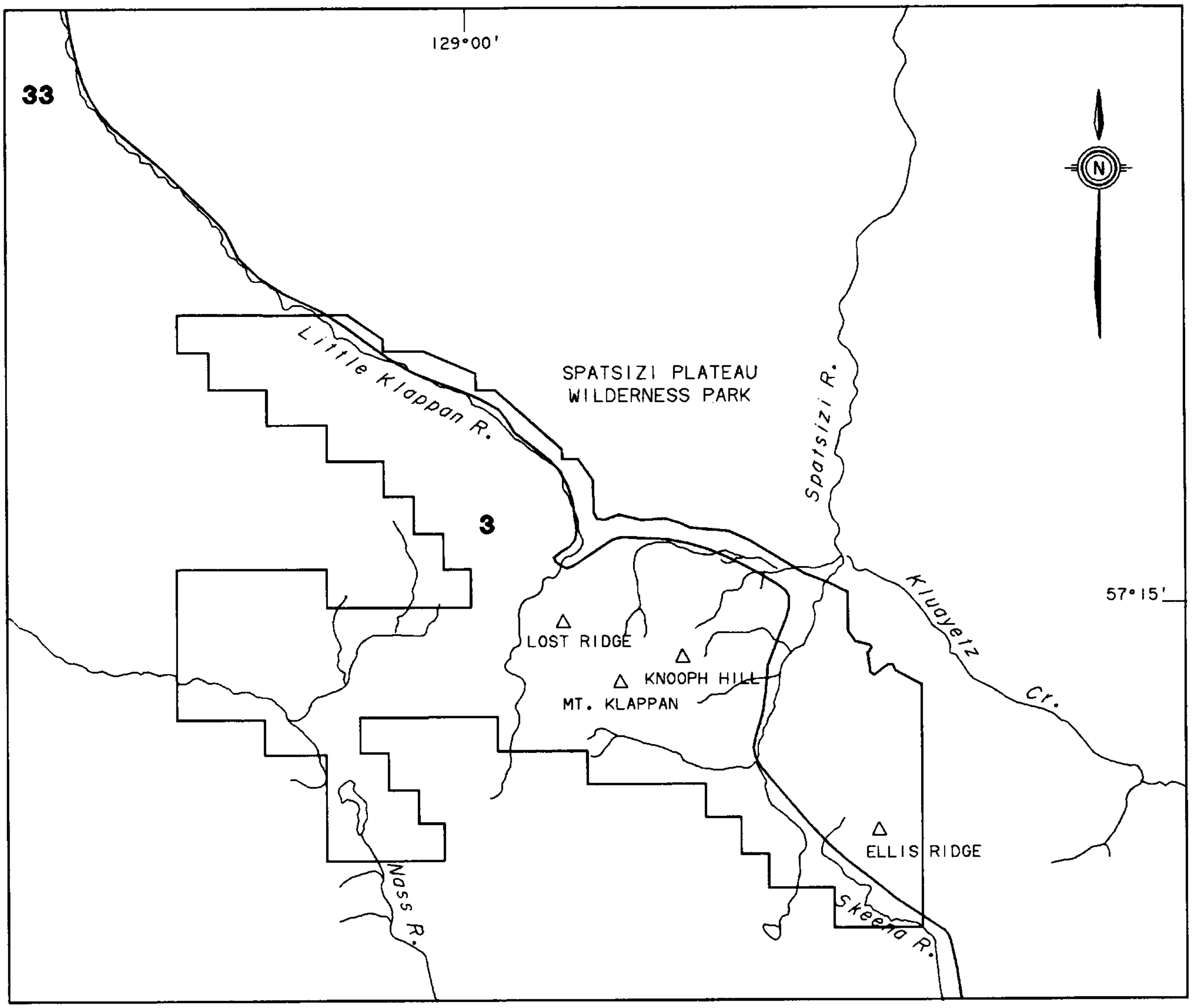
FIGURE 4-6

MOUNT KLAPPAN ANTHRACITE PROJECT

DISTRIBUTION OF CARIBOU OBSERVATIONS
DURING THE MID-SUMMER PERIOD,
JULY 17 - SEPT. 18, 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
08/12/86
KLAP:[205057]860601021.LOC



0 2 4 6 km

3 NUMBER OF ANIMALS SITED

FIGURE 4-7

MOUNT KLAPPAN ANTHRACITE PROJECT

DISTRIBUTION OF CARIBOU OBSERVATIONS DURING THE FALL AND RUT PERIOD, SEPT.19 - OCT.15, 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
08/12/86
KLAP:[205057]860601019.LOC

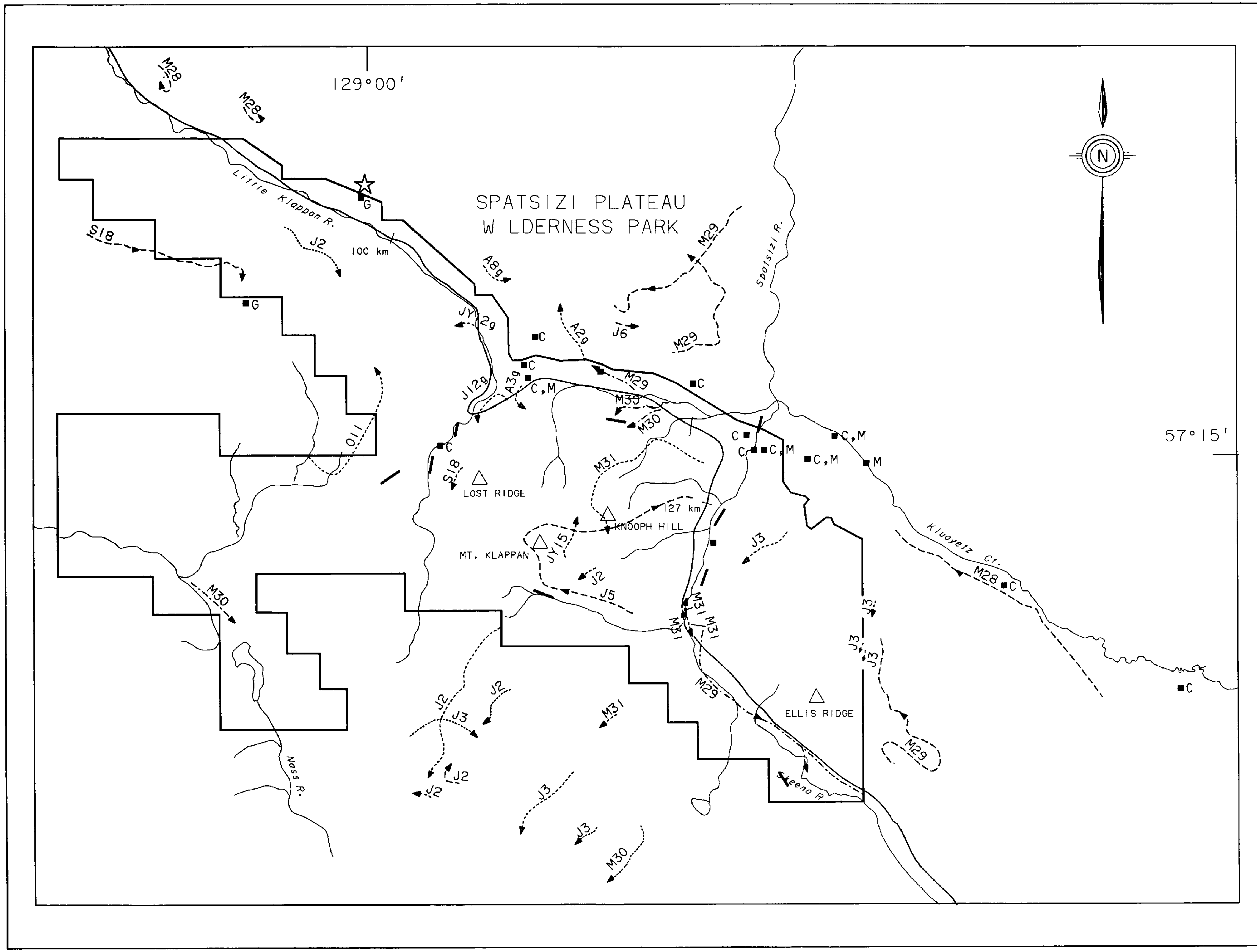


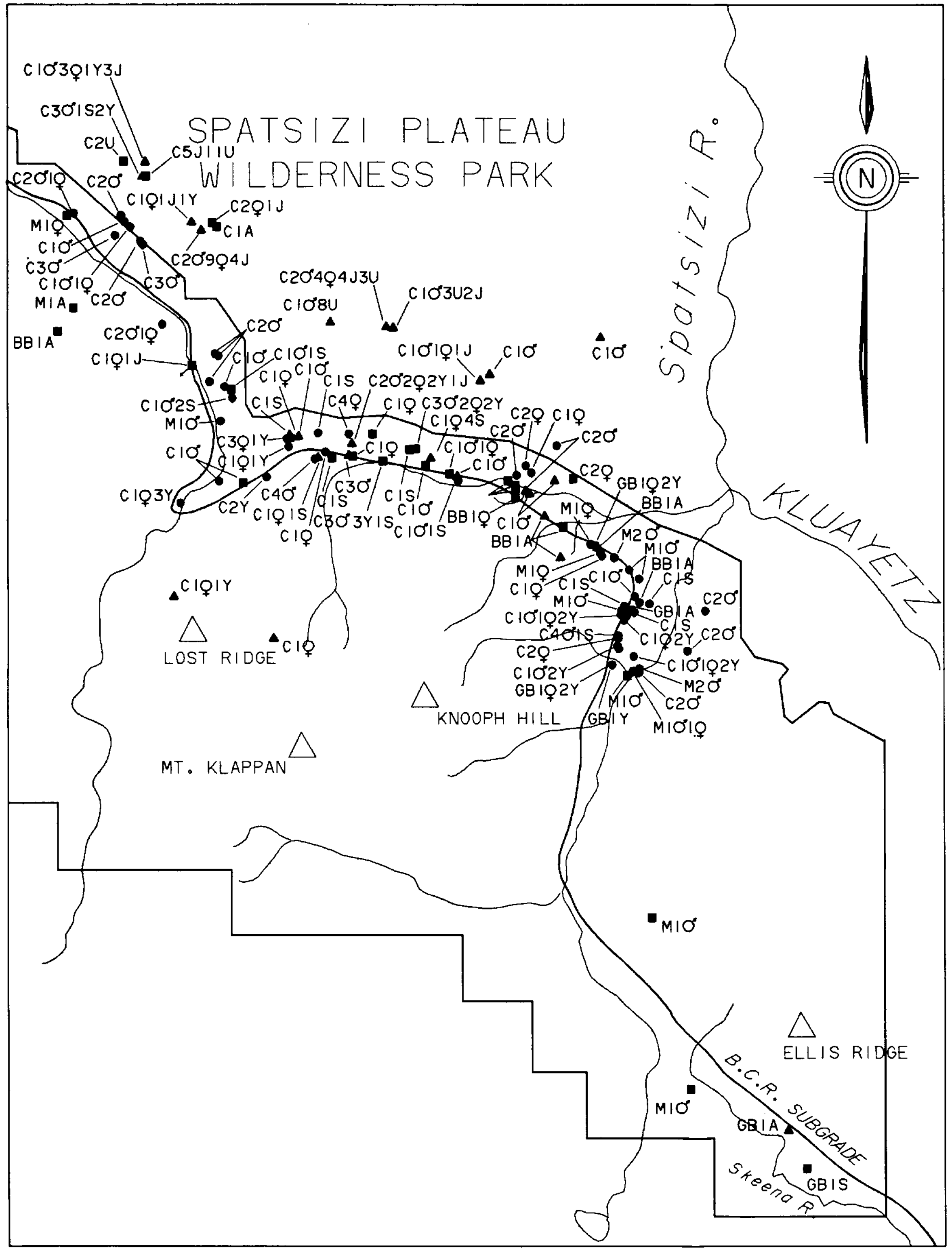
FIGURE 4-8

MOUNT KLAPPAN ANTHRACITE PROJECT

WILDLIFE MOVEMENTS

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
22/12/86
KLAP:[205057]860601036.LOC



LEGEND

C	CARIBOU
M	MOOSE
GB	GRIZZLY BEAR
BB	BLACK BEAR
•C	JUNE
▲C	JULY
■C	AUGUST
♂	ADULT MALE
♀	ADULT FEMALE
A	ADULT
S	SUB-ADULT
Y	YEARLING
J	JUVENILE CALF,CUB)
U	UNCLASSIFIED

EXAMPLE: C3♂2♀1S

CARIBOU: 3 ADULT MALES
2 ADULT FEMALES
1 SUB-ADULT

——— LICENCE AREA BOUNDARY

0 2 4 6 km

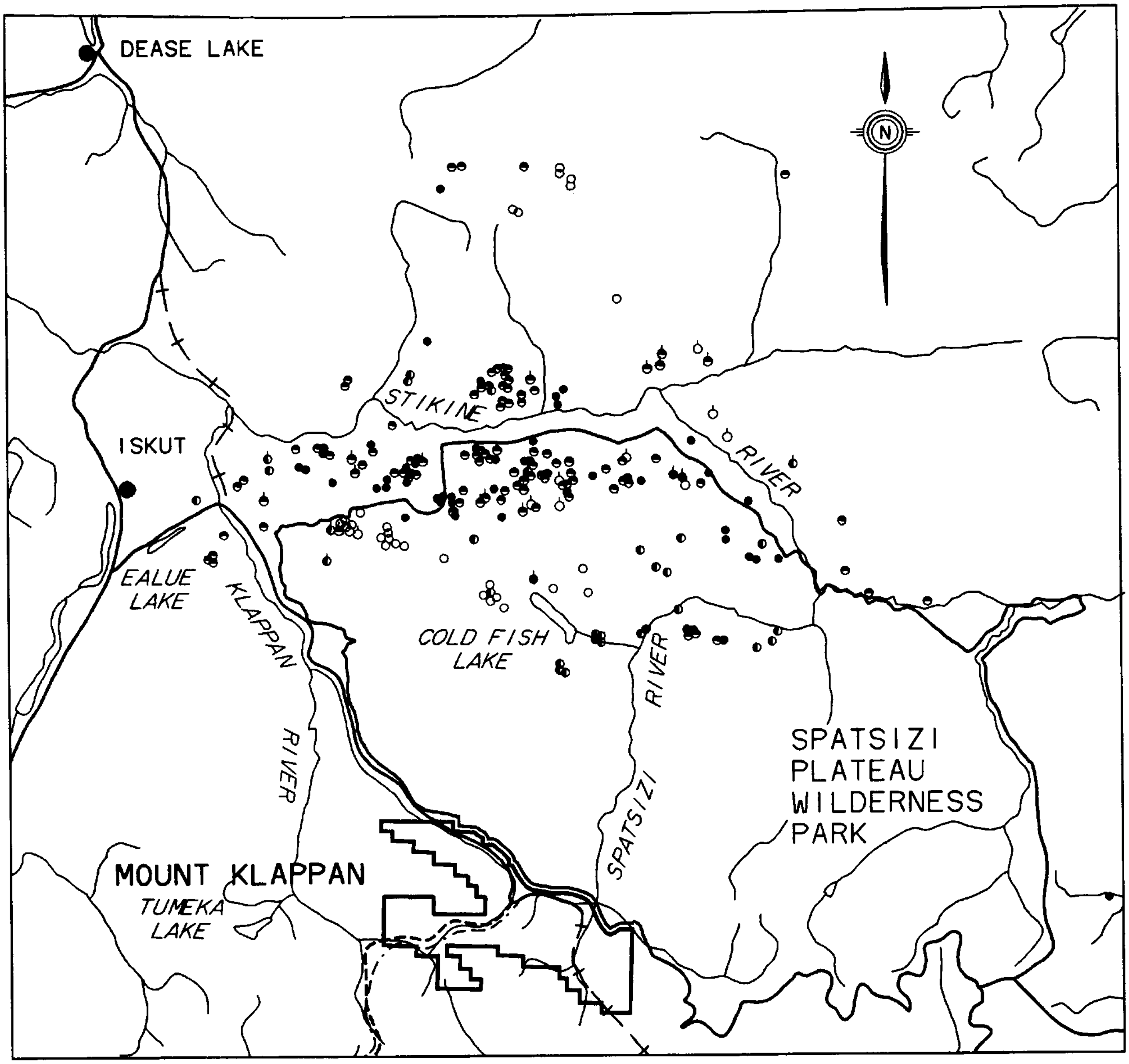
FIGURE 4-9

MOUNT KLAPPAN ANTHRACITE PROJECT

OBSERVATIONS OF WILDLIFE MADE FROM THE B.C.R.GRADE IN THE VICINITY OF THE MINESITE, JUNE 9 - AUGUST 11, 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
30/01/87
KLAP:[205057]860601037.LOC



SCALE 0 20 40km

LEGEND

	FEMALES	MALES
1980 - 81	○	♁
1981 - 82	◐	◐
1982 - 83	⊖	⊖
1983 - 84	●	●

FIGURE 4-10

MOUNT KLAPPAN ANTHRACITE PROJECT

FEBRUARY AND MARCH LOCATIONS OF RADIO-COLLARED CARIBOU IN THE SPATSIZI AREA, B.C., 1980-1984

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
01/12/86
KLAP:[205057]860629001.LOC

At the beginning of the spring migration and calving period (May 27), systematic searches were made by helicopter of all passes anticipated to be used by migrating caribou. The first tracks of caribou were found off the licence area on May 27 in lower Kluayetz Creek. The first evidence (tracks) of caribou on the licence area was found on May 31 when two animals were tracked from the BCR grade between Hobbit and Broatch Creeks upslope to the summit of Knooph Hill, across the eastern perimeter of Lost-Fox Basin and into the Grizzley Creek drainage where they were lost.

Caribou were not observed on the licence area until June 11. This was the only on-licence observation during the spring migration and calving period. Snow cover on the licence area was essentially 100 percent until June 10. Minor snow-free areas existed in the lower on-licence reaches of Didene Creek, and the Spatsizi and Little Klappan rivers.

As Table 4-9 and Figure 4-4 show, in the period May 30 - June 6, nearly all of the observations of caribou were made in the Kluayetz Creek - Spatsizi River area. The first observation of a cow with a newborn calf at its birthsite was made on June 2 south of the licence area at 2042 m above sea level near the summit of a peak in the upper Tahtsedle Creek drainage. No birthsites were discovered on the licence area. Several birthsites were discovered in the mountains east of the Spatsizi River and north of Kluayetz Creek.

During the post-calving period (Table 4-10, Figure 4-5) observations of caribou on the licence area were more numerous than during the spring migration and calving period. Nevertheless, many more observations of caribou were made in off-licence areas, particularly the Kluayetz Creek/ Spatsizi River/Fire Flats area. No post-calving aggregations of the size reported by Bergerud and Butler (1978) were observed on the licence area; however, an aggregation of 69 caribou was observed on July 16 at Fire Flats and on the same day smaller groups were scattered along the Kluayetz Creek meadows. Several "nursery herds", consisting primarily of cows with calves, were observed in alpine areas both on- and off-licence during this period.

Small male-dominated herds were observed in the alpine meadows of "Nass Pass" leading from the Little Klappan drainage over to the upper Nass and Klappan rivers. While no evidence of movement from the Little Klappan River up to the "Nass Pass" was detected in spring, the increasing numbers of caribou in this corridor at higher elevations, coupled with the evidence of regularly-used trails (Figure 4-8) strongly suggest that this is a well-used corridor during summer months.

During the mid-summer period (Table 4-11, Figure 4-6), caribou were observed as frequently in the valley bottom meadows of the licence area as in the equivalent off-licence habitats along Kluayetz Creek. In August, caribou were observed with increasing regularity in the alpine areas of the Lost-Fox basin (Mount Klappan Area) in the vicinity of the pit access road and trial cargo pit. After ground surveys ceased in mid August, few caribou were observed in the licence area during September and October aerial surveys. Aggregations were observed in September on the alpine plateau between the Klappan and Little Klappan Rivers in the same location where a rutting aggregation was observed in October (Table 4-12, Figure 4-7). This was the only rutting aggregation observed with no rutting caribou being observed in the licence area. The location of the rutting aggregation observation is approximately 15 km northwest of the licence area boundary.

3.2.2.2 Evidence of Movements

Figure 4-8 shows the locations of routes taken by caribou that were tracked by helicopter. Tracking was only possible when snow cover was sufficient; that is, in late May-early June, in July, August and September at high altitudes, and in October. Tracks may not have been visible from the air if caribou followed routes across hard-crusted snow. A limited number of movements were observed from the ground during the summer months. These are also depicted in Figure 4-8.

Most information on movements was collected in late May-early June. At this time, nearly all of the routes taken by caribou followed a general south or southwest direction. In most cases, either individual adult caribou or groups of two adult caribou were tracked. Several of the tracks were followed in alpine areas or across permanent icefields. South of the licence area, they led to passes between the high mountain peaks and were usually lost in forest cover at lower elevations. The suggested trend of movements is one emanating from the Spatsizi River valley southwesterly across the licence area to the east of Lost Ridge towards the Nass River drainage. No tracks of this kind were found through the Lost Ridge area. One set of two adult tracks passed through the eastern Lost-Fox Basin on May 31. Similar tracks were not found in the Nass or Summit areas of the license.

The fact that (i) these tracks and others were of individual or paired adult caribou, (ii) following a strong directional trend over several kilometres, (iii) through inhospitable terrain, and (iv) showing no sign of foraging suggest that they were made by adult females en route to the traditional sites at which they would drop their calves.

Tracking routes followed at other seasons are insufficient in number to generalize as to their significance. It is clear from general observations that caribou in summer followed and foraged in the river flats of Didene Creek, Little Klappan River, Spatsizi River and the higher meadows of the pass from the Little Klappan River over to the Nass/Upper Klappan drainage. Evidence of historic movements of this kind (i.e., when snow was either minimal or absent in summer months) in these areas was obtained by locating caribou trails on aerial photographs. The locations of these trails are shown in Figure 4-8.

3.2.2.3 Occurrence in the Vicinity of Exploration Activities

During the period mid-May to December, 1985, exploration activities were constant in relation to the Lost-Fox mine with the purpose of further delineating the geology of the anthracite resource and extracting a bulk sample to be used as a trial cargo. Caribou frequenting the vicinity of exploration activities were monitored. Figure 4-9 shows the location of all caribou observed in the period early June to mid-August. Tables 4-13 to 4-15 give details of observations.

The large majority of observations were, as expected, made in the open meadow and river flat areas through which the BCR grade passes. Caribou of all age classes and both sexes were observed. Several mineral licks were located in these areas; their locations are mapped in Figure 4-8. These licks were observed to be used regularly by caribou, and are one of the habitat features attracting caribou to this habitat type.

A total of 15 observations were made during the spring migration and calving period (May 20-June 15), 82 during the post-calving period (June 16-July 16), and 54 during part of the mid-summer period (July 17-August 11). Of the caribou that could be classified as to age and sex, 110 were adult males, 97 were adult females, 23 were subadults (body size indicating either yearlings or small adults, with sex undetermined), 33 were yearlings and 25 were calves. The remaining caribou (131 individuals) could not be classified. Of the 25 calves observed, only one was observed in valley bottom habitat; the remainder were observed by means of the spotting scope at elevations of 1600 m or often considerably higher, usually in groups consisting of more than six caribou.

As an aid in assessing the distribution of caribou in relation to potential development areas, the ground observation data were analyzed by location in relation to the BCR grade (Table 4-16). The purpose of this analysis was to determine whether, in the presence of exploration activities, any trends in area preferences could be detected. The BCR grade was divided into intervals reflecting either zones of particular exploration activity, or zones of expected ecological importance to caribou. Thus Km's 98-105 & 121-134 could be expected to be frequented by caribou as summer range is present in these areas and exploration activities were of relatively low intensity. By contrast, Km's 105-115 and 115-121 carried the most traffic in relation to exploration activities.

TABLE 4-16

LOCATIONS OF CARIBOU IN RELATION TO BCR GRADE

Km Marker Interval[a]	Interval Description	No. of Caribou Observed On Road Surveys	Reports	Total	# Road Surveys[b]
98-105	BCR Grade on lower Little Klappan	6	10	16	72
105-115	Zone of potential major development	10	25	35	76
115-121	Didene Creek flats to Exploration Camp	50	23	73	78
121-134	From Exploration Camp along Spatsizi River Valley	27	14	41	91
134-Garner Creek	Upper Skeena River Valley	0	1	1	10

[a] See Figure 4-9.
[b] Return trips.

Table 4-16 shows that between Km 115-121 (the Didene Creek flats area), 64 percent of the road surveys resulted in an observation of caribou, while between Km 105-115 (the zone where major development is currently planned) 13 percent of the road surveys resulted in an observation of caribou. The percentages for Km's 98-105 and 121-134, where summer range habitat exists but little exploration was ongoing, were 8 percent and 30 percent respectively. It should be noted that the relative observability of caribou in the Didene Creek flats zone is greater due to it being wider and flatter than any of the other zones.

