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PLACER DOME INC. BERG PROJECT
ENVIRONMENTAL AND ROAD CORRIDOR STUDY

Prepared for

PLACER DOME INC.
1600 - 1055 Dunsmuir Street
Vancouver, British Columbia

Prepared by

NORECOL ENVIRONMENTAL CONSULTANTS LTD
700 - 1090 West Pender Street
Vancouver, British Columbia

in conjunction with

STEFFEN ROBERTSON AND KIRSTEN (B.C.) INC.
and
THURBER CONSULTANTS LTD.

December 1989

File: 1-168-02.12

GEOLOGICAL BRANCH
ASSESSMENT REPORT

19,749

PART 1 OF 2

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

ASSESSMENT REPORT
TITLE PAGE AND SUMMARY

TYPE OF REPORT/SURVEY(S)	TOTAL COST
Enviromental & Road Corridor Study	$149,500.00

AUTHOR(S) Norecol Enviromental Consultants SIGNATURE(S) R. Clodson for Norecol

DATE STATEMENT OF EXPLORATION AND DEVELOPMENT FILED August 15th. YEAR OF WORK 1989

PROPERTY NAME(S) Berg

COMMODITIES PRESENT Cu, Mo

B.C. MINERAL INVENTORY NUMBER(S), IF KNOWN

MINING DIVISION Omineca NTS 93-E-13

LATITUDE 53° 48' LONGITUDE 127° 33'

NAMES and NUMBERS of all mineral tenures in good standing (when work was done) that form the property [Examples: TAX 1-4, FIRE 2 (12 units); PHOENIX (Lot 1706); Mineral Lease M 123; Mining or Certified Mining Lease ML 12 (claims involved)]:

Berg 1-9, 251, 253, 255, 257-262 & Berg 15 Sun 1-80

OWNER(S)

(1) Kennco Exploration (Western) Limited (2)

Placer Dome Inc.

MAILING ADDRESS

P.O. Box 49330 Bentall Postal Stn.

Vancouver, B.C. V7X 1P1

OPERATOR(S) (that is, Company paying for the work)

(1) Placer Dome Inc. (2)

MAILING ADDRESS

P.O. Box 49330 Bentall Postal Stn.,

Vancouver, B.C. V7X 1P1

SUMMARY GEOLOGY (lithology, age, structure, alteration, mineralization, size, and attitude):

The Berg property is located in an area of mainly Middle Jurassic Hazelton group volcanic and sedimentary rocks, consisting of volcanic breccias, tuffs and flows of acid to intermediate composition. Copper and molybdenum mineralization occur mainly in the volcanics and partly in an adjacent diorite intrusive. The mineralization lies concentric to a quartz monzonite plug which is the source of the mineralization.

REFERENCES TO PREVIOUS WORK Assessment Reports 5429, 5500 & 9036

(over)

TYPE OF WORK IN THIS REPORT	EXTENT OF WORK (IN METRIC UNITS)	ON WHICH CLAIMS	COST APPORTIONED
GEOLOGICAL (scale, area)			
Ground			
Photo			
GEOPHYSICAL (line-kilometres)			
Ground			
Magnetic			
Electromagnetic			
Induced Polarization			
Radiometric			
Seismic			
Other			
Airborne			
GEOCHEMICAL (number of samples analysed for ....)			
Soil			
Silt			
Rock			
Other			
DRILLING (total metres; number of holes, size)			
Core			
Non-core			
RELATED TECHNICAL	Enviromental and road corridor Study	Berg 1-9, 251, 253, 255, 257-262 & 15 Sun 1-80	$149,500
Sampling/assaying			
Petrographic			
Mineralogic			
Metallurgic			
PROSPECTING (scale, area)			
PREPARATORY/PHYSICAL			
Legal surveys (scale, area)			
Topographic (scale, area)			
Photogrammetric (scale, area)			
Line/grid (kilometres)			
Road, local access (kilometres)			
Trench (metres)			
Underground (metres)			
		TOTAL COST	$149,500.00

FOR MINISTRY USE ONLY	NAME OF PAC ACCOUNT	DEBIT	CREDIT	REMARKS:
Value work done (from report)				
Value of work approved				
Value claimed (from statement)				
Value credited to PAC account				
Value debited to PAC account				
Accepted .... Date	Rept. No.			Information Class

Norecol
Environmental
Consultants Ltd.

Suite 700
1090 West Pender Street
Vancouver, B.C.
Canada V6E 2N7
Telephone: (604) 682-2291
Fax: (604) 682-8323

1989 British Columbia Export Award

December 31, 1989
File: 1-168-02.12

Placer Dome Inc.
1600-1055 Dunsmuir Street
Vancouver, British Columbia
V7X 1P1

Attention: **Mr. Ed Kimura**
Manager, Western Exploration

Dear Mr. Kimura;

RE: THE BERG PROJECT REPORT

Norecol is pleased to submit to Placer Dome Inc. our report on environmental studies for the Berg Project.

The following is a break down of the amounts charged to Placer Dome Inc. to conduct studies and provide the Berg Project Report. Work concentrated on the claims area; less emphasis was placed on adjacent access areas.

ACTIVITY	COST
Hydrology	$35,000
Water Quality	$25,000
Fisheries	$18,000
Wildlife	$8,500
Acid Generation	$36,000
Mine Site Geology	$6,000
Access Road Geotechnical Studies	$15,000
Report Preparation	$6,000
TOTAL	$149,500

Norecol

I trust this meets with your approval. Please give me a call if you have any questions.

Yours truly,

NORECOL ENVIRONMENTAL CONSULTANTS LTD.

Bruce S. Ott, Ph.D.
Project Manager

BSO/sip

EXECUTIVE SUMMARY

Placer Dome Inc. holds the Berg claims, covering a porphyry copper-molybdenum deposit, in joint ownership with Kenco Exploration Ltd. The deposit is located 120 km south of Houston, B.C. and at about 1500 to 2400 m elevation. Estimated reserves are 188 million tonnes of copper-molybdenum ore with average grades of 0.4% copper and 0.05% molybdenum; a minor amount of silver is also present. Mining would be by open pit with a probable production in the 35 000 tonnes per day range and a mine life of 17 years on known reserves.

Norecol Environmental Consultants Ltd. (B.C.) Inc. conducted environmental studies at the deposit site and along possible access corridors from the east and north during 1988 and 1989. Possible impacts from mine development at Berg were qualitatively assessed as part of the study. A more quantitative assessment awaits engineering feasibility studies. Steffen, Robertson and Kirsten (B.C.) Inc. conducted deposit area geotechnical studies; Thurber Consultants Ltd. conducted geotechnical studies along the proposed corridors.

The deposit is a porphyry copper with mineralization centred on a zoned quartz monzonite stock. Main phases in this stock are biotite quartz feldspar porphyry, quartz plagioclase porphyry and quartz feldspar porphyry. Major ore minerals are chalcophyrite and molybdenite. Primary lithological and alteration patterns have been overprinted by deep weathering of the deposit following continental deglaciation about 15 000 years before present.

Access would be either from the Morice Lake forest road 35 km to the north of the Berg deposit or Twinkle Lake, 40 km to the east. The major land use in the area is forestry. Logging is occurring in eastern and northern parts of the proposed deposit site access

corridors. A potential conflict for access from the north is flooding of the Nanika-Kidprice lakes area by Kemano completion. Alcan Aluminum has a flooding reserve on all lands in the lakes area up to 938 m (3000 feet).

Climate of the area is between coastal and interior plateau modified by montane physiography. Mean annual temperature is 2.1°C; January minimum -9°C and July-August maximum 12°C. Average annual precipitation at the proposed mill site in Bergeland Creek is approximately 1400 mm; at 1500 m, the lowest pit elevation, pit is 1600 mm. Precipitation likely falls as snow from November through March at the proposed mill site and October through June at the pit.

Two small tributaries drain the deposit area and flow into Berg Creek which flows into Bergeland Creek. Total drainage area to the junction between Berg and Bergeland creeks is 84 km^2. The creeks draining the deposit are steep, mountainous streams characterized by rocky chutes and small pools. Bergeland Creek, except at its headwaters, forms a meandering channel with numerous sand bars. Mean annual runoff at Bergeland Creek is about 1200 mm. Average monthly flows increase slightly in October and November due to fall rainstorms. Monthly discharge then gradually decreases from December onward with minimum values typically occurring in February.

The largest stream crossed by the eastern access corridor is Mystery River which drains the north side of the Sibola Range and empties into Kidprice Lake. The largest river in the northern access corridor is Nanika River which drains Nanika and Kidprice lakes and empties into the northeast end of Morice Lake. The northern corridor parallels this river for most of its length.

Water quality for project area streams except those draining the deposit is fairly typical of undisturbed interior streams. The waters of Bergeland Creek are soft, low alkalinity and slightly acidic. Nutrient and metal concentrations are low, often below detection; cyanide is undetectable. High metal levels are coincident with large suspended sediment loads. Berg deposit streams, especially Red Creek have elevated metals, particularly aluminum, copper, iron and manganese. Cadmium, cobalt, nickel and zinc are also elevated. Observations can be explained by the naturally low pHs (4 to 4.5) caused by acid formation in gossan, or weathered, areas of the deposit.

The fisheries values of Bergeland Creek are limited due principally to high sediment loads. Some resident Dolly Varden char are present in the creek. Deposit streams (Berg, North Berg, Red and Pump Creeks) apparently contain no fish. Nanika Lake which is upstream of the proposed development contains rainbow trout and Dolly Varden char, as does Kidprice Lake just to the north of the former lake. A falls at the outlet of Kidprice Lake prevents salmon migrating into Kidprice Lake, or above. A major spawning area for rainbow trout and Dolly Varden char occurs in the Nanika River upstream of Bergeland Creek and near the outlet of Nanika Lake, but would be out of the influence of any possible mine effluent.

Forest cover in the study area is dominated by subalpine fir, Englemann spruce and lodgepole pine; whitebark pine is common at mid to higher elevations. The entire area including the access corridors is within the Sub-Boreal Spruce biogeoclimatic zone. Logging of commercial forests to the north and east of the deposit is within 20 km. Logging at the site is not slated for at least 20 years, however.

Wildlife in the proposed deposit site and access corridor areas include moose, mule deer (lower elevations), mountain goats, grizzly (higher elevations) and black bear, wolf, and wolverine. Game animals are not hunted near the Berg deposit because of its remoteness. Areas currently penetrated by logging roads experience greater hunting pressure.

The deposit site is given a low potential for unrecorded archaeological sites due to its rugged terrain. The potential for sites in the northern corridor around Stepp Lake is high; potential for sites in the eastern corridor is moderate to low. Conflicts with heritage sites can probably be resolved by minor rerouting of right-of-ways.

The principal environmental factors affecting mine design are water quality and fisheries resources. Preventing adverse degradation of these resources by acid drainage or tailings water will need to be the objectives of the mine waste disposal plan and the water management plan.

There is presently no time frame for development of the Berg deposit.

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1.0

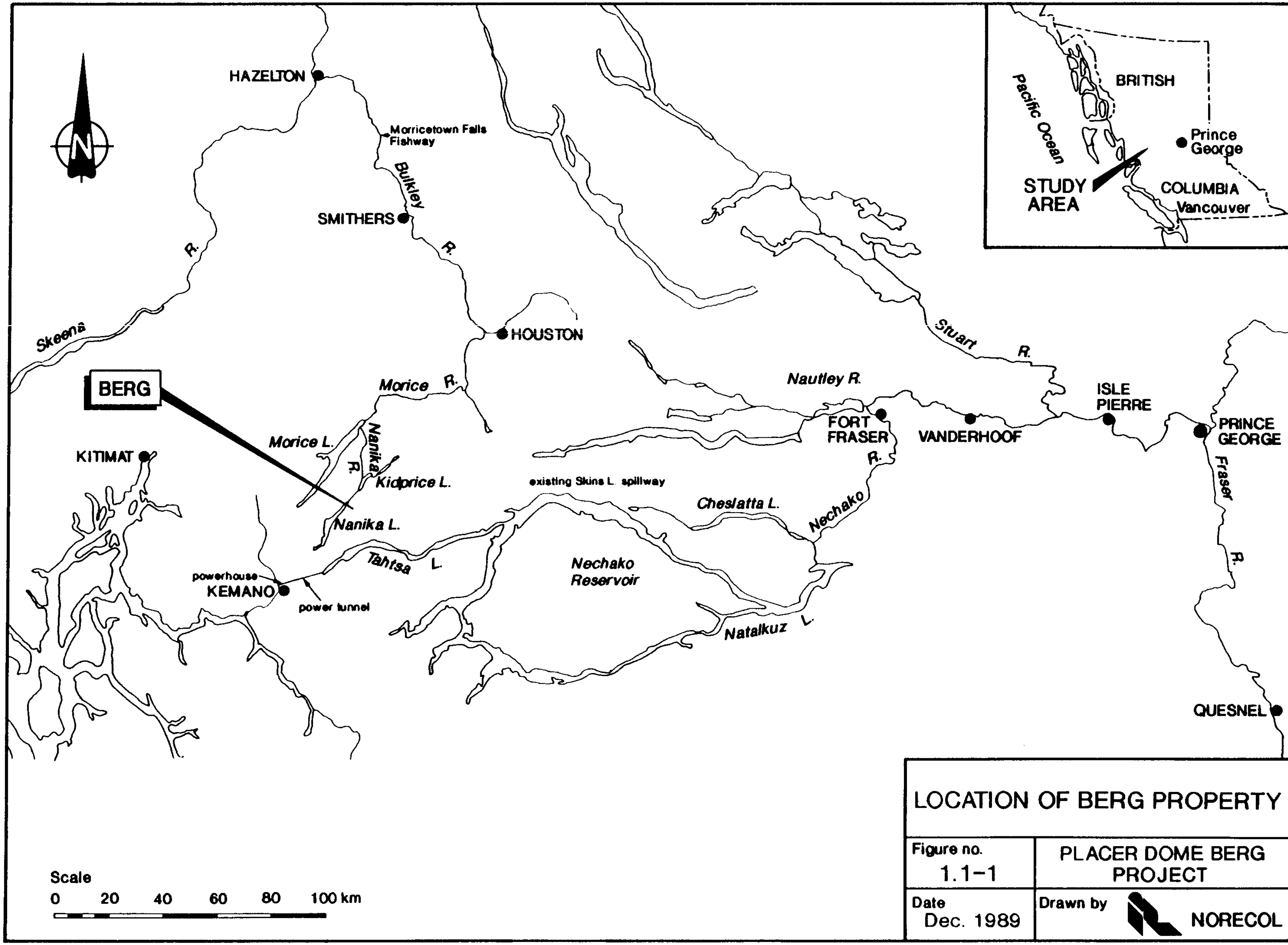
Introduction

1.0 INTRODUCTIONN

1.1 Background

Placer Dome Inc. holds the Berg claims, covering a porphyry copper-molybdenum deposit, in joint ownership with Kenco Exploration Ltd. The deposit is located 120 kilometres (km) south of Houston, B.C. by existing logging roads and trail (Figure 1.1-1). Estimated reserves are over 188 million tonnes (t) of ore grading 0.395% copper, 0.053% molybdenum and 15.6 grams per tonne silver. A production of 35 000 tonnes per day for 17 years is possible with these reserves. Open pit methods will likely be used to mine the ore from a deposit located between 1500 and 2400 metres (m) elevation in a south facing alpine cirque along North Berg Creek.

North Berg Creek is a tributary of Berg Creek which joins Bergeland Creek 7 km downstream from the Berg Deposit. Bergeland Creek is a low lying, meandering stream that empties into the Nanika River just above Kidprice Lake on the southeast shore. Kidprice Lake is in the upper part of the Nanika River system. This system is dominated by two large lakes: Nanika and Kidprice; Nanika Lake is the larger of the two. The upper Nanika River flows from Nanika Lake into Kidprice Lake, traversing a distance of approximately 8 km through low-lying swampy terrain. The Nanika River system is located in the southwest portion of the Bulkley River drainage basin. This drainage is predominantly from heavily glacierized coast mountains and the Bulkley system eventually empties into the Fraser River.



LOCATION OF BERG PROPERTY

Figure no. 1.1-1

PLACER DOME BERG PROJECT

Date Dec. 1989

Drawn by NORECOL

Access to the property is currently via helicopter. During active exploration in the late 1970s a 40 km tote road linked the Berg camp with the forest access road at Twinkle Lake. Access to the forest road is from Houston, B.C. The camp and tote road are now closed. An access road from existing forestry roads will be required for mine operation, both to ship in mine equipment during construction; personnel, equipment and supplies during operation, and to ship out the copper concentrate. Access from Morice Lake, north of the property, or Twinkle Lake, east of the property are both possible and logging is slowly encroaching on the deposit from both these directions.

Alcan currently holds a flooding reserve over lowlands in the Nanika-Kidprice lakes area. All land up to 938 m (3000 feet) would be flooded if the Kemano completion project goes ahead. The main implication of flooding would be for northern access since the corridor crosses lowland in the flooding reserve.

The Berg deposit is not economic at current copper prices, but could possibly become so if a number of conditions changed. For instance, if copper prices increased, or if access and hydropower to the deposit site became available.

1.2 Study Objectives

Placer Dome Inc. requested Norecol Environmental Consultants to conduct baseline studies in the deposit area and potential access corridors, and to assess possible impacts from development of an open pit copper mine at the Berg site. A preliminary geotechnical assessment of access corridors was included as part of the study objectives. The purpose of the work was to collect information on the physical and biological environment in the development area and to qualitatively assess the likely level of impact from development. Broadly defined mitigation measures to minimize potential impacts were then formulated. Mitigation measures are preliminary and very conceptual because engineering prefeasibility studies have not been done. The biophysical and geotechnical data bases for the project are materially increased by the work reported here. Previous geotechnical data were practically non-existent and biophysical information was restricted to several government resource agency reports and a consultant's report for Alcan (Envirocon 1981) based on work done in the early to late 1970s.

1.3 Organization of the Report

The report is divided into six chapters: (1) introduction (this chapter), (2) key data and access corridor description, (3) deposit site environment, (4) access corridor environment, (5) potential deposit site impacts, and (6) potential impacts from road building.

Descriptions of the deposit site and access corridor environments cover surfical geology, terrain analyses, water resources, water quality, fisheries, wildlife, existing and potential resource uses and heritage values. Native Indian Land Claims were dealt with in detail in a previous report (Norecol 1988) and are omitted from consideration in this report.

The discussion on potential deposit site impacts and mitigation options includes acid generation potential, hydrology, biological resources, and competing land uses (such as logging and recreation).

The discussion on potential impacts of the access options includes consideration of all of the above except acid generation.

1.4 Study Team

The study and report were coordinated by Norecol Environmental Consultants Ltd. who also conducted biophysical surveys and acid generation tests. Deposit site terrain analysis was the responsibility of Steffen Robertson and Kirsten (B.C.) Inc. Access corridor geotechnical studies and corridor terrain analyses were conducted by Thurber Consultants Ltd.

2.0

Key Data and Access

2.0 KEY DATA AND ACCESS

2.1 Key Data

Company

Placer Dome Inc.
1600 - 1055 Dunsmuir Street
Vancouver, British Columbia
V7X 1P1

Location

120 km S of Houston, B.C.	Latitude 53°47′N Longitude 127°25′W

Metal Reserves

Metals	Copper, molybdenum, minor silver
Geological Reserves	188 million tonnes av 0.395% copper (at 0.25% cut-off), .053% molybdenum, and 15 g silver/t

2.2 Property Access

2.2.1 Introduction

Geotechnical and terrain conditions were studied along proposed road corridors to the Berg property which lies some 120 km south of Houston in the Hazelton Mountains of British Columbia.

The geotechnical study comprised the following tasks:

- Analysis of 1:21 000-scale aerial photographs, as listed in Table 2.2.2-1.
- A reconnaissance site visit made on July 11.
- Terrain mapping on 1:50 000-scale NTS base maps using the results of the aerial photo analysis and site reconnaissance (Appendix 2.2.1-1).

Descriptions of terrain and geotechnical conditions, based on field observations and photo mapping studies, are presented in Sections 2.2.2 and 2.2.3. Although a corridor study, the terms "route" and "road" are used to facilitate the discussion. Kilometre stations are approximate and based on scaled measurements along each corridor.

The corridor alternatives are shown in Figure 2.2.1-1.

2.2.2 Route alternatives

2.2.2.1 Description of alternative route 1 - Twinkle Lake to deposit site

This 31 km long corridor follows a previously built road and cat trail between a forestry road near Twinkle Lake and the Berg deposit.

TABLE 2.2.1-1

AERIAL PHOTOS USED IN STUDY

BC	83059	047 - 953
BC	7723	020 - 025
BC	83048	102 - 107
BC	83048	040 - 050
BC	83047	225 - 235
BC	83047	165 - 180
		083 - 083
		084 - 100
		031 - 041
		024 - 029
BC	7744	069 - 074
		021 - 030

Notes:

1. Photos are listed in order from north to south.
2. Lines are east-west.
3. Photo scale is approximately 1:21 000.

2.2.2.2 Description of alternative route 2 - Nanika Valley to proposed mill site

This corridor begins at the end of a forestry road on the east side of the Nanika River and requires 29 km of new road construction past Kidprice Lake to a possible mill site north of Berg Creek.

2.2.2.3 Corridor connections

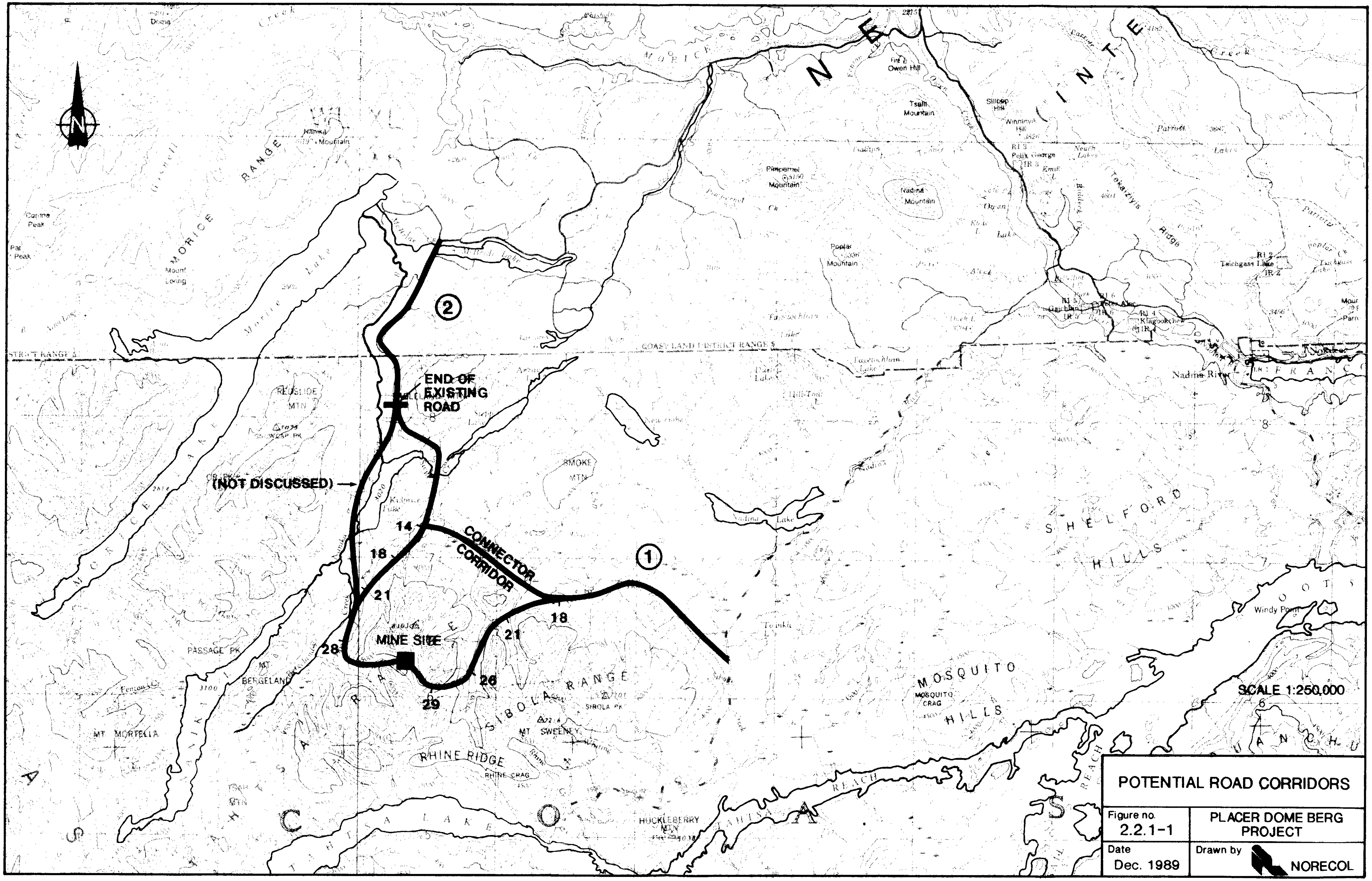
Connection of the end of Corridor 1 at the mineral deposit pit site to the end of Corridor 2 at a possible mill site by a surface route requires a 2 to 3 km long road which would be severely constrained by grades and terrain hazards including extremely steep bedrock, snow avalanches and rock falls. At present, we do not believe such a road is feasible and alternatives, such as a tunnel, should be considered.

An alternative connection between the mineral deposit and possible mill sites is available by constructing a road about 12 km long between km 18 of Corridor 1 and km 19 of Corridor 2. From Twinkle Lake, a total of 52 km of road construction is required to serve both sites. From the Nanika valley, about 53 km of road is required. Several route options are available for the connection.

2.2.3 Geotechnical assessment of corridor 1

2.2.3.1 Km 0 to km 18

This portion of the proposed access road follows a rough road and trail built across low-relief till and alluvial



POTENTIAL ROAD CORRIDORS

Figure no. 2.2.1-1	PLACER DOME BERG PROJECT
Date Dec. 1989	Drawn by NORECOL

19749 Part 1

fan deposits. The existing road and trail avoids several large muskegs and makes significant stream crossings at km 3.5, 7.0, 10.0 and km 11. Wet areas were observed along the roadway at many locations during the site reconnaissance.

Possible gravel sources are located in alluvial fans near km 4, 6.0, 10.0 and 16.5. This gravel will be needed to improve the present road-trail system.

A major stream crossing will be required at km 18.

2.2.3.2 Km 18 to km 21

This short sector follows the ancient course of Ney Creek on the existing trail system to a proposed major bridge crossing of the creek at km 21. Much of this sector will encounter till and small amounts of bedrock. Several muskegs can be avoided.

Possible granular borrow occurs in kame and fan deposits are located near km 19.

2.2.3.3 Km 21 to km 26

This is a difficult sector which follows the existing trail system on the left (west) side of Ney Valley. From the Ney Creek crossing at km 21, the route crosses till, alluvium and areas of wetland. Large snow avalanches are likely to reach the existing trail alignment on some occasions, especially in the area of km 23 to 24. Granular borrow can probably be found in small terrace deposits along this portion of the corridor.

From km 25.5 to 26.0, the trail turns west across colluvial fan deposits on the approach to the alpine valley of Ney Creek.

2.2.3.4 Km 26 to km 29

This is a difficult sector in which the future mine road will have to ascend at maximum grades to the alpine pass at km 29. The existing trail climbs at approximately 25% grade and is subject to snow avalanches on steep slopes to the north. We anticipate switch backs and significant rock work will be required on the final approach to the pass in the area of km 28.

The exact location of the access road will be determined by constraints of curvature and grade. A road alignment south of the existing trail must contend with bedrock terrain, avalanches and a glacier on the opposite side of the valley.

Bedrock and colluvium is expected along this sector with frost heave and related geomorphic processes. Heavy snow fall is also expected.

2.2.3.5 Km 29 to km 31

The final length of Corridor 1 follows the trail on a descending grade to the deposit site. The entire sector is in alpine terrain with colluvium and bedrock. Alpine geomorphic processes including frost heave and snow avalanches are expected along much of the route. Heavy snow fall is also expected.

2.2.4 Geotechnical assessment of corridor 2

2.2.4.1 Km 0 to km 10

This sector ascends the Nanika Valley across gentle side slopes formed by till and local shallow bedrock. Just north of Kidprice Lake, the route turns eastward on its approach to the Stepp Creek crossing at km 10.

Three significant stream crossings are required in the first 4 km. Small alluvial fans near km 2 and 3.5 may provide granular borrow. Alluvial deposits, some wet ground and bedrock are expected on the final approach to Stepp Creek.

2.2.4.2 Km 10 to km 14

After the major crossing of Stepp Creek, the route turns southeastward and begins its ascent to a bedrock controlled drainage divide at km 14 between Stepp and Ney Creeks. Near km 12.5, glacial outwash terraces have good potential for granular borrow.

Much of this portion of the route crosses till and bedrock controlled terrain. Significant amounts of bedrock will be encountered between km 13 to 14.

2.2.4.3 Km 14 to km 18

The route will descend across more bedrock controlled terrain on the approach to the crossing of lower Ney Creek at km 18. This portion of the route must avoid several muskegs and the canyon of Ney Creek. A debris slide from the steep bedrock slopes north of the route can be avoided near km 17.

Some granular borrow may be found in small terraces near the Ney Creek crossing.

2.2.4.4 Km 18 to km 21

This sector of the road will require a significant amount of bedrock excavation across a number of hills and ridges on a generally ascending grade to the broad valley occupied by the Nanika River and Bergland Creek.

The alluvial fan of Ney Creek below the route near km 20 may provide granular borrow.

2.2.4.5 Km 21 to km 28

This portion of the route crosses gentle side slopes with comparatively thick till. As the route ascends the valley on its approach to the mill site, more bedrock excavation may be required.

The exact mill location is not known at present but its approaches will be controlled by major snow avalanche tracks between km 25 and 28. Large avalanche runouts near km 26 and 27 may be unavoidable and require special road design considerations.

A large alluvial fan near km 23 may provide abundant granular borrow. The stream above this fan will be a significant crossing.

2.2.5 Summary of geotechnical considerations

2.2.5.1 Corridor 1

This road corridor can use an existing road and cat trail system that will facilitate required survey and geotechnical investigation. Granular borrow is expected to be reasonably well distributed except in the alpine areas along the final 7 km where granular colluvium may substitute.

Comparatively small amounts of bedrock excavation are expected along this corridor. The switch back ascent of the alpine pass at km 29 is an exception.

Snow avalanches may be a significant hazard in the Ney Valley. Snow avalanches and heavy snow accumulations are expected to present major operational constraints along the final 7 km to the deposit site.

Bridge crossings are expected to encounter minimal geotechnical constraints. Culvert designs may have to accommodate excess debris loads which issue from erosional processes in alpine and subalpine areas.

2.2.5.2 Corridor 2

This corridor will require right-of-way clearing and road construction for its entire length. The location of a mill site will determine the significance of snow avalanche tracks which must be negotiated in the final 3 km.

This corridor will require comparatively more rock work, especially between km 10 and 18. Granular borrow is poorly distributed in the corridor.

Bridge crossings are expected to have minimal geotechnical constraints. Culvert may have to be designed to accommodate high debris loads produced by erosional processes in alpine and subalpine areas.

2.2.5.3 Corridor connection

The 12 km connection described in Section 2.2.2.3 will require a significant amount of rock work and several major stream crossings. Granular borrow is available and reasonably distributed in several alluvial fans.

2.2.6 Road construction costs

Approximate construction costs for roads in Corridors 1 and 2 are estimated to be as follows:

Corridor 1	$2,500,000
Corridor 2	$3,500,000

These estimates are based on unit road construction costs varying between $60,000 and $120,000 per kilometre, depending on the difficulty of construction in each corridor, and bridge costs of $300,000 for Corridor 1 and $500,000 for Corridor 2. Much more information is required to improve the accuracy of these estimates.

2.2.7 Geotechnical recommendations

The following recommendations are based strictly on geotechnical considerations:

- Corridor 1 is geotechnically favoured to reach the proposed deposit site.

- Corridor 2 is geotechnically favoured to reach a possible mill site near Berg Creek.

- Connection of the mineral deposit and possible mill sites by a 2 to 3 km surface road on the north side of Berg Creek is not believed to be feasible. The economic desirability of a connection using a tunnel or 12 km long road between the 2 corridors should be given further consideration and confirmed by field surveys and geotechnical traverses.

- Field surveys are required along the chosen route. Geotechnical fieldwork, including foot traverses and soil sampling, is required. Granular borrow areas should be confirmed by field mapping, sampling and geotechnical testing. The suitability of granular borrow for road construction, culvert bedding and concrete aggregate should be determined by laboratory tests.

3.0

Description of Deposit Environment

3.0 DESCRIPTION OF DEPOSIT ENVIRONMENT

3.1 Bedrock Geology

3.1.1 Regional bedrock geology

The Berg deposit is located in the Intermontane Belt 8 km from the Coast Plutonic Complex (CPC) to the east. The CPC consists of Triassic and earlier gneissic and granitic rocks as well as younger granitic intrusions. The Intermontane Belt in this region consists of bedded volcanic and sedimentary rocks of pre-Middle Jurassic to Early Cretaceous age assigned to the Hazelton and Skeena Groups. These rocks are intruded extensively by granitic plutons and stocks, several of which are mineralized with copper and molybdenum.

The Cretaceous Skeena group is composed principally of clastic sedimentary rocks (greywacke, siltstone conglomerate), but includes intermediate to acidic volcanic flow, breccia and tuff units, which are major component in the immediate area of the deposit. Strongly calcareous units of any type have not been reported in the geological literature, reflecting the geological setting of the region.

The Jurassic Hazelton Group is a predominantly volcanic unit consisting of breccia and tuff units. In places, there are interbedded volcanic conglomerate, breccia and greywacke units. Panteleyev (1981) reports minor exotic rocks consisting of chert and crystalline limestone.

Regional metamorphic grade is sub-greenschist facies. Chlorite and epidote are the most abundant metamorphic minerals, however, calcite and quartz are widespread.

Broad hydrothermal zones around intrusions are reflected in the occurrence of skarn minerals, and iron oxides and sulphides.

3.1.2 Property bedrock geology

The deposit has several geological features which are common to similar porphyry copper and molybdenum deposits located throughout the Cordilleran chain in Canada, U.S.A and South America. These features may be divided into host rock geology, hydrothermal alteration zones, and recent weathering patterns.

Surface mapping and extensive diamond drilling indicates that the mineralization is centred on a zoned quartz monzonite stock. Main phases in this stock are biotite quartz feldspar porphyry, quartz plagioclase porphyry and quartz feldspar porphyry. Quartz monzonite-granodiorite forms dykes. The stock intrudes the Hazelton Group, which here consists of andesitic flow and pyroclastic units with related sedimentary rocks. A fine-grained biotite hornblende quartz diorite is located to the east and is potentially a major unit in the final phase of pit development. Steeply dipping distinctive basic dykes up to three metres thick occur but are not spatially extensive. These dykes commonly contain small amydules of calcite. Contacts between all units are generally considered to be vertical to sub-vertical.