During ground observations, the behaviour of various group sizes of caribou in the presence of activities connected with anthracite exploration were recorded and are presented in Tables 4-17 and 4-18. For the purposes of analysis, caribou were grouped according to the numerically-dominant sex (adult male, adult female) or age-class (sub-adult, yearling) where sex could not be distinguished. Groups containing females with calves were also separated owing to the more nervous nature of their reported behaviour (Bergerud and Butler 1978). Behaviour was classified into three categories as follows:

No Observable Reaction: Caribou continued feeding, resting and moving as they had done prior to the disturbance, or did not appear alarmed by or interested in the disturbance.

Mild Reaction: Caribou oriented towards the disturbance, exhibited "tail-up" posture, or slowly moved away either walking or slow trotting.

Strong Reaction: Caribou fled from the disturbance at a fast trot, canter or gallop, frequently into cover.

Table 4-17 shows that of 85 groups of caribou, 66 showed no observable reaction, 8 showed a mild reaction, and 11 showed a strong reaction. Where a mild or strong reaction was recorded, 15 of these were within 100 m of the BCR grade, three were within 100 to 500 m of the BCR grade, and one was

TABLE 4-17

BEHAVIOR OF CARIBOU AT VARYING DISTANCES FROM HUMAN ACTIVITIES ON THE BCR GRADE[a]

	Group Size											
	1			2			3-6			>6		
Reaction	N[b]	M	S	N	M	S	N	M	S	N	M	S
A. 0-100 m From Grade												
Male	1	2	1	1		1	2	2	1			
Female	1		2	1	2	1						
Female/Calf						1						
Sub-ad/Ylg/Uncl.	2					1		1				
Total	4	2	3	2	2	4	2	3	1			
B. 100-500 m From Grade												
Male	7			2			1			1		
Female				1	1		1		1			
Female/Calf												
Sub-ad/Ylg/Uncl.	3						2		1	2		
Total	10			3	1		4		2	3		
C. >500 m From Grade												
Male	4		1	10			2					
Female	3			2			3			3		
Female/Calf				1			1					
Sub-ad/Ylg/Uncl.	3			1			2			3		
Total	10		1	14			8			6		
D. Total Observations												
Male	12	2	2	13		1	5	2	1	1		
Female	4		2	4	3	1	4		1	3		
Female/Calf				1		1	1					
Sub-ad/Ylg/Uncl.	8			1		1	4	1	1	5		
Total	24	2	4	19	3	4	14	3	3	9	0	0

a See also Table 4-18 for specific disturbance sources.

b N - No Observable Reaction; M - Mild Reaction; S - Strong Reaction.

TABLE 4-18

BEHAVIOR OF CARIBOU IN THE PRESENCE OF SPECIFIC DISTURBANCE SOURCES AS OBSERVED FROM THE GROUND

	Group Size											
	1			2			3-6			>6		
Reaction	N[a]	M	S	N	M	S	N	M	S	N	M	S
A. Pick-up Truck/Car												
Male	9	2	2	14		1	5	2	1	1		
Female	4		2	4	2	1	4		1	3		
Female/Calf				1			1					
Sub-ad/Ylg/Uncl.	8			1		1	4	1	1	4		
Total	22	2	4	19	2	3	14	3	3	8		
B. Gravel Truck												
Male	1											
Female					1							
Female/Calf						1						
Sub-ad/Ylg/Uncl.												
Total	1				1	1						
C. People												
Male	1											
Female												
Female/Calf												
Sub-ad/Ylg/Uncl.												
Total	1											
D. Helicopter (206B)												
Male	1											
Female												
Female/Calf					1							
Sub-ad/Ylg/Uncl.												
Total	1				1							
E. Fixed-Wing Air-Craft												
Male												
Female												
Female/Calf					1							
Sub-adult/Unid.					1			1				
Total					1			1				

[a] N - No Observable Reaction; M - Mild Reaction; S - Strong Reaction.

more than 500 m from the BCR grade.

In terms of group size, six of 30 solitary caribou (20 percent), seven of 26 groups of two caribou (27 percent), six of 20 groups of three- to-six caribou (30 percent), and zero of nine groups of more than six caribou showed an observable reaction to the disturbances. These data suggest that caribou in groups of from two to six animals are more likely to react to disturbance than solitary caribou or caribou in group sizes larger than six.

In terms of the different age/sex groups of caribou, eight of 39 adult male groups (20 percent) showed a reaction, seven of 22 adult female groups (32 percent) showed a reaction, and three of 21 sub-adult/yearling/ unclassified groups (14 percent) showed a reaction. The behaviour of adult females with calves was classified three times, two of which were more than 500 m from the BCR grade. The one adult female with a calf recorded within 500 m of the BCR grade reacted strongly to the disturbance. These data suggest that adult female-dominated groups are likely to react more strongly to disturbances than other groups when encountered within 500 m of the BCR grade.

Table 4-18 associates reactions with specific disturbance sources, and is complementary to Table 4-17. The large majority of disturbance sources recorded were pick-up trucks and cars on the BCR grade. Other sources of disturbances are too limited to allow comparison of reactions between sources.

3.2.3 Grizzly Bears

Table 4-19 and Figure 4-11 show the observations of grizzly bear during 1985. Neither grizzly bears nor their tracks were ebserved during aerial surveys in mid-April and late April/early May when emergence from dens was expected. One freshly-excavated den site was discovered in July at timberline in the bed of a creek flowing into the Little Klappan River downstream of Conglomerate Creek which is just off the license area.

TABLE 4-19

OBSERVATIONS OF GRIZZLY BEARS DURING 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
May 28											1S	1676	L. Klappan R.
May 29											1F,2Y	1676	Above Didene Cr. & Spatsizi R.
May 31*											1U		Lower Klappan R.
June 10			1F,2Y	1280									km 125
June 11*					1S	1280							km 104
June 12*			1F,2S	1341									km 125
June 14*			1M	1280									km 123
June 16*			1F,2S	1341									km 127
June 17*			1F,1S	1311									km 127
June 17			1F,2Y	1280									km 125
June 25*			3A	1311									km 124
June 29*					1A	1189							km 102
June 29*											3U	1128	Skeena R.
June 29*			1A	1311									km 108
June 29			1F,2Y	1280									km 123
June 30			1F,2Y	1341									km 126
June 30*											2A	1128	Skeena R.
July 1			1A	1311									km 125
July 8*			2U	1341									km 129
July 10*									1U	1265			km 144 Garner Cr. Strip
July 12*											1F,2J	1829	km 100 near Conglomerate Cr.
July 19*	1U	1646											Fox Creek
July 21			1F,2Y	1341									near BCR Camp
July 23*			1S	1341									km 125
July 23*			1A	1341									km 129
July 24*									1A	1250			km 144 Garner Cr. Strip

Continued ....

Table 4-19
Concluded

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
July 25*									1M	1250			km 144 Garner Cr. Strip
July 25*									1S	1341			km 133 Grade - Spatsizi R.
July 25*									1S	1250			km 144 Garner Cr. Strip
July 25									1S	1250			km 144 Garner Cr. Strip
July 30*	1A	1524											L. Klappan R.
August 3*	1A	1768											near Drilling Rig
August 3									1A	1250			km 142.6
August 4*	1U	1615											Lost Ridge
August 5*	1F,2Y	1676											Lost Ridge
August 6*			1F,2Y	1493									South of Camp
August 6							1A	1676					
August 7*									1F,2Y	1280			km 123 On Grade
August 7*									1Y	1250			km 145 On Grade
August 8*			1A	1311									North of Camp
August 8*									1A	1250			km 144
August 8							1A	1524					"Nass Pass"
August 9											1A	1250	Kluayetz Cr.
August 9											2A	1402	McCumber Cr.
September 18											1A	1463	L. Klappan R. trib.
October 11							1U	1676					Upper L. Klappan R.

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult;
U - unclassified.

* reported observation

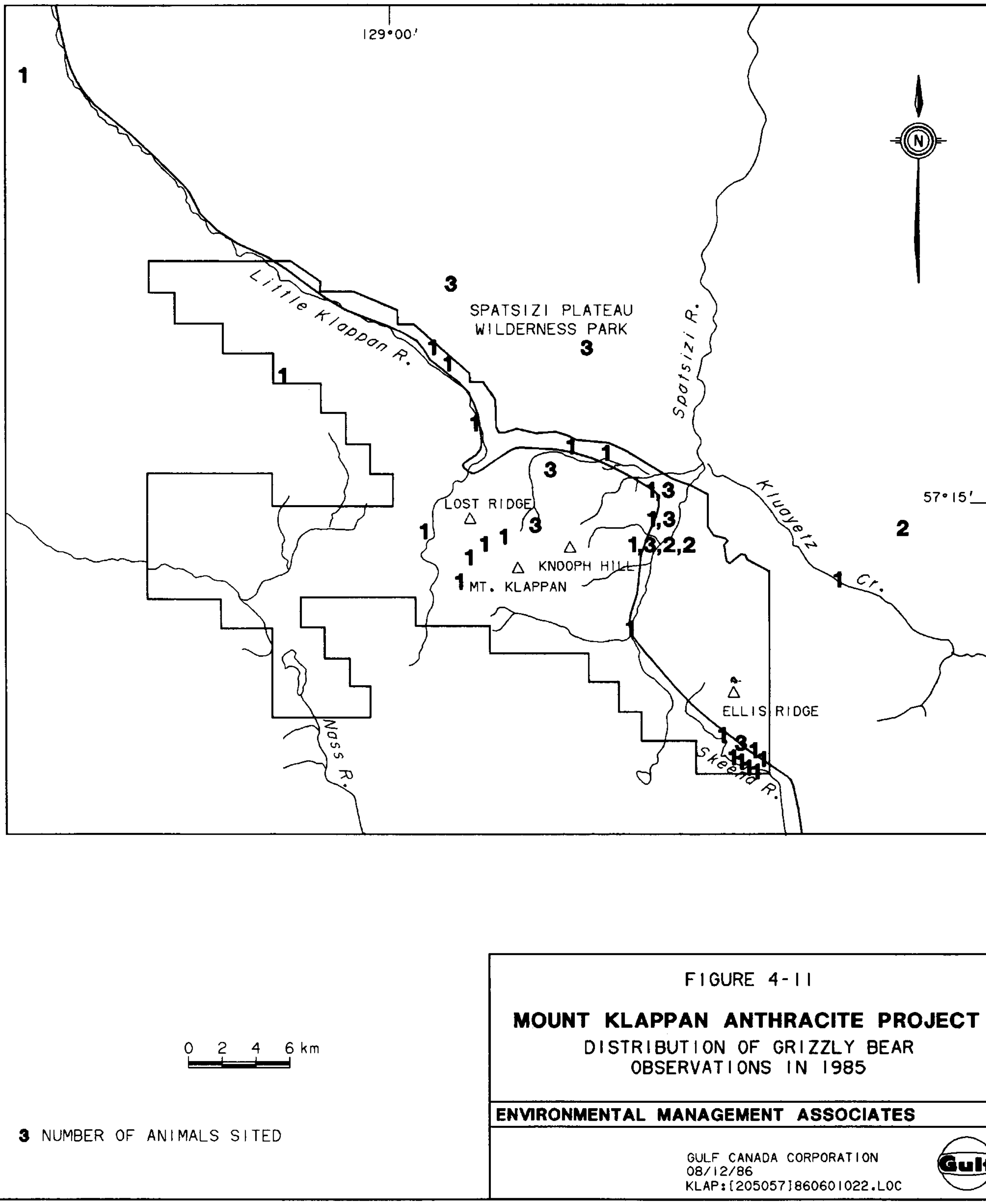


FIGURE 4-11

MOUNT KLAPPAN ANTHRACITE PROJECT

DISTRIBUTION OF GRIZZLY BEAR OBSERVATIONS IN 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
08/12/86
KLAP:[205057]860601022.LOC

The first observation of a grizzly bear was made on May 28 in a snow-covered alpine area just off the licence area on the Little Klappan River, and a sow with two second-year cubs was observed on May 29 in a snow-covered alpine area north of the exploration camp. During 1985, grizzly bear were observed in all parts of the licence area in a wide variety of habitats at all elevations. The majority of observations were made from the ground in the vicinity of the BCR grade. Few observations of grizzlies were made or reported after the continuous ground surveying period ended in mid-August. During subsequent visits in September and October, exploration camp personnel could not recall any observations of grizzlies during this period when canvassed by study biologists. Reported obsorvations of grizzlies had formed a marked proportion of total observations in preceding months (Table 4-19). This suggests that grizzlies made less use of the vicinity of exploration activities in late August, September and October than was the case in June and July. One grizzly was observed in October in the upper Little Klappan River alpine area during aerial surveys.

During June, July and August, grizzlies were regularly observed in the vicinity ef the BCR grade (Table 4-19); however, grizzlies were not observed at the exploration camp. A larger proportion of these observations was made in the Spatsizi River/Hobbit Creek/Broatch Creek area, particularly in June. In July, the headwaters of the Skeena River was an area where several observations were made. This followed the time when access was opened south along the BCR grade beyond Hobbit Creek, thereby permitting observations from the ground.

In spring, when snow cover facilitated tracking, grizzly bears were tracked by helicopter on several occasions (See Figure 4-8). In all cases, the tracks appeared to be a maximum of 48 hours old. On May 28, three grizzlies, probably a sow with two cubs, were tracked across 95 percent snow cover for 16 km along the banks of Kluayetz Creek, moving consistently northwest (downstream). The tracks were lost where snow cover became more sparse towards the Spatsizi River confluence. There were no obvious food sources (e.g., vegetation, small mammals) in the tracking area and no sign of pauses during movement.

On May 29, a sow and two second-year cubs were tracked for a distance of approximately 10 km in 100 percent snow-covered alpine valleys and ridges and observed in an area immediately north of the exploration camp.

These bears moved from one marmot colony to the next, and were tracked to a steep south-facing slope just below an alpine ridge top, where they rested for approximately one hour in some small snow-free patches. The route followed by these bears was erratic, meandering across slopes and valleys. Tracks of a solitary adult grizzly in the same area were also followed on May 29 for a distance of 10 km; this bear also was moving along a meandering route. Evidence of feeding on ptarmigan eggs was found, and of frequent checking of marmot and ground squirrel holes in the snowpack.

On June 5, a solitary adult grizzly was followed for a distance of 15 km from Lower Tahtsedle Creek upstream through forested areas to the high alpine areas on the south side of Mount Klappan. This bear followed a high ridge and then either jumped over or fell through a cornice at 1920 m elevation into the Lost-Fox basin, which it crossed on the east side. It passed through a small cirque on the east side of Knooph Hill, and then descended into the forested area where its tracks were lost near the BCR grade. This bear checked a few marmot holes, but generally did not pause during this movement.

On May 29, an adult grizzly was tracked along the east side of Garner Creek for a distance of 15 km. This bear followed a route mostly ecross high alpine meadows and scree slopes, through deep snow-covered areas and bare patches. It also descended through subalpine forest to cross one valley, and eventually the tracks were lost after it had descended through forest to the Garner Creek meadows. This bear did not appear to pause and check marmot holes, but continued in a general directional trend north towards Kluayetz Creek.

In the fall, on September 18 an adult grizzly (probably a female) was tracked for approximately seven kilometres and observed in the mountains between the Little Klappan and Klappan rivers. This bear followed a general east-southeast direction over a snow-covered pass in the high alpine zone down a valley to forested areas in the vicinity of a mineral lick regularly visited by mountain goats. No evidence of foraging was observed; however, tracking conditions were only fair.

3.2.4 Other Species

Other species or species groups for which observations were recorded included moose, mountain goat, black bear, furbearers and raptors. The observations are listed in Tables 4-20 to 4-24 and mapped (moose, mountain goat and black bear) on Figures 4-12 to 4-14. Some movements of moose and mountain goats are also mapped on Figure 4-8.

Moose were not observed during mid-April and late April/early May aerial surveys (Table 4-20). During aerial surveys between May 27 and June 4, moose were not observed in the licence area, but were commonly observed in the Kluayetz Creek/Spatsizi River area. After June 4, moose were observed regularly during ground surveys in the licence area. A cow with a newborn calf was observed south and upslope of the exploration camp in an area still 95 percent snow-covered on June 6.

In general, moose were restricted to lower elevation sections of the licence area. Moose were rarely observed above timberline in the Lost- Fox basin or Mount Klappan and mountain ranges overlooking the Nass River valley. Cast antlers were occasionally observed in the Little Klappan River valley from Conglomerate Creek upstream; however, no observations were made of moose. From the number of observations in the Didene-Ellis Area, it is clear that moose are common in thet area in spring, summer and fall, particularly near the confluence of Didene Creek and the Spatsizi River.

Some movements of moose were recorded by tracking with a helicopter. On May 27, an adult male was tracked for 2 km moving upstream on the north

TABLE 4-20

OBSERVATIONS OF MOOSE DURING 1985

Date	LICENCE AREA										OFF LICENCE AREA		LOCATION
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA				
	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	
May 27											1M	1371	Didene Cr.trib.
May 27											1F	1158	Spatsizi R.
May 27											2F	1433	Buckinghorse L.
May 28											2M	1214	Kluayetz Cr.
May 28*											2M		Ealue Lake Rd.
May 28*											1M		L. Klappan R.
May 29											1M	1219	Skeena R.
May 29											1F	1554	Garner Cr. Pass
May 30											1F,1Y	1219	Spatsizi R.
May 30											1F,1Y	1219	Kluayetz Cr.
May 30											2M	1189	Kluayetz Cr.
May 30											2M,3F,3Y	1189	Kluayetz Cr.
May 30											1F,2Y	1280	Didene Cr.
May 31											3U	1524	Kluayetz Cr.
June 2											1Y	1524	Buckinghorse L.
June 2											1F,1Y	1646	Taylor Peak
June 3											1F	1524	Garner Cr. Pass
June 4											6M,6F		Didene Cr. - Spatsizi R. - Kluayetz Cr.
June 5			1F	1250									
June 5			1F	1250									
June 5											1F	1067	Klappan R.
June 6*			1F,1J	1433									
June 12*			1F	1219									Hobbit Cr.
June 12*			2M,1F	1219									edge of forest
June 12*			1A	1219									hill break

Continued ...

Table 4-20
Continued

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
June 12*			1F, 1J	1219									Grizzley Cr.
June 12*			2A	1219									km 133 on grade
June 12			1F	1341									km 122.8
June 13			2M	1219									Off Hobbit Tr.
June 15											1F, 1J	1493	Other - Park
June 15*			1M	1341									km 124
June 16			1M, 1F	1311									Off Hobbit Tr.
June 17*			1F	1341									km 127 - Hobbit Pit
June 18			1M	1219									
June 18			1M	1280									km 124.2
June 19*					2Y	1280							km 102 Gravel Pit
June 22			1M	1311									km 125
June 23			1F	1371									km 122
June 23*	1M	1311											Grizzley Cr.
June 24*			1F	1311									km 124
June 25*			1F	1311									km 118
June 25*			1M	1280									km 124
June 25*			2M	1280									km 123
June 25			2M	1280									km 123.5
June 25	1F	125											
June 25			1M	1189									
June 25			1M	1219									
June 27			1M	1280									km 108
June 27			1M	1280									km 124.7
June 27*			1F	1280									km 123
June 30*			1F	1250									km 124

Continued ...

Table 4-20
Continued

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
July 1					1F	1189							km 101
July 4*					2Y	1128							km 102 Gravel Pit
July 6			1M	1250									Off Hobbit Tr.
July 7*			2U	1341									South of Camp
July 9*			2M	1341									km 128
July 9*			1F,2J	1341									km 129
July 10*			1F	1371									BCR Camp
July 15*											1M	1280	Kluayetz Cr.
July 16									2M	1311			
July 16											1M	1250	Skeena R.
July 17*	1F,1J	1420											Fox Cr.
July 17*			2F	1341									km 132
July 17*			1F,1J	1219									Spatsizi R.
July 19									1M	1524			km 134 In Park
July 20*			1F,1J	1341									km 108
July 23*			1F,1J	1371									BCR Camp
July 23*			1M	1311									Spatsizi R.
July 25*			1F,1J	1371									BCR Camp
July 26									1M	1250			Between Jack & Blume creeks
July 26*			1M	1341									km 127
July 27					1A	1493							km 104
July 28*			1F,1J	1341									km 119
July 30*			1F,1J	1524									Knooph Hill
July 30*			1F	1524									Knooph Hill
August 6*			1F	1524									Knooph Hill
August 6											1F	1097	Spatsizi R.
August 7			1F	1219									
August 7					1M	1524							

Continued ...

Table 4-20
Concluded

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
August 7*	1F	1524											Lost Fox
August 9			1M	1250									
August 9			1F,1J	1250									
August 9			2M	1493									
August 9					1M	1341							
August 9											1F	1250	Kluayetz Cr.
August 9											1F,1J	1250	Kluayetz Cr.
August 9											2F	1219	Kluayetz Cr.
August 9											2M	1554	Mt. Thule
August 10*			2Y	1371									BCR Camp
September 16			1M	1280									
September 16					1M	1554							
September 16							1M,1F	1128					
September 16							1M,1F	1128					
September 18			1M,1F	1493									
October 13			1F,1J	1585									
October 13			1M,1F	1615									
October 13			1M,2F,2J	1433									
October 13											1M	1189	Spatsizi R.
October 13											1M,1F	1463	Mt. Thule
October 13											1M	1371	Buckinghorse L.

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult; U - unclassified.

* reported observation

TABLE 4-21

OBSERVATIONS OF MOUNTAIN GOATS DURING 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
April 29											1A	1463	Klappan R. trib.
May 27											1U	1768	Nass R. trib.
May 27											1U	1311	Klappan R.
May 28					1A	1981							
May 28											1A	1981	Klappan R. trib.
May 28											2A	1737	L. Klappan R. trib.
May 28											1A	1768	Conglomerate Cr.
May 30											4A	1829	Mt. Gunanoot
May 30											1F,1J,1A	1768	Buckinghorse Cr. trib.
May 31											1M	1951	Mt. Gunanoot
May 31											1F,1Y	1524	Mt. Gunanoot
June 2					2F,1J	1798							
June 2											1A	1920	Tsetia Cr. trib.
June 2											2U	1981	Taylor Peak
June 3											1F,1Y	1676	Garner Cr. trib.
June 3											3M	1707	Mt. Gunanoot
June 3											3A	1727	Mt. Gunanoot
June 4											5U,1J	2103	Mt. Gunanoot
June 25*											3F,3J	1524	East of Garner Cr.
June 28					6A,1J	1829							above km 98.5
June 29					3A	1829							above km 98.5
June 29*											3F,2J	1524	East of Garner Cr.
July 2					7A,1J	1829							above km 98.5
July 6*					2F,2J	1829							near Repeater
July 12*											3A	2012	Other - Park
July 12*					7A,2J	1829							near Repeater
July 12											1A	2103	Conglomerate Cr.
July 15											4F,4J,1S	1402	L. Klappan R. trib.

Continued ...

Table 4-21
Concluded

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
July 15											1F,1S	1829	Klappan R. trib.
July 15											4U	1829	Klappan R. trib.
July 15											1F,2S	1981	Conglomerate Cr.
July 16											2F,2J,1S	1829	Skeena R. trib.
August 9					8F,3J,2S	1707							
August 9											1M	1707	Conglomerate Cr.
September 18											1M	2195	Mt. Gunanoot
October 11											3U	1829	Klappan R. trib.

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult;
U - unclassified.

* reported observation

TABLE 4-22

OBSERVATIONS OF BLACK BEARS DURING 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
May 28*											1U	on grade	km "76" L. Klappan R.
May 29*											1A	on grade	km 72 Tsetla Cr.
June 5*											1S	on grade	near "76"
June 9*											2U	1524	km 83
June 11*											1U		Ealue Lake Road
June 13*			1A	1250									km 124
June 14*			1U	1341									km 121
June 17			1A	1341									km 125
June 18*											1S	on grade	km 84 L. Klappan R.
June 21*			1F,1J	1341									km 123
June 23*									1A	1250			Tahtsedle Cr.-Spatsizi R.
July 1*			2A	1371									Near Summit Strip
July 3*											1S	on grade	km 82
July 8					1A	1493							km 105
July 11*			1S	1341									km 118
July 12											1A	1402	Conglomerate Cr.
July 17*			1U	1341									km 124
July 20*			1U	1341									km 110 Summit Strip
July 20*			2U	1341									km 123
July 20*	1U	1341											km 112 Prep. Plant Access
July 24*			1A	1341									km 121

Continued ....

Table 4-22
Concluded

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
July 25-27			1F	1341									km 120
July 27*			1A	1341									km 121
July 31			1A	1341									km 121
August 1			1A	1341									km 121
August 1*			1A	1341									km 118
August 2*			1A	1341									km 115 Didene Cr.
August 3			1A	1250									km 123
August 9											1F,1J	1433	L. Klappan R.
August 10			1A	1341									Old BCR Camp Tr.

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult;
U - unclassified.