Mineralization processes have resulted in extensive zoned alteration of the intrusive and host rocks. Alteration is distinctive and generally decreases in intensity (that is, measured by destruction of primary minerals) from the centre of the stock outwards. Zoned alteration also occurs around veinlets. Potassic alteration is restricted to the centre of the stock and consists of K-feldspar, quartz, sericite and biotite. Strongest alteration is marked by the occurrence of abundant quartz veinlets (silicic alteration). Phyllic alteration locally occurs on the periphery of the stock and is recognized by occurrence of abundant sericite. Biotitic alteration, consisting of biotite, occurs in a halo in the Hazelton Volcanics, and coincides with the best copper grades. This in turn is surrounded by a broad zone of propylitic alteration in which epidote, chlorite and calcite are common. Argillic alteration (sericite, kaolinite, epidote, calcite) occurs locally. Volume of pyrite varies from less than 2% in the centre of the stock to 3 to 5% in the biotitic alteration zone and greater than 5% in the propylitic alteration zone. Major ore minerals are chalcopyrite ($CuFeS_2$) and molybdenite (MoS_2). Sphalerite (ZnS), galena (PbS) and tetrahedrite ($Cu_{12}(As,Sb)_4S_{13}$) occur in veinlets and disseminated in haloes.

Finally, primary lithological and alteration patterns have been overprinted by deep weathering of the deposit following continental deglaciation circa 15 000 years before present. Weathering and oxidation is particularly extensive in the region of the deposit where pyrite and sulphides are widespread. The weathering has produced a strongly oxidized cap about 40 m thick (composed of quartz, sericite, clay minerals, limonite and silica), and a copper enriched supergene zone 100 m thick. The transition from the weathered zone to unweathered rock is marked by the occurrence of gypsum in fractures.

3.2 Physiography

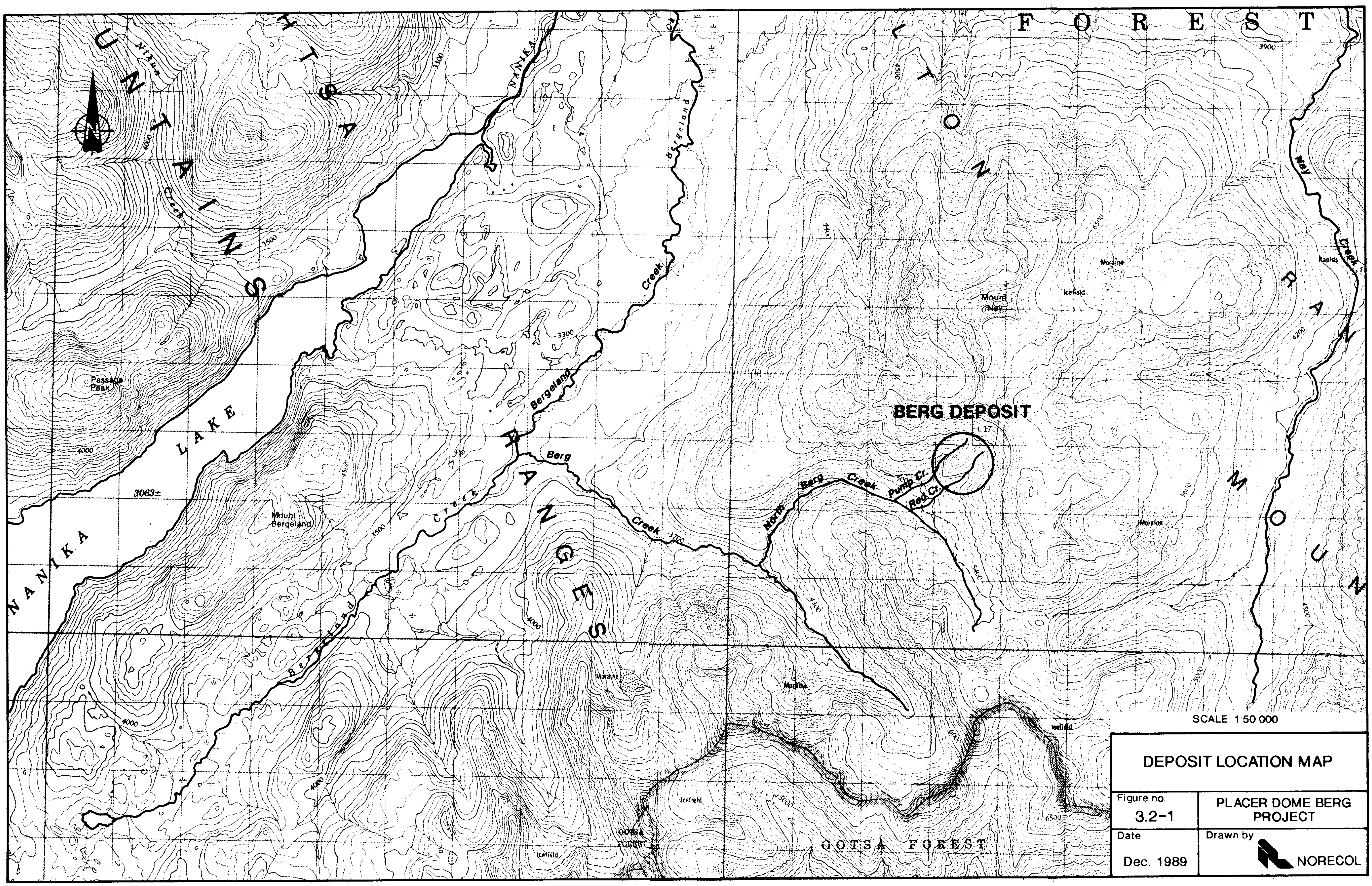
3.2.1 Surfical geology

3.2.1.1 Regional

The Berg deposit is located on the eastern side of the coastal mountains of B.C., specifically in the Tahtsa Range of the Hazelton Mountains (Figure 3.2-1). Topography ranges from 900 m to over 2500 m. The main features of the area are Mount Ney and, on its west, a glacially excavated valley trending southwest - northeast. Within the valley is Nanika Lake and Bergeland Creek. The area receives approximately 1500 mm/y of precipitation of which 50% falls as snow at lower elevations and over 70% falls as snow at higher elevations.

The interpreted surficial geology of the Berg Creek area is shown on Figure 3.2-2. The interpretation is based on a study of areal photography and limited traverses of the area. The principle landforms and surficial deposits are the result of glacial and periglacial processes. These processes are still active although primarily at the higher elevations and at a much reduced rate than in the past. The Tahtsa region was covered with ice sheets as recently as 7000 years ago. All of the glaciers in the area appear to be receding at this time.

Additional landforms and some of the surfical deposits are the result of fluvial processes and landslides.



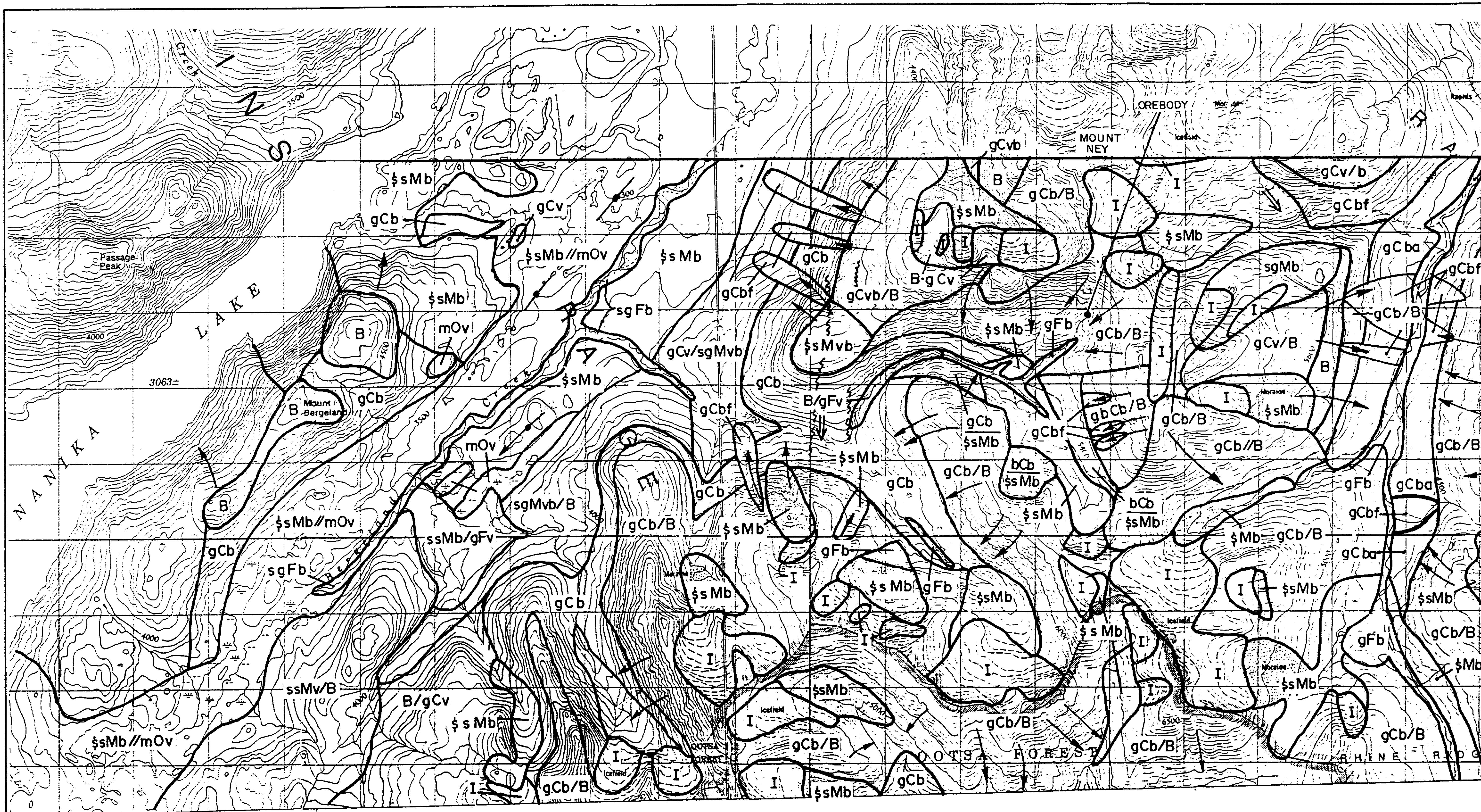
DEPOSIT LOCATION MAP

Figure no. 3.2-1

PLACER DOME BERG PROJECT

Date Dec. 1989

Drawn by NORECOL



TEXTURE

- b = boulder
- g = gravel
- s = sand
- ∳ = silt
- m = moss bog

GENESIS

- M = morain till
- C = colluvium
- F = fluvial
- B = bedrock
- O = organic
- I = snow or ice

SURFACE EXPRESSION

- v = veneer; < 2m thick
- vb = veneer-blanket; 2-5 m thick
- b = blanket; > 5 m thick
- a = apron - gently sloping surface
- f = fan

NOTE: Bedrock outcrops on ridges and minor avalanche tracks omitted for clarity

COMPOSITE UNITS

- • The units are of equal distribution
- / The left unit is more extensive than the right unit
- // The left unit is much more extensive than the right unit
- — The top unit overlies the lower unit

SYMBOLS

- Avalanche path
- Crag and tail
- Glacial fluting
- Landslide

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Bedrock is exposed on nearly all of the alpine ridges in the area. In the interest of clarity these have not been identified in Figure 3.2-2 as separate units.

3.2.1.2 North Berg and Berg creek area

North Berg Creek, is located south of Mount Ney, drains west and south to Berg Creek which flows west to Bergeland Creek. The Berg deposit is located in North Berg Creek (Figure 3.2-1).

There are two cirque glaciers on the south side of the valley and numerous perennial snowfields. There is very little vegetation above the 1500 m elevation.

The centre of the valley floor is underlain by a fluvial deposit of sand and gravel which likely contains pockets of silt. The deposit is expected to be medium dense and moderately pervious. The till is estimated to be up to 10 m thick, based on observations in North Berg Creek.

The bottom of the valley on either side of the fluvial deposit is filled with glacial till. Along North Berg Creek bedrock is exposed below the 1500 m elevation. The till is hummocky, which suggests that at least the upper several metres are an ablation till, and may be loose to medium dense. The till is likely silty and hence has a moderate to low permeability. However, due to the ablation nature of the till, water worked channels containing gravels and sands with relatively high permeabilities, may be present within the upper layers. Denser basal till likely underlies the hummocky ablation till. Frost activity may be partially responsible for the hummocky nature of the deposit. Ground ice may be present.

There is a small end moraine below the eastern glacier/snowfield which presently impounds a small snow and ice filled lake. The depth of the lake is not known but it is not likely more than 5 m deep, based on the surrounding topography (Figure 3.2-2).

The left (south) side of the valley, above the hummocky ground, consists of glacial moraine and is partially overlain by colluvium. Downstream of the western glacier the glacial moraine is nearly completely covered with colluvium.

Below the western glacier are several end moraines which are covered with a cap of boulders. This is interpreted to be a lag deposit, probably a result of avalanche activity.

The right (north) valley wall consists of a boulder and gravel colluvium overlying bedrock. Much of the colluvium at lower elevations has been reworked into coalescing fans. Based on lithology, much of the recent colluvium is derived from near the crest of the ridge. The fans and colluvium are active, and creek channels will likely wander about on top of the fans.

Within the cirque containing the deposit there are several drill holes which are presently discharging groundwater. This implies that the area is a groundwater discharge area and that there may be natural springs discharging below the colluvium cover. This colluvium may be greater than 50 m thick toward the bottom of the slopes.

Between the two creeks draining the deposit cirque and downhill of the 1500 m elevation, is a water filled depression which may be the result of melting ground ice.

There are many rock and snow avalanche paths on both sides of the valley. Most or all of these are currently active. Frost action causes considerable ravelling of the rock ridges which is evident in the deposit cirque and the present access road from Ney Creek where many of the drill access roads have been buried in less than 15 years.

All of the bedrock in the North Berg Creek area appears to be extensively brecciated because very few blocks of colluvium larger than 1 m diameter were observed during the field investigation.

Several north-south lineations have been observed in the air photographs on the ridge north of Berg Creek, as shown on Figure 3.2-2. These are interpreted to be faults. A small rock slide, which is now inactive, appears to have occurred along the trace of one of the faults.

Downstream of the faults there is an anomalous bowl shaped depression on the right bank of Berg Creek. The area does not have a debris fan or a well defined scarp. The feature may be a remnant terrace cut by Berg Creek. Field verification of the origin of this feature should be undertaken during future studies.

The river channel of the lowest 1000 m of Berg Creek is poorly defined. The sediments are braided and a debris fan has formed. The river channel wanders and often seeks new paths through the forest to Bergeland Creek.

3.2.1.3 Bergeland Creek area

Bergeland Creek is located between Mount Ney and Nanika Lake (Figure 3.2-1). It flows northeast into Nanika River which in turn flows northeast into Kidprice Lake.

The Bergeland Creek area is a U-shaped valley formed by glaciation. Glacial flutings and drumlinoid or crag and tail ridges are present throughout the valley. Mount Bergeland appears to be a massive crag and tail structure. The direction of ice movement was towards the north east.

The majority of the valley floor is interpreted to be underlain by basal till. The till is likely to be dense to medium dense, silty, sand and gravel, and will likely have a low to medium permeability. It's thickness is not known, however, observations along Berg Creek suggest it may be greater than 5 m thick.

The central part of the valley along the existing creek channel, contains fluvial deposits of silt and sand with traces of gravel and lag boulders. The fluvial deposits will likely be moderately to highly pervious.

Organic deposits, likely less than 1 m thick and consisting of moss, are present near the southern end of Bergeland Creek.

Creek deposits from overbank flooding of fine sand and silts mixed with organics are expected to be present as a thin discontinuous veneer over much of the valley. The soft silts occur in topographic depressions formed by glacial flutings.

Bedrock, as observed in outcrops, does not appear to be as extensively brecciated as in the North Berg Creek area.

3.2.1.4 Ney Creek area

Ney Creek is located west of Mount Ney and flows northward.

Ney Creek flows in a U-shaped glacierized valley. The centre of the valley contains fluvial deposits of silty sand and gravel. Overbank deposits of fine sand and silt with some organics occur primarily on the west side of the creek between the colluvial flans.

The colluvial fans are active on both sides of the valley. Debris from the fans on the east side of Ney Creek has deflected the creek to the west.

There appears to be a terrace structure located on the west side of Ney Creek upstream of the confluence of Camp Creek. This should be investigated further if any facilities are to be located in this area.

3.2.2 Natural hazards

Active rock and snow avalanche paths are present throughout the region except for the Bergeland Creek area. Major avalanche paths are shown on Figure 3.2-1 however, for clarity the lesser paths are omitted. Avalanches will have to be considered in the layout of all facilities in the North Berg Creek area. Two areas which warrant additional investigation are the headwall above the western glacier along North Berg Creek, as this may influence waste disposal activities, and the small rock slide on the north side of Berg Creek, as additional failure may affect the proposed haul road.

Two possible landslide areas were examined in detail to assess their stability and potential influence on the project. The sites are described individually below.

Site number one, located on the left (north) bank of Packhorse Creek (located on the east side of Mount Ney), appears to be two adjacent rock slides. The slides cover a surface area of 25 to 35 hectares. The slides may have been triggered by toe erosion, high water table in the slope, seismic activity, or a combination of these. The slides should not have any impact on the presently proposed mine layout.

Site number two lies on the right (east) bank of Camp Creek (located on the southeast side of Mount Ney), above the confluence of Camp and Ney Creeks. This area was suspected of being a slide due to an anomalous curve in Camp Creek. Detailed examination of the air photographs in this area did not reveal firm evidence of any landslide activity. The lack of a scarp and the lack of a well defined debris pile imply that this area is not a slide. However, development in this area should only be undertaken following detailed field assessment of this feature.

Overbank flooding appears to occur on most of the creeks in the area.

3.2.3 Seismic activity

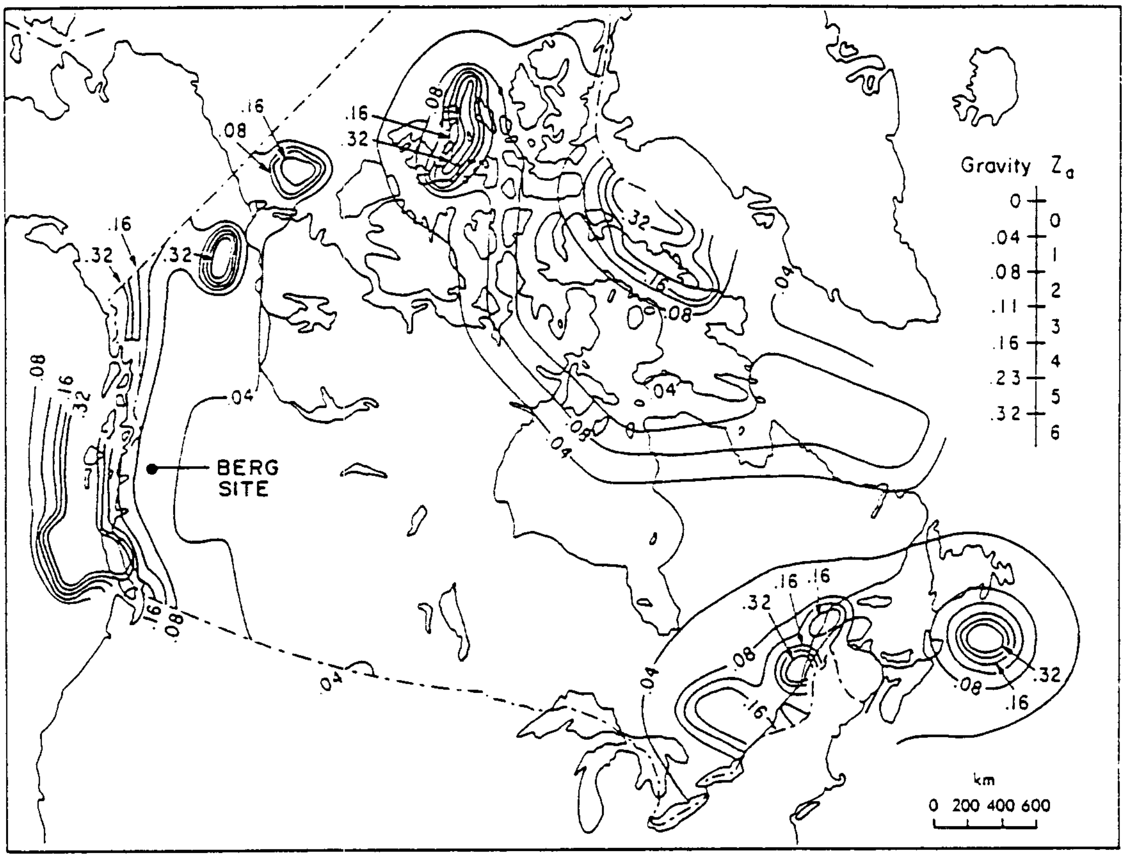
The Berg project is located in a region of low seismic activity. The National Building Code of Canada (1985) places the region within Zone 1, the second lowest seismic hazard in the country. The site is shown in relation to peak horizontal acceleration contours with a 10% probability of exceedence in 50 years, on Figure 3.2-3.

The peak horizontal acceleration at the site is estimated to be less than 0.08 g (gravity). This acceleration is described by the Modified Mercalli Scale as: slight; like vibration due to a passing truck; felt by people at rest, especially on upper floors of buildings.

3.2.4 Climate

3.2.4.1 Climate setting

The climate of the Tahtsa Ranges is affected by the proximity of the Pacific Ocean to the west and by the continental Arctic air masses to the north and east. The Coast Mountains limit the incursion of the moist-mild Pacific air masses and by orographic uplifting force the air masses to release much of their moisture on the windward slopes of the mountains.



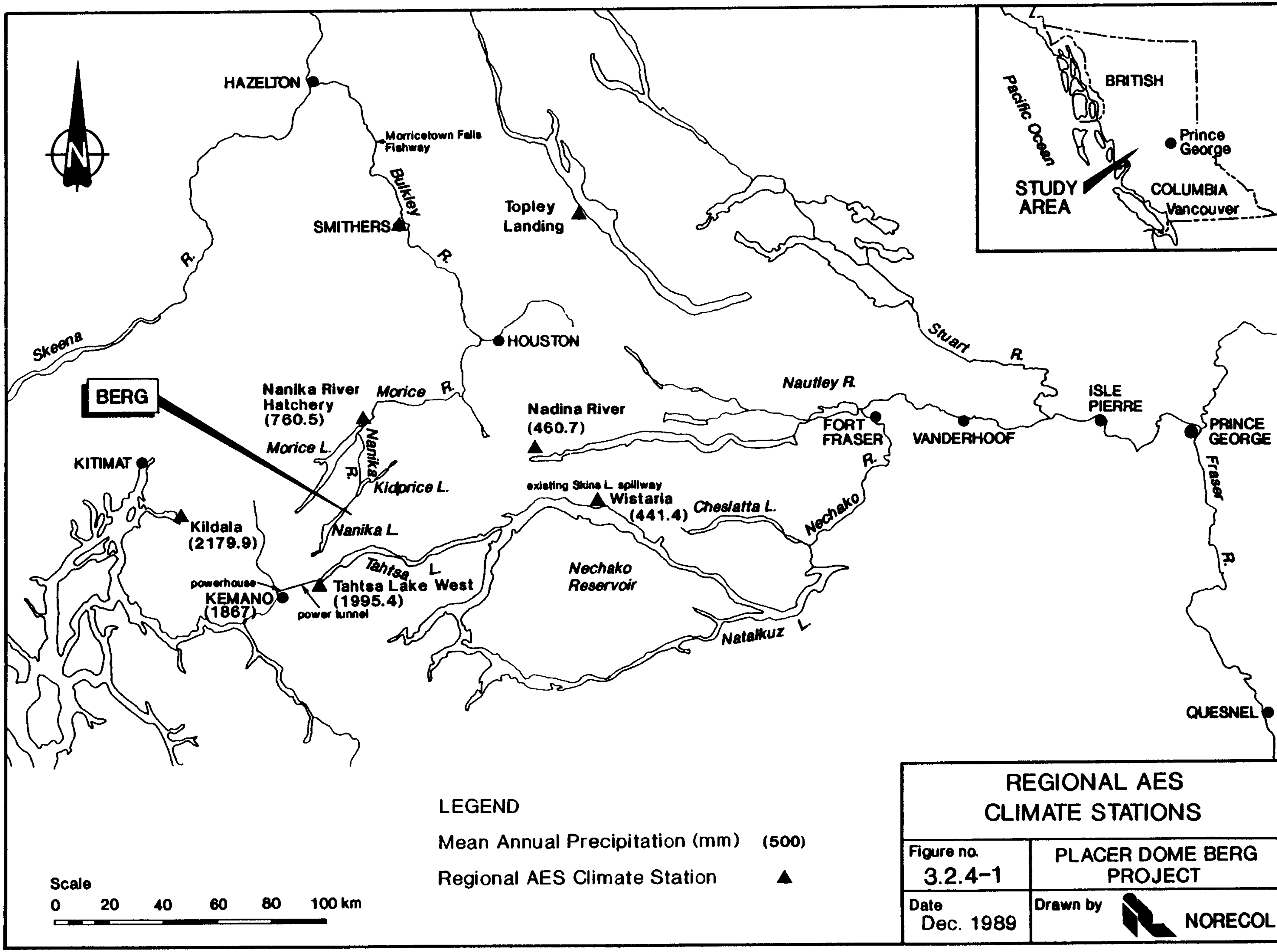
PLACER DOME INC.	BERG PROJECT	DATE NOV. 1989
CONTOURS OF PEAK HORIZONTAL GROUND ACCELERATION IN UNITS OF 'g' HAVING A PROBABILITY OF EXCEEDANCE OF 10% IN 50 YEARS ; Za = SEISMIC ZONE BASED ON ACCELERATION		PROJ. NO. 52107
		APPROVED
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers		NO. 3.2-3

The climate of the study area is influenced primarily by eastward-moving Pacific air masses. When the moist maritime air encounters the Coast Mountains, large amounts of cloud develop and heavy precipitation results. The most extreme precipitation in the study area is associated with the passage of these low pressure zones accompanied by unstable air and frontal activity eastwardly through the study area. Therefore as the air masses travel inland from the coast, moisture is lost and the climate becomes increasingly dry and temperatures less moderated by the coastal influence.

3.2.4.2 Available data

There are five Atmospheric Environment Service (AES) climate stations in the vicinity of the Berg property with long-term records (over 30 years) and one climate station with 5 years of records. The location of these regional climate stations are shown on Figure 3.2.4-1 and their locations relative to the Berg property are listed in Table 3.2.4-1. Table 3.2.4-1 also lists the relevant climatic parameters measured at each climate station.

Due to the limited amount of precipitation data gathered in the immediate vicinity of the Berg project area, and with the nearest climate station being 26 km to the SSW and in a wetter physiographic region, Norecol installed a continuous recording rain-gauge near the confluence of Berg and Bergeland creeks. Hourly rainfall data were collected for the period May 6 to September 20, 1989.



REGIONAL AES CLIMATE STATIONS

PLACER DOME BERG PROJECT

TABLE 3.2.4-1

SELECTED REGIONAL CLIMATE STATIONS NEAR THE BERG PROJECT AREA

STATION NAME[a]	LOCATION IN RELATION TO BERG PROPERTY	ELEVATION (m)	PERIOD OF RECORD	AGENCY[b]	MEASURED PARAMETERS[c]
Kildala	70 km W	30	1966-current	AES	TP
Kemano	42.5 km SW	72	1951-1972	AES	TP
		70	1972-current	AES	TP
Tahtsa Lake West	26 km SSW	863	1951-current	AES	TP
Nadina River	72.5 km ENE	808	1931-1932	AES	P
		732	1934-1962	AES	P
Wistaria	82.5 km E	873	1926-current	AES	TP
Nanika River Hatchery	35 km N	808	1961-1966	AES	TP

Source: compiled by Norecol

[a] Refer to Figure 3.2.3-1 for location of stations
[b] AES - Atmospheric Environment Service
[c] T - Temperature, P - Precipitation

The decision was made not to collect on site temperature data as it was judged that project design was not particularly sensitive to this parameter and sufficiently accurate temperature information could be extrapolated from existing regional information. Previous studies (Norecol 1988) had shown that temperature showed a fairly predictable distribution through the region that was consistent with the physiographic and climatic zones and hence could be estimated from data collected at regional climate stations.

Information on snowfall in the study area was based on two snow courses located near the project area at Tahtsa Lake and Kidprice Lake (Figure 3.2.4-1).

3.2.4.3 Temperature

Mean monthly temperatures for climate stations in the vicinity of the Berg property are summarized in Table 3.2.4-2. Data from Tahtsa Lake West and Nanika River Hatchery were judged (based on consideration of physiographic and climatic zones) to provide the most representative information on temperature in the vicinity of the Berg property.

The Kemano and Kildala climate stations which are located to the west of the project area exhibit mean annual temperatures approximately 5°C higher than the inland climate stations (Tahtsa Lake West, Nanika River Hatchery and Wistaria) because of the moderating influence of the Pacific Ocean. As well, the range in mean monthly

TABLE 3.2.4-2

MEAN MONTHLY TEMPERATURES FOR REGIONAL CLIMATE STATIONS NEAR THE BERG PROJECT AREA (°C)

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Kemano	-4.3	-0.6	1.8	5.8	10.1	13.5	15.9	15.8	12.3	7.1	1.7	-1.7	6.5
Kildala	-3.9	-0.6	2.2	5.7	9.5	12.9	15.3	15.2	11.9	7.1	1.5	-1.7	6.3
Nadina River							No Data						
Tahtsa Lake West	-9.1	-5.6	-3.5	0.9	4.6	8.0	11.3	11.3	8.0	3.2	-2.3	-5.7	1.8
Wistaria	-11.6	-6.5	-3.1	2.1	6.9	10.6	13.3	12.8	9.0	3.9	-2.9	-7.6	2.2
Nanika River-Hatchery	-8.9	-3.6	-3.0	1.7	5.3	9.4	13.0	14.2	9.0	3.8	-3.6	-8.7	2.4

Source: Data from Environment Canada 1980.

temperatures between winter lows and summer highs increases as one moves eastward from the coast mountains. The Wistaria temperatures are cooler in the winter and warmer in the summer than Tahtsa Lake West.

Mean monthly temperatures in the study area, for the 1000 m level, were estimated by averaging the data from the Tahtsa Lake West and Nanika River Hatchery climate stations (Table 3.2.4-3). The two stations are approximately the same distance from the project site, are at approximately the same elevation and are located in the two climatic zones which influence the region.

The higher elevations of the Berg property will have lower mean monthly temperatures. A temperature gradient of -0.6°C/100 m would result in the pit area at the 1500 m level having a mean annual temperature of about -0.9°C.

3.2.4.4 Precipitation

Precipitation exhibits considerable spatial and temporal variability over north western British Columbia. The annual total precipitation for the region decreases as one move eastward from the crest of the Coast Mountains onto the Nechako Plateau. The Berg property, located within the Tahtsa Range physiographic subdivision, is expected to have precipitation characteristics that are in between the wet coastal region and the dry central interior.

TABLE 3.2.4.3

ESTIMATED MEAN MONTHLY TEMPERATURES FOR THE BERG PROJECT AREA (°C)

MONTH	TEMPERATURE (°C) (1000 m a.s.l.)
January	-9.0
February	-4.6
March	-3.3
April	1.3
May	5.0
June	8.7
July	12.2
August	12.8
September	8.5
October	3.5
November	-3.0
December	-7.2
Year	2.1

Source: Norecol

Annual total precipitation data was available for the six AES climate stations in the vicinity of the Berg project area (Table 3.2.4-4). The annual total precipitation for the Berg project area was expected to be somewhere between the 2000 mm/year recorded at Tahtsa Lake West and 800 mm/year recorded at Nanika River Hatchery. In order to refine the annual total precipitation estimate for the Berg project area, the annual precipitation values for the regional AES climate stations were plotted onto a map.

An isohyet map of annual total precipitation was then plotted, showing lines of equal precipitation. This map took into consideration the orientation of the coastal mountains and the annual total precipitation values for the regional climate stations and as a result the isohyets are oriented in the NW-SE direction, and decrease in value as one moves inland. The project area was located between the 1200 and 1400 mm/a isohyets.

To estimate the average annual total precipitation for a watershed, for example the Nanika River at the outlet to Kidprice Lake drainage basin, the watershed divide was plotted over top of the annual isohyets produced for the region. The watershed's annual total precipitation was then calculated by summing the products of the percent areal coverage of the watershed times the corresponding isohyet interval value (for example 4.8% of the drainage area was multiplied by the 1750 mm isohyet and then added to the other values). The Nanika River at the outlet to Kidprice Lake watershed had an estimated average annual

TABLE 3.2.4-4

MEAN MONTHLY PRECIPITATION FOR REGIONAL CLIMATE STATIONS
NEAR THE BERG PROJECT AREA (mm)

STATION	PRECIPITATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	YEAR
KEMANO	RAIN	117.3	118.2	102.5	97.7	54.3	51.6	55.5	83.1	168.0	326.3	231.8	178.4	1584.7
	SNOW	106.3	58.2	25.2	2.6	0.0	0.0	0.0	0.0	0.0	0.8	27.6	75.3	296.0
	TOTAL	211.3	176.4	127.8	100.3	54.3	51.6	55.5	80.7	168.0	327.1	259.3	254.7	1867.0
KILDALA	RAIN	127.9	129.7	110.8	124.6	89.8	76.4	78.8	94.8	174.1	338.9	233.7	214.1	1793.6
	SNOW	120.1	66.2	34.9	5.0	0.0	0.0	0.0	0.0	0.0	0.6	25.3	79.3	331.4
	TOTAL	255.2	198.1	156.7	126.5	77.4	75.8	84.1	99.9	181.6	353.9	268.8	301.9	2179.9
NADINA RIVER	RAIN	3.6	4.9	2.4	6.8	22.1	38.6	40.8	46.0	41.2	41.5	21.6	9.0	278.5
	SNOW	46.6	22.4	17.7	7.1	0.7	0.0	0.0	0.0	0.6	9.1	25.6	47.5	177.3
	TOTAL	52.1	25.7	20.3	15.2	23.2	38.6	40.8	46.0	41.8	51.1	48.7	57.2	460.7
NANIKA RIVER HATCHERY	RAIN	4.5	1.8	5.6	13.5	12.2	20.6	77.4	21.4	61.8	62.8	38.2	5.4	325.2
	SNOW	99.6	57.6	66.2	16.7	2.7	0.0	0.0	0.0	0.0	17.6	64.1	110.8	435.3
	TOTAL	104.1	59.4	71.8	30.2	14.9	20.6	77.4	21.4	61.8	80.4	102.3	116.2	760.5
TAHTSA LAKE WEST	RAIN	42.7	32.7	29.5	40.5	44.3	55.3	56.3	74.6	155.3	249.2	117.7	56.2	954.3
	SNOW	214.3	170.1	131.1	71.1	11.1	0.0	0.0	0.0	1.7	45.1	154.8	241.2	1040.5
	TOTAL	257.0	202.8	160.6	111.6	55.3	55.3	56.3	74.6	157.0	295.0	272.5	297.4	1995.4
WISTARIA	RAIN	1.8	1.9	1.2	4.9	22.6	38.4	39.9	44.5	38.5	30.4	11.7	5.2	241.0
	SNOW	45.7	24.5	20.8	12.5	3.8	0.0	0.0	0.0	1.1	13.0	31.4	47.4	200.2
	TOTAL	47.5	26.4	22.1	17.4	26.5	38.4	39.9	44.5	39.6	43.4	43.2	52.5	441.4

Source: 1951-1980 climate normals, Environment Canada (1980)

Notes: Daily rainfall = daily total precipitation minus daily snowfall water equivalent.
Snow water equivalent is estimated by dividing snow depth by 10.

total precipitation of 1300 mm, based on the isohyetal map. However the mapped values were extrapolated from the Tahtsa Lake West and Nanika River hatchery climate stations with an average elevation of 836 m. Knowing that in mountainous regions there is generally increases in precipitation with increases in elevation it was necessary to estimate the vertical precipitation gradient (increase in precipitation with increase in elevation) for the project area.