* reported observations

TABLE 4-23

OBSERVATIONS OF FURBEARERS DURING 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
April 16					Wolver-ine	1676							
April 16					Wolver-ine	1524							
May 29											Wolver-ine	1920	Taylor Peak
May 30											1A Wolf	1341	Fire Flats
June 9*			Marten	1341									km 120 at camp
June 19*					Marten	on grade							km 105
June 23*	1A Fox	1829											Lost Ridge
June 24*					1U Wolf	on grade							km 92
June 24			1U Fox	1341									km 115
June 29					1U Fox	1280							km 99
July 3*	1A Wolf	1341											Lost Ridge Access Rd.
July 4			Wolver-ine	1371									
July 16							1J Wolf	1524					
July 17*			Wolver-ine	1341									km 123
July 18*					1A Wolf	1890							alpine
July 18*											1A Wolf	1250	km 150
July 19			Wolver-ine	1341									km 127.2
July 20*			1A Wolf	1341									North of Camp

Continued ...

Table 4-23
Concluded

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
August 1	1U Fox	1524											Lost Ridge Access Rd.
August 8											Wolverine		In Park
August 9*	Wolver-ine	1402											Lost Ridge Access Rd.
August 9											Wolver-ine	1036	Spatsizi R.
August 9											2A Wolf	1676	Above Didene Cr.
September 17									Beaver	1158			Spatsizi R.
September 17									Beaver	1189			Skeena R.
September 17											Beaver	1189	Skeena R.
October 11							1A Fox	1676					

Abbreviations: M - adult male; F - adult female; J - juvenile (<12 mos); Y - yearling (> 12 mos); S - subadult; A - adult;
U - unclassified.

* reported observation

TABLE 4-24

OBSERVATIONS OF RAPTORS DURING 1985

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
April 29							1GE	1219					
April 29											1GE	1676	L. Klappan R. trib.
May 27	1GE	1890					1GE	1615					
May 27			1GE	1951									
May 27							1GE	1615					
May 27											1GE	1433	Buckinghorse L.
May 27							1GE	1615					
May 28	1GE	1737											
May 28							Inactive GE Nest	1951					
May 28											Inactive GE Nest	1768	L. Klappan R.
May 28											1GE	1707	Spatsizi R. trib.
May 30	2GE	1707											
May 30							1GE	1402					
May 30									1GE	1829			
May 30											1GE	1646	Klappan R. trib.
May 30											1BE	1280	Buckinghorse Cr.
May 31	1GE	1737											
May 31	1GE	1798											
June 1											1GE	1524	Didene Cr. trib.
June 2	1GE	2012											
June 2					1GE	1676							
June 2					2GE	1676							
June 2											1GE	1981	Mt. Gunanoot
June 2											1GE	2042	Mt. Gunanoot
June 2*			1GE	1341									km 115
June 3											1GE	1524	Mt. Gunanoot
June 3											1GE	2134	L. Klappan R. trib.
June 4											2GE	1219	Kluayetz Cr.

Continued ...

Table 4-24
Continued

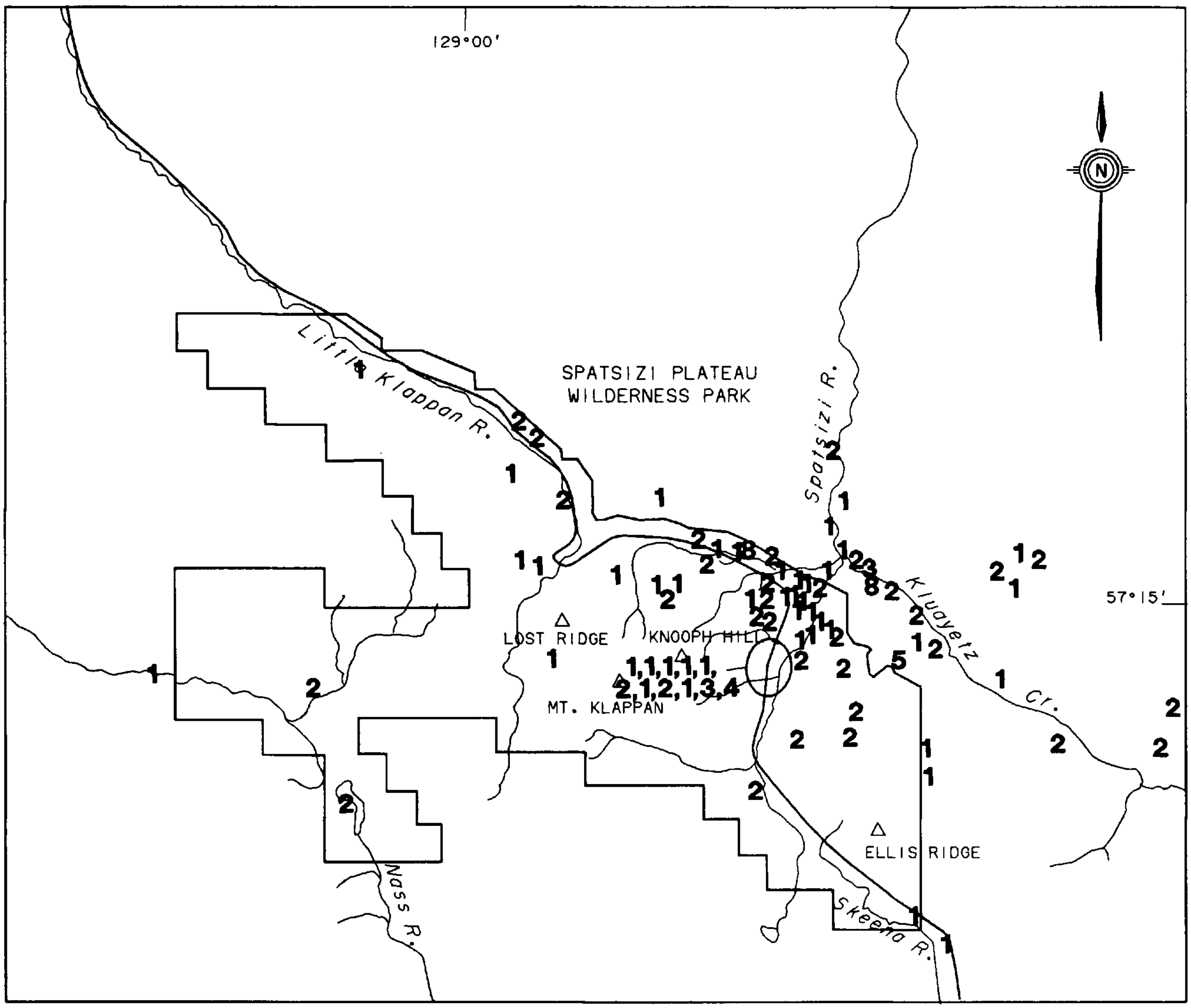
Date	LICENCE AREA: MT. KLAPPAN Age/Sex	MT. KLAPPAN Elev(m)	DIDENE-ELLIS Age/Sex	DIDENE-ELLIS Elev(m)	SUMMIT Age/Sex	SUMMIT Elev(m)	NASS Age/Sex	NASS Elev(m)	SKEENA Age/Sex	SKEENA Elev(m)	OFF LICENCE AREA Age/Sex	OFF LICENCE AREA Elev(m)	LOCATION
June 5	1GE	1981											
June 5	2GE	1707											
June 5							1GE	1524					
June 5											1BE	1067	Klappan R.
June 6											1GE	1859	Above Spatsizi R.
June 12*	1GE	1676											Lost Ridge
June 18			2GE	1341									km 114 Met. Stn.
June 26*	1GE	1676											Lost Ridge
June 27*	1GE	1493											Lost Ridge
June 29			1GE	1371									
July 4	1GE	1676											Fox Cr. Basin
July 4			1NH	1341									km 116
July 4	1GE	1676											
July 4											1BE	1128	Spatsizi R.
July 4											1F	1341	Spatsizi R.
July 7*	1GE	1585											Lost Ridge
July 8											1GE	1829	In Park
July 8			1RT	1341									km 119
July 16	1GE	1707											
July 23			1RT	1341									km 104.5
July 23			1NH	1341									km 119
July 24			1NH	1311									km 106.1
August 1											3GE	1585	In Park
August 1											1GE	1585	In Park
August 2											1GE	1585	In Park
August 3											3GE	1585	In Park
August 5											1GE	1585	In Park
August 6							1GE	1615					Above Upper-L. Klappan R.
August 8											2GE	1585	In Park

Continued ...

Table 4-24
Concluded

	LICENCE AREA												
	MT. KLAPPAN		DIDENE-ELLIS		SUMMIT		NASS		SKEENA		OFF-LICENCE AREA		
Date	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	Age/Sex	Elev(m)	LOCATION
August 8			1SH	1341									km 120.8
August 8											1BF	1585	In Park
August 9			1SH	1311									km 117.7
August 9			1GE	1829									
September 16	1GE	1798											
September 16											1GE	1829	Didene Cr. trib.
September 18			1GE	1890									
September 18									1GE	1981			
September 18											1GE	1737	L. Klappan R. trib.
September 18											1GE	1646	L. Klappan R. trib.
September 18											1GE	1829	Butler Cr.
September 18											1GE	1981	Above Spatsizi R.
September 18											1GE	1676	Kluayetz Cr. trib.
September 18											1GE	1890	Kluakaz Cr.
September 18											1GE	1951	Nass. R. trib.
September 18											1GE	2073	Tahtsedle Cr.
October 13											1BE	1219	Spatsizi R.

Abbreviations: GE - Golden Eagle; BE - Bald Eagle; NH - Northern Harrier; RT - Red-tailed Hawk; SH - Swainson's Hawk; F - Unidentified Falcon
* reported observations



0 2 4 6 km

3 NUMBER OF ANIMALS SITED

FIGURE 4-12

MOUNT KLAPPAN ANTHRACITE PROJECT

DISTRIBUTION OF MOOSE
OBSERVATIONS IN 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
08/12/86
KLAP:[205057]860601017.LOC

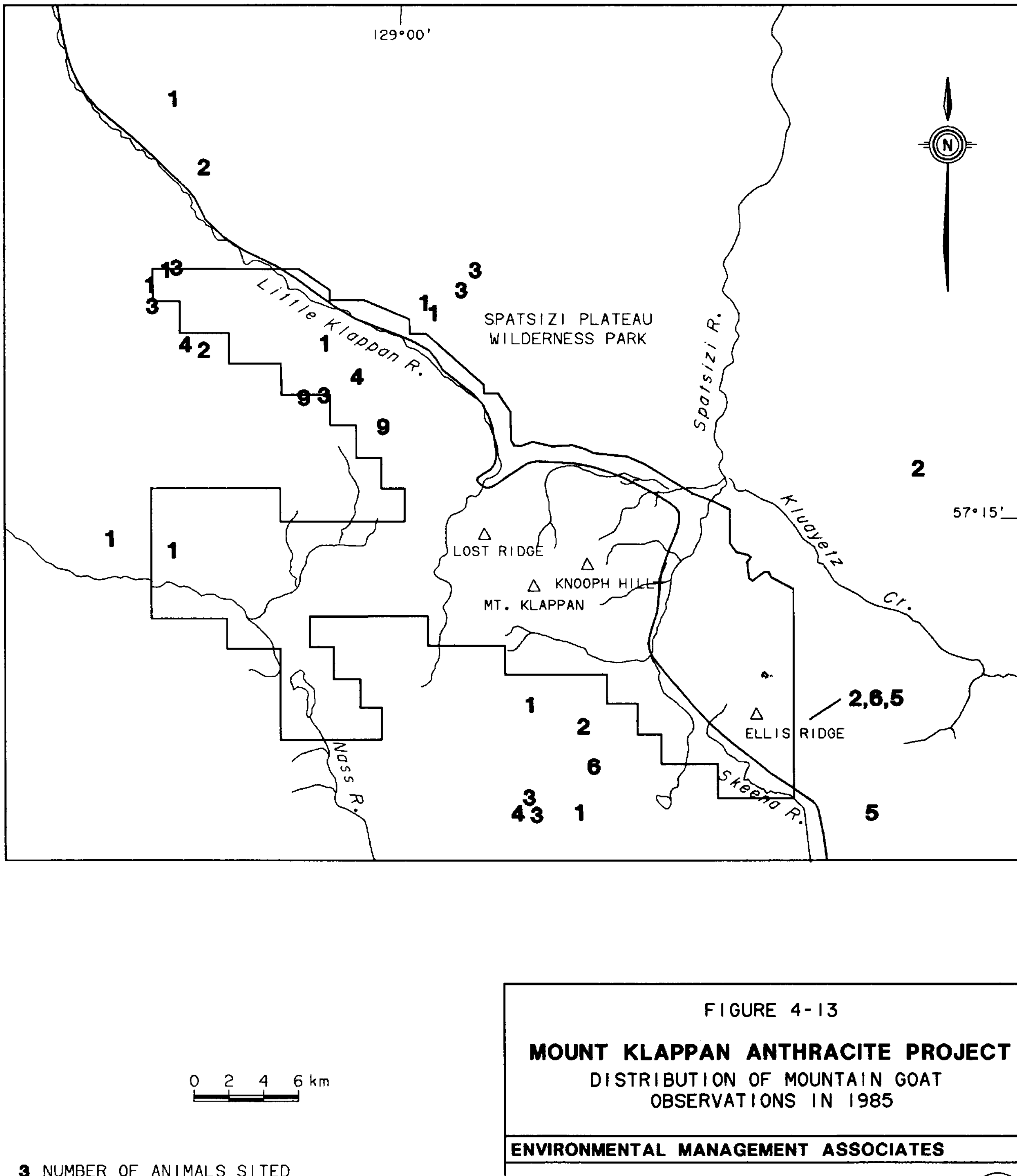


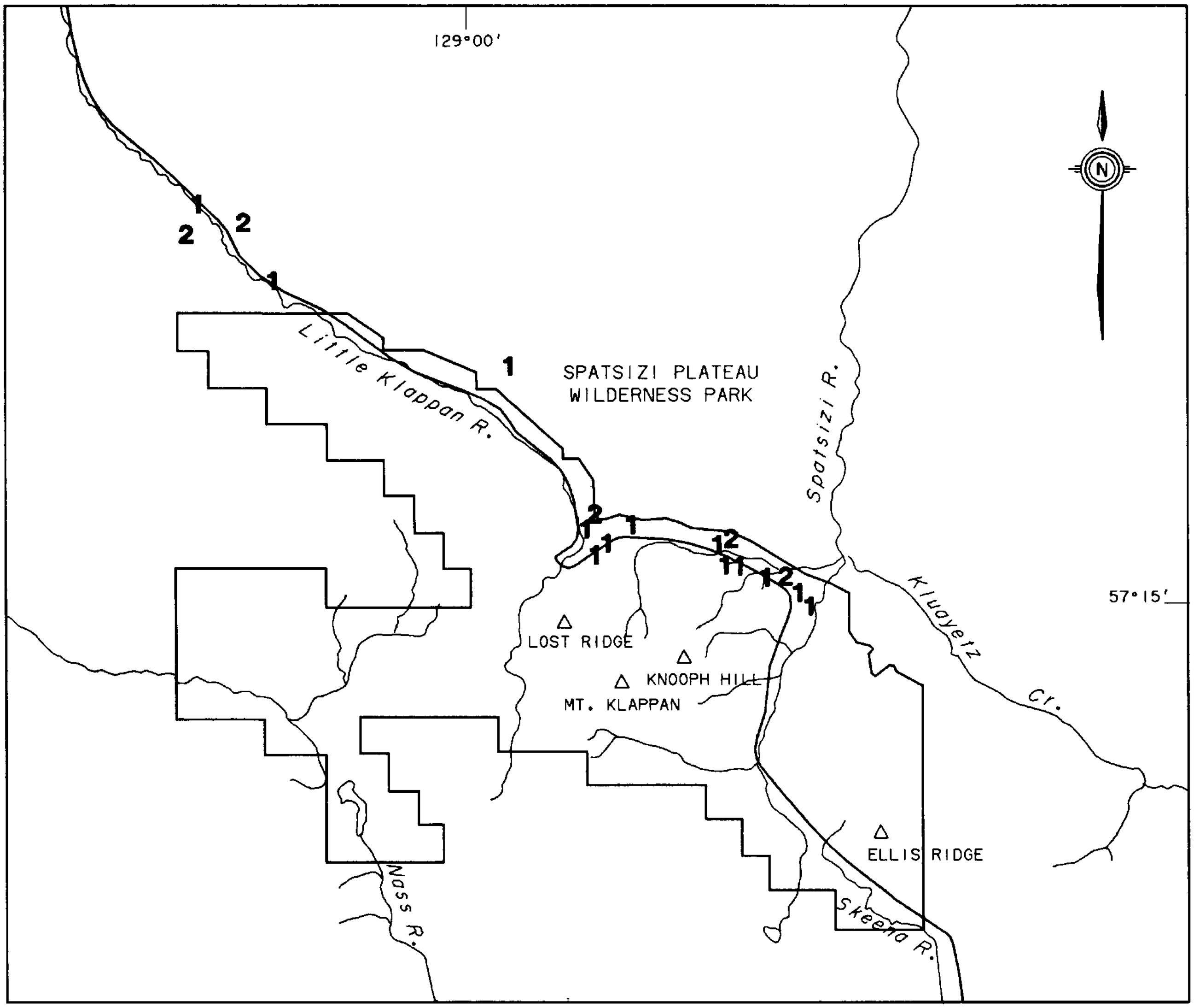
FIGURE 4-13

MOUNT KLAPPAN ANTHRACITE PROJECT

DISTRIBUTION OF MOUNTAIN GOAT OBSERVATIONS IN 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
08/12/86
KLAP:[205057]860601023.LOC



0 2 4 6 km

3 NUMBER OF ANIMALS SITED

FIGURE 4-14

MOUNT KLAPPAN ANTHRACITE PROJECT

DISTRIBUTION OF BLACK BEAR OBSERVATIONS IN 1985

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
08/12/86
KLAP:[205057]860601018.LOC

side of Didene Creek. Another unobserved moose was tracked for a similar distance on May 29 in the same location. On May 30, fresh tracks were followed upstream into the forested area on the south side of Didene Creek, south of the exploration camp, for 1.5 km generally following shallow ravines. On May 29, two movements from the Spatsizi River headwaters area into the Skeena River drainage were recorded. Both of these were approximately 6 km, and both involved walking on top of heavily-encrusted snow, leaving very little indentation, and walking on the BCR grade. One of these moose - a young male - was observed in a small snow-free patch of willow on the banks of the Skeena River. On May 30, two moose were tracked for 3 km, but not observed, moving upstream along the edge of sedge meadows on the north bank of the headwaters of the Klappan River.

The above movements suggest spring movement upstream along river valleys towards the higher-elevation habitats of the licence area. The movements upstream along the Spatsizi River and Didene Creek are corroborated by the observations of Ray and Reg Collingwood (pers. comms.) further downstream on the Spatsizi River. In both 1984 and 1985, exploration personnel at the Didene camp have reported sudden concentrations of moose, numbering 10-20 animals, in November in the Spatsizi/Hobbit/ Broatch areas, during or just prior to major snowfalls. This is suggestive of a fall movement to lower elevations to escape deep snow.

Moose were regularly (but not commonly) observed in summer in the vicinity of lower elevation exploration activities, usually where activities were less intense (e.g., downstream on the Little Klappan River; east in the Spatsizi River area).

Observations of mountain goat (Table 4-21, Figure 4-13) did not reveal new distributional information beyond that reported in the Stage I Submission. More goats were observed in the mountains south of the licence area (Mount Gunanoot area) than in 1984, and some movements were recorded along ridge tops (Figure 4-8). The Summit Area remains the most important goat range in the licence area.

Black bears (Table 4-22, Figure 4-14) were observed more frequently in 1985 than in 1984 owing to the presence of a ground survey biologist. Observations were more frequent in the Little Klappan River valley than in the Spatsizi River/Didene Creek valleys. Black bears were observed occasionally at the exploration camp.

Furbearers (Table 4-23) were observed in a wide variety of habitats throughout the licence area. Seven observations of wolves, totalling eight individuals, were made. In all but one instance, the wolves were solitary. These spring, summer and fall observations may be in contrast to the winter, when wolf social behaviour may change, and packs are formed (D. Hatler, Ray and Reg Collingwood, pers. comms.). Wolverines were observed nine times, usually at or above timberline. This species and the red fox (observed five times) appear to be relatively common in the licence area.

Golden eagles (Table 4-23) were recorded during almost every aerial survey, and are common and widespread at higher elevations (above timberline) in the licence area. No new nest sites were discovered. Bald eagles were rarely observed.

3.3 HABITAT ANALYSIS

In order to assess the relative importance of areas alieneted from wildlife use by project development, a detailed analysis of the wildlife habitats affected by the project was conducted. Since many of the development areas have already been influenced by human activities, it was decided that a set of comparative habitats would also be evaluated, which have not been disturbed by recent activity, and would serve as surrogate indicators of the importance of the habitat type to wildlife.

"Development" areas associated with the Lost-Fox project are the pit area, waste disposal area, water reservoir, camp site, anthracite preparation plant site, power plant site and the tailings pond area. For each development area, a corresponding "control" area was selected to duplicate the principal characteristics of the wildlife habitats represented in development areas. Control area selections considered the following factors:

1. It emulates the degree of historic or human disturbance of the development area.

2. It has an overall relevance to the sensitive life history stages of the wildlife similar to that of the development area.

3. It is topographically comparable te the development area in position, elevation above sea level, slope aspect and slope angle.

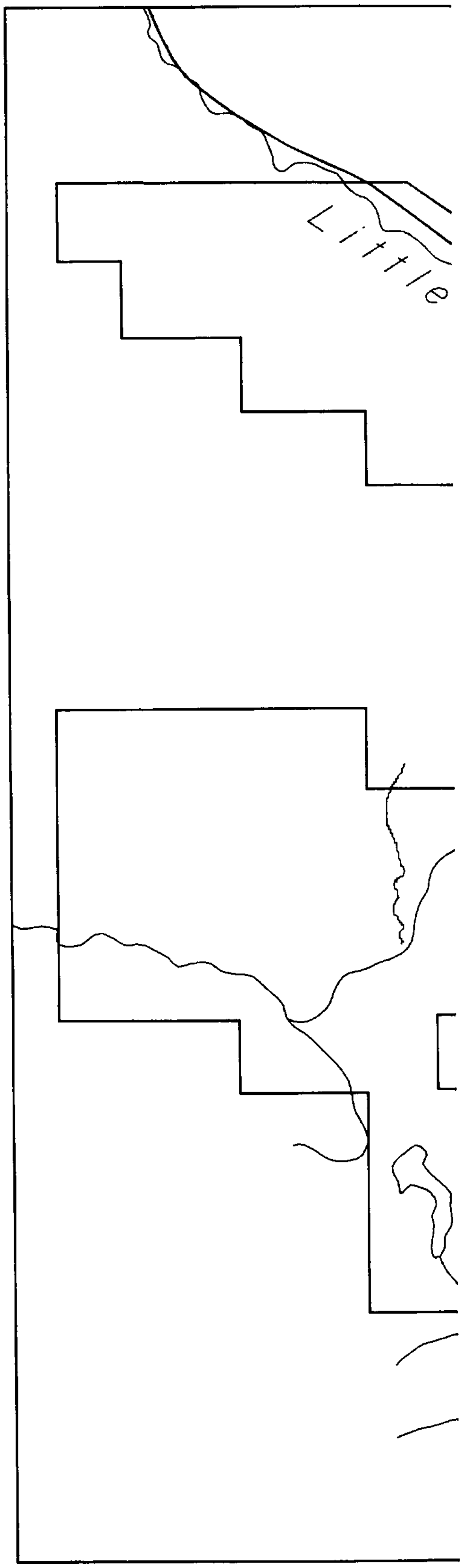
4. The vegetation association is comparable to the development area.

The methods by which the comparative areas were selected were as follows.

Aerial photographs at two scales (1:8 000 and 1:30 000) were interpreted for Land Type comperability. Plots for field examination within each of the development areas were located on these photographs. Potential control sites comparable to the mine development sites were similarly selected. The intent here was to match the biophysical characteristics and relevance to wildlife of the mine development sites. Figure 4-15 indicates the locations of the sampled sites.

Twenty-one development and control sites were sampled in July, 1985 using transect surveys. The configuration and direction of these transects were dictated by (i) land type boundaries; (ii) consistency of pattern; and (iii) compass bearings to facilitate replicability.

Along each transect, data on habitat composition (biophysical site conditions and plant species list) and wildlife sign were collected. Wildlife sign included pellet groups and tracks of ungulates, diggings of bears, tracks, trails, burrows, scats and colonies of small mammals, and scats of upland game birds. Gnazing and browsing were also assessed using circular plots along the transect. Grazing and browsing use were related to the estimated available cover of the forage species.



GUIDE TO DEVELOPMENT AND CONTROL SAMPLING SITE NUMBERS

	SAMPLING SITE NUMBER	CONTROL SAMPLING SITE NUMBER
PIT SITE	1	1c
PIT SITE	2	2c
WASTE ROCK DISPOSAL	3	3c
WASTE ROCK DISPOSAL	4	4c
WASTE ROCK DISPOSAL	5	5c
RESERVOIR	6	6c
CAMP	7	10c
PREPARATION PLANT	8	12c
POWER PLANT	9	12c
TAILINGS POND	10	10c
TAILINGS POND	11	11c
TAILINGS POND	12	12c
TOTAL SITES	12	9

EXTENSION OF STUDY AREA

0 2 4 6 km

FIGURE 4-15

MOUNT KLAPPAN ANTHRACITE PROJECT

WILDLIFE HABITAT LOCATIONS

ENVIRONMENTAL MANAGEMENT ASSOCIATES

GULF CANADA CORPORATION
18/12/86
KLAP:[205057]860601027.LOC

3.3.1 Description of Comparative Sites

Mine Sites and Control Sites

Mine Site 1, alpine tundra is a moderately sloping, exposed south-facing ridge at an elevation of 1760 to 1790 m. A thin mantle of discontinuous colluvial material covers the underlying bedrock restricting soil development to Orthic Regosols.

Periglacial and colluvial processes are active throughout the year, with snowfree periods limited to only two or three months annually. The vegetation consists of alpine forbs and grasses, comprising a mosaic of Altai fescue bunches interspersed with reindeer lichens, mosses and bare ground. Moss campion, alpine forget-me-not, saxifrage and mountain avens add diversity.

Mine Site 2, subalpine grassland/forb heath is located at an elevation of 1700 to 1730 m. The topography consists of a series of short, incised slopes below the upper ridge which are blanketed in a variable thickness of colluvial material. The soil is typically a sombric Ferro-Humic Podzol characterized by a gravelly, sandy-clay texture. Dwarf willow occur within the plot as shrub species become more abundant with reduced elevation and exposure. The heath vegetation is made up predominantly of Altai fescue, cotton grass, sedge and cassiope.

The control sites were located on a south-facing ridge in the Mount Klappan-Tahtsedle Creek Area. This ridge afforded a similar juxtaposition of land types and conformity to the same biophysical characteristics of the two mine sites. The essential characteristics are those as described for the two mine sites. Minor differencos include a higher elevation for the alpine tundra site and slightly steeper, wetter slopes within the subalpine grassland/forb heath site.

Waste Rock Disposal Sites and Control Sites

The waste rock disposal site development area encompasses three dominant land types on the west-facing slopes of the Little Klappan valley. These include: alpine tundra, subalpine fir-Englemann spruce, and subalpine fir-mixed conifer/ shrub. This represents the typical transition in vegetation zones found in the mine development area from the high alpine to the upper valley slopes.

Waste rock disposal Site 3, alpine tundra is similar to that described for Mine Site 1. It is located at a comparable elevation on the west-facing crest of Lost Ridge. Slopes are incised and the surface expression is generally more complex at this site, enabling a range of plant species to establish on a variety of micro-habitats. Dwarf willow, sedge and moss species are found in association with ephemeral drainage channels. Altai fecue and mountain heaths are prevalent on intervening dry sites. Loose scree and avalanche slopes are characteristic of this elevation within the waste rock disposal site area.

Waste rock disposal Site 4, subalpine fir-Englemann spruce is characterized by Krumholz subalpine fir at upper elevations, grading gradually into Englemann spruce at lower elevations. Numerous creeks and seepage sites drain the hummocky mid-slopes producing a complex terrain characterized by patches of subalpine fir and crowberry on well-drained ridges, intermingled with willow, sedge and Labrador tea along drainage courses. This patchwork of vegetation associations makes this one of the most distinctive land types in the area.

Waste rock disposal Site 5, subalpine fir-mixed conifer-shrub is at the lower elevations of the dump site and is found at the break of slope above the immediate valley floor. Colluvial material derived from the upper slopes is responsible for the development of Orthic Ferro and Humic Podzols, which are fine to medium-textured and generally well-drained. Subalpine fir forms the dominant canopy coverage intermixed with minor amounts of Englemann spruce. The well-developed shrubcover is comprised primarily of willow species and affords plentiful browse and cover opportunities for widlife.

The control sites for the waste rock disposal area, 3C, 4C and 5C are located on the west-facing slopes of Garner Creek. This is outside the licence area as no adequately comparable sites were found within the licence area. Elevations were comparable for each control site, and the same transition of land types was evident on the slope. The mid-slope control site (4C) lacked Englemann spruce cover. However, the typical subalpine fir mosaic was clearly evident, and satisfied the criteria for site selection.

Reservoir Site and Control Site

Reservoir Site 6 occupies the lower alluvial floodplain of the Little Klappan River. The site is characterized by wandering meander loops and low-relief fluvial sands and gravels. Soil development is restricted to Orthic Regosols, supplemented by annual sediment derived from spring flooding.

The vegetation is dominated by short shrub willow species with an understory of sedge and moss cover. Other common species include: colt's foot, marsh marigold and horsetail. Such alluvial valley sites are typical of rivers within the study area.

The control site (6C), within the Spatsizi River valley, was selected for its similar alignment and morphological characteristics. At this point the valley is restricted by a series of alluvial terraces composed of sand and gravel deposits. The sites provide abundant browse species for ungulates, but are subject to snow accumulation during the winter months. At other times of the year, floodplain terraces may be used as travel corridors within the study area, particularly by caribou.

Camp, Preparation Plant and Power Plant Sites and Control Sites

The camp (Site 7), preparation plaot (Site 8), and power plant (Site 9) are located within the white spruce-willow land type on the lower, north-facing slopes of Lost Ridge. The camp and preparation plant sites occur at an elevation of 1340-1370 m, adjacent to the BCR grade. Soils are typically Orthic Humic and Ferric Podzols, developed on a blanket of colluvial material which in turn overlies a deep till deposit.

Mature white spruce dominates the overstory vegetation, which is relatively open (35 percent cover) and affords a variety of short and tall shrub cover. Willow, bog birch, crowberry, bearberry and blueberry are typical components of the understory, which is often complemented with deadfall to provide good thermal and hiding cover for wildlife. Open sedge meadows within the forest canopy result from seepage points at minor breaks in slope or where impervious clays pond water near the surface. Evidence of solifluction is revealed in the "ribbed" surface expression of many of these wet meadows. Although not extensive in size, these wet meadows occur throughout this land type, and often show signs of utilizatioo by caribou or moose where food species such as marsh marigold, sedge and dwarf willow are abundant.

The power plant would be located to the north of and downslope of the preparation plant. Although similar to Site 8 in overall habitat characteristics, the lower elevation, reduced slope angle and proximity to the Little Klappan River reduce efficiency in soil drainage and lead to a more open canopy coverage where willow, bog birch and moss species typify the vegetation association. Other common components of the understory include crowberry, blueberry, fireweed, arctic lupine and bunchberry.

The canopy coverage increases to about 40 percent along the steeper slopes immediately below the BCR grade where drainage conditions are locally improved. At the break of the slope, however, the canopy coverage is sparse and affords little cover for wildlife. Arboreal lichen is plentiful throughout this land type.

The control site (12C) for the camp, preparation and power plant sites is located within the same land type, at the same elevation, on the north-facing, lower colluvial slope bordering Didene Creek. The vegetation cover is very similar to that of Sites 7, 8 and 9, and attests to the uniformity of this land type throughout the study area.

Tailings Pond Sites and Control Sites

Three sites were selected within the area to be occupied by the tailings pond: one site from the lower, southwest-facing slopes of the Little Klappan River terrace (Site 10), one site from the central sedge-willow alluvial floodplain (Site 11) and one site from the north-facing slopes of the Little Klappan River terrace (Site 12).

Site 10 was located at an elevation of 1305 to 1340 m on a gentle, moraine-covered slope overlooking the alluvial floodplain. The overstory is dominated by a canopy of subalpine fir with an understory of willow species, fireweed, cloudberry and grasses. White spruce are common as seedlings, and may succeed subalpine fir at these elevations. Soils are typically moderate to coarse grained Ferro Humic Podzols, and are generally well drained.

Site 11 covers part of the alluvial valley of the Little Klappan River, and represents the lowest elevation of all the sites investigated. Although generally level, minor topographic relief is afforded by remnant braided channels, the slopes of which are well drained and grass covered. Vegetation cover is dominated by willow and bog birch with a sedge understory. Periodic flooding and a water table characteristically close to the surface limits the range of understory species present within depressions and channel bottoms. Soils are typically Orthic Regosols or Terric Mesisols.

Site 12 occupies the north-facing lower slope of the Little Klappan River terrace. It is characterized by a relatively closed-cover white spruce overstory, with willow, fireweed, horsetail and groundsel common in the understory. Site elevation is similar to Site 10. Seepage sites occur along the break of slope at the junction of the lower colluvial slopes and the alluvial valley. Willow, horsetail and mosses typify such sites. Soils are typically sandy-loam Ferric Humic Podzols, with grain size increasing with depth and proximity ot the alluvial floodplain.

Three comparable control sites (Sites 10C, 11C and 12C) were selected along Didene Creek where the general elevation, topography and juxtaposition of land types afforded a location essentially similar to the tailings pond sites. Of particular importance to the selection of the control sites was similarity of drainage conditions and slope aspect. There is an abundance of browse species available in the willow-sedge valley bottom as well as good hiding and thermal cover in adjacent forested land types.

3.3.2 Habitat Utilization of Comparative Areas

Mine Sites and Control Sites

The occurence of wildlife at Mine Site 1, characterized by exposed, alpine tundra slopes which are only periodically free of snow, is restricted to occasional use by caribou and small mammals especially adapted to these conditions (Table 4-25). Caribou pellet density was 6.6/ha and a caribou trail ran through the site. Grazing utilization was exclusively limited to Altai fescue bunch grass which was cropped throughout the plot. High use of this site by small mammals was noted.

Control Site 1C showed little wildlife use. Some grazing of Altai fescue bunches was evident. Small mammal sign was present but reflected only limited use.

Mine Site 2, subalpine grassland/forb heath, showed evidence of use by ungulates. Caribou tracks and browse utilization were noted (Table 4-26). No pellet groups were recorded. Small mammal sign was particularly prevalent, with ground squirrel, marmot and ptarmigan comprising the dominant

TABLE 4-25

COMPARISON OF WILDLIFE SIGN IN PIT SITE[1] 1 AND CONTROL SITE 1C

	Pit Site 1		Control Site 1C	
A. Pellet Groups	Total	Density/ha	Total	Density/ha
Caribou	2	6.6	0	0
Moose	0	0	0	0
Goat	0	0	0	0
TOTAL	2	6.6	0	0
B. Browse (Grazing)	Total Stems	% Utilization	Total Stems	% Utilization
(*Festuca altaica*)	635	8.2	581	5.2
TOTAL	635	8.2	581	5.2
Lichens	Arboreal	Ground	Arboreal	Ground
% cover	0	18.0	0	7.2

C. Other Sign	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel	12		1		11		24	1				2		3
Vole								1		3		4		8
Marmot			3		1	1	5		1	2				3
Ptarmigan			3				3			2				2
Grouse														
Grizzly Bear														
Caribou	1						1							
Moose														
Goat														
Unknown	4						4							
TOTAL	17		7		12	1	37	2	1	7		6		16

D. Summary Index	Pit Site 1	Control Site 1C
Total Pellet Groups Density/ha	6.6	0.0
Total Browse Utilization (%)	8.2	5.2
Total Other Sign	37	16

1 For locations of sites, see Figure 4-15

2 Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

TABLE 4-26

COMPARISON OF WILDLIFE SIGN IN PIT SITE[1] 2 AND CONTROL SITE 2C

	Pit Site 1		Control Site 1C	
A. Pellet Groups	Total	Density/ha	Total	Density/ha
Caribou	0	0	0	0
Moose	0	0	0	0
Goat	0	0	0	0
TOTAL	0	0	0	0
B. Browse (Grazing)	Total Stems	% Utilization	Total Stems	% Utilization
(*Carex aquatilis*)		10.0	0	0
(*Festuca altaica*)	142	9.9	608	2.8
Salix arctica	81	0	0	0
TOTAL	223	6.3	608	2.8
Lichens	Arboreal	Ground	Arboreal	Ground
% cover	0	14.0	0	5.5

	Pit Site 1							Control Site 1C						
C. Other Sign	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel	4	1	2		14	1	22	3		3		12		18
Vole					1		1			1		7		8
Marmot	7	1	16		5	2	31	3	2	17		1		23
Ptarmigan			4				4			3				3
Grouse														
Grizzly Bear			2				2							
Caribou		12					12		6					6
Moose														
Goat														
Unknown		1	1		1		3	9						9
TOTAL	11	15	23	2	21	3	75	15	8	24		20		67

D. Summary Index	Pit Site 1	Control Site 1C
Total Pellet Groups Density/ha	0.0	0.0
Total Browse Utilization (%)	6.3	2.8
Total Other Sign	75	67

[1] For locations of sites, see Figure 4-15

[2] Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

species. Control Site 2C showed a comparable degree of wildlife use with caribou tracks and browse utilization noted.

Overall, the use of the mine sites and the control sites was generally low and non-specific, reflecting primarily spring (late May), summer and early fall (September) utilization by wildlife.

Waste Rock Disposal Sites and Control Sites

Waste Rock Disposal Site 3, alpine tundra, showed limited use by caribou (Table 4-27). This site is similar to Mine Site 1 in biophysical characteristics, and exhibits a similar level of wildlife use. Browse utilization was low despite the presence of dwarf willow. This site is in an area of low utilization by wildlife.

Control Site 3C, in contrast, exhibits very high utilization levels by both caribou and mountain goats. Caribou and goat tracks were numerous. Although the overall browse utilization was less than that at Waste Rock Disposal Site 3, the percentage browsed on arctic willow was higher at 50 percent. This corresponds to the level of use one might expect given the high density of ungulate species present. Although the reasons for such widely different levels of use within the same habitat type are unknown, in this case variations in use by caribou may result from traditional behaviour. Some evidence to support this was found during the 1985 season. Groups of female caribou were observed near Control Site 3C in July in "nursery groups" above timberline.

Small mammal use was also greater at Control Site 3C compared to Waste Rock Disposal Site 3. Noticeable within the control site was the presence of two marmot and two ground squirrel colonies which greatly contribute to the overall abundance of small mammal sign.

Waste Rock Disposal Site 4, subalpine fir/Englemann spruce, exhibited a similar level of use to Waste Rock Disposal Site 3 (Table 4-28). Caribou pellet density was the same, and a similar level ef browse utilizatiаn was

TABLE 4-27

COMPARISON OF WILDLIFE SIGN IN WASTE ROCK DISPOSAL SITE[1] 3 AND CONTROL SITE 3C

	Waste Rock Disposal Site 3		Control Site 3C	
A. Pellet Groups	Total	Density/ha	Total	Density/ha
Caribou	1	3.3	34	113.3
Moose	0	0	0	0
Goat	0	0	7	23.3
TOTAL	1	3.3	41	136.6
B. Browse (Grazing)	Total Stems	% Utilization	Total Stems	% Utilization
Salix arctica	374	3.7	6	50.0
(*Festuca altaica*)	109	6.4	448	3.1
Abies lasiocarpa	0	0	41	0
TOTAL	483	4.3	495	3.4
Lichens	Arboreal	Ground	Arboreal	Ground
% cover	0	7.4	0	12.0

	Waste Rock Disposal Site 3							Control Site 3C						
C. Other Sign	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel	2		5		15		22	1	4	1		21	2	29
Vole										1				1
Marmot	10		11	1	5	2	29	1	4				2	7
Ptarmigan			18				18			12				12
Grouse														
Grizzly Bear											2			2
Caribou		1					1		33					33
Moose														
Goat									1					1
Unknown	5						5	32	2					34
TOTAL	17	1	34	1	20	2	75	34	44	14	2	21	4	119

D. Summary Index	Waste Rock Disposal Site 3	Control Site 3C
Total Pellet Groups Density/ha	3.3	136.6
Total Browse Utilization (%)	4.3	3.4
Total Other Sign	75	119

[1] For locations of sites, see Figure 4-15

[2] Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

TABLE 4-28

COMPARISON OF WILDLIFE SIGN IN WASTE ROCK DISPOSAL SITE[1] 4 AND CONTROL SITE 4C

	Waste Rock Disposal Site 4		Control Site 4C	
A. Pellet Groups	Total	Density/ha	Total	Density/ha
Caribou	1	3.3	13	43.3
Moose	0	0	2	6.6
Goat	0	0	2	6.6
TOTAL	1	3.3	17	56.6
B. Browse (Grazing)	Total Stems	% Utilization	Total Stems	% Utilization
Salix arctica	33	6.1	148	10.1
Abies lasiocarpa	170	0	372	0.8
(*Festuca altaica*)	192	3.1	173	9.8
TOTAL	395	2.0	693	5.0
Lichens	Arboreal	Ground	Arboreal	Ground
% cover	0	11.0	0	4.5

C. Other Sign	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel					2		2	3				2		5
Vole										1		1		2
Marmot			1		1		2			1			1	2
Wolverine									1					1
Ptarmigan			4				4			5				5
Grouse														
Grizzly Bear									1					1
Caribou	4						4		5					5
Moose														
Goat														
Unknown									3					3
TOTAL	4		5		3		12	3	10	7		3	1	24

D. Summary Index	Waste Rock Disposal Site 4	Control Site 4C
Total Pellet Groups Density/ha	3.3	56.6
Total Browse Utilization (%)	2.0	5.0
Total Other Sign	12	24

1 For locations of sites, see Figure 4-15

2 Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

found. Four caribou trails occurred within the site. Control site 4C exhibited a much higher level of utilization and was similar to Control Site 3C. Small mammal sign was reduced primarily because of tree cover and reduced drainage efficiency. Wolverine and a grizzly bear track were noted as well as high numbers of ptarmigan scats.

Waste Rock Disposal Site 5 showed caribou presence, pellet groups and tracks, but limited browse utilization (Table 4-29). Control Site 5C showed a greater diversity of ungulate use with moose and goat sign in addition to caribou sign. Browse utilization was also greater within the Control Site, particularly of such preferred species as arctic willow.

Overall there appears to be a markedly lower level of wildlife use of the dump sites as compared to the control sites. This was apparent not only in the relative density of individual species sign, but also in the relative diversity of wildlife species present throughout each site.

Reservoir Site and Control Site

Reservoir Site 6 and Control Site 6C, both shrub fen, showed limited use by ungulates (Table 4-30). Despite an abundance of browse species preferred by moose no pellets were observed on either site. Moose tracks were noted at the control site. Noticeable within the reservoir site was the presence of numerous caribou trails. Regularly-used caribou trails are observable along the Little Klappan River valley, as evidenced from large scale aerial photography. Direct use of these areas for feeding appears to be limited based on the data collected to date. Small mammal use of both areas was severely restricted, probably due to spring flooding.

Camp, Preparation Plant and Power Plant Sites and Control Sites

Camp site 7 showed evidence of moderate use by moose and caribou (Table 4-31). Caribou tracks were present throughout the site, while six distinct

TABLE 4-29

COMPARISON OF WILDLIFE SIGN IN WASTE ROCK DISPOSAL SITE[1] 5 AND CONTROL SITE 5C

	Waste Rock Disposal Site 5		Control Site 5C	
A. Pellet Groups	Total	Density/ha	Total	Density/ha
Caribou	3	10.0	1	3.3
Moose	0	0	5	16.6
Goat	0	0	1	3.3
TOTAL	3	10.0	7	23.3
B. Browse	Total Stems	% Utilization	Total Stems	% Utilization
Betula glandulosa	23	0	0	0
Salix glauca	380	3.4	187	16.6
Salix glandulosa	116	1.7	116	14.6
Abies lasiocarpa	162	0	181	0
TOTAL	681	2.2	484	9.9
Lichens	Arboreal	Ground	Arboreal	Ground
% cover	0	0	0	3.0

C. Other Sign	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel														
Vole														
Marmot														
Ptarmigan			1				1			2				2
Grouse														
Grizzly Bear														
Caribou		10					10		3					3
Moose		3					3	2	24					26
Goat									2					2
Ungulate	2	1					3		1					1
TOTAL	2	14	1				17	2	30	2				34

D. Summary Index	Waste Rock Disposal Site 5	Control Site 5C
Total Pellet Groups Density/ha	10.0	23.3
Total Browse Utilization (%)	2.2	9.9
Total Other Sign	17	34

[1] For locations of sites, see Figure 4-15

[2] Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

TABLE 4-30

COMPARISON OF WILDLIFE SIGN IN RESERVOIR SITE[1] 6 AND CONTROL SITE 6C

	Reservoir Site 6		Control Site 6C	
A. Pellet Groups	Total	Density/ha	Total	Density/ha
Caribou	1	3.3	1	3.3
Moose	0	0	0	0
Goat	0	0	0	0
TOTAL	1	3.3	1	3.3
B. Browse	Total Stems	% Utilization	Total Stems	% Utilization
Salix glauca	539	2.0	411	6.6
Salix glaudulosa	108	8.3	207	3.4
Betula glandulosa	44	0	13	0
TOTAL	691	2.9	631	5.4
Lichens	Arboreal	Ground	Arboreal	Ground
% cover	0	0	0	0

C. Other Sign	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel					1		1							
Vole														
Marmot								1						1
Ptarmigan														
Grouse														
Grizzly Bear														
Caribou	6	35					41	2	8					10
Moose									7					7
Goat														
Unident. Ungulate								1						1
TOTAL	6	35			1		42	4	15					19

D. Summary Index	Reservoir Site 6	Control Site 6C
Total Pellet Groups Density/ha	3.3	3.3
Total Browse Utilization (%)	2.9	5.4
Total Other Sign	42	19

1 For locations of sites, see Figure 4-15

2 Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

TABLE 4-31

COMPARISON OF WILDLIFE SIGN IN CAMP SITE[1] 7 AND CONTROL SITE 10C

A. Pellet Groups	Camp Site 7 Total	Camp Site 7 Density/ha	Control Site 10C Total	Control Site 10C Density/ha
Caribou	0	0	1	3.3
Moose	2	6.6	2	6.6
Goat	0	0	0	0
TOTAL	2	6.6	3	10.0

B. Browse	Camp Site 7 Total Stems	Camp Site 7 % Utilization	Control Site 10C Total Stems	Control Site 10C % Utilization
Betula glandulosa	223	0	0	0
Abies lasiocarpa	0	0	163	0
Salix glauca	193	0.5	475	1.7
Salix glandulosa	183	0	145	3.4
TOTAL	599	0.2	783	1.7

Lichens	Camp Site 7 Arboreal	Camp Site 7 Ground	Control Site 10C Arboreal	Control Site 10C Ground
% cover	0	4.0	0	2.2

C. Other Sign	Camp Site 7 TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	Control Site 10C TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel					1		1							
Vole														
Marmot					1		1							
Ptarmigan										1				1
Grouse														
Grizzly Bear														
Caribou	6	10					16							
Moose	2	3					5		13					13
Goat														
Ungulate								1						1
TOTAL	8	13			2		23	1	13	1				15

D. Summary Index	Camp Site 7	Control Site 10C
Total Pellet Groups Density/ha	6.6	10.0
Total Browse Utilization (%)	0.2	1.7
Total Other Sign	23	15

[1] For locations of sites, see Figure 4-15

[2] Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

trails indicate regular use. Browse utilization was very low. Moose presence was indicated by pellet groups, two trails and three tracks. Such evidence appears to be typical of river valley sites such as the reservoir site, tailings pond site and Control Site 10C.

Preparation Plant Site 8, white spruce-willow, exhibited moderately low levels of use by wildlife (Table 4-32). Wildlife utilization was limited to caribou and moose tracks. No pellets were found, and total browse utilization was limited despite an abundance of preferred browse species.

Control Site 12C showed a similar low level of use by caribou though there was evidence of greater use by moose. Moose appeared to be making moderately high use of this habitat type compared to other types in the area. Good interspersion of habitat afforded by a mosaic of sedge meadows and semi-closed white spruce-subalpine fir forest may be the preferred habitat of moose in this area. Small mammal sign was almost completely absent from both areas.

Power Plant Site 9 is located a short distance downslope of the preparation plant within the same white spruce-willow land type. Control Site 12C was also used for this site as both types are in close proximity and within the same land type. Wildlife usage of Site 9 was similar to the control (Table 4-33). Evidence of moose utilization was recorded by the presence of pellets. Browse utilization was low despite an abundance of preferred browse species. No small mammal sign was seen within the site.

Tailings Pond Sites and Control Sites

Wildlife utilization was evaluated for three sites within the tailings pond area (Site 10, 11 and 12). Site 10 showed signs of relatively high usage by ungulates (Table 4-34). A well used caribou trail as well as moose tracks were observed. Browse utilization was high for all major browse species present within the site. The willows, *Salix glauca*, *S. commutata*, and *S. glandulosa*, were most utilized. Arboreal lichen were present on the lower branches of subalpine fir and white spruce within the site.