With the available data base for the area there was no simple method of calculating the vertical precipitation gradient for the Berg project area. Instead, a basic hydrologic relationship relating average annual precipitation, runoff and evapotranspiration for the Nanika River at outlet of Kidprice Lake watershed was used. This hydrologic relationship states that for a given watershed (with a given average elevation) precipitation is equal to runoff plus evapotranspiration.

Using the isohyetal map (based on data for an elevation of 836 m), the Nanika River watershed has an estimated mean annual total precipitation of 1300 mm. The runoff for this watershed as measured at the Water Survey of Canada (WSC) hydrometric station at the Nanika River at the outlet of Kidprice Lake (Section 3.3.2.2) is 1177 mm with a corresponding average basin elevation of 1250 m. The evapotranspiration for the Nanika River watershed (elevation 1250 m) is estimated at 300 mm/a (Section 3.2.4.5). These arguments yield a mean annual total precipitation for a 1250 m elevation of 1477 mm (1177 mm runoff plus 300 mm evapotranspiration).

To estimate the vertical precipitation gradient for the project area we have two precipitation estimates for the

Nanika watershed corresponding to two different elevations. The above data gives a precipitation gain of 177 mm (1477 - 1300 mm) with an elevation gain of 414 m (1250 m - 836 m). Therefore, there is an increase of approximately 43 mm of precipitation with each 100 m gain in elevation. The Berg project area would therefore have an average annual total precipitation of 1371 mm at 1000 m (the approximate elevation of the mill site) and 1586 mm at 1500 m (the approximate elevation of the lower pit area).

The next step was to estimate the long-term mean monthly precipitation values for the project area. The Tahtsa Lake West climate station is the closest AES station to the project area and the only one in the region influenced by both the coastal and interior climate regimes. For those reasons the distribution of percent monthly precipitation values from this station were used to calculate values for the Berg project area, at elevations of 1000 m (representative of the proposed mill site) and 1500 m (representative of the pit area) with the results given in Table 3.2.4-5.

Preliminary monthly rainfall values for May to September 1989 were obtained from the AES for the Tahtsa Lake West and Wistaria climate stations. The purpose was to determine how the 1989 monthly rainfall values compared to the long-term averages, (Appendix 3.2.4-1, Table 1). The May 1989 data for Tahtsa Lake West was rejected (Coatta, pers. comm.) so no definite conclusions can be made on how the 1989 monthly values compare to the long-term averages. (These conclusions will be checked when the final data become available and reported as an adendum). The estimated average long term-mean monthly precipitation values for the project area (Table 3.1.4-5) were also compared to the monthly precipitation values collected by Norecol from May to September 1989 (Appendix 3.2.4-1, Table 1 and 2). The monthly rainfall values collected near the proposed mill site during 1989 compare well with the estimated long-term monthly rainfall values and indicate that 1989 was a normal year.

Return periods of extreme 24 hour rainfall events were calculated from information presented in the Rainfall Frequency Atlas for Canada (Hogg and Carr 1985) for the Berg project area (Table 3.2.4-6). These values were compared with the maximum recorded rainfall in 24 hours at Nadina River, Tahtsa Lake West and Wistaria of 79.8, 133.4 and 39.6 mm, in 28, 29, and 54 years of record respectively (Environment Canada 1980). The 25 year return period values compare well with the maximum recorded 24 hour rainfall event at Tahtsa Lake West of 133.4 mm in 29 years of record. The Nanika River and Wistaria rainfall values are much lower than areas subject to orographically enhanced precipitation such as the Berg project area which receives approximately 1.25 times more rain than low level stations.

Two snow courses stations are located near the Berg project area. They are located at Tahtsa Lake, elevation 1300 m, and at Kidprice Lake, elevation 1370 m. A comparison of snowpack data for 1989 from these regional stations (Table 3.2.4-7) to long-term average snowpack levels was used in interpreting the 1989 streamflow data

TABLE 3.2.4-5

MEAN MONTHLY % PRECIPITATION DISTRIBUTION FOR REGIONAL CLIMATE STATIONS
NEAR THE BERG PROJECT AREA WITH MEAN MONTHLY PRECIPITATION (mm) ESTIMATES FOR THE PROJECT AREA

STATION	PRECIPITATION %	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	YEAR
NADINA RIVER	RAIN	0.8	1.1	0.5	1.5	4.8	8.4	8.9	10.0	8.9	9.0	4.7	2.0	60.5
	SNOW	10.1	4.9	3.8	1.5	0.2	0.0	0.0	0.0	0.1	2.0	5.6	10.3	38.5
	TOTAL	11.3	5.6	4.4	3.3	5.0	8.4	8.9	10.0	9.1	11.1	10.6	12.4	100.0
TAHTSA LAKE WEST	RAIN	2.1	1.6	1.5	2.0	2.2	2.8	2.8	3.7	7.8	12.5	5.9	2.8	47.8
	SNOW	10.7	8.5	6.6	3.6	0.6	0.0	0.0	0.0	0.1	2.3	7.8	12.1	52.1
	TOTAL	12.9	10.2	8.0	5.6	2.8	2.8	2.8	3.7	7.9	14.8	13.7	14.9	100.0
WISTARIA	RAIN	0.4	0.4	0.3	1.1	5.1	8.7	9.0	10.1	8.7	6.9	2.7	1.2	54.6
	SNOW	10.4	5.6	4.7	2.8	0.9	0.0	0.0	0.0	0.2	2.9	7.1	10.7	45.4
	TOTAL	10.8	6.0	5.0	3.9	6.0	8.7	9.0	10.1	9.0	9.8	9.8	11.9	100.0
BERG PROJECT AREA (1000m a.s.l.)	RAIN	29.3	22.5	20.3	27.8	30.4	38.0	38.6	51.2	106.7	171.2	80.9	38.6	655.7
	SNOW	147.2	116.9	90.1	48.9	7.6	0.0	0.0	0.0	1.1	30.9	106.4	165.7	714.9
	TOTAL	176.5	139.3	110.4	76.7	38.0	38.0	38.6	51.2	107.8	202.1	187.2	204.3	1371.0
BERG PROJECT AREA (1500m a.s.l.)	RAIN	33.9	26.0	23.5	32.2	35.2	43.9	44.7	59.2	123.4	198.1	93.5	44.6	758.5
	SNOW	170.3	135.20	104.2	56.5	8.8	0.0	0.0	0.0	1.3	35.8	123.0	191.7	827.0
	TOTAL	204.2	161.2	127.7	88.7	44.0	43.9	44.7	59.2	124.7	234.45	216.5	236.3	1586.0

Source: Based on data from 1951-1980 climate normals, Environment Canada (1980)

TABLE 3.2.4-6

ESTIMATED RETURN PERIODS FOR EXTREME 24 HOUR RAINFALL EVENTS FOR BERG PROJECT AREA

RETURN PERIOD (Years)	RAINFALL (mm)
2	77.8
5	96.5
10	109
25	125
100	148
200	159

Source: Hogg and Carr 1985.

TABLE 3.2.4-7

MAY 1st WATER EQUIVALENTS AT SELECTED SNOW COURSE LOCATIONS IN THE VICINITY OF THE BERG PROJECT

STATON	ELEVATION (m)	YEARS RECORD	MEAN MAY 1st EQUIVALENT (mm)	RANGE (mm)	MAY 1st 1989 (mm)
Tahtsa Lake (1B02)	1300	36	1190	701-1770	1272
Kidprice Lake (4B01)	1300	36	912	501-1367	932

Source: Ministry of Environment 1989.

for the area creeks. The water equivalent of snow on May 1 was used for this purpose as it is approximately equal to the seasonal maximum amount of water stored in the snow pack and is a good indicator of the subsequent summers streamflow. The snowpack data summarized in Table 3.2.4-7 indicates that 1989 was a normal year and hence streamflow measured in the area streams during 1989 would be expected to be close to normal (as summer rainfall was also close to normal as indicated earlier).

3.2.4.5 Other climatic parameters

Estimates of evapotranspiration were prepared for incorporation into water budget calculations for the project area. Evapotranspiration estimates also help in verifying the mean annual precipitation and runoff estimates made in Section 3.2.4.4 (precipitation = runoff + evapotranspiration).

Pan evaporation measurements are made at the Topley Landing climate station, 140 km NE of the project area. Lake evaporation estimates are made by multiplying the measurements by a pan coefficient, to reflect the lower energy input a lake would receive under the same meterological conditions. Evaporation pans probably provide the best method of obtaining an index of potential evapotranspiration (Dunne and Leopold 1978).

The annual calculated lake evaporation for the Topley Landing climate station is 367.1 mm (Table 3.2.4-8). The annual evaporation for the project area would be somewhat lower because of the higher elevation and cooler temperatures. Average potential evapotranspiration for the project area is estimated to be 300 mm/year.

TABLE 3.2.4-8

REGIONAL EVAPORATION AND POTENTIAL EVAPOTRANSPIRATION DATA NEAR THE BERG PROJECT AREA

	TOPLEY LANDING CALCULATED LAKE EVAPORATION[a]		SMITHERS POTENTIAL EVAPOTRANSPIRATION (mm)	OPEN WATER EVAPORATION[b] (mm)
	MEAN	SD		
January				
February				
March			9.3	18.5
April			34.9	51.4
May	73.1	5.5	70.4	96.8
June	93.0	17.1	83.8	113.7
July	92.5	12.4	90.3	122.4
August	74.3	12.9	69.0	96.2
September	34.2	3.9	28.4	44.5
October			2.5	9.6
November				
December				
Total	367.1	51.8	389.0	553.1

Source: [a] Environment Canada 1984.
[b] Davis (unpublished)

Potential evapotranspiration and open water evaporation values were calculated for Smithers by Davis (unpublished). The monthly potential evapotranspiration values are comparable to the calculated lake evaporation values from Topley Landing (Table 3.2.4-8).

Significant differences in topography, and elevation must be interpreted in making site specific estimates of otherclimatic parameters from regional data. Solar radiation data for stations in the same general latitude as the Berg deposit are available for Sandspit and Prince George. The Berg area is approximately in between these two climatically; that is precipitation and temperature regimes are between maritime and continental. Envirocon (1984) estimated the Nanika-Kidprice area to have a total of about 1700 hours sunshine per year and an average monthly solar radiation range from 1.75 MJ/m^2 in December to 19.5 MJ/m^2 in July.

Prevailing winds in the region including the Nanika and Kidprice lakes areas are westerlies. When funnelled along Nanika Lake, surface wind direction becomes predominantly northeast-southwest.

3.3 Surface Water Resources

3.3.1 Watershed characteristics

The Berg deposit is located in the headwaters of Berg Creek, a tributary of Bergeland Creek which drains into the Nanika River. The Nanika River in turn flows northward into Morice Lake (Figure 2.2.1-1).

The watersheds of immediate interest to mine development at the Berg property are tributary streams flowing from the deposit and into Berg and Bergeland Creeks. Depending on the extent of ore deposit development, the first major stream to the east, Ney Creek, may also be affected by access road development.

Study area drainage basin characteristics are summarized in Table 3.3.1-1. Basin areas range from 1.10 km^2 for Red Creek (a tributary to North Berg Creek) to 53.0 km^2 for Bergeland Creek upstream of Berg Creek. Red and Pump Creeks both drain the deposit area and are located in the headwaters of North Berg Creek, at an elevation between 1490 and 2286 m (Figure 3.2-1). They both flow southeasterly into North Berg Creek and are unglacierized (do not presently have glaciers). North Berg Creek above the deposit is approximately 4 percent glacierized and has an elevation range from 1490 to 2100 m.

The above mentioned creeks are all tributaries of Berg Creek, a watershed 30.6 km^2 in size and approximately 13 percent glacierized. The watershed is primarily oriented to the west with all of its glaciers located on the southern faces of the headwater tributaries.

Ney Creek is similar to Berg Creek in terms of its elevation range and amount of glaciation. The creek flows northward in its upper reaches, before turning east and discharging to the Nanika River.

Bergeland Creek drains a lower elevation watershed and has a much lower stream gradient than the other creeks in the study area.

TABLE 3.3.1-1

WATERSHED CHARACTERISTICS OF GAUGED CREEKS IN THE BERG PROJECT AREA

STATION NUMBER	STATION NAME	LATITUDE	LONGITUDE	DRAINAGE AREA (km^2)	MAXIMUM ELEVATION (m)	MINIMUM ELEVATION (m)	PERCENT GLACIATED
H1	North Berg Creek above deposit	53°47′52"	127°26′23"	3.23	2286	1490	4
H2	Red Creek	53°47′55"	127°26′23"	1.10	2286	1490	0
H3	Pump Creek	53°48′03"	127°26′34"	1.25	2225	1460	0
H4	Berg Creek near the mouth	53°48′24"	127°31′44"	30.6	2286	990	13
H5	Bergeland Creek upstream of Berg Creek	53°48′19"	127°31′50"	53.0	1890	990	2
H8	Ney Creek	53°49′45"	127°31′43"	48.7	2469	1180	16

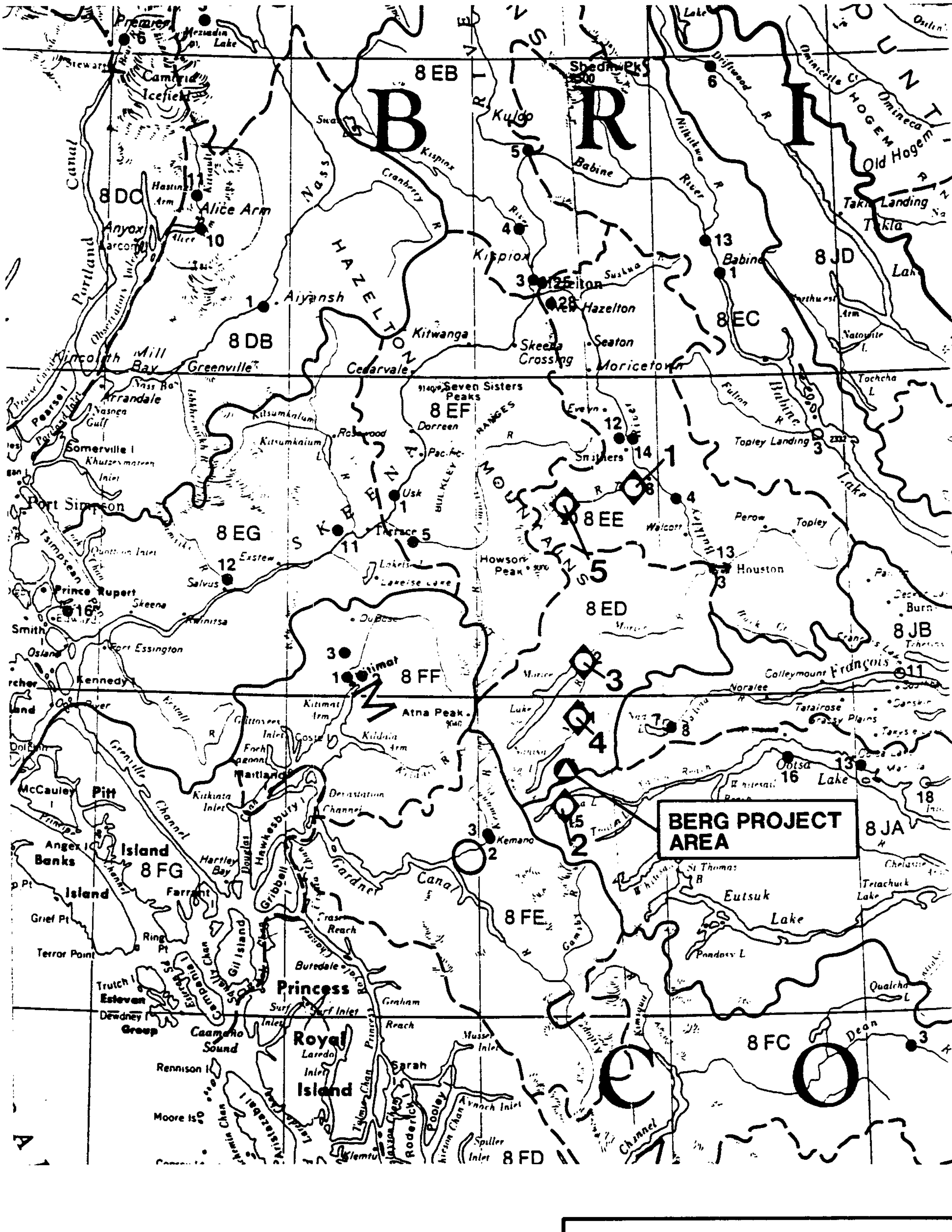
3.3.2 Hydrology

The hydrologic analyses focus on two types of streams, the high elevation ones which are located near the deposit and the lower elevational ones, specifically Bergeland Creek, which drain the valley region upstream of the proposed mill site.