TABLE 4-32

COMPARISON OF WILDLIFE SIGN IN PREPARATION PLANT SITE[1] 8 AND CONTROL SITE 12 C

	Preparation Plant Site 8		Control Site 12C	
A. Pellet Groups	Total	Density/ha	Total	Density/ha
Caribou	0	0	0	0
Moose	0	0	0	0
Goat	0	0	0	0
TOTAL	0	0	0	0
B. Browse	Total Stems	% Utilization	Total Stems	% Utilization
Salix glauca	373	0	334	7.2
Salix planifolia	357	2.8	0	0
Abies lasiocarpa	0	0	274	0.0
Salix glandulosa	0	0	72	0
TOTAL	730	1.4	680	3.5
Lichens	Arboreal	Ground	Arboreal	Ground
% cover	0	0	6.0	3.0

	Preparation Plant Site 8							Control Site 12C						
C. Other Sign	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel														
Vole												1		1
Marmot														
Ptarmigan														
Grouse														
Grizzly Bear														
Caribou		5					5	1						1
Moose		11					11		16					16
Goat														
Ungulate	3						3	3						3
TOTAL	3	16					19	4	16			1		21

D. Summary Index	Preparation Plant Site 8	Control Site 12C
Total Pellet Groups Density/ha	0	0
Total Browse Utilization (%)	1.4	3.5
Total Other Sign	19	21

1 For locations of sites, see Figure 4-15

2 Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

TABLE 4-33

COMPARISON OF WILDLIFE SIGN IN POWER PLANT SITE[1] 9 AND CONTROL SITE 12C

	Power Plant Site 9		Control Site 10C	
A. Pellet Groups	**Total**	**Density/ha**	**Total**	**Density/ha**
Caribou	0	0	0	0
Moose	3	10.0	0	0
Goat	0	0	0	0
TOTAL	3	10.0	0	0
B. Browse	**Total Stems**	**% Utilization**	**Total Stems**	**% Utilization**
Salix planifolia	389	0.5	0	0
Salix barclayi	159	0	0	0
Salix glauca	0	0	334	7.2
Salix glandulosa	0	0	72	0
Betula glandulosa	8	0	0	0
Abies lasiocarpa	0	0	274	0
TOTAL	556	0.4	680	3.5
Lichens	**Arboreal**	**Ground**	**Arboreal**	**Ground**
% cover	0	0	6	3.0

C. Other Sign	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel														
Vole												1		1
Marmot														
Ptarmigan														
Grouse														
Grizzly Bear														
Caribou		3					3	1						1
Moose		5					5		16					16
Goat														
Ungulate	3						3	3						3
TOTAL	3	8					11	4	16			1		21

D. Summary Index	Power Plant Site 9	Control Site 10C
Total Pellet Groups Density/ha	10.0	0
Total Browse Utilization (%)	0.4	3.5
Total Other Sign	11	21

1 For locations of sites, see Figure 4-15

2 Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

TABLE 4-34

COMPARISON OF WILDLIFE SIGN IN TAILINGS POND SITE[1] 10 AND CONTROL SITE 10C

	Tailings Pond Site 10		Control Site 10C	
A. Pellet Groups	Total	Density/ha	Total	Density/ha
Caribou	3	10.0	1	3.3
Moose	2	6.6	2	6.6
Goat	0	0	0	0
TOTAL	5	16.6	3	10.0
B. Browse	Total Stems	% Utilization	Total Stems	% Utilization
Betula glandulosa	125	8.8	0	0
Abies lasiocarpa	0	0	163	0
Salix glauca	213	13.1	475	1.7
Salix commutata	153	11.1	0	0
Salix glandulosa	0	0	145	3.4
TOTAL	491	11.4	783	1.7
Lichens	Arboreal	Ground	Arboreal	Ground
% cover	15.0	3.0	0	2.2

C. Other Sign	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel														
Vole														
Marmot														
Ptarmigan										1				1
Grouse														
Grizzly Bear														
Caribou	1	1					2							
Moose		2					2		13					13
Goat														
Ungulate		7					7	1						1
TOTAL	1	10					11	1	13	1				15

D. Summary Index	Tailings Pond Site 10	Control Site 10C
Total Pellet Groups Density/ha	16.6	10.0
Total Browse Utilization (%)	11.4	1.7
Total Other Sign	11	15

1 For locations of sites, see Figure 4-15

2 Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

Control Site 10C had a lower level of utilization by caribou but a similar and perhaps higher utilization by moose. The relatively higher use by moose may in part be due to the greater abundance of preferred browse species within the control site.

Tailings Pond Site 11, sedge fen meadow, showed a relatively low level of use by ungulates (Table 4-35). No evidence of use by caribou was present and use by moose was only evident by one pellet group and moderate browse utilization. In contrast Control Site 11C showed a high caribou pellet density and numerous tracks. Browse utilization within the site was low and attributable to caribou. It appears that the caribou are using the valley bottoms as movement corridors, only opportunistically browsing on preferred species. No evidence of utilization by small mammals was recorded for Site 11, although Control Site 11C showed evidence of ground squirrel, vole and ptarmigan.

Tailings Pond Site 12 was located on the lower, north-facing slope of the Little Klappan River valley in close proximity to Preparation Plant Site 9. General use of this area by ungulates was light (Table 4-36). Willow (Salix glauca) appeared to be the preferred browse species. In addition to the ungulate sign, one grizzly bear scat was found within the site, providing some evidence of periodic use of this lowland habitat. Control Site 12C showed little use by caribou but moderately high use by moose. Browse utilization was evident in the control site.

Overall, the tailings pond area appears to be of low to moderate use for foraging by ungulate species. Moose appear to use the sedge fen meadow habitat for browsing while caribou utilize the river banks as movement corridors.

3.4 WILDLIFE UTILIZATION CONCLUSIONS

3.4.1 Caribou

Hatler (1985) stresses that impact assessment studies relating to caribou

TABLE 4-35

COMPARISON OF WILDLIFE SIGN IN TAILINGS POND SITE[1] 11 AND SITE 11C

A. Pellet Groups	Tailing Pond Site 11 Total	Tailing Pond Site 11 Density/ha	Control Site 11C Total	Control Site 11C Density/ha
Caribou	0	0	6	20.0
Moose	1	3.3	0	0
Goat	0	0	0	0
TOTAL	1	3.3	6	20.0

B. Browse (Grazing)	Tailing Pond Site 11 Total Stems	Tailing Pond Site 11 % Utilization	Control Site 11C Total Stems	Control Site 11C % Utilization
Salix glauca	224	8.9	474	3.4
Salix glandulosa	0	0.0	19	0
Salix barclayi	88	15.9	0	0
Betula glandulosa	201	3.5	55	1.8
TOTAL	513	8.0	548	3.1

Lichens	Tailing Pond Site 11 Arboreal	Tailing Pond Site 11 Ground	Control Site 11C Arboreal	Control Site 11C Ground
% cover	0	1.8	0	3.0

C. Other Sign	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
	Tailing Pond Site 11							Control Site 11C						
Gr. Squirrel								1				14		15
Vole												2		2
Marmot														
Ptarmigan										6				6
Grouse														
Grizzly Bear														
Caribou									19					19
Moose														
Goat														
Ungulate	1						1							
TOTAL	1						1	1	19	6		16		42

D. Summary Index	Tailing Pond Site 11	Control Site 11C
Total Pellet Groups Density/ha	3.3	20.0
Total Browse Utilization (%)	8.0	3.1
Total Other Sign	1	42

[1] For locations of sites, see Figure 4-15

[2] Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

TABLE 4-36

COMPARISON OF WILDLIFE SIGN IN TAILINGS POND SITE[1] 12 AND CONTROL SITE 12C

A. Pellet Groups	Tailing Pond Site 12 Total	Tailing Pond Site 12 Density/ha	Control Site 12C Total	Control Site 12C Density/ha
Caribou	1	3.3	0	0
Moose	1	3.3	0	0
Goat	0	0	0	0
TOTAL	2	6.6	0	0

B. Browse (Grazing)	Tailing Pond Site 12 Total Stems	Tailing Pond Site 12 % Utilization	Control Site 12C Total Stems	Control Site 12C % Utilization
Salix glauca	463	6.5	334	7.2
Salix commutata	22	0	0	0
Salix glandulosa	0	0	72	0
Abies lasiocarpa	0	0	274	0
Betula glandulosa	98	6.1	0	0
TOTAL	583	6.2	680	0

Lichens	Tailing Pond Site 12 Arboreal	Tailing Pond Site 12 Ground	Control Site 12C Arboreal	Control Site 12C Ground
% cover	3.2	3.0	6.0	2.0

C. Other Sign	Tailing Pond Site 12							Control Site 12C						
	TL[2]	TR	SC	DG	BU	CO	SIGN TOTAL	TL	TR	SC	DG	BU	CO	SIGN TOTAL
Gr. Squirrel														
Squirrel	2						2							
Vole												1		1
Marmot														
Ptarmigan			1				1							
Grouse														
Grizzly Bear			1				1							
Caribou		2					2	1						1
Moose		2					2		16					16
Goat														
Ungulate	2						2	3						3
TOTAL	4	4	2				10	4	16			1		21

D. Summary Index	Tailing Pond Site 12	Control Site 12C
Total Pellet Groups Density/ha	6.6	0
Total Browse Utilization (%)	6.2	3.5
Total Other Sign	10	21

[1] For locations of sites, see Figure 4-15

[2] Abbreviations: TL - Trail; TR - Track; SC - Scat; DG - Dig; BU - Burrow; CO - Colony.

should be based on data resulting from more than simple visual contact with caribou, and that the studies must account for temporal as well as spatial components in tha life cycle. Gulf has supported Hatler's radio-collaring studies of caribou by means of grants to the Spatsizi Association for Biological Research. As a result, Gulf's two years of consultant field studies have received significant benefit from the radio-collaring study in interpreting the results of visual-contact ground and aerial surveys.

The two years of caribou study on the property combined with information obtained from five years of radio tracking by the Spatsizi Assocation for Biological Research has provided information relative to the behavior of caribou during the sensitive phases of their life history which allows an assessment of the impact of the Lost-Fox mine development on this species. These sensitive life history phases are described below.

Winter Range

Impacts on caribou can be expected to be more significant if a development impinges upon an area of seasonal concentration such as winter range, where tolerance of disturbance is low owing to reduced food energy budgets. Gulf's studies have demonstrated that caribou winter range is not an issue at the Mount Klappan anthracite property, and that contact with caribou will occur primarily during spring and summer. Hatler's (1985) findings strongly support this contention. Nearly all of the February and March locations of radio-collared caribou are along the Stikine River valley or the lower Klappan River at least 60-70 km distant from the proposed site of mining activities.

Hatler states "the Lower Stikine winter range appears to be the most important single area used by the Spatsizi caribou" and it is his belief that "caribou move to upland habitats when they have difficulty subsisting in the forest. At Spatsizi, winter occurrence of caribou in the alpine zone represents a forced situation, during which animals may be dying. To consider the alpine areas as the critical range would be a serious misinterpretation. If the objective is to maintain a large viable population, the large area which normally supports large numbers of animals over the bulk of most winters must be more critical over the long term than are a few last ditch survival areas.

If there are any relatively small areas that can be properly classifed as critical they would probably be some of the low land migration corridors through which a large proportion of the population travel, especially in spring".

Hatler has also indicated that the Spatsizi caribou feed primarily on terrestrial rather than arboreal lichen and that the timing of major spring movements depends upon weather factors including residual snowpack. These factors limit the period of potential caribou contact with the mine development to approximately 4.5 months per year from late May to mid-October.

Migration Routes to Birth Sites

During spring movements, some adult females evidently travel considerable distances from the winter ranges south to calving areas near or in the licence area. Hatler (1985) has confirmed that mountains in the Klappan and Nass river areas are used by Spatsizi Park caribou. Data collected suggests that migration through the licence area to birth sites does take place but there is no evidence to indicate that these movements go through the proposed Lost-Fox mine development area although some migration routes are nearby.

Birth Sites

One, and perhaps two, birth sites have been located on the Klappan property and that was on the rugged ridge between the Klappan and Little Klappan River, north of the mine site. Several birth sites have also been located on high ground to the east and south of the licence area.

Bergerud et al (1984) emphasized the importance of habitats above timber line on south facing slopes in rugged terrain as birth sites. Lost Ridge, the highest ridge in the mine development area, does not possess the ruggedness and relative inacessibility to predators that characterizes the ridges to the north of the mine site. The 1985 habitat utilization studies of the mine development area discovered none of the physical evidence associated with birth such as either cast female antlers or spring type pellet groups in dense aggregations. Such evidence would be more difficult to observe below timber line in the mine area.

Gulf's studies and those of Hatler (1985) confirm the predictability of long distance movements of females prior to calving. This predictability aids in assessing impacts of the proposed development. Hatler (1985) has documented the occurrence of birth sites below timberline where visibility of caribou during aerial survey is significantly reduced. The majority of birth sites he found were in alpine situations, as described by Bergerud et al (1984). In these situations visibility of caribou during aerial survey is good. Our studies have emphasized the early June calving period using aerial surveys as the principal technique, and have found only two birtb sites on the licence area. None have been located in the principal mine development area despite intensive surveys.

Post Calving Period

During the post calving period caribou, including some females with calves, were frequently observed in the vicinity of the Lost-Fox development area. This is not a critical time for these females, nor does it suggest the proximity of birth sites. Females with calves can travel considerable distances. For example, one radio-collared female and calf observed by the Spatsizi Association travelled from Gladzo Lake in Spatsizi Park to the Upper Skeena River, a straight line distance of 50 km between June 14 and July 24. This is an average straight line speed of 1.2 km/day.

Caribou of all ages and both sexes were observed regularly in the valley bottom habitats during the post-calving period, with an increasing number of observations at or above timberline in August. They are the caribou that will come into regular contact with activities in the mine area along the Little Klappan River. Several mineral licks used by caribou were located in the vicinity and evidence of regular caribou passage is clearly visible along well-defined trails in valley bottoms. The fact that these trails are so distinct suggests that they were made during periods of little or no snow cover, thus indicating primarily summer use.

During the spring and summer the potential for significant impact is reduced, as caribou do not concentrate in one area, but are widely scattered. For example, radio collared caribou, with numerous uncollared companions, occupied an area of less than 2 000 km^2 and moved little from about December to early May. However, in June they dispersed to an immense area of between 6 000 and 10 500 km^2 (Hatler 1985). Between late May and mid-October, Hatler (1985) is of the opinion that habitats selected are the most variable and widely scattered in the annual cycle, and an expression of diverging individual traditions when environmental limitations due to such factors as snow cover and food availability are fewest.

Rutting Activities

Hatler (1985) has found that rut concentration areas identified in previous studies were regularly and predictably occupied by numbers of caribou in the fall, but that many animals did not attend those areas at that time. In two years of study of the licence area, one rut area outside the licence area was found to be occupied in both years, but no evidence of rutting was found in or near the principal mine development area. On the other hand, the nearest rutting area to the licence area (on a plateau between the Klappan and Little Klappan rivers, to the northwest) was seen to be used by rutting caribou in both 1984 and 1985. This information suggests either that rutting fidelity to the Lost-Fox basin is weak, or that it is not a traditional rutting area. The Spatsizi population of caribou is generally perceived by caribou biologists to be at a historic "low" in 1984 and 1985. From this viewpoint, it is possible that in the past, at times of population "highs", caribou may have rutted in the Lost-Fox basin but a population increase would presumably have to occur, and fidelity to the basin be re-established, for the area to be consistently used in the future.

Reaction to Disturbances

Gulf's studies have indicated that lowland valley bottom habitats are those most used by caribou for travel. Hatler (1985) indicates that the heaviest use of non-forested lowland habitats takes place in April and May, when the animals are seeking new, green vegetation in bogs, riparian areas, and open meadows, and when they were migrating along river bottom corridors to their summer locations.

Consequently, the vast majority of caribou sitings on the property during the spring and summer of 1985 were in the valley bottom habitats although caribou were observed in the full range of habitats including alpine tundra. This finding is probably linked to habitat preference, but the data are affected by the visibility of caribou in this habitat type and the comparative frequency of surveys in all habitat types. The results of monitoring reactions to disturbance suggest that adult females are most likely to react observably to disturbance; although, the number reacting is small. Also, the circumstances of disturbance may vary to the point of making observations incomparable.

Hatler (pers. comm.) recorded an adult female with a calf and two unclassified adults on an alpine snowbank on July 26 within one kilometre of the Lost-Fox trial cargo pit, where activities were continuous. Excepting adult females with calves, all ages and both sexes were recorded close to activities in valley bottom habitats. A large proportion of observations of caribou and other wildlife was made adjacent to and sometimes on the current access road along the BCR grade.

Development Area Habitat Utilization

The data collected in 1985 on habitat utilization by caribou indicate general comparability between development and control sites. Evidence of habitat utilization by caribou was almost universal, with only two sites, (1C and 11) failing to contain evidence. As a wide variety of Land Types were sampled, this is further evidence of the wide-ranging movements of caribou. In the development area, Tailings Pond Site 10 clearly contained above average evidence of utilization. In the control sites, all three of the Waste Rock Disposal Site Controls (3C, 4C, 5C) contained evidence of above-average utilization. Control site 3C, in particular, showed high-intensity utilization by caribou. This suggests that the Waste Rock Disposal Site, although possessing similar characteristics to the control area on the east side of Garner Creek, is relatively unimportant to caribou. In general, the habitat utilization data indicate that the development sites receive average amounts of utilization, and are not unique.

3.4.2 Grizzly Bear

Unlike caribou, the on-licence studies have provided the only source of information on grizzly bear. The northern interior grizzly bear, (the ecotype inhabiting the Mount Klappan property) lives at low population densities and has a low reproductive rate (Pearson, 1975). As a result, it is not often observed, as is evidenced by the results of the 1984 - 1985 on-licence studies. Because of the elusiveness of bears, chance encounters produced more information than the systematic surveys carried out by the biologists. Of the 46 observations made in the 1985 study only 16 were reported by the biologists. Nevertheless, the number of observations of grizzly bears is sufficient evidence to conclude that the species is relatively abundant and widespread throughout the licence area.

As a result of its normal low population density, collection of sufficient data to describe the seasonal habitats of grizzly bears takes very much longer than for more common species. The objective of studies at Mount Klappan has been to document evidence of critical habitat use in relation to the proposed mine development, as this was seen as more practical in terms of the mine development schedule.

Denning Habitat In Development Areas

The most critical use of habitat by grizzly bears is denning because the bears are highly vulnerable if disturbed during denning. From the large number of bears observed, it seems apparent that they must den on the licence area but the 1985 survey of habitat suitable for denning failed to find any dens except one discovered near Conglomerate Creek.

On the north facing slopes of Lost Ridge at timber line a grizzly denned in the winter of 1982-1983 (Karl Oysmueller, pers. comm.). This den was not observed in 1984 or 1985 and has probably been abandoned.

The long distance movements of grizzlies and their large home ranges has been described (e.g., Pearson 1975) although they do return to the same general area to den. The loss of the Lost Ridge habitat does not appear significant in this context because there are several areas with the same characteristics as Lost Ridge within 10 km of the ridge. These other areas are easily within the average home range of grizzlies.

Foraging Habitat In Development Areas

The observation data for grizzly bears do not allow discussion of comparative habitat utilizatien patterns. It is clear that extensive use of valley bottom areas is made in June and July, and there is a suggested trend to utilize higher elevation habitats in August, September and October. In terms of habitats exemplified in the development and control sites, three of 21 sites sampled showed evidence of grizzly bears. These were Mine Site 2, Control Site 4C, and Tailings Pond Site 12, all three in different habitat types. The data collected therefore leads to the conclusion that specific foraging habitat preferences in the Mount Klappan area cannot be identified.

Conflicts with People

Given the results of both 1984 and 1985 studies, there is no doubt that grizzly bears will come into contact with proposed mine development areas in alpine, subalpine forest and valley-bottom meadow habitats. The fact that 30 of 46 observations of grizzlies in 1985 were reported by exploration personnel is evidence of this. During 1985 one close encounter occurred between two geologists and a sow with two cubs-of-the-year. Such encounters are likely to increase as numbers of people in the mine development area increase.

During the five years of exploration activities no garbage-related problems with grizzly bears have occurred even though the workforce on site was periodically equal to 50% of the projected mine operating workforce. If Gulf continues with these good practices then there will be no problem with either grizzly or black bears related to garbage disposal. However, there have been instances of black bears becoming a nuisance in the camp area and this type of encounter is likely to continue and will require removal of black bears.

The results of the 1985 study for both grizzly bears and caribou do not change the conclusion of the 1984 study that none of the concerns identified appear to preclude mine development given that a wildlife protection and monitoring plan and impact mitigation measures are employed.

3.5 ENVIRONMENTAL IMPACTS AND MITIGATION

3.5.1 Caribou

Caribou use the Mount Klappan property as a migration route and as an area of summer forage. The mine development area does not provide a unique habitat and utilization of the mine area by caribou is relatively low. The loss of this area of summer forage is therefore not a concern and the impact will be negligible.

The development area lies in an area through which caribou pass regularly. Old caribou trails indicate that the Upper Didene Creek/Little Klappan River valleys are movement corridors. Data collected during the baseline field studies indicate that caribou move through or near the zone from late May/early June through to October. In late May and early June, the caribou involved are mest likely adult females moving south on migration to calving areas in the Nass River drainage. In late June, July and August, males and non-parous females move into and through the development zone en route to summer foraging habitat. Some females with calves also move through the zone at this time. In September and October all ages and both sexes of caribou move through the development area, most likely en ròute back to rutting and winter ranges to the north. The time period and age/sex class of caribou considered most sensitive to any obstructions or deflections of movements are the late May/early June pregnant adult females on migration to calving areas.

Two questions relating to impacts of the mine development on caribou movements are therefore pertinent:

(i) To what degree will the location of facilities obstruct movements?

(ii) To what degree will the positioning and alignment of facilities deflect movements?

By year 20 of the mine development, the pit site and waste rock disposal site will present easily the largest surface disturbance and potential impediment to movements. However, being located largely in alpine and subalpine habitats, they are unlikely to obstruct movements significantly for the following reasons. Firstly, during spring calving migration, snow is crusted at this altitude and can carry the weight of caribou, particularly at night when temperatures drop well below freezing. Caribou are therefore likely to be able to move around the mine area. Secondly, no evidence has been collected to date of spring migration movements passing through the projected pit or waste disposal area. Thirdly, there are no topographic features (such as water courses) involved which might guide or constrain movements. During summer and fall months, snow will not constrain caribou movements, and caribou can avoid the mine area.

For the facilities lying in the Little Klappan River valley, surface disturbance and buildings will occupy areas substantially smaller than the pit and waste rock disposal sites. They will lie in a valley where caribou movements are frequent, probably including spring calving migration movements. The facilities include the anthracite preparation and power plants, camp, reservoir, tailings pond and coarse refuse pile.

In spring, snow melts progressively upstream along the banks of rivers in the Spatsizi area, providing snow-free movement opportunities along the river banks, and (compared to higher elevations), relatively soft, sometimes deep snow adjacent to the banks. The river courses, including the Little Klappan River, may therefore encourage caribou to follow them and hence encounter the mine facilities. The BCR grade has also been documented as providing a relatively snow-free travel route from the north and east leading through the development zone into the "Nass Pass" area. Some of the facilities (tailings pond, coarse refuse pile, reservoir) are unlikely to be crossed by caribou, while the preparation plant/power plant/ camp area is likely to be avoided due to ongoing mine activity. The degree of movement obstruction in spring will likely depend upen the snow conditions in relation to the concentration of activity. In summer, caribou are likely to avoid the area of concentrated activity, and will probably seek travel routes which skirt it at more than 100 m distance.

The new pit access road and the 13.8 kv overhead power line from the power plant to the pit site are not expected to present an obstruction to caribou movements. Based on experience with barren-ground caribou in Alaska in relation to pipelines (Eide **et al** 1986; Curatolo and Murphy, 1986), caribou at Mount Klappan are expected to cross over the road and under the powerline. However, their crossing frequency may be reduced by traffic on the road.

In summary, the facilities are not expected to obstruct caribou movements but may deflect them slightly, perhaps into less favourable travel routes. Based on information collected to date, the numbers of caribou which might be affected are at no time expected to be large. Small groups of from two to six animals in summer and fall months are likely to be involved, while in spring, the number of pregnant females migrating are unknown, but will probably consist of an occasional, solitary animal.

Because caribou have been documented as utilizing the BCR grade as a travel route in spring it seams highly likely that they will adopt the new access road to Highway 37 as a travel route also, especially as it follows a directional trend similar to the general movement pattern observed in spring during calving migration. The snow may be piled on either side of the road, and impede escape from the right-of-way. This could present a traffic hazard and cause the death of caribou through collisions.

Despite the low probability of this being a problem, it is Gulf's intention to plough breaks in the snow berm to allow escape by caribou, and to monitor the use of the breaks. The breaks will be planned in accordance with the road design and maintenance procedures to allow regular opportunity for caribou to leave the right-of-way.

Potential for collisions to occur between mine related vehicles and wildlife is very low due to the slow speed of travel by these vehicles.