3.3.2.1 Available data and analysis

The Water Survey of Canada (WSC) operates a network of stream gauging stations in British Columbia. A review of the stations in the vicinity of the Berg property indicates that there are five hydrometric stations with characteristics similar to the project area. All of the stations are on the leeward side of the coast mountains. Other stations, such as those located on the windward side of the coast mountain or on the interior plateau are located in significantly different climatic and hydrologic zones and are not expected to have characteristics representative of the project area. The selected WSC gauging stations are shown in Figure 3.3.2-1 and listed in Table 3.3.2-1.

The WSC hydrometric stations which best represent the study area creeks are expected to be the Laventie Creek near the mouth and Nanika River at outlet of Kidprice Lake stations. The Laventie Creek station is more representative of the glacierized basins within the study area while the Nanika River station is more representative of the lower valley basins.



Note: See Table 3.2.2-2 for reference numbers	SELECTED REGIONAL WSC GAUGING STATIONS	
	Figure no. 3.3.2-1	PLACER DOME BERG PROJECT
	Date Dec. 1989	Drawn by NORECOL

TABLE 3.3.2-1

SELECTED REGIONAL WATER SURVEY OF CANADA GAUGING STATIONS IN THE VICINITY OF THE BERG PROJECT AREA

REFERENCE NUMBER	STATION NAME	DRAINAGE AREA (km^2)	PERIOD OF RECORD
1	Goathorn Creek near Telkwa	132	1960-86
2	Laventie Creek near the Mouth	86.5	1976-86
3	Morice River near Houston	1910	1961-86
4	Nanika River at outlet of Kidprice Lake	741	1950-52 1972-86
5	Telkwa River below Tsai Creek	368	1975-86

Source: Environment Canada 1988.

In order to compare streamflow from watersheds with different catchment areas and to compare streamflows to precipitation, discharges were standardized according to the following formulae:

mean annual runoff (mm)

$$= \frac{\text{discharge } (m^3/s)}{\text{drainage area } (km^2)} \times 31,536$$

mean monthly runoff (mm)

$$= \frac{\text{discharge } (m^3/s)}{\text{drainage area } (km^2)} \times \text{days/month} \times 86.4$$

Runoff in mm per day can be computed either by dividing mean annual runoff by 365 or the mean monthly runoff by the number of days in the month.

3.3.2.2 Regional stream flows

Mean annual runoff (mm/year) for regional hydrometric stations are listed in Table 3.3.2-2. Annual runoff ranges from approximately 400 mm to 1800 mm. The two stations closest to the project area, Nanika River and Laventie Creek, have mean annual runoffs of 1180 and 1815 mm respectively.

Mean monthly runoff (mm) from the gauged regional watersheds are also presented in Table 3.2.2-2. Peak runoff, due to snowmelt, usually occurs in June with approximately 70 percent of the annual runoff occurring

TABLE 3.3.2-2

MEAN MONTHLY RUNOFF FROM GAUGED WATERSHEDS NEAR THE BERG PROJECT AREA (mm)

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Goathorn Creek near Telkwa	4.57	3.23	3.55	12.9	99.4	104.9	70.2	38.1	24.9	30.2	19.2	7.10	418
Laventie Creek near the mouth	17.7	11.9	13.1	28.6	224	467	378	242	163	158	86.0	26.0	1815
Morice River near Houston	35.6	28.4	24.4	22.1	89.3	255	240	171	108	111	86.4	50.6	1223
Nanika River at the outlet of Kidprice Lake	26.3	19.2	17.0	20.5	146	290	237	137	80.5	93.6	71.7	39.8	1177
Telkwa River below Tsai Creek	17.3	12.8	13.1	27.1	160	279	237	167	101	97.5	52.1	22.4	1188

Source: Based on data from Environment Canada 1988.

from May to August. Generally higher elevational watersheds, with the presence of more extensive areas of snow (or glaciation), are likely to have a later maximum runoff than lower elevational basins.

Average monthly flows increase slightly in October and November for some of the gauged watersheds due to fall rainstorms. Monthly discharge then gradually deceases from December onward with minimum values typically occurring in February.

3.3.2.3 Regional flood analysis

The annual maximum daily discharges in the vicinity of the project area occur principally as either snowmelt generated floods in the spring or as rainstorm generated floods in the fall. The unit discharge (L/s/km^2) for the mean annual flood and maximum recorded flood for each station is listed in Appendix 3.3.2-1, Table 1. The mean annual (2.33 year return period) and maximum recorded discharge for regional hydrometric stations were plotted against basin area and the results presented in Appendix 3.3.2-1, Figure 1 and 2, respectively. The precise slope of the curves drawn through the points is difficult to determine because of the small number of stations. However, the resulting curves are thought to represent reasonable estimates of the upper limits of the relationships and thus provide conservative values for design purposes.

The results of a frequency analysis of annual maximum daily discharge are presented in Appendix 3.3.2-1, Table 2. The ratios of estimated flood magnitudes to mean annual flood for various recurrence intervals between 2 and 100 years are listed in Appendix 3.3.2-1, Table 3.

This regional analysis has been limited to mean daily discharge because there is little information on instantaneous peak discharges. However, for comparative purposes, the average and maximum ratio of instantaneous to mean daily discharge for stations with both mean daily and instantaneous discharge data are given in Appendix 3.3.2-1, Table 1. As expected from the theory of runoff generation, these data indicate the generally flashier nature of smaller watersheds, particularly those basins where there are no lakes to provide storage of runoff.

3.3.2.4 Regional low flow

Following the onset of subzero temperatures and precipitation in the form of snow, river discharge begins to decline and falls steadily throughout the winter months. The annual minimum discharge usually occurs between December and the beginning of May, but most frequently in February and March. Occasionally the annual minimum discharge for the smaller watersheds occurs in late summer following prolonged periods of high temperature and low precipitation.

The mean and minimum recorded flow, expressed as a discharge per unit area, are listed in Appendix 3.3.2-1, Table 1 for each hydrometric station. The mean minimum discharge for each of the regional hydrometric stations is plotted against basin area in Appendix 3.3.2-1, Figure 3.

Minimum flows for larger basins will be generally greater than those for smaller watersheds or those at higher elevations. This is because low flows in major rivers are maintained by the large volume of water stored in lakes and deep deposits of surficial materials typical of lower elevations and river floodplains. In a somewhat similar way, per unit area low flows in glacierized basins are typically higher than those in unglacierized basins because of the release of water stored in the glacier.

One of the objectives of this section was to estimate the ten year seven-day low flows in Berg and Bergeland creeks. Discharge records on the study streams, (May 6 to September 20, 1989), are too short to estimate ten year seven-day low flows using frequency analysis techniques. However, estimates may be made by transferring the low flow frequency curve from the Nanika river at the outlet of Kidprice Lake hydrometric station to the study area streams. This may be accomplished by developing a relationship between concurrent base-flows on the study area streams and the Nanika River station. These relationships may then be used to transfer points on the low flow frequency curve for the Nanika River station to the study streams (Riggs 1985).

Base-flow periods in the study area streams can be identified from the precipitation records of the Tahtsa Lake West climate station and the on-site continuous recording rain-gauge (Appendix 3.2.4-1, Table 2). To ensure that measured discharges were primarily from groundwater sources, the dates selected should occur three days after a rain event, when stormflow would no longer be contributing to stream discharge.

The discharge measurements for Berg and Bergland creeks (Appendix 3.3.2-2, Table 2) for the dates selected can be used to develop regression equations between baseflow in the study area streams and the Nanika River. The frequency analysis results for the 7 day low flow discharge for the Nanika River and other regional hydrometric stations are listed in Table 3.3.2-3.

Mean daily discharges for 1989 have not been calculated for the Nanika River at the outlet to Kidprice Lake and Laventie Creek near the mouth hydrometric stations. Therefore, when the final data becomes available the 7 day low flow estimates for Berg and Bergland Creeks can be developed and reported as an addendum.

3.3.2.5 Stream flow in the study area

Norecol's baseline hydrometric program was initiated in September 7, 1988 with the installation of staff and crest gauges on Bergeland and Ney creeks. Due to extreme discharges in these creeks because of heavy rains discharge measurements could not be made on this initial trip. The Berg camp area also could not be accessed due to high wind conditions.

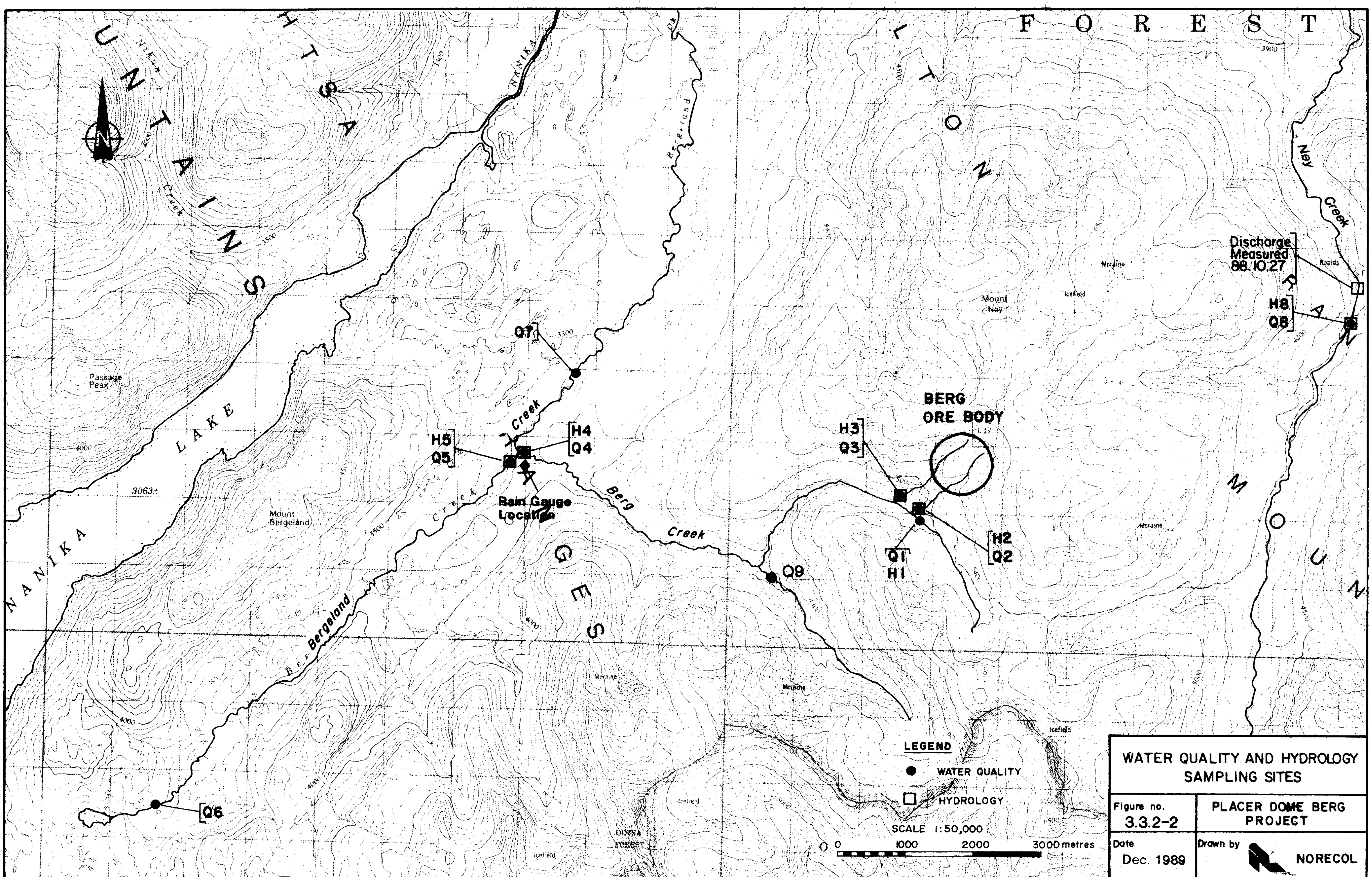
Norecol and Placer personnel returned to the project area in October of 1988 to collect more hydrometric data. A staff gauge was installed on Pump Creek (H1) and discharge measurements were carried out at sites H1, H2, H3, H4, H5 and H8. The sites are shown in Figure 3.3.2-2 and listed in Appendix 3.3.2-2, Table 1.

TABLE 3.3.2-3

LOW FLOW ESTIMATES FOR WSC GAUGING STATION NEAR THE BERG PROJECT AREA

RETURN PERIOD (Years)	7 DAY LOW FLOW MEAN DISCHARGE ($L/s/km^2$) GOATHORN CREEK NEAR TELKWA	LAVENTIE CREEK NEAR THE MOUTH	NANIKA RIVER AT OUTLET TO KIDPRICE LAKE	TELKWA RIVER BELOW TSAI CREEK
2	0.960	3.52	5.02	3.89
5	0.680	2.29	4.32	3.10
10	0.596	1.78	4.06	2.69
20	0.553	1.43	3.90	2.36
50	0.524	1.13	3.77	2.01
100	0.513	0.980	3.71	1.80
200	0.507	0.873	3.67	1.62

Source: Based on unpublished data from Environment Canada. (Nagy pers. comm.)



WATER QUALITY AND HYDROLOGY SAMPLING SITES

PLACER DOME BERG PROJECT

In planning the hydrometric data collection program for 1989 it was taken into account that no project personnel would be in the area to conduct routine hydrometric monitoring tasks such as recording staff gauge measurements. Therefore to ensure that sufficient baseline data was collected continuous water level recorders were installed on Berg and Bergeland creeks in May 1989.

Since estimates of stream discharges are required to assess the water quality impacts from mining and milling operations two continuous water level recorders were installed. This allowed the hourly discharges on Berg and Bergeland creeks to be monitored over the period, May 6 to September 20, 1989.

The sites for continuous water level recorders were selected to provide hydrological data for designing the tailings pond, assessing the mine water supply and determining effluent concentrations at sites downstream potential discharge points. Berg (H4) and Bergeland (H5) creeks were selected for detailed data collected because they both flow through the proposed project area and each represents one of the two basic watershed types characteristic of the region. The two basic watersheds types are high elevation glacierized basins and lower elevation unglacierized basins.

As well as the recorder installation sites, other hydrologic sites were selected for spot discharge measurements. All flow measurements were converted to runoff per unit area units so they could be compared to each other and the regional hydrometric stations.

Sites H1, H2 and H3 were established to provide information on the headwater drainage basins that encompassed the upper project area. Pump (H1) and Red (H2) creeks drain the deposit while North Berg Creek (H3) above the deposit (H3) occupied the proposed waste rock area.

In May, 1989, discharge measurements were conducted at sites H4, H5 and H8. The creeks in the upper Berg project area were inaccessible due to ice and snowpack conditions. In July and September 1989 discharge measurements were made at sites H1, H2, H3 H4, H5 and H8. Spot discharge measurements were also made at Sites H9 and H10 in July 1989.

Spring runoff from the study area in 1989 was assumed to be close to average because May 1st water equivalent at the two nearest snow courses (Tahtsa Lake and Kidsprice Lake, Table 3.2.4-5) are within 2 and 7 percent of the long-term averages, respectively.

The discharge measurements made at the two continuous recording water level sites H4 and H5 were used to develop a discharge curve for the stations. Mean daily stream heights were calculated (the average hourly voltage for each day converted to water depth) and then converted into mean daily discharges using the equation developed from the voltage/discharge curve.

Mean daily discharges for Berg Creek near the mouth and Bergeland Creek upstream of Berg Creek are listed in Appendix 3.3.2-2, Table 2. To compare the runoff from the two drainage basins the discharge values were converted into unit runoff values:

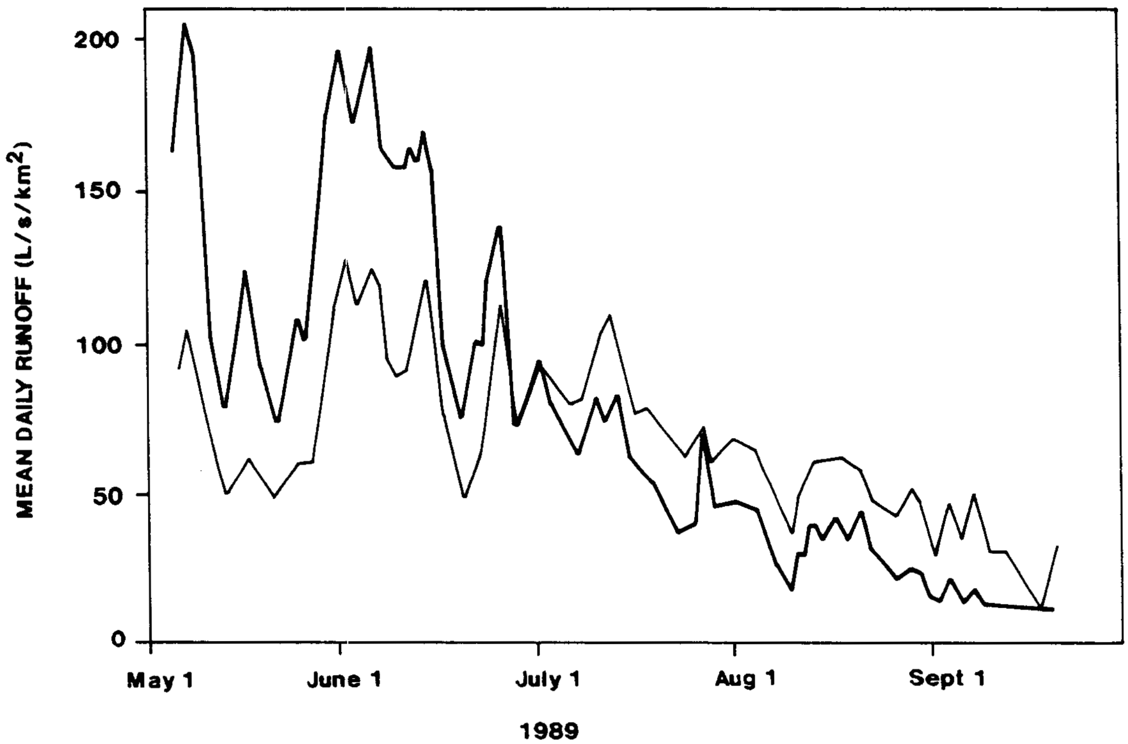
$$\frac{\text{discharge } (m^3/s) \times 1000}{\text{drainage area } (km^2)} = \text{unit runoff } (L/s/km^2)$$

The mean daily runoff ($L/s/km^2$) values for Berg and Bergeland creeks are plotted in Figure 3.3.2-3. The runoff patterns for the two creeks are quite similar when one analyzes the day to day flow fluctuations. However, the two creeks drain completely different types of watersheds.

Bergeland Creek upstream of Berg Creek has a more pronounced snowmelt peak. This is due to the basin having a lower average elevation and being unglacierized. An unglacierized basin generally has a peak runoff earlier in the spring and a lower flow during the summer months then a glacierized basin.

The runoff from Berg Creek (glacierized) is lower during May and June and higher July through September when compared to Bergeland Creek (unglacierized). This is primarily due to the watershed being glacierized, and spring runoff being stored in the glaciers and then released more slowly though the summer months (Fountain and Tangborn 1985). The Berg Creek basin would also be expected to have a later peak runoff due to the basin having a greater average elevation.

Monthly runoff comparisons can be carried out between the local streams and the regional WSC gauging stations once the 1989 data becomes available. The glacierized Laventie Creek station could provide comparable data for the Berg Creek runoff values while the Nanika River station could provide comparable data for the Bergeland Creek runoff values.



LEGEND

Bergeland Creek Upstream of Berg Creek —— (thick line)

Berg Creek Near the Mouth —— (thin line)

MEAN DAILY RUNOFF COMPARISON	
Figure no. 3.3.2-3	PLACER DOME BERG PROJECT
Date Dec. 1989	Drawn by NORECOL

3.3.3 Water quality

3.3.3.1 Introduction

A limited amount of historical water quality data is available for Nanika and Kidprice lakes and Bergeland Creek. Most of the data were collected by Fisheries and Marine Service (Cleugh and Lawley 1979), Ministry of Environment (1979), and Envirocon (1981, 1984) and are reviewed in the previous overview report by Norecol (1988). The detection limits for metal concentrations reported at the time of data collection were well above those normally considered adequate for present environmental work.

To provide an adequate data set, Norecol has since collected water quality samples on Bergeland, Berg, North Berg and Ney creeks on September 28 and October 27 in 1988, and on May 5/6, July 12/13 and September 21 in 1989. The late September sample was repeated because streams were sampled during a storm event in September 1988. Up to nine sites were sampled on each occasion depending on site accessibility on the sample date. These sites are indicated on Figure 3.3.2-2. Sites Q1, Q2 and Q3 are located on the north headwaters of North Berg Creek near the Berg deposit while Site Q9 is located on the southern headwaters of Berg Creek. Site Q4 is located on Berg Creek just prior to its confluence with Bergeland Creek. Sites Q5 and Q6 (upstream of confluence) and Site Q7 (downstream of confluence) are located on Bergeland Creek. Site Q8 is located in another drainage basin on Ney Creek (formerly referred to as Rhine Creek in the previous report). Assays are contained in Appendix 3.3.3-1. Field and laboratory quality control, detection limits, and so forth, are contained in Appendix 3.3.3-2.

3.3.3.2 Bergeland Creek drainage basin

Up to 8 sites were sampled by Norecol for water quality in the Bergeland Creek drainage basin on five occasions in 1988 and 1989 (Appendix 3.3.3-1). Dissolved oxygen was not measured, but would be expected to be at or above saturation because of the turbulent flow regime in these creeks.

Suspended solids (and consequently turbidity) were generally low (less than 10 mg/L) but varied seasonally with high values (ranging from 34 mg/L at site Q6 to 584 mg/L at site Q7) found in September 1988. The suspended solids and turbidity values increased in a downstream direction on Bergeland Creek. Total solids followed a similar pattern seasonally but were generally much higher than suspended solids ranging from 16 to 818 mg/L. High total solids ranging from 138 to 561 mg/L were also found at sites Q2 and Q3 which are seeps from the deposit. Specific conductance was highest (up to 539 umhos/cm) at the seep sites (Q2 and Q3) and decreased in a downstream direction to about 50 umhos/cm at site Q4 on Berg Creek. Conductance in Bergeland Creek ranged from a low of 8 umhos/cm upstream (site Q6) to a high of 37 umhos/cm downstream (site Q7).

The waters of Bergeland Creek are soft (less than 25 mg $CaCO_3$/L), have low alkalinity (less than 15 mg $CaCO_3$/L) and are slightly acidic (pH 5.9 to 6.8). The waters of Berg Creek are similar to Bergeland Creek except those emanating from the seeps (Q2 and Q3) which are hard (up to 300 mg $CaCO_3$/L) and have a pH of 4.0 to 4.6 with no measurable alkalinity. Except for the seep sites sulphate concentrations were generally low (less than 10 mg/L). The seep sites had sulphate concentrations ranging from 74 to 365 mg/L. Between the seepage sites, Q2 had poorer water quality than Q3 with a lower pH and higher sulphate concentrations.

Measured nutrient levels were generally low and comparable to those previously reported for Nanika and Kidprice lakes (Envirocon 1981). Ammonia was generally less than 0.005 mg N/L, nitrite generally less than 0.002 mg N/L and nitrate often less than 0.005 mg N/L. The highest ammonia and nitrate concentrations up to 0.055 and 0.028 mg N/L, respectively were found at the seep sites (Q2 and Q3). Occasional elevated nitrate concentrations were observed at sites Q4, Q5 and Q7, while at the upstream Bergeland Creek site (Q6) nitrate was below detection limits on all dates except September, 1989 when an anomalously high value of 0.177 mg/L was apparently found. This value is higher than any others found and a sampling error is suspected. The low nitrite levels are likely the result of the high dissolved oxygen levels resulting from turbulent flow.

Total phosphorus varied seasonally with a pattern similar to suspended solids. Concentrations increased in a downstream direction, highest levels ranging up to 1.10 mg P/L found at site Q7 (furthest downstream). The low levels of total phosphorus at times of low suspended solids suggest that a large percentage of the phosphorus is not available to aquatic plants and that these streams probably have low rates of primary productivity.

Total cyanide values were collected at all sites and were in all cases below the detection limit (0.001 mg/L). The purpose of collecting these data is to provide background concentrations in case cyanide were to be used in the extraction process.

Both total extractable and dissolved metals were analyzed for at all sites (Appendix 3.3.3-1). Total metals varied seasonally with highest concentrations occurring with high suspended solids. Total metal concentrations were lowest in the headwaters (sites Q1, Q9 and Q6) increasing in a downstream direction. Highest concentrations were found at the seepage sites (Q2 and Q3) and included elevated concentrations of aluminum, cadmium, cobalt, copper, iron, manganese, nickel and zinc. The following metals exceeded the recommended provincial receiving water criteria (Pommen 1989) (maximum observed; criteria) at the seepage sites: aluminum (12 mg/L; 0.020 mg/L), cadmium (0.012 mg/L; 0.0002 mg/L), copper (6.0 mg/L; 0.002 mg/L), iron (1.30 mg/L; 0.3 mg/L) and zinc (1.13 mg/L; 0.030 mg/L). Sites Q4 and Q7 (located downstream of the seepage sites) occasionally exceeded provincial criteria for aluminum, cadmium, copper, iron, lead and zinc. Most sites on occasion exceeded provincial criteria for aluminum and iron.

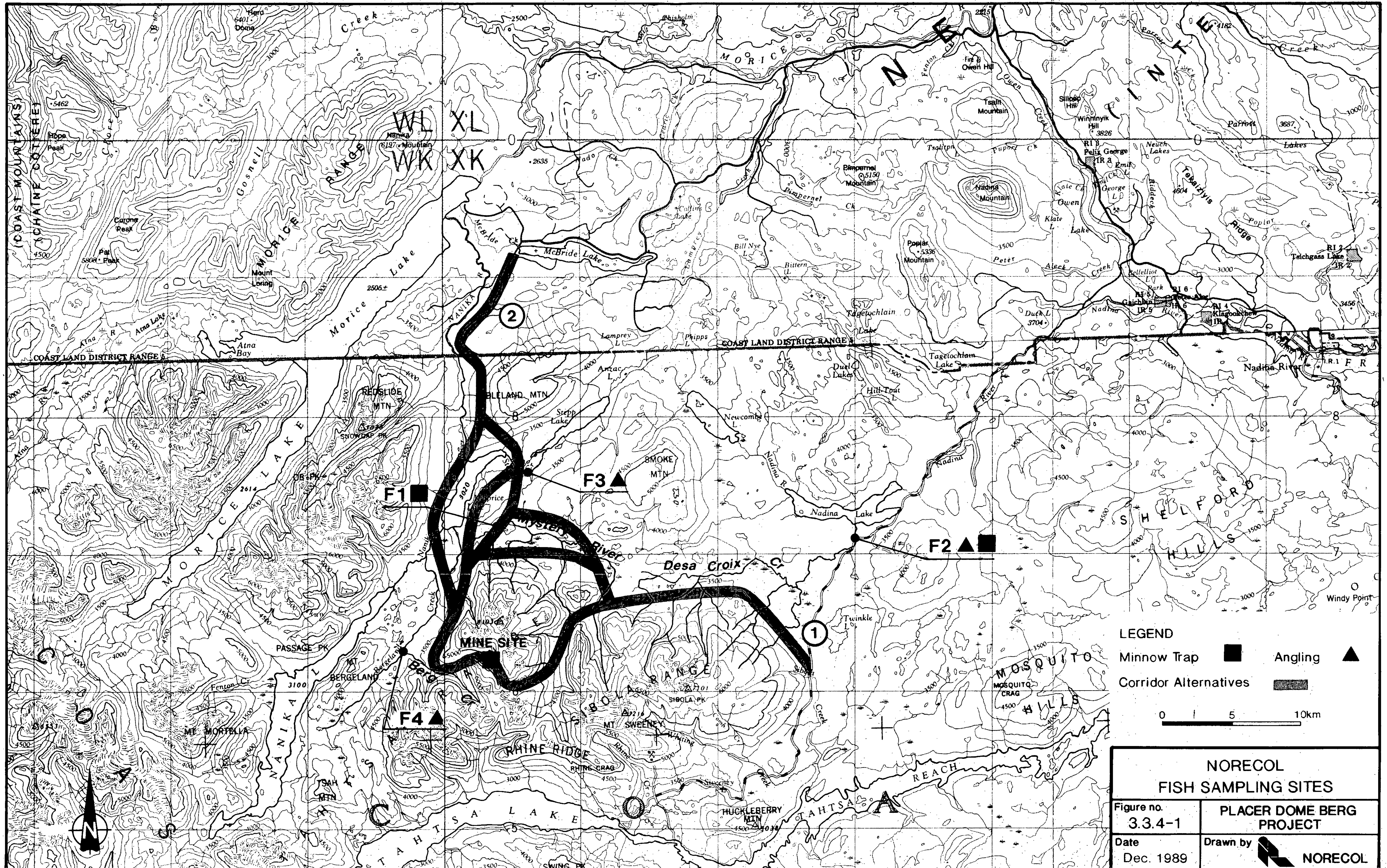
3.3.4 Fisheries

3.3.4.1 Introduction

The Berg project area lies in the Nanika River watershed which drains the heavily glacierized Coast Mountains in northwest British Columbia. The Nanika River is located in the southwest portion of the Bulkley River drainage, a major tributary of the Skeena River. Study area drainages related to the proposed mine development include Kidprice Lake, Berg Creek, Bergeland Creek and the Nanika River between Nanika and Kidprice lakes (upper Nanika River) (Figure 3.3.4-1). Nanika Falls, at the outflow of Kidprice Lake, is a fish migration barrier and is the limit of anadromous fish (salmon and trout) migration in the Nanika River system. The fisheries resources in the lower Nanika River, between Nanika Falls and Morice Lake, are discussed in detail in Section 4.2.2.5 under Road Option 2, Northern Access.

Considerable information on the fisheries resources in the Nanika Kidprice lakes area is available from studies associated with the Alcan Kemano Completion Project. Morley and Whately (1974) collected fisheries data during September 1974, and the Ministry of Environment (1979) conducted fisheries studies between late September and early October 1974 and from early August to late September 1975. These studies included gill netting and collection of physical and chemical data in Kidprice Lake, and identification and evaluation of spawning and rearing habitat in tributary streams. Envirocon (1984) supplemented earlier information on major spawning areas and habitat in the Nanika Kidprice lakes area with helicopter and ground surveys on tributary streams in June 1979. The Department of Fisheries and Oceans (1980) also collected fish in Kidprice Lake in August 1980 for virus assay.

Norecol conducted a fish sampling program in the project area in mid July 1989. Since considerable information on the fisheries resources in the project area was available from previous studies, sampling was limited to a few areas where information was lacking. The emphasis



NORECOL

FISH SAMPLING SITES

Figure no. 3.3.4-1

PLACER DOME BERG PROJECT

Date Dec. 1989

Drawn by NORECOL

was placed on streams potentially affected by the proposed access road route options, and included sites on the Mystery River (lower Ney Creek), Bergeland Creek, Stepp Creek and Desacroix Creek (Figure 3.3.4-1). Fish sampling activities and fork lengths of fish specimens collected are presented in Appendix 3.3.4-1. Fisheries information for watercourses are presented in the following sections.

3.3.4.2 Kidprice Lake

The Ministry of Environment (1979) describe Kidprice Lake as a typically oligotrophic lake with a maximum depth of 47 m, a mean depth of 29 m, and a surface area of about 7 km^2. Surface level fluctuations average about 1.2 m, and maximum levels occur in June. The northern, southern and western shores are gently sloping and shallow littoral zones occur in much of this area. There is an extensive shallow area by the southern shore and a smaller one at the outlet of Stepp Creek. The eastern shore has steep, rocky bluffs with a limited littoral zone. Shoreline vegetation is predominantly balsam fir, willow, alder and cottonwood and low lying areas have small ponds and sedge meadows. Extensive growths of marsh grasses are present in several marshy areas near stream mouths.

Nanika Falls, at the outflow of Kidprice Lake, is approximately 18 m in height and is the upper limit of migration for fish species from downstream locations. Resident fish populations in Kidprice Lake are comprised of rainbow trout (Oncorhynchus mykiss), Dolly Varden char (Salvelinus malma) and longnose sucker (Catostomus catostomus). Kidprice Lake appears to have areas of good juvenile rearing habitat due to the presence of shallow areas and an abundance of aquatic macrophytes.

Gill net catch data and percent species composition for Kidprice Lake from previous studies are summarized Table 3.3.4-1. Gill net studies over the three year period from 1973 to 1975 indicate that Dolly Varden were the most common species and represented on average 44% of the catch. The reason for the high (80%) composition of longnose sucker in the 1980 sampling is not apparent and further studies would be required to determine if this represents a trend. Comparative data on age-length relationships for rainbow trout and Dolly Varden char from other lakes in British Columbia and Alberta suggest that the sampled Kidprice Lake populations generally have lower growth rates (Table 3.3.4-2).

Morley and Whately (1974) reported light fishing pressure in Nanika and Kidprice lakes. Recent Forest Service data (Singer, pers. comm.) indicate fishing pressure is still light. Some angling probably results from mining exploration camps periodically set up in the area.

3.3.4.3 Upper Nanika River

The upper Nanika River, which is approximately 8 km in length, flows northeast from Nanika Lake into Kidprice Lake. The river meanders through a low-lying, poorly drained area over 2 km wide which has numerous small ponds and sedge meadows. Bergeland Creek joins the Nanika River approximately 3.5 km upstream of Kidprice Lake.

TABLE 3.3.4-1

PLACER DOME BERG PROJECT
PERCENT COMPOSITION AND RANGE OF FORK LENGTHS OF GILL NET CATCHES FROM KITPRICE LAKE

	RAINBOW TROUT			DOLLY VARDEN CHAR			LONGNOSE SUCKER		
DATE	NO.	%	SIZE RANGE	NO.	%	SIZE RANGE	NO.	%	SIZE RANGE
September 1973[a]	22	15.0	10.0 to 39.8	61	41.5	11.8 to 36.5	64	43.5	9.5 to 29.5
September/October 1974[b]	19	23.2	16.0 to 37.0	32	39.0	16.0 to 23.5	31	37.8	14.5 to 31.0
August/September 1975[b]	54	39.7	15.2 to 38.6	69	50.7	15.9 to 33.3	13	9.6	14.6 to 27.6
August 1980[c]	34	11.0	---	28	9.0	---	248	80.0	---

[a] Moreley and Whately. 1974.
[b] Ministry of Environment. 1979.
[c] Fisheries and Oceans. 1980.