In summary, nothing has been found in these studies of caribou in the Mount Klappan region to indicate that there will be any significant impact on these animals. No critical habitats are involved, the animals are not present in the mine development area during critical periods of their life-cycles and the project will not seriously impede their migratory movements. The only aspect where some mitigation is indicated has to do with attempting to avoid collisions between vehicles and caribou on roads.

3.5.2 Bears

Baseline studies have revealed that grizzly and black bears are regularly encountered in the licence area. During construction and operation of the mine, the probability of encounters between mine personnel and bears is relatively high, and Gulf intends to initiate a bear management plan in order to (i) reduce the likelihood of encounters and (ii) reduce or eliminate the need to destroy or relocate problem bears.

The management plan will focus on camp layout, garbage managment and education of personnel. The first objective will be to eliminate wastes and waste odours that would attract bears into locations where they are likely to come into close contact with personnel, and become accustomed to human presence. A second objective will be to instruct personnel on correct behaviour in the event of encountering a bear and procedures for avoiding encounters. The bear management plan will expand upon the garbage disposal and bear reporting approaches used during the exploration program. It will be incorporated into the operational planning for the mine.

Despite these efforts, some potentially dangerous encounters could occur. In these circumstances, the exact nature of the problem will have to indicate the appropriate remedial action. No denning activity or other important habitat relative to bears has been discovered in the mine development area. Bears range over very large domains and the loss of use of the project area will have no significant impact on them.

3.5.3 Other Important Wildlife Species

During 1985, a second year of baseline wildlife studies was conducted, focussing on caribou and grizzly bear, but allowing further data collection on moose, mountain goat, black bear, Stone's sheep, furbearers and raptors. The objective of the second year of study was to refine issues relating to the mine. The results of the study have not changed the basic conclusions stated in the Stage I submission; namely, that the mine plans will not affect Stone's sheep on the licence area, and will have very minor or indirect effects on moose, mountain goat, furbearers and raptors. Black bears will come into contact with mine activities; however, black bears are not common on the licence, and are abundant and widespread in other parts of the province. Black and grizzly bears will be the focus of the impact-mitigative bear management plan.

3.5.4 Monitoring Program

In the Stage I submission, Gulf committed to an ongoing program of environmental surveillance. This will involve contractural obligations by the prime contractor to meet environmental standards, and use of previous Gulf practices, such as assignment of a full-time environmental coordinator during construction and start-up and subsequently if required.. As part of this environmental surveillance, a wildlife monitoring program will be carried out in association with specific aspects of the mine. Its objective will be determine and mitigate any problem directly associated with development and operation of the mine.

In addition, Gulf will continue its liaison with the Spatsizi Association for Biological Research and its caribou radio-collaring study. Information from this study has provided important information in terms of the overall impact assessment for the mine development, and will continue to be useful during the monitoring program.

3.5.5 Mine Reclamation Program

A major objective of the mine reclamation program is the restoration of wildlife habitat. Caribou utilization of the mine area is low, consequently restoration of the relatively small area of the mine to caribou habitat is of little benefit. It is proposed that the ecological benefits of providing habitat for prey species such as marmots, ground squirrels, and ptarmigan in an area of predator diversity such as grizzly bear, fox, wolverine, wolves and golden eagles, is a more practical approach.

The reclamation program described in Part VI of Volume II will pursue this objective.

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PART FIVE - HERITAGE RESOURCES

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PART FIVE - HERITAGE RESOURCES

1.0 INTRODUCTION

Gulf's Stage I assessment of the Mount Klappan Anthracite Project noted that a heritage resource assessment study had been commissioned and an interim report resulting from this study was submitted to the Heritage Conservation Branch in September, 1985. On the basis of the interim report, the Branch found that the heritage resource concerns in the project area are resolvable. However, it was noted that two heritage sites located at the minesite required further investigation and three others needed to be studied further if the project configuration affected them. The Branch also requested that heritage resource issues outside the immediate mine area also be addressed through a "proposed strategy" if there was high-probability these areas should be affected in the future.

The following discussion of heritage resources incorporates the findings of the previous intarim report and addresses the comments of the Heritage Conservation Branch.

Heritage resources are non-renewable evidence of prehistoric, protohistoric or historic human occupation and/or utilization. These resources are protected in British Columbia by the Heritage Conservation Act. Under Section 7 of this Act, the Minister of Provincial Secretary and Government Services is empowered to order archaeological investigations prior to implementation of a major development program.

The objectives of conducting an impact assessment are outlined in the Guidelines for Heritage Resource Impact Assessment in British Columbia issued by the Heritage Conservation Branch (1982). Following are the major objectives of the study conducted within the Mount Klappan Anthracite Property:

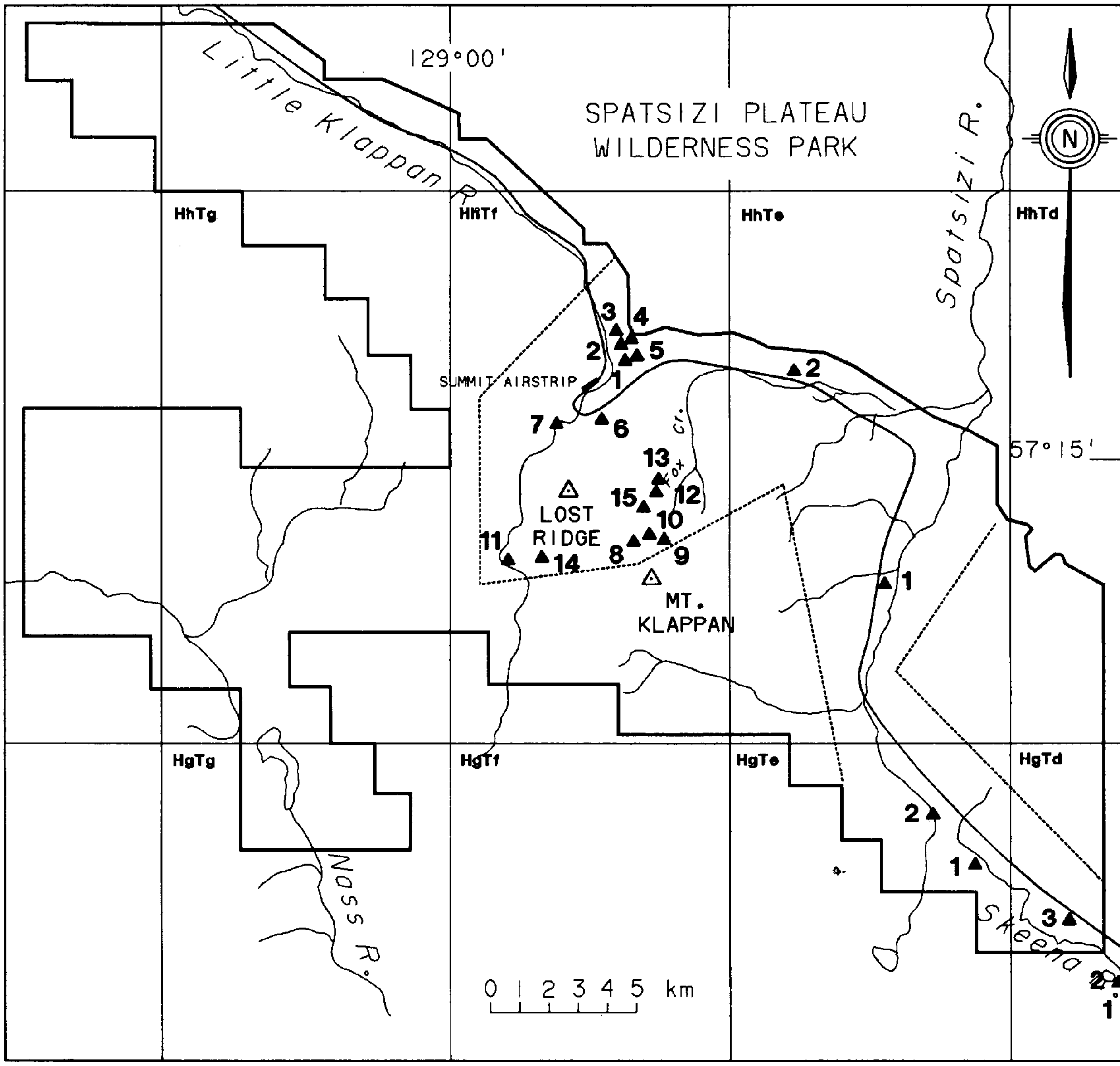
- to identify and evaluate heritage resources in the project area;

- to identify and assess all impacts on heritage resources imposed by the development; and

- to recommend viable alternatives or options for managing or mitigating adverse impacts, including preliminary programs for resource management, surveillance or monitoring where appropriate.

The study area for these investigations incorporated the region around the Lost-Fox Mine area extending from the headwaters of the Little Klappan River in the southwest and eastward across the west and north sides of Mount Klappan. The northern boundary of the study area was the limit of the Mount Klappan Coal License. Figure 5-1 indicates the study area and the Mount Klappan Property Limits.

The study area was also extended to the southeast of the Lost-Fox Development Area, along the BCR grade corridor, as far as the southeast corner of the coal licenses on the Skeena River. This area, which incorporates the Didene Creek flats, upper Spatsizi River and upper Skeena River valleys, were considered potentially important resource areas.



LEGEND

▲ **ARCHAELOGICAL SITE**

·············· **STUDY AREA**

FIGURE 5-1

MOUNT KLAPPAN ANTHRACITE PROJECT

STUDY AREA AND SITES LOCATED

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2.0 PREHISTORIC AND ETHNOGRAPHIC BACKGROUND

2.1 REGIONAL PREHISTORY

Previous research within the study area has been negligible. In 1974, a survey was carried out along the British Columbia Rail (B.C.R.) right-of-way (Drew and Stoffels, 1974). However, the central section of the route between the Little Klappan River on the north and Chipmunk Camp on the south, was not studied because it was felt that the area held little potential for important sites. The Mount Klappan Property falls in this zone.

Prehistoric pictographs and cairns are known in the lower Stikine, Iskut and Skeena valleys but not in the highland, interior areas of the project. Intensive studies have been conducted in the Telegraph Creek area (Smith 1969, 1970, 1971) which suggests that relatively continuous human activity has occurred in this portion of the Stikine Valley for over 10,000 years.

Several prehistoric obsidian quarries and workshops have been identified in Mount Edziza Provincial Park to the west of Telegraph Creek (Fladmark and Nelson, 1977). Other studies have identified prehistoric sites in the upper Stikine and Spatisizi Plateau north of the project site and signs of fishing activity on the Skeena River south of Mount Klappan. However, the hunting and fishing activities associated with these sites apparently do not extend into the project area.

The earliest artifacts discovered in the region suggest microblade industry activity possibly dating back to 8000 years Before the Present (8000 B.P.). Most dated assemblages of microblade artifacts are within the 5000-4000 B.P. time span. Between 4000 and 2800 B.P., non-microblade assemblages occur. These are characterized by medium-sized notched, stemmed and/or lanceolate points.

Pit houses which were common in southern B.C. in this period have not been recorded in northern B.C. but house platforms excavated in stream embankments and sloping hillsides have been found. Other archeological features of the region include rectangular or circular storage pits, rock cairns, meat caches and tree caches.

2.2 ETHNOGRAPHY

The study area falls within the territory traditionally exploited by three Athapaskan groups, the Tahltan, Tsetsaut and the Sekani (Emmons, 1911 and Duff,1964). The Tahltan were centered at the confluence of the Stikine and Tahltan Rivers but exploited a much larger area. Their territory was bounded on the west by the Coast Range. They occupied the headwaters of the Nass, some of the headwaters of the Skeena and parts of the Liard and Dease Rivers.

The Tsetsaut occupied territory immediately south of the Tahltan and inland from the Tlingit. Hostilities between at least one of the Tahltan Tribes and Tsetsaut have been recorded.

A small group of Bear Lake Sekani presently reside in the village of Iskut. They have only recently entered the area. The Sasuchan and Tseloni, two bands of the Sekani, occasionally hunted the plateau regions of the Upper Stikine. Each group is discussed separately below.

2.2.1 Tahltan Tribe

Sources of ethnogrpahic data concerning the Tahltan include Hodge(1912), Jenness (1927), Morice (1893), Thorman (n.d.), Teit (1906, 1912, 1956) and White (1913). Emmons (1911) is the most authoritative account. Recently, Albright (1984) has recorded Tahltan ethnographic data and conducted ethno-archaeological investigations.

The Tahltan are a small group of Athapaskan speakers who occupy part of the Canadian Subarctic or Boreal Forest Region. The nuclear family is the basic unit of the Tahltan social organization. Their society was divided into four "traditional" families with a matrilinial descent system, and was further divided into two primary classes or moieties. The four families generally occupied different areas within Tahltan territory.

The Tahltan were semi-nomadic and their subsistence activities centered around winter hunting and summer fishing. During the summer, Tahltan families met at traditional fishing villages which were centered on the Stikine between the Tahltan and Tuya Rivers but extended to the southern branches of the Taku. Large quantities of salmon were caught, dried and stored.

When the fishing season was over in late August, the Tahltan dispersed into nuclear family units to hunt marmots and ground squirrels. Sheep, goats, and bear were hunted at higher elevations and berries were gathered and preserved. Major fall and winter hunting camps were utilized on a regular basis. In spring, freshwater fish, beaver, bear, grouse, rabbit and porcupine were exploited.

2.2.2 Tsetsaut Tribe

The Tsetsaut tribe are an extinct group of Athapaskan speakers. They numbered about 500 people at the beginning of the 19th century. When Boas encountered them in 1895, they had been all but exterminated by the Tlingit. The few remaining members were slaves of the Nisga who, along with the Tahltan, had taken over the Tsetsaut territory.

The territory of the Tsetsaut extended from north of the Unuk River east to Observatory Inlet. They are reputed to have made excursions to the head-waters of the Stikine, Nass and Skeena Rivers.

Unlike the Tahltan, the Tsetsaut had no fixed villages. They relied on temporary shelters and they hunted bear, beaver, mountain goat, marmot, and porcupine. During the spring, they gathered at the Portland Canal to catch oolachan and in summer, they caught salmon.

2.2.3 Sekani Tribe

The Sekani are Athapaskan speakers whose traditional territory centered in the valleys of the upper Peace River and its tributaries, on the western slopes of the Rocky Mountains. Although their territory extended to the eastern slopes of the Rockies, they were pushed west by the Cree during the fur trade era. Jenness (1937) has conducted most of the ethenographic research on the Sekani.

The Sekani consist of numerous bands which were neither politically nor socially cohesive. Unlike the Tahltan, the Sekani were of patrilineal descent. Sekani bands were highly nomadic, hunting moose, caribou, bison, bear, lynx, rabbit, marmot and beaver. The Sekani caught and dried a variety of freshwater fish but their territories lacked the salmon runs that Tahltan and Tsetsau groups relied on.

A group of Bear Lake Sekani entered the region settling in the Metsantan Caribou Hide area within the last century. They probably originated in the Fort Graham area on the Finlay River. In 1948 they moved to Iskut and on to Telegraph Creek in 1952, but they moved back to Iskut in 1962. The move to Iskut probably represents the culmination of a westward migration of this group over the last 150 years.

2.2.4 Summary

Ethnographic accounts suggest that a pattern of seasonal movement between the mountain and lower elevations occurred for much of the year but large groups formed to exploit seasonally abundant resources such as salmon. Since the study area does not contain runs of salmon, the anticipated settlement pattern would feature short term occupations by small groups (one or two nuclear families). One possible exception would be the establishment of larger settlements associated with the migratory caribou. In addition, the area was probably important for marmot or groundhog hunting.

Archaeologists generally attempt to gain a better understanding of prehistoric site potential from the broad geographical and environmental context. Studies focus on possible patterns of settlement, resource exploitation, seasonal movements, travel routes, trade and length of site occupancy.

Ecological characteristics such as physiography and climate and the availability of specific resources such as flora, fauna, lithic materials and water are important indicators of previous activities.. These environmental variables may have influenced cultural activities associated with site selection, travel within and through the area and resource exploitation. Much of the information used for establishing this background has been taken from Gulf's studies of the Biophysical Environment.

3.0 STUDY METHODOLOGY

3.1 SITE POTENTIAL INDICATORS

The field program was organized to address three basic objectives. A prime goal was to inventory and assess sites within the known impact zones. A second objective was to locate and assess those heritage resources which were of concern to native informants. A third and final objective was to survey as many areas identified as being of medium to high archaeological potential as time allowed.

With the exception of known sites reported by native informants or by Gulf Canada Corporation personnel, surveyed areas were judgementally selected. The critieria used to identify areas of potential included the following:

- Ethnographic or historic evidence of land usage: those areas reported to have been utilized for various activities in the past.

- Proximity to sources of water: this includes the Little Klappan, Didene, Spatsizi and Skeena Rivers as well as numerous creeks. Bodies of water such as the lakes at the headwaters of the Spatsizi and Skeena Rivers could also have been attractive locations for campsites.

- Proximity to firewood: this is especially important in areas at higher elevations where firewood is scarce.

- Dry, level or gently sloping localities: these were preferred campsite locations and include river terraces, lake shores, level hilltops such as knolls along the Skeena and Spatsizi Rivers, and gently sloping terrain such as parts of Lost Ridge.

- Prominence: these may be good campsite locations as well as providing vantage points for locating game or intruders. Knolls along water courses could contain campsites or tool manufacturing localities.

- Locally or regionally distinctive physiographic features: these include potential site locales which have attracted occupants on a "seasonal" basis. Such localities include the headwaters of the Spatsizi and Skeena Rivers, river-creek tributary junctions and prominent landforms such as Lost Ridge.

- Areas of seasonally abundant food sources: such areas are obvious in their value but are often difficult to identify. For example alpine areas favoured by marmots would be important in the study area.

- Transportation routes: Overland routes possibly marked by trails or blazed trees may be of importance to site location.

3.2 FIELD SURVEY PROCEDURES

The 1985 field program employed a crew of two for a period equivalent to three work weeks. Access to a particular area was generally on foot but occasionally helicopter support was necessary. Areas were visually examined and during foot traverses, fortuitous or man-made exposures such as dead falls, rodent burrows, heavy equipment tracks and blow outs were inspected. Shovel tests measuring approximately 40 x 40 cm, were dug where appropriate. These were excavated until sterile soil was reached.

All heritage sites were mapped, photographed and recorded on British Columbia archaeological site inventory forms. A series of shovel tests were excavated (usually 40 cm on a side) to ascertain horizontal and vertical site dimensions. As part of the assessment procedure, soil from several sites was screened. This procedure is detailed in the site descriptions below.

3.3 LABORATORY PROCEDURES

Lithic Analysis

All artifacts were washed and sorted into lithic, faunal or historic categories. The lithic analysis is described in detail below. The faunal remains were identified by comparison with specimens from the University of Calgary. All artifacts were catalogued according to the site Borden number.

An initial examination of all lithics was done to separate out those which conformed to recognized tool types or which showed some form of modification or use wear. Some of the standard tool types recognized include a biface, unifaces, microblades, and a burin.

Flake debitage was sorted into categories according to morphology and an inferred core reduction/flake production sequence. Core reduction flakes are large flakes (>10 mm) often with some cortex remaining on their dorsal surface. These flakes are presumed to have been removed in an initial stage of the preparation of a core or tool. Thinning flakes are long thin flakes, often exhibiting prepared striking platforms which are inferred to have been removed in the process of thinning a core or preform in tool preparation. Retouching flakes are small (<5 mm) and were removed in the process of finishing a tool edge or in resharpening a tool edge. They often exhibit remnants of the previous, dulled, cutting edge of a used tool.

One final flake category is that of flake fragments or shatter. Due to its fragile nature, obsidian flakes often break leaving numerous small fragments which exhibit no striking platform or other recognizable morphological features. These flake fragments can be produced in any stage of core reduction or tool manufacture.

Several microblades were noted in the collection as well as one "pseudo" blade which was removed much as a burin spall is taken off leaving a remnant bifacially worked edge on the dorsal surface. All the microblades are obsidian. These flakes are removed using a specialized technique which results in a long, parallel sided flake.

Finally, all lithics were described, according to its debitage stage, use wear attributes and material type. Materials present include obsidian, chert, shale, quartzite, siltstone, and chalcedony. Several types of obsidian were observed including opaque, translucent and transparent, each in a variety of colours. All tools, modified flakes, and some utilized flakes were drawn to scale.

4.0 STUDY FINDINGS AND SITE DESCRIPTIONS

Heritage sites recorded during the project are plotted on Figure 5.1. A total of twenty-two sites were recorded and seven hundred and eight pieces of cultural material were collected. The sites are detailed in Table 5.1 and the artifact and material types collected from each site and summarized in Table 5.2. Site labels have been designated numerically within the map sectors shown on figure 5-1.

HhTf-1

This site is located on the large northwest-southeast trending knoll which is northeast of the present airstrip, northwest of the meteorological station and 1 km east of the Little Klappan River. The site consists of an oval depression measuring approximately 1.5 m N-S x 2 m E-W and an adjacent linear mound of earth. Ten shovel tests excavated in and around the mound and depression proved to be negative.

The function of this site is difficult to interpret. Its location is suggestive of a hunting lookout but features present may represent a burial. In either case, the site should be avoided. It is situated approximately 125 m south of the Spatsizi Plateau Wilderness Park boundary and since Gulf Canada Corporation does not plan any developments in this area, adverse impacts are not anticipated.

HhTf-2

This site is located about 750 m east of the Little Klappan River towards the northwest end of the knoll containing HhTf-1. The two sites are approximately 400 m apart.

The site represents an "Indian Graveyard" referred to in William Fleet Robertson's 1912 Notes on a Trip to Dease Lake and the Groundhog Coalfield (Robertson, 1913). Robertson states the following:

TABLE 5-1
SITE SUMMARY

SITE	SITE TYPE	UTM	WATER SOURCE	LOCAL PHYSIOGRAPHY	ELEVATION	ARTIFACTS	IMPACT STATUS	RECOMMENDATION
HhTf-1	POSSIBLE BURIAL	9VWPO66492	LITTLE KLAPPAN RIVER - 1 km	SOUTH AND WEST FACING KNOLL	1340 m	NONE	NOT SCHEDULED FOR IMPACT	AVOID
HhTf-2	BURIALS	9VWPO63495	LITTLE KLAPPAN RIVER - 400 m	WEST FACING KNOLL	1330 m	NONE	IN SPATSIZI WILDERNESS PARK	PROTECT/AVOID
HhTf-3	GENERAL ACTIVITY	9VWPO63496	LITTLE KLAPPAN TRIBUTARY - 200 m	KNOLL TOP	1340 m	HISTORIC DEBRIS OBSERVED, FLAKE AND BONES COLLECTED	IN SPATSIZI WILDERNESS PARK	AVOID
HhTf-4	GENERAL ACTIVITY	9VWPO63497	LITTLE KLAPPAN TRIBUTARY - 200 m	KNOLL TOP	1340 m	SQUARE NAILS, CARTRIDGES, BONE, FLAKES - 549 ITEMS	IN SPATSIZI WILDERNESS PARK	AVOID
HhTf-5	HISTORIC CAMP	9VWPO68493	LITTLE KLAPPAN TRIBUTARY - 150 m	KNOLL TOP	1350 m	HISTORIC DEBRIS OBSERVED	NOT SCHEDULED FOR IMPACT	NO FURTHER WORK
HhTf-6	HISTORIC CABIN	9VWPO56472	LITTLE KLAPPAN TRIBUTARY - 5 m	CREEK TERRACE	1320 m	HISTORIC DEBRIS OBSERVED	NOT SCHEDULED FOR IMPACT	NO FURTHER WORK
HhTf-7	GENERAL ACTIVITY	9VWPO41469	LITTLE KLAPPAN RIVER - 300 m	KNOLL TOP	1350 m	FLAKES, BURIN SPALL, MICROBLADES 71 ITEMS COLLECTED CARTRIDGES OBSERVED	POSSIBLE IMPACT BY GULF CAMP	12 TO 20 1 x 1 m UNITS
HhTf-8	GENERAL ACTIVITY	9VWPO67426	FOX CREEK - 150 m	ROCK OUTCROP	1650 m	FLAKES, SHOTGUN SHELL, MICROBLADES, 37 ITEMS COLLECTED	NOT SCHEDULED FOR IMPACT	16 1x1 m UNITS
HhTf-9	GENERAL ACTIVITY	9VWPO72425	FOX CREEK - 100 m	BENCH	1640 m	6 FLAKES COLLECTED	NOT SCHEDULED FOR IMPACT	FURTHER ASSESS-MENT IF IMPACTED
HhTf-10	GENERAL ACTIVITY	9VWPO69427	FOX CREEK - 200 m	LOW LYING TERRACE	1650 m	MICROBLADE AND TWO BLADE-LIKE FLAKES COLLECTED	NOT SCHEDULED FOR IMPACT	NO FURTHER WORK
HhTf-11	ISOLATED FIND	9VWPO22421	LITTLE KLAPPAN RIVER - 300 m	KNOLL TOP	1462 m	1 FLAKE COLLECTED	NOT SCHEDULED FOR IMPACT	NO FURTHER WORK
HhTf-12	GENERAL ACTIVITY	9VWPO76447	POND - 50 m	SOUTH-FACING SLOPE	1550 m	6 FLAKES AND A CORE COLLECTED	WITHIN 50 m OF IMPACT BY ROAD CONSTRUCTION	NO FURTHER WORK
HhTf-13	ISOLATED FIND	9VWPO76448	POND - 20 m	NORTH-FACING SLOPE	1550 m	1 FLAKE COLLECTED	WITHIN 50 m OF IMPACT BY ROAD	NO FURTHER WORK
HhTf-14	ISOLATED FIND	9VWPO33420	UNNAMED CREEK -100 m	ROCKY PLATEAU	1640 m	1 UTILIZED FLAKE COLLECTED	ALREADY IMPACTED	ASSESSMENT
HhTf-15	ISOLATED FIND	9VWPO71438	UNNAMED CREEK -50 m	ROCK OUTCROP	1660 m	1 SCRAPER COLLECTED	NOT SCHEDULED FOR IMPACT	ASSESSMENT
HhTe-1	GENERAL ACTIVITY	9VWP154407	SPATSIZI RIVER -130 m	TERRACE	1210 m	6 FLAKES COLLECTED	NOT SCHEDULED FOR IMPACT	NO FURTHER WORK
HhTe-2	GENERAL ACTIVITY	9VWP125476	DIDENE CREEK -40 m	KNOLL TOP	1320 m	4 FLAKES COLLECTED	NOT SCHEDULED FOR IMPACT	NO FURTHER WORK
HaTd-1	GENERAL ACTIVITY	9VWP244261	SKEENA RIVER -120 m	KNOLL TOP	1220 m	4 FLAKES COLLECTED	NOT SCHEDULED FOR IMPACT	FURTHER ASSESS-MENT IF IMPACTED
HaTd-2	ISOLATED FIND	9VWP237269	SKEENA RIVER -50 m	KNOLL TOP	1220 m	1 FLAKE COLLECTED	NOT SCHEDULED FOR IMPACT	NO FURTHER WORK
HaTd-3	GENERAL ACTIVITY	9VWP222292	SKEENA RIVER -200 m	KNOLL TOP	1280 m	1 BIFACE AND 1 FLAKE COLLECTED	NOT SCHEDULED FOR IMPACT	NO FURTHER WORK
HaTe-1	GENERAL ACTIVITY	9VWP193314	SKEENA RIVER -60 m	TERRACE	1280 m	2 SHATTER, 1 FLAKE AND 1 SCRAPER COLLECTED	NOT SCHEDULED FOR IMPACT	FURTHER ASSESS-MENT IF IMPACTED
HaTe-2	ISOLATED FIND	9VWP174327	SPATSIZI RIVER -80 m	KNOLL TOP	1280 m	1 FLAKE COLLECTED	NOT SCHEDULED FOR IMPACT	FURTHER ASSESS-MENT IF IMPACTED

TABLE 5-2

BONE, ARTIFACT AND MATERIAL TYPES

ARTIFACT AND MATERIAL TYPE	HhTf-1	HhTf-2	HhTf-3	HhTf-4	HhTf-5	HhTf-6	HhTf-7	HhTf-8	HhTf-9	HhTf-10	HhTf-11	HhTf-12	HhTf-13	HhTf-14	HhTf-15	HhTe-1	HhTe-2	HgTd-1	HgTd-2	HgTd-3	HgTe-1	HgTe-2	TOTALS
BIFACE/OBSIDIAN																				1			1
UNIFACE/OBSIDIAN															1						1		2
MICROBLADE/OBSIDIAN							12	2		1													15
PSEUDO-BLADE/OBSIDIAN										2													2
BURIN/OBSIDIAN							1																1
CORE/OBSIDIAN								2				1											3
CORE REDUCTION FLAKE																							
OBSIDIAN			1	10			5		1		1	3	1	1		4		1	1		1	1	31
CHERT							1																1
THINNING FLAKE/OBSIDIAN				33			20	20	1			2				2	2	2					82
CHALCEDONY				4				3															7
SHALE								1															1
QUARTZITE				1																			1
SILTSTONE							3																3
CHERT							5	1															6
RETOUCHING FLAKES/OBSIDIAN				227																			227
FLAKE/SHATTER FRAGMENTS																							
OBSIDIAN				266			14	5	1		1						2	1		1	1		292
CHERT							9	2															11
SHALE																					1		1
UTILIZED FLAKE/OBSIDIAN									2			1											3
RETOUCHED FLAKE/CHERT									1														1
SQUARE NAIL				3																			3
CARTRIDGE				2			1	1															4
BONE			8	2																			10
BURNED BONE				1																			1
TOTALS	0	0	9	549	0	0	71	37	6	3	2	7	1	1	1	6	4	4	1	2	4	1	709

KLAP:[205057]870008009.LOC 16/01/87 JTH

"This camping-ground is a famous rendezvous for the Indians hunting in the district, and is known as the "Indian Graveyard", from the fact that a number of Indians have been buried there; the Indians keep a lot of whipsawed lumber here to make coffins in case of emergency. The fugitive Indian Gun-a-noot uses this as a headquarters, and buried one of the women of his family here last season".

Native informants are aware of this graveyard and reported its general location. Two burials were found. They are situated side-by-side and consist of collapsed wooden cribbing. Observations of their size indicate that one is an adult burial and the other is a child burial. Approximately 4.5 m north of these burials is a rock-lined feature which may also represent a burial. Two other possible burials were observed, one to the north and the other to the south of the described burials. The description by Robertson implies that there are numerous graves at the site. Although the site area has probably been cleared and at present there is minimal vegetation, natural undulations of the ground make identification of additional burials difficult. If cribbing was associated with these burials, it is likely that they would be detectable.

These burials lie approximately 100 m north of the south boundary of the Spatsizi Plateau Wilderness Park and any impact on them is likely to be an indirect result of development caused by the ease of access into the general area and the number of people working in the area. Gulf will inform its field staff about the need to protect these sites and will post signs obtained from the Heritage Branch to warn others of the penalties provided for contravening the Heritage Conservation Act.

HhTf-3

This site is located northeast of HhTf-2 in an area where informants from Iskut reported that there had been a village. Three trails are visible in the site area. One trail leads from HhTf-3 to the burial grounds described above (HhTf-2). Bits of coal, and historic debris such as tin cans (unidentifiable as to contents) and enamelware were found on one of the trails.

Cut and blazed trees were also evident in the site area. A tree cache is located in the treed area at the southeast end of the site.

Twelve shovel tests were excavated in the site area measuring approximately 80 m N-S x 100 m E-W. Three of the tests were positive.

Collections included a tooth, 7 bones or bone fragments and an obsidian core reduction flake. In addition, a large unidentifable square tin can was uncovered in Test 6 and left in-situ. Identifiable bone includes a caribou (Rangifer tarandus) molar, an antler fragment, and distal metacarpal or tarsal fragment. The remaining bone consisted of unidentifiable long bone fragments of large land mammals. Two bones have been cut and ground to a point and are highly polished indicating that they were used as awls or knives.

There is no danger to this site because it is within the Spatsizi Plateau Wilderness Park.

HhTf-4

The site is located on the same northwest-southeast trending knoll as the sites discussed above. It is located at the northwest extremity of the knoll, about 100 m north of HhTf-3. This site is distinguished from HhTf-3 on the basis of archaeological material encountered, distance and change in landform.

The site area is approximtely 80 m N-S x 160 m E-W. The site is situated on a knoll covered with alpine fir, spruce and willow. Several open areas occur, covered only by mossess and lichens. A tributary of the Little Klappan River lies approximately 200 m north of the site.

In the central area of the knoll a concentration of buried cultural material was uncovered. Approximately 20 axed trees are located in the vicinity. At the eastern perimeter of the site, near the edge of the knoll, a pit has been excavated. It measures approximately 2.2 m E-W x 2.6 m N-S x 0.7 m deep. Tests placed in this feature were negative. Near the western edge of the knoll, blazed trees flank either side of the trail leading from the site to the Little Klappan River.

A total of 549 artifacts were recovered from the ten shovel tests (all soil was screened) excavated at the site. These artifacts consisted of obsidian, chalcedony and quartzite flakes as well as unidentifiable bone and burned bone fragments, three square nails and two 44 calibre cartridges. Many of the flakes (227) were retouching flakes which result from tool finishing or resharpening. Other flakes include tiny flake er shatter fragments of indeterminant origin (266), thinning flakes (38) or core reduction flakes (10). Tools were not found, nor did any of the flakes exhibit retouch or evidence of utilization.

Test 1 at HhTf-4 contained more lithic artifacts than any other test. Additional tests were excavated adjacent to Test 1 in an attempt to recover more of the artifact concentration. When only minimal amounts of material were found in additional tests, it became obvious that the concentration was localized, this Test 1 was expanded to a 1 x 1 m unit. In total, 534 artifacts were excavated from this unit. Most of these were uncovered between 3 and 6 cm below surface. The assemblage consists of obsidian, chalcedony and quartzite flakes. Bone fragments, some of which were burnt, were also observed in association.

A significant attribute of the site is two 7.5 cm (3 inch) square nails found in direct association with an obsidian flake at 4-5 cm below surface. These were collected from a test located approximately 1.5 metres north of Test 1. The two nails were encased in wood which was poorly preserved and therefore not collectable. A portion of a hearth was encountered in the same unit. The site lies within the Spatsizi Plateau Wilderness Park and will not be affected by project developments.

HfTf-5

This is an historic site located near the southeastern extremity of the knoll discussed above and just north of the trail which extends east along the top of the knoll from the burials (HhTf-2).

The site contains a stove, a wooden bench and table, piles of cut wood, poles for a tree cache and poles joined with wire nails (function unknown). Scattered around the area, particularly down the steep slope in the northern portion of the site, are several cans and bottles. Opposite this area, on the south side of the trail, is a poorly preserved wooden cradle and a caribou rack. The precise location or type of habitation utilized could not be determined. It may have been located near the table, bench and stove. The absence of logs or wood other than that described indicates that a tent rather than a cabin was used. On the basis of material observed, the site does not appear to be more than twenty or thirty years old.

Although the site is within the Gulf's coal licences approximately 100 m south of the Spatsizi Plateau Wilderness Park boundary, the site will not be impacted by proposed developments. The recording of this site constitutes adequate investigation at present but it should be preserved for future researchers.

HfTf-6

This is a historic site located adjacent to the BCR railway grade, about 1.2 m east of the Little Klappan River crossing. The site consists of the remains of a log cabin, previously owned by Mr. Ronald Woodcock of Hazelton. Attempts to reach Mr. Woodcock were unsuccessful.

The site has been severely disturbed by the construction of the railway grade which is within 10 metres of the cabin. Further investigation at this site was not recommended by the consultant.

HhTf-7

This is a prehistoric campsite located on a high knoll south of the airport runway, west of the Little Klappan River and south of an unnamed creek. The knoll affords a good view, particularly of the Little Klappan River valley. The site measures approximately 40 m N-S and 20 m E-W but it probably extends into treed areas adjacent to the known site area, which is free of tree cover.

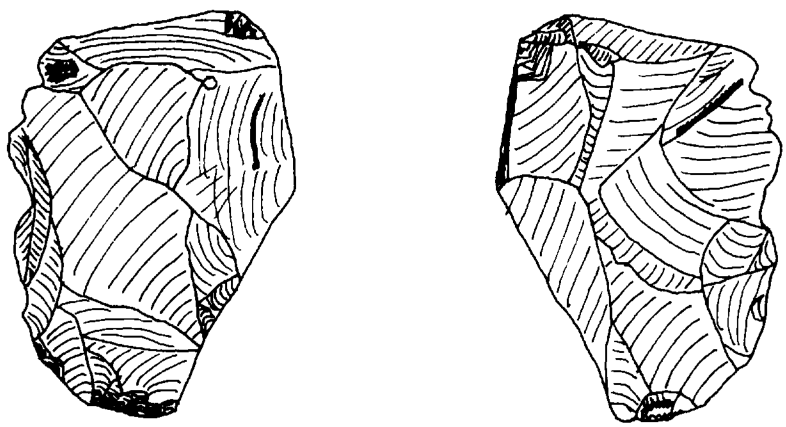
An obsidian flake and calcined bone were exposed on the surface and subsequent shovel testing revealed a buried component at this site. Six of nine 40 x 40 cm shovel tests excavated were positive. All soil was screened through 6 mm mesh. The majority of artifacts recovered were distributed between 2 - 6 cm below surface, in grey silty loam. Evidence of two separate components occurs in two of the tests as artifacts are distributed over a vertical distance of 8 cm and are concentrated at two levels. The evidence is suggestive of separate occupations.

Seventy-one artifacts were found including twelve obsidian microblades, a burin, and 57 flakes. Although obsidian is the predominant material type, siltstone and chert were also found. Surface evidence of more recent site use includes a pile of cut wood and several cartridges associated with calcined bone.

This site is situated on a high knoll with a good vantage of prime large ungulate habitat. The site has a southern aspect, is well-drained, and firewood and water are readily accessable. The Little Klappan River is 300 m east and a tributary is situated 200 m north. The location of the site provides access to both the Little Klappan and Didene valley system.

HhTf-7 lies within an area which may be disturbed by the mine facilities. If the site must be disturbed Gulf will undertake an excavation of the area.

HhTf-7:14



HhTf-12:1

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FIGURE 5-2

ARTIFACTS FROM HhTf-7 and HhTf-12

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HhTf-8

This site is located on a bedrock outcrop in a valley or pass between Lost Ridge and Klappan mountain. The site is a campsite with both buried and surface components. Surface materials were initially noted by Gulf geologists working in the area.

The site, measuring approximately 15 m N-S and 40 m E-W, is located on an east-west trending outcrop which rises 20 m above the ground surface. Fifteen artifacts were collected from the surface and 22 were recovered from five shovel tests. As at other prehistoric sites, most of these artifacts are thinning flakes. Two of the fifteen microblades collected during the project were found at this site. Artifacts of chert, chalcedony and shale material were found in addition to obsidian. The site appears to be stratified with separate components at 2-7 cm below surface and 11-15 cm below surface. A possible hearth was noted in one of the shovel tests. Much of the surface area is rocky and sediments are limited to glacial sands and gravels. This outcrop, and the adjacent one are the only high, dry vantage points along this wet corridor. Although the adjacent outcrop is not of sufficient width to support a campsite, marmots, an important subsistence resource, were observed here.

The presence of microblades, a variety of lithic material types and hearth deposits which may be datable all contribute to the significance of this site. The status of this site in terms of project impact is not certain at this time but it will be excavated if any disturbance of the site by mining activity becomes necessary.

HhTf-9

This site is located approximately 500 m southeast of HhTf-8 near the base of Klappan Mountain. The site is situated on a high, broad bench adjacent to a small pond. As with other sites in the pass between Lost Ridge and Klappan Mountain, vegetation consists of moss, lichen and willow.

Artifacts were located on the ground surface over an area measuring 60 m N-S and 20 m E-W. Two utilized flakes (one was in a shovel test) and one retouched flake were found (Figure 5.3). The remaining artifacts are unmodified flakes. All but one of the artifacts were located on the surface. The unifacially retouched flake is made of chert and the other artifacts are obsidian.

This area of the property is not scheduled to be impacted but should disturbance be proposed the site will undergo further examination.

HhTf-10

This site is also located in the low lying area between Lost Ridge and Klappan Mountain. It is approximately 200 m east of of HhTf-8.

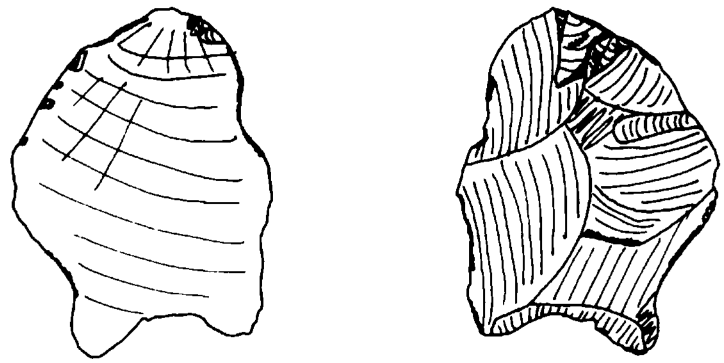
The site consists of three surface finds. One is an obsidian microblade and the other two are obsidian "pseudoblades" or attempts at microblades. These finds were discovered within an area measuring 2 m x 2 m. No additional finds were located on the surface nor in the eight shovel tests.

Due to the location of this site and the paucity of artifacts, it is probably not a campsite. The artifacts observed could either be discards produced during manufacture or accidental loss. No further work is recommended.

HhTf-11

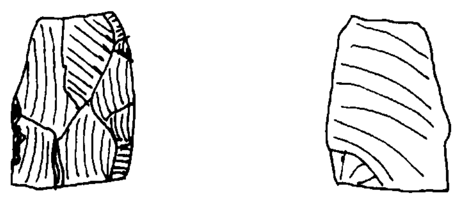
This site is located on a knoll overlooking the Little Klappan River, 300 m to the west. It is southwest of Lost Ridge and is at the base of the western portion of the corridor between Lost Ridge and Klappan Mountain. Although the vegetation on the knoll is primarily grasses, the surrounding area has a thick cover of willows.

The site consists of an isolated find. One obsidian core reduction flake was found on the surface. Extensive surface examination and four shovel



HhTf-9:1

HhTf-9:4



HhTf-9:6

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FIGURE 5-3

ARTIFACTS FROM HhTf-9

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tests were negative. Due to the scarcity of artifacts, no further work is recommended at the site.

HhTf-12

This site is represented by a lithic scatter and is located on the east side of Lost Ridge. Site materials are exposed on the surface of south and southeast facing side slopes. The site overlooks a pond located about 50 m south. Seven artifacts were recovered from an area measuring approximately 15 m N-S and 30 m E-W.

The site matrix consists of anthracite, slate and pea gravel overlying glacial till. An anthracite test trench, measuring approximtely 10 m x .75 m, has been excavated in the area of the highest artifact concentration. A road and storage area have been built 40 m north of the site.

Finds include an obsidian core (Figure 5.2), core reduction flakes and thinning flakes. There is minimal soil development throughout most of the site. The five shovel tests excavated in areas of soil deposition were negative.

This site was impacted prior to the heritage study by an anthracite test trench. Although additional artifacts may be present at this site these are likely to be limited and no further testing is recommended here.

HhTf-13

This site is also located on the east side of Lost Ridge, about 150 m north of HhTf-12. It consists of an isolated find (a core reduction flake) exposed on a northfacing slope, and a pond is located about 20 m to the west.

This site has similar physical characteristics to HhTf-12. The find was located in an unvegetated area. Surrounding vegetation includes mosses, lichens and dwarf juniper. Several good exposures here have been examined and two shovel tests excavated in areas of soil deposition were negative.

On the basis of extensive surface examination and two shovel tests, further investigation is not recommended.

HhTf-14

This site was located in August 1984 by a Gulf geologist. The site, an isolated find, is located at the western extremity of Lost Ridge. There is an unnamed creek 100 m to the north and the Little Klappan River is 1.7 km to the west.

The site consists of a long (6 mm) obsidian flake which has been utilized on one end. This find was on the surface and no other artificts were observed. The site is situated on fine scree that lacks vegetation. If impacts on the site are anticipated, it should be assessed by subsurface and surface examination.

HhTf-15

This site was also found by a Gulf geologist. It is located on a rock outcrop, in the eastern portion of Lost Ridge.

The site consists of an obsidian flake which has been unifacially retouched and probably used as a scraper. In addition, the tip may have been used as a burin. This artifact was found on the surface of the outcrop.

This particular area of Lost Ridge was not considered to have high potential for heritage resources because it is relatively steep.

HhTe-1

This site is a surface lithic scatter located on the upper west terrace of the Spatsizi River. The Spatsizi River is approximately 130 m to the east and about 20 m below the terrace edge on which the site is located. Grizzly

Creek is 630 m to the north.

The site area is 11 m N-S and 2 m E-W. It has been virtually destroyed by a working road associated with construction of the BCR railway grade. It is probable that the site originally extended to the edge of the terrace and measured approximately 15 m N-S and 5 m E-W.

All five flakes from this site were found on the surface. One is a large bifacially-worked secondary decortication flake with additional unifacial retouching and evidence of utilization. It is grey opaque obsidian. The site is located at the edge of the working road and extensive trowelling produced negative results. This site will not be impacted by Gulf developments. Further work is not recommended since the site is heavily disturbed.

<u>HhTe-2</u>

This site is located just west of the existing Gulf camp. It is 100 m north of the BCR grade and 20 m north of Didene Creek. It is situated on a high, elongated (110 m long), east-west trending knoll. The west end of the knoll has been disturbed by gravel extraction. Square and circular pits which probably relate to railroad construction also occur on the knoll. A dense dwarf juniper forest covers all but the western portion.

Four flakes were found in three of the eleven shovel tests excavated. The site appears to be limited to the cleared area at the west end. This area is so disturbed by the railway construction test pits mentioned above that finding a spot to shovel test was difficult.

There are no plans to impact the site but it is so disturbed that further investigation is not recommended.

<u>HgTd-1</u>

This is the southernmost site recorded during the heritage resources study.

It is actually outside the property boundary on a landform which was briefly examined because of its obvious high potential. It is located on the east side of the Skeena River near its confluence with Porky Creek. The site is located on a dry, elevated bench which is the only accessible landform of this nature in the area.

Three flakes and a piece of shatter were recovered from one shovel test. Six tests in the immediate vicinity and four tests on adjacent landforms were negative. While much of the landform on which the site was located is devoid of tree cover, the one positive test was placed adjacent to a patch of white spruce and alpine fir.

This site is not within the Mount Klappan Anthracite Property and will not be impacted.

HgTd-2

This site is located 1 km north along the Skeena River from HgTd-1. This site is also located just south of the study area and was found during a quick reconnaissance of the landform because of the obvious potential. The site is situated on a long north-south trending ridge that is only 50 m west of the Skeena. There are two parallel ridges or knolls at this location. The vegetation consists of moss and lichen, and small patches of juniper, willow, black spruce and fir. The site consists of a single obsidian flake, located in a shovel test. Fourteen shovel tests were excavated, but only one was positive.

This site is located outside of the property consequently no further investigation is deemed necessary.

HgTd-3

This site is located near the headwaters of the Skeena River. The site is located on an isolated knoll overlooking the Skeena River 200 m to the west.

An obsidian biface fragment and a flake were exposed on the surface of the knoll. The biface represents the only specimen found to date in the study area. It is illustrated in Figure 5.4. The surface of the knoll has been heavily disturbed by activity related to the construction of the BCR grade, therefore further examination is not recommended.

HgTe-1

This site is also located near the headwaters of the Skeena RIver. It is located on a large bench on the east side of the river and has been exposed by construction of the BCR grade and an associated road.

The site consists of an obsidian uniface, two obsidian flakes and a piece of shale shatter. The uniface has been utilized as a scraper (Figure 5.4). These artifacts were found on the surface within an area measuring approximately 30 m N-S and 20 m E-W. Although the bench is dissected by a road, disturbance in the actual site area is limited to tree clearance and cat tracks.

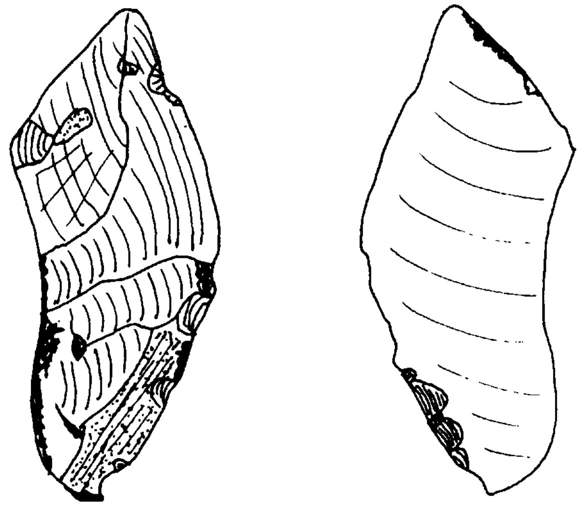
Shovel tests were not excavated at the site and no impacts are anticipated.

HgTe-2

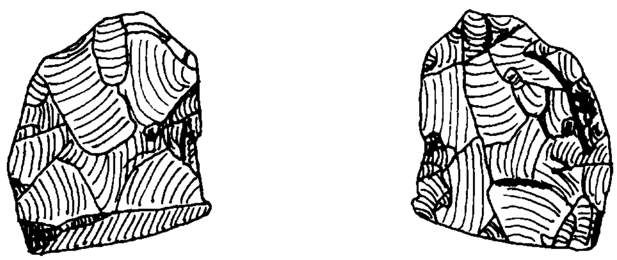
This site is located near the headwaters of the Spatsizi River. The site is situated on one of several knolls which flank an unnamed pond for a distance of about 1 km.

The site consists of a single obsidian flake, found on the surface. Four shovel tests, in the vicinity of the flake and four on adjacent landforms, were negative. The eastern portion of the knoll has been disturbed by the construction of the BCR grade.

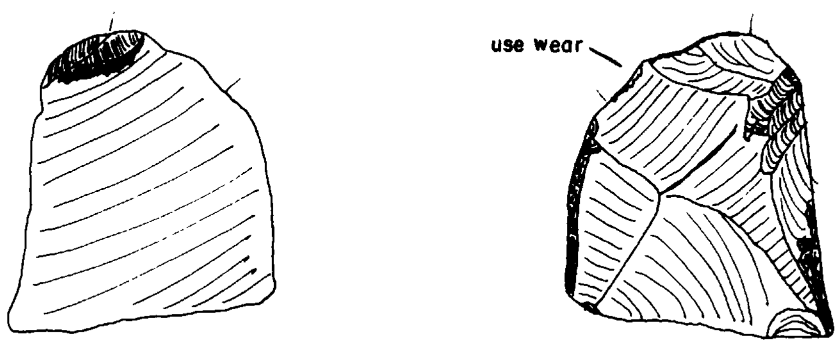
There are no immediate plans that would impact on this site and further investigation is not recommended.



HhTe-1:1



HgTd-3:1



HgTe-1:1

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FIGURE 5-4

ARTIFACTS FROM HhTe-1, HgTd-3, AND HgTe-1

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5.0 SUMMARY AND IMPACT ASSESSMENT

Inventory of the Mount Klappan Anthracite Property resulted in discovery of seventeen heritage sites. Two sites are associated with historic activities, one is a potential burial of unknown age and the remainder are prehistoric. Three additional sites were recorded adjacent to the property, in the Spatsizi Plateau Wilderness Park. These include a native burial ground and two sites containing both historic and prehistoric material. Two prehistoric sites were found to the south of the study area.

As anticipated, flakes are the dominant artifact type, comprising 94 percent of the 708 collected artifacts. However, 62 percent (541 flakes) occur at a single site (HhTf-4). Analysis indicates that the majority of flakes were produced during lithic reduction and tool resharpening activities as only three flakes show evidence of utilization and only one has been retouched. Diagnostic artifacts or tools of any description are scarce. The most common tools encountered were microblades. Fifteen microblades, plus two blades that probably represent poorly manufactured specimens, were recovered from three sites (HhTf-8, 9 and 10). According to Fladmark (1983), microblade assemblages in northern British Columbia probably pre-date 4000 B.P. and may occur as early as 6000 or 7000 B.P. Other tools recovered include a biface, two unifaces and a burin.

Obsidian constitutes the bulk of the lithic material recovered. Obsidian was probably obtained from quarries on Mount Edziza, located approximately 120 km northwest of the study area. Similarities in colouration and texture, and the relative preximity of Edziza obsidian sources, provide the basis for this contention. Other material types, representd by 32 artifacts, include chert, chalcedony, siltstone, shale and quartzite. These raw materials were probably obtained locally.

Eleven bone fragments were collected from sites HhTf-3 and 4, both containing prehistoric and historic components. Three are identified as caribou bones but the remainder cannot be identified to species level. Two bone fragments have been cut or ground and utilized as toels.

The boundaries of the Heritage Resource study area as identified represent that portion of the property where developments are most likely to occur within the forseeahle future although a reconnaissance of several high potential areas was also conducted. Should they occur, significant changes to the siting of elements of the mine development will be reviewed by Gulf for potential Heritage Resource impact. Particular attention will be paid to high probability areas.

None of the sites recorded to date have been directly impacted but should development proceed, two sites, HhTf-7 and 8, may have to be excavated.

In addition, should disturbances become necessary site HhTf-14 located by Gulf personnel, should be assessed by shovel testing. Additional assessment of site HhTf-9, HgTd-1 and HgTe-2 will also be done if impact is imminent. Additional investigation is deemed unnecessary at the remaining sites.

Gulf considers that education is often the best approach to mitigating impacts and will, by pnsting the signs distributed by the Heritage Conservation Branch and by instruction to key project personnel, encourage an awareness of the need to protect such sites.

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PART SIX - SUMMARY OF IMPACTS AND MITIGATION

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1.0 ENVIRONMENTAL MANAGEMENT

The development plan for the Mount Klappan Anthracite Project incorporates a number of features and procedures which have as their primary objective the control, elimination or mitigation of negative environmental impacts. Part Six of Volume II - Environmental Management, provides details of many of these features of the project.

A variety of waste management programs addressing everything from garbage to tailings have been developed to insure that all wastes and discharges associated with the project are handled in an environmentally sound manner. A comprehensive water management scheme is incorporated in the project plans to capture and treat all drainage water and other water discharges if they are contaminated by sediment or other effluents. A detailed spill contingency plan will be developed to handle accidental chemical and petroleum product releases at the site.

If an on-site power generating plant is construoted for the project, its design and operating parameters include a range of provisions for controlling sulphur dioxide and nitrogen oxide emissions.

Revegetation will be done as it becomes practical and reasonable to do so in conjunction with the mine plans.

It is recognized that some environmental impact is unavoidable with a project such as the Lost-Fox Mine. Some vegetation and wildlife habitat will be temporarily unavailable during operations. Millions of tonnes of rock will be moved and some of the terrain will be permanently altered. Most impacts however will be transitory and there is no reason to believe that the existing natural environment will not be re-established a short time after mining ceases.

Alpine and sub-alpine vegetation of mosses, lichens, grasses and shrubs will re-colonize the development area and the wildlife uses now found in the area will reappear. Marmots and squirrels and other small mammals will readily re-establish their burrows in the soft materials left behind in the waste rock and pit areas. Caribou will again graze the grassy areas in the summer and grizzly bear will forage for the small mammal prey species in the area.

In the meantime however, there will be environmental impacts and all reasonable efforts must be made to moderate them. The following sections summarize the more significant potential impacts and the proposed methods for mitigating these effects.

2.0 STAGE I ENVIRONMENTAL IMPACT FINDINGS

A comprehensive set of studies to establish baseline conditions and identify potential environmental impacts associated with development of the Lost-Fox Mine were conducted on behalf of Gulf Canada Corporation primarily in 1984 and 1985.

Results of these studies were reported to the British Columbia Mine Development Steering Committee in a Stage I Assessment submitted in 1985. Volume III of that submission contained the assessment of the biophysical environment. Reference should be made to that volume to obtain details of the assessment.

The principal impacts and proposed mitigation measures identified in the Stage I Assessment are summarized in the following paragraphs.

Fisheries

Fox Creek and Didene Creek to the east of the project area do not contain fish as there is a barrier to fish access in Didene Creek near the Spatsizi River. The upper portion of the Little Klappan River on the west side of the project area has very limited fish presence and is considered poor fish habitat. Construction of a water supply reservoir in this area will have negligible impact on fish. Waste water and drainage entering these creeks will be treated such that harm to fish populations downstream of the property in either the Spatsizi River or Little Klappan River will be prevented.

Water Quality

Surface and groundwater quality in the area is good. Drainage from disturbed areas and groundwater collected from the mine pit will be cycled through sediment ponds to ensure that discharged water meets regulatory requirements. The bulk of the rock and anthracite to be excavated in the mine is acid-consuming and the production of acidic runoff water is unlikely.

Soils

Soils are generally thin and are characterized as having only poor to medium suitability for stockpiling and reclamation use in the mine area. Initial revegetation tests however indicate good first-year germination on disturbed sites and it is expected that reclamation techniques can be developed to revegetate sites where soils have been removed.

Vegetation

Species are typical of alpine and subalpine areas at this latitude and no unique associations were identified. Some relatively rare species are known to occur in the general region but development of the mine will not result in the loss of any rare populations.

Wildlife

The Mount Klappan property does not provide critical winter range for ungulates such as moose and caribou, nor is it significant in the sensitive calving and rutting cycles of these animals. The area is utilized as summer range by a small population of ungulates but concentrations are low. The range area lost to the mine development by these animals is minimal. Grizzly bears are known to use the area as well but their activities are widely dispersed and no indication of intense use of the mine area was found.

In the course of the Stage I Environmental Studies, and as a result of the government's review of the Stage I, several requirements for more detailed or additional environmental assessment work were identified. These additional efforts are reported primarily in this volume of the Stage II Environmental Assessment. The key findings of these studies are highlighted in the following sections.

3.0 ATMOSPHERIC ENVIRONMENT

3.1 CLIMATE

Two years of additional data collection at the site has confirmed the general meteorological regime described in the Stage I Assessment. The climate is in many ways ideal for mining and extremes of temperature, wind or precipitation are not expected to be of such frequency or magnitude as to cause any significant operational problems.

Data indicative of atmospheric turbulence, in the form of vertical wind velocities, were also recorded for a period of one-and-a-half years. Analysis of this data has allowed classification of seasonal wind regimes into atmospheric stability classes. Stability of the air mass is a significant factor in determining the extent of plume dispersion from an air emission source such as the optional power plant at Mount Klappan.

Analysis of the wind velocity data revealed a high incidence (about 25%) of very stable air during winter and spring months. The air mass was only slightly unstable another 50 to 60 percent of the time. Therefore, during the winter and spring, it is expected that air turbulence will be relatively infrequent and will not be a major factor assisting in the dispersion of air emissions. The situation changes during the summer and fall months. Here, the incidence of the three least stable classes is between 30 and 40 percent. Strong stability occurs only 6 percent of the time. Accordingly, it is expected that plume dispersion by atmospheric turbulence will be more pronounced in the summer and fall.

3.2 AIR QUALITY

The most significant effect of the project on ambient air quality will result from power plant stack emissions. An extensive program to quantify the level of emissions, the influence on ambient air quality and the extent of harm to the natural environment has been conducted by Gulf.

A test burn program, utilizing actual reject anthracite from Mount Klappan as fuel in a pilot plant scale circulating fluidized bed burner, was commissioned in part to ascertain the characteristics of the flue gas emissions, should a similar plant be installed at Mount Klappan. The test burn revealed that the low operating temperature characteristic of the C.F.B.C. boiler using high ash, reject anthracite, is extremely effective in retarding the formation of nitrogen oxides (NO_x). Test burn concentrations in flue gases were consistently less than 17 percent of British Columbia's strictest air emission standard for NO_x.

The other component of stack emissions causing concern is sulphur dioxide (SO_2). The tests showed that the combination of calcium inherent to the ash content of the fuel and in supplemental limestone added to the combustion chamber reacts with sulphur to reduce SO_2 emissions. Sulphur capture of 75 percent was achieved in the tests and the resulting SO_2 emissions are less than British Columbia's most stringent objective of 0.09 mg S/kJ of heat input. Total sulphur emissions are predicted to be only about 0.3 tonnes per day or less for a commercial scale plant such as that contemplated for the mine development. This total volume is quite small when compared with many other industrial plants in British Columbia and Canada such as pulp and paper mills, smelters, gas plants or utility power plants which measure sulphur emissions in terms of tens to hundreds of tonnes per day.

Once the volumes of pollutants were established by the test burn program, the data was used in a dispersion modelling exercise to estimate ambient air quality in the Mount Klappan area resulting from these emissions. Accepted mathematical models were employed to identify ground level concentrations of SO_2 and NO_x. These models rely on data describing the surrounding terrain and the atmospheric stability frequencies discussed above in the plume dispersion calculations.

The models predict that maximum annual concentrations of air pollutants will occur on the steep slope 2 to 3 kilometres west-northwest of the powerplant location. The expected annual average concentration of SO_2 at this location is about 0.003 parts per million (volumetric). Maximum concentrations at the boundary of the Spatsizi Plateau Wilderness Park are estimated at between 0.0003 and 0.0004 ppmv. All of the values are much lower than the British Columbia's most stringent ambient air quality objective of 0.01 ppmv for rural and pristine environments.

A worst case scenario was also developed to estimate the maximum short-term SO_2 concentration associated with very stable conditions. A one-hour peak concentration of 0.03 ppmv was derived for this case. This level is significantly lower than the B.C. Pollution Control Objective of 0.17 ppmv.

The dispersion pattern for NO_x will be the same as that for SO_2. NO_x is less damaging to the environment and consequently, pollution control objectives are higher. Since NO_x emissions were shown to be even lower than SO_2 emissions in the test burn program, ambient concentrations are estimated to be well within safe levels.

A modification of the dispersion model was also used to predict sulphur deposition in the project area. Maximum deposition levels were found to be 5.5 kg/ha/annum. Again, this value is exceedingly low due to the small amount of sulphur actually released from the power plant.

It should be noted that this discussion dwells on the areas of maximum concentrations and it is predicted that in all cases even these maxima are comfortably within the strictest provincial standards. The areas of maximum concentrations however, encompass only very small portions of the Lost-Fox Basin. All other areas would have much lower concentrations and in many cases, the increased levels of SO_2 and NO_x will not even be detectable. Taken as a whole, it is expected that operation of a power plant to service the Lost-Fox Mine will have very minimal impact on the quality of the Lost-Fox airshed.

4.0 AQUATIC ENVIRONMENT

4.1 SURFACE WATER QUALITY

Existing surface water quality is good. Levels of nutrients and heavy metals are low with the exception of iron, aluminum and copper, which were present in relatively high background concentrations. No surface water quality factor was identified which would hinder project development.

Possible impacts associated with the proposed development include increased levels of suspended solids and/or changes in water chemistry. These changes could induce either positive or negative effects on stream biota or suitability of the water for human consumption.

All effluent, including surface drainage from the development area, will be passed through sediment ponds if required to reduce suspended solids to the pollution control objective of 50 mg/l in the discharges. With the low suspended solids concentrations anticipated in discharges from the water management facilities, impacts on stream biota in site watercourses and downstream systems will be negligible.

Assessments of anticipated changes in water chemistry were conducted through the monitoring program of water draining the Hobbit-Broatch test pit area and the supernatants collected in the tailings and sediment ponds at the pilot wash plant operated at the site. There was no detected change in Hobbit Creek water adjacent to the test pit. Water ponded within the pit itself was found to be well within final effluent objectives.

Analysis of tailings pond effluent showed no chemical characteristics which would be expected to create environmental problems and all parameters were well within pollution control ebjectives. Bioassay tests of the tailings pond water resulted in high fish mortality (30%, 40% and 50%) on three occasions. No mortality was observed on two occasions. Efforts to discover toxic constituents which could explain these results were unsuccessful.

Elevated levels of iron and zinc were identified in settling pond water but the concentration were within the most rigorous Ministry of Environment objectives for effluents. Dissolved manganese concentrations were found to slightly exceed the strictest effluent standards. The concentrations observed however would not pose a threat to aquatic life. Since the analysis of both the tailings and settling pond remained consistently good it can only be assumed that the mortality was due to other factors pertaining to the fish.

Acid generation by anthracite and waste rock appears to be extremely unlikely and accordingly, water quality impacts are expected to be negligible.

Nitrogen contamination of the Little Klappan River from explosives residuals will occur but it is expected that inorganic nitrogen levels will not exceed water quality criteria and may in fact be beneficial.

Taken togethor, the studies of changes in water chemistry associated with tailings and sediment pond waters, acid generation and nitrogen contamination indicate that there will be no problems with meeting final effluent objectives.

4.2 HYDROLOGY

Clearing of vegetation and removal of soils in areas disturbed by the mine development will increase erosion and siltation and the effects will depend on timing, location and quantity. Siltation would also be associated with gravel removal from watercourses, creek crossings and pit dewatering.

The sediment control measures incorporated in the water management plan will reduce suspended solids loads in runoff to acceptable levels. The lower perimeters of all disturbed lands will be protected by well-vegetated buffer strips, filters, dykes or sediment basins, or a combination of such control measures as required if the actions are warranted by field conditions.

Cut and fill slopes will be designed and constructed to minimize erosion and all diversion and drainage channels will be designed to accommodate expected runoff flow velocities without erosien. Stream crossings and borrow pits in streambeds will be minimized or avoided to the extent possible.

No factor in surface water hydrology has been identified which would preclude development of the Lost-Fox Mine or which would create unmanageable impacts.

4.3 FISHERIES

Fisheries resources in the project area range from nonexistent in Fox Creek and Didene Creek to very limited in the upper Little Klappan River. Planned sedimentation controls will result in minimal siltation in these watercourses and the impacts on downstream fisheries is expected to be negligible.

Increased sport fishing in the lower Little Klappan River and the upper Spatsizi River may have some impact but mine employee access to these areas will be limited.

5.0 TERRESTRIAL ENVIRONMENT

5.1 SOILS

Soils in the project area are typically thin and of low nutrient value. This is particularly true at higher elevation, well-drained sites, such as much of the pit area, where soils are relatively coarse and less than 1 metre deep. Stockpiling of such soils for later reclamation use is of little value. In addition, it would be uneconomic to strip and salvage such a thin layer.

Some low-lying areas have peat and bog materials overlying till and bedrock. These organic soils will be removed in isolated locations where excavation to bedrock is required for building foundations. Soils in the area do not present any unusual or significant construction problems.

5.2 VEGETATION

5.2.1 Rare Species

Additional work has been completed to identify the locations of any vegetation populations which could be considered rare. All known vegetation species in the study area were classified according to rarity. Most species identified are quite common and widely distributed around the region. Individuals in this group will be destroyed in the course of project site clearing activities but no population is threatened.

Fourteen species found in the study area were classified as rare primarily because the Mount Klappan area is near the southern geographical limit of their distribution. All are common throughout the region however and with the exception of four species, also occur in the Gladys Lake Ecological Reserve. It is likely that further botanical study of northern B.C. would reveal that many of the species listed as rare would be deleted from the list.

The impact of the Lost-Fox Mine on the rare species identified will be limited to the loss of a few individuals but no populations. These species occur in other locations unaffected by the development.

5.2.2 Air Emission Effects on Vegetation

Review of the scientific literature on the sensitivity of vegetation to SO_2 emissions indicates that 1-hour concentrations of between .41 and .87 ppm can cause injury to vascular plants occurring in the area. Willow shrubs and larch are the most sensitive species. Lichen appear to have roughly equivalent sensitivity on a short term basis with .5 ppm being noted as causing injury. The peak 1-hour concentration predicted for the Mount Klappan area under worst case conditions is 0.03 ppm. This level is significantly below the concentrations where observable damage would be expected. As such, impacts from short-term, worst case fumigations are expected to be undetectable.

Sensitivity of plants exposed to SO_2 over the longer term has also been examined. Studies in the vicinity of Alberta gas plants emitting about 140 tonnes per day of SO_2 have found little or no measurable effects on trees. One study found a slight reduction in forest undergrowth however. The power plant at Mount Klappan is expected to produce about 0.6 tonnes per day of SO_2, less than 1 percent of the output of the gas plants cited above.

Studies of lichen response to long-term SO_2 exposure suggest mean annual concentrations as low as 0.01 ppm may injure the more sensitive species. Several studies of Alberta gas plant lichen response have indicated however little or no identifiable impacts. Lichen and moss communities have declined in the vicinity of two oil-sands plants near Fort McMurray, Alberta, but the combined SO_2 output of these developments is 485 tonnes per day, or 800 times the emissions predicted at Mount Klappan.

Maximum mean annual concentrations of SO_2 predicted for the Mount Klappan area are 0.003 ppm. This maximum level occurs in an area of sparse vegetation on the ridge west-northwest of the power plant location and is quite limited in aerial extent. All other areas in the region will be exposed to concentrations even lower than this. The predicted concentrations are so low that expected impacts on lichen vegetation from ambient SO_2 concentrations are negligible.

Maximum sulphur depositicn is predicted to be 5.5 kg/ha/a. Again, this maximum level occurs only in a very limited area. All other areas will have less deposition. This deposition rate is not expected to alter soil chemistry to a sufficient extent such that vegetation will be affected.

Plants are much less sensitive to NO_x concentrations. Studies have indicated that injury occurs with long-term exposures of .13 to .6 ppm. These values are from 26 to 120 times greater than the maximum annual ground level concentration of 0.005 ppm predicted for the Mount Klappan area. As such, it is expected that the impact of NO_x emissions from the power plant will be negligible.

5.3 WILDLIFE

5.3.1. Caribou

Extensive investigations of caribou life-cycle and migration patterns has established that the animals will not be likely to come into contact with the Lost-Fox Mine Development during sensitive stages of their seasonal activities. Caribou do not use the Mount Klappan area for winter range as they remain some 60 kilometres north in the Stikine River valley.

It is expected that isolated individuals will migrate through the project area moving generally southward toward the Kluayetz Creek Flats area in the spring. some of these will be pregnant females moving to birthing sites. No birthing sites have been discovered in the mine development area.

During summer months, the caribou become widely dispersed and some will use the Lost-Fox basin area as summer range. No concentrations of animals occurs at this time however. In the fall, many of the caribou will migrate north again to rutting grounds near the Little Klappan River downstream from the project area. No rutting areas have been identified near the project.

It is not expected that caribou will be particularly disturbed by the project, provided their movement is not impeded. In some cases, the animals may choose to skirt the project area but this is not expected to have significant impact on them. Some summer range will be lost to the mine development but the absolute area involved is very minor compared to the total range used. Their is no intensive use of the project area by the caribou and there is no expectation of serious impact on the Spatsizi area caribou.

One area of concern regarding caribou and other ungulates is the potential for collisions on mine area roads and the access road to Highway 37. Regular gaps will be cut in roadside snowbanks during the spring season to give the animals an opportunity to get off the roadway when vehicles approach. The incidence of animal collisions will be monitored and if a significant problem becomes apparent other action may be required.

5.3.2 Grizzly Bear

Grizzly bears are known to hunt and forage in the vicinity of the proposed mine but no denning sites have been discovered in or near the project development area. Grizzly roam over a wide region and do not congregate in large numbers . The loss of the development area to their use is not expected to have any significant impact on these animals.

Grizzlies will generally keep their distance from areas of human activity and will not approach the area unless attracted, usually by unattended garbage. Strict garbage management practices entailing daily burial of the material in the mine waste rock disposal area will continue to deter both grizzlies and black bears from entering the project area.

Still, potentially dangerous encounters with bears could occur and the wildlife monitoring program and employee training will be utilized in an effort to minimize the danger.

5.3.3 Wildlife Habitat

An extensive comparative analysis of wildlife habitats which will be lost as a result of mine development has indicated that the development area does not encompass any uniquely valuable habitats. In general, the mine and infrastructure areas represent zones of only modest wildlife utilization. No intense or critical use by any species has been identified.

The characteristics of habitats lost are replicated in many settings throughout the region which will be unaffected by development. The impacts from the loss of habitat are expected to be negligible.

6.0 HERITAGE RESOURCES

Prehistoric artifacts, primarily flakes with a few microblades, have been discovered at a number of sites in the region. The most significant site lies within the Spatsizi Plateau Wilderness Park and appears to contain a prehistoric burial ground. One site, where evidence of prehisteric tools was found, is near the proposed water reservoir. This site will be excavated and studied further if project activities will disturb the site. Another site near Fox Creek to the east of the proposed mine area also showed some artifacts. This area is not scheduled for any disturbance. If any other sites are to be disrupted, additional assessment work may be conducted as appropriate.

Signs prepared by the Heritage Conservation Branch will be posted at known heritage sites and project personnel will be instructed as to the need to protect such sites.

7.0 CONCLUSION

A certain level of environmental impact is associated with any development or undertaking on the scale of the Mount Klappan Anthracite Project. Some impacts, such as the physical disturbance of land, at least temporary loss of vegetation or wildlife habitat, alteration of natural drainage patterns and similar impacts are largely unavoidable. Based on Gulf's assessment of the environmental implications of the project, none of the unavoidable impacts are sufficiently serious or irreversible such that project development is inappropriate. Many of the potential impacts however are to varying degrees manageable and controllable.

Gulf has adopted a wide range of environmental management practices in its project plans. In developing environmental controls it is always difficult to establish what levels of environmental impact are acceptable and what mitigation efforts are practical and reasonable. Gulf has used applicable regulatory guidelines in many of these cases to determine what mitigation is necessary. As a result of this approach, it is expected that the Mount Klappan Anthracite Project will meet the most rigorous applicable regulatory guidelines, objectives or standards promulgated by the Government of British Columbia relating to environmental protection.

Adherence to these principles will insure that the overall, long-term environmental impacts associated with the Lost-Fox Mine development will be minimal and reasonable given the nature of the project.

It is recognized that the proposed Lost-Fox mine development would introduce a significant industrial complex adjacent to the Spatsizi Plateau Wilderness Park. This area has been set aside and protected by the Government of British Columbia to preserve the wilderness recreation values it offers. It is submitted that the mine development will have only very minor impacts on the park. Access to the southwestern corner of the park will be improved but since no roads will enter the park, human incursions will be limited. A portion of the mine development area will be visible from some isolated areas of the park, and as a result, aesthetic values may be diminished slightly. Nothing has been identified in the assessment of project impacts however, which would result in any significant effect on natural ecosystems within the park. No element of the project suggests that the wilderness character of the park will be threatened.