TABLE 3.3.4-2

PLACER DOME BERG PROJECT
COMPARATIVE GROWTH RATES FOR RAINBOW TROUT AND DOLLY VARDEN CHAR FROM OTHER LAKES IN BRITISH COLUMBIA AND ALBERTA

		AGE							
LOCATION		1	2	3	4	5	6	7	8
Rainbow Trout									
Pyramid Lake, Alta.	FL cm	6.1	13.5	19.0	23.6	29.5	37.6	45.5	-
Kootenay Lake, B.C.	FL cm	6.2	12.5	28.9	44.5	59.8	78.5	-	-
Okanagan Lake, B.C.	FL cm	6.5	12.0	29.0	43.5	51.5	59.0	71.0	-
Buttle Lake, B.C.	FL cm	-	25.4	26.7	29.2	31.5	-	-	-
Nanika Lake, B.C.	FL cm	-	-	-	30.0	34.0	34.0	-	-
Tahtsa Lake, B.C.	FL cm	-	-	21.4	30.4	33.0	-	-	-
Kidprice Lake, B.C.	FL cm	-	-	21.3	28.6	30.5	-	-	-
Dolly Varden Char									
Bow River, Alta.	FL cm	16.5	21.1	24.6	26.9	32.0	33.5	-	-
Jasper Nat. Pk.	FL cm	-	20.0 23.0	25.0 30.0	33.0 40.0	41.0 46.0	50.0 54.0	56.0 62.0	- -
Upper Campbell Lake, B.C.	FL cm	23.1	23.9	29.0	-	-	-	-	-
Kidprice Lake, B.C.	FL cm	-	-	17.3	19.3	21.2	24.3	26.0	31.7

Source: Ministry of Environment. 1979.
FL: Fork Length

A major spawning area for rainbow trout and Dolly Varden char from Nanika and Kidprice lakes occurs in the Nanika River upstream of Bergeland Creek. The main spawning area is an 80 m section at the outlet of Nanika Lake, and Envirocon (1984) observed 300 spawning trout and the Ministry of Environment (1979) observed 80 trout fry in this area. The Nanika River within 1 km of Kidprice Lake also appears suitable for rainbow trout spawning and rearing. Morley and Whately (1974) indicate that, although the river is relatively fast flowing in this area, there are numerous log jams, back eddies and an abundance of suitable streamside vegetation (willow, spruce and scattered pine) which would all contribute to good rearing potential. Spawning gravels of 2 to 8 cm diameter also occur in this section.

Rainbow trout spawning in the area usually occurs in late May and June at water temperatures of around 7°C, and fry emerge in late August and early September. Some fry move into the lakes while others remain in the river. Rainbow trout fry were captured by the Ministry of Environment (1979) in Kidprice Lake at the mouth of the Nanika River. Dolly Varden char spawning probably occurs in late October and early November and fry probably emerge in June and July.

3.3.4.4 Bergeland Creek

Bergeland Creek generally appears to have good spawning, fry rearing and adult holding habitat areas in the lower 6 km of the stream. The lower 2 km tends to be lower gradient where it flows through the low-lying area adjacent to the Nanika River. In this area, the stream is sinuous and there are a wide variety of habitats ranging from shallow, gravelly riffles to moderately deep pools. Numerous small log jams occur in the lower 1 km of the stream. However, only a few Dolly Varden char fry have been observed in the stream, and fish sampling in the stream has been unproductive. Envirocon (1984) electrofished 400 m^2 of margin habitat in Bergeland Creek, but no fish were captured. Angling by Norecol in July 1989 (site F4, Figure, 3.3.4-1) was also unsuccessful and it was noted that spawning gravels in the lower reach are compacted with fines.

Envirocon (1984) suggests that productivity is low in Bergeland Creek and other glacial tributaries in the area due to low water temperatures and high turbidity. They report that Bergeland Creek was 6°C in early June and only 5.4°C in late July. This is below the 7°C or greater at which rainbow trout spawning typically occurs in this area. High suspended sediment loads occur in Bergeland Creek in late spring and summer infilling interstitial spaces in spawning gravels thereby reducing the spawning potential of available spawning areas. The Ministry of Environment (1979) indicate that ice penetration of gravels in the winter may preclude spawning by Dolly Varden char.

3.3.4.5 Berg Creek

Berg Creek is a small tributary of Bergeland Creek. It is a relatively high gradient, glacial stream with predominantly cobble and boulder substrate. The fish habitat capabilities are low and it appears to be an unproductive stream. Low numbers of Dolly Varden char may utilize this stream, but this is unsubstantiated. The project area is located on North Berg Creek, a small, high gradient tributary of Berg Creek. The lower 1 km has a poorly defined channel which appears to shift from year to year. This stream has no perceived fisheries values.

3.4 Terrestrial Resources

3.4.1 Vegetation and soils

Field studies for the deposit site area did not include investigation of vegetation and soils. Information presented here was derived from a literature review and maps.

Vegetation and soils in the proposed mill site area were described in Norecol (1988). Additional information pertinent to elevations above 1000 m was derived from 1:50 000 scale forest cover maps.

3.4.1.1 Major vegetation types

There is not a clear correlation between elevation and dominant vegetation types in the proposed mine and mill areas. The upper Berg deposit site is contained entirely in the alpine biogeoclimatic zone which is as low as 1300 m on north-facing slopes. The average elevation for the tree line in the area is about 1500 m. From the tree line, the Englemann Spruce-Subalpine Fir Zone extends down to Bergeland Creek. The area at lake level and the lower drainage area of Bergeland Creek are in the sub-Boreal Spruce biogeoclimatic zone.

White spruce (Picea glauca) is the climax tree in the Sub-Boreal Spruce Zone. Its distribution in the Nanika-Kidprice area is limited to the extensive riparian areas bordering on Bergeland Creek. The Subalpine Zone is dominated by alpine fir (Abies lasiocarpa), whitebark pine (Pinus albicaulis), lodgepole pine (Pinus contorta var. latifolia) and mountain hemlock (Tsuga mertensiana). The occurrence of whitebark pine at relatively low elevations along Bergeland Creek is unusual. The Ecological Reserves Unit of British Columbia had at one time targeted an area of Bergeland Creek as an ecological reserve to preserve this feature. However, an ecological reserve in this area is not currently being considered.

Envirocon (1981) identified ten broad vegetation types in the Nanika Kidprice area and mapped the area at a scale of 1:20 000. The major zones found in the Berg-Bergeland Creek drainage are discussed here.

3.4.1.2 Whitebark Pine-Fir conifer forest

This is one of the two forest types surrounding the Berg deposit and extends from the tree line to Bergeland Creek. As noted previously, whitebark pine is usually not the dominant tree species in this zone with either alpine fir or lodgepole pine having this position. Mountain hemlock may also occur sporadically. The most common understory shrub is blueberry (Vaccinium membranaceum) with lesser and varying amounts of false azalea (Menziesia ferruginea). The dominant herbaceous plant is wintergreen (Orthilia secunda). Mosses and lichens are also locally abundant.

Soils under this forest cover type are podzols, including Duric Humo Ferric and Orthic Humo Ferric types.

3.4.1.3 Fir-Hemlock forest

The commonest tree cover in the upper Bergeland Creek drainage is a Subalpine Fir-Mountain Hemlock Forest.

This forest extends over the same elevation range as whitebank pine. Stands vary from almost pure mountain hemlock to pure alpine fir. Stands are usually well-stocked, and a large variety of shrubs and herbs may occur in the understory.

In moist areas willows (Salix spp.), alder (Alnus spp.), false azalea (Menziesia ferruginea), twinberry (Lonicera involucrata), current (Ribes sp.), squashberry (Viburnum edule), and Sitka mountain ash (Sorbus sitchensis) are commonly encountered shrubs. The herb layer includes a number of common flowering plants including bunch berry, violets, raspberries, lupines and others. Ferns may also be locally abundant.

On mesic to drier slopes blueberries (Vaccinium spp.), raspberries (Rubus sp.), and currents (Ribes spp.) are common.

Soils on drier sites are typically Brunisolic, probably representative of a Dystric Brunisol.

3.4.1.4 Lodgepole Pine-Fir forest

A Lodgepole Pine-Fir forest cover is developed in drier patches around Bergeland Creek and its tributaries. The pine forest is sub unit in the Boreal Spruce Zone and is found at elevations around 1000 m at this location. On the driest sites (terraces, sand or gravel benches) the forest is pure lodgepole pine. The understory in this forest cover type is dominated by blueberries and lichens, with occasional willows, bearberry (Arctostaphylos uva-ursi) and lupines. Whitebark pine and mountain hemlock are scattered in these areas.

Soils under this forest cover are typically Humo Ferric Podzols.

3.4.2 Wildlife

Appendices 3.4.2-1 and 3.4.2-2 describe field study activities and methods, and identify previous wildlife surveys applicable to the study area. For wildlife considerations, the proposed deposit site development area can be divided into two distinctly different habitat units, the Upper and Lower. The upper deposit site area, because of its characteristically sparse vegetation and snow cover persisting over many months, generally has severe limitations for supporting all but a few local species of wildlife. The Lower unit, along the forested sections of Berg Creek and along Bergeland Creek, lies within the ESSF (Engelmann Spruce-Subalpine Fir) biogeoclimatic zone, which may be used seasonally by a number of local species. The following accounts summarize the applicable historic and recent data (Appendices 3.4.2-3-3.4.2-7), and provide an interpretation on the nature and extent of wildlife occurrence in the area.

3.4.2.1 Ungulates

As mapped by the Canada Land Inventory (CLI 1972), the Tahtsa and Sibola Range uplands (AT Zone) and surrounding subalpine forests (ESSF Zones) are mostly in the "Class 4" category, i.e., having "moderate limitations to the production of ungulates". Moose (Alces alces), caribou (Rangifer tarandus), and mountain goats (Oreamnos americanus) were the indicator species for that classification, and snow depth was considered a primary limiting factor. The lowlands around Bergeland Creek and northward from there along the Nanika-Kidprice system have the highest capability rating in the present study area (Class 3), reflecting their apparent local importance as summer moose range. As listed in Appendix 3.4.2-4, the Bergeland sub-unit was among the most productive of moose observations during summer/fall surveys in the mid-1970's. Recent (1989) observations can only confirm that moose, including cows with calves, still use that area (Appendix 3.4.2-6).

Although occasional moose probably travel along the forks of Berg Creek and over the headwaters passes during the summer-fall period, further discussion for the higher elevation area is limited to the only two species of local ungulates, mountain goat and caribou, that are specifically adapted for regular, persistent occurrence in such upland habitats.

Mountain Goat - The winter survey (March 1989) revealed tracks and pawed areas (feeding sites) at several locations along the ridge and south-facing slope between the two forks of Berg Creek. Those tracks suggested that 4-5 goats were present in the general area, but only one was seen--a young billy at the east end of the ridge. During the July 1989 visit, fresh tracks of a single goat were seen among the workings of the old exploration site, and there were a few well-used trails across the talus upslope. In addition, five goats including two nanny/kid pairs were seen on slopes over the south fork and lower section of Berg Creek at that time.

It seems evident, therefore, that at least small numbers of goats occur in and near the upper deposit site area throughout the year. It is difficult to put that fact in perspective, because there is little comparative information on numbers, distribution, and seasonal habitats of goats in the Tahtsa-Sibola upland as a whole. During a Canada Land Inventory (CLI) survey in February 1974 (see Appendix 3.4.2-5), 35 goats were seen in the Tahtsa-Sibola uplands, and 29 of those were on the ridge between the two main forks of Berg Creek (hereafter referred to as Berg Ridge). We saw only 14 goats in the Tahtsa Range and none in the Sibola Range during our July 1989 survey. Taking the existing data at face value, over 80% of the known local population in 1974 (29 of 35) and up to 30% of the known population in 1989 apparently wintered in or near the Upper deposit site area. The 1972 CLI map shows the Berg Ridge area as supporting one of only two "Class 2W" winter ranges for goats in the area. The other is on the east end of the Sibola Range, but no goats were seen there on the 1974 CLI surveys, and it was not covered because it was considered outside the terms of reference for our 1989 winter survey.

Caribou - No caribou or sign were observed in the general Tahtsa-Sibola uplands in either March or July 1989, and apparently none have been documented there since the mid-1970s (see Appendix 3.4.2-7). If caribou still occur in the general area at least occasionally, some use of ridges and slopes around the Upper deposit site would be expected, but would not likely be significant in terms of local population dynamics.

3.4.2.2 Carnivores

As described in the road corridor accounts, the general area supports a number of big game and furbearer carnivores. Individuals of all of those species doubtless travel and forage in the Bergeland Valley, and all might be found in the Upper deposit site area occasionally, en route overland to appropriate habitats in adjacent forested areas. However, only three--wolf (Canis lupus), wolverine (Gulo gulo), and grizzly bear (Ursus arctos)--would be expected to appear in the uplands regularly, both in travel and in response to foraging opportunities:

Wolf

In July 1989, a fresh wolf track was seen in association with a fresh goat track among the old mine workings, but no sign was seen in that area or in adjacent uplands during the March survey. In addition to an occasional chance at a goat, the upper Berg Creek area offers to wolves (in summer) a variety of smaller prey species such as hoary marmots (Marmota caligata), voles (Microtinae), and ptarmigan (Lagopus sp.), However, the entire deposit site area would constitute only a fraction of the total foraging range for any one individual or pack.

Wolverine

During the March survey, tracks of two animals were present along lower Berg Creek and in the high valley near the old mine workings. Summer occurrence was not documented, but should be expected. The same food sources listed above for wolf, available either as prey or carrion, would also be the primary local attraction for this species (see Hatler 1988). Also as for the wolf, the deposit site area would be only a small portion of each individual's total seasonal range.

Grizzly Bear

No specific sightings or sign were recorded in the Upper deposit site area during the July survey, but the species has been reported to occur in "above average" densities throughout the Kemano II Nanika-Kidprice study area (Sutherland 1979), and the upper Berg Creek Valley would likely be within the range of one or more local bears. The Upper deposit site area does not appear to have any outstanding local bear habitats, thus most use would be for travel and associated casual foraging for marmots, small mammals, and various plant foods, especially along the stream courses and lower slopes.

3.4.2.3 Other mammals

Detailed ground studies have not yet been undertaken in the deposit site area, thus the local distribution and relative abundance of resident mammals in the area are not known. The most conspicuous of those species in the Upper area is the hoary marmot, whose main strategy for subsistence in harsh northern upland environments is to spend much of each year (six to eight months) in hibernation. Microtine rodents, especially brown lemmings (Lemmus sibiricus), and a chipmunk (Eutamias sp.) are also present in the uplands.

3.4.2.4 Birds

Two species officially designated as threatened or endangered in B.C. (Munro and Low 1979), the White Pelican (Pelecanus erythrorhynchos) and a subspecies of the Peregrine Falcon (Falco peregrinus anatum), are potentially present in the general study area, but no evidence of significant occurrence (e.g., nesting) was found. Ptarmigan, both L. lagopus and L. leucurus (Willow and White-tailed Ptarmigan, respectively), are present and possibly common in the Tahtsa-Sibola uplands, and Blue Grouse (Dendragopus obscurus) occur to the upper edges of local subalpine habitats. Based on observations from the air, there is no reason to suspect that the deposit site area has any special significance for any of those species. Cliffs and outcrops in the upland area offer some potential as nesting habitat for certain raptors, e.g., Golden Eagle (Aquila chrysaetos) and falcons (Falco sp.) but no evidence of such nests was seen.

3.5 Resource Use

The most important resource in the Berg area is the copper mineralization. Lower elevation land also supports some merchantable timber and mine development could accelerate logging in the area. The area, especially Nanika and Kidprice lakes, has a limited recreational potential at present because of lack of access. Access improvement from mine development could raise recreational value of the area. The Berg deposit is within a guiding territory and a trap line traverses the site. Capability for agriculture is poor or non existent.

3.5.1 Land status

The area covered by the site is on Crown land. The mine and mill site areas are on mineral claims held by Placer Dome and Kennicot. A staking reserve exists around Nanika and Kidprice lakes up to the 938.8 m (3000 ft) contour. The land below this contour in the reserve would be flooded when the Kemano completion project proceeds.

3.5.2 Forestry

The forest resource was discussed in an overview report (Norecol 1988) and is summarized again in this report. The Berg property is near the southern boundary of the Morice Timber Supply Area (TSA) administered by the B.C. Forest Service. This area contains 348 583 ha of productive forest, including 233 747 ha of merchantable mature and overmature forest. Major species include hemlock and balsam; minor species include spruce and lodgepole pine.

There are currently no plans to log timber around Nanika Lake for at least 20 years (D. Singer, BCFS, pers. comm.) The majority of merchantable timber in the Nanika Kidprice lakes area is between the lakes and outside of the influence of any likely mine development at the Berg, except road access from the north.

3.5.3 Recreation

The greatest recreational potential for the Berg area is hunting, angling, hiking and canoeing. Hunting is discussed with guiding. Other recreational activities are discussed more fully under the access corridors, since there is limited recreational potential at the Berg deposit because of its remoteness and lack of access.

3.5.4 Hunting, guiding and trapping

The Berg deposit lies in Management Unit 6-9 of the Skeena Sub-region, administered by the Smithers office of the Ministry of Environment. Hunting seasons for the following game animals exist for this unit: moose (bulls and calves - fall), mule deer (bucks only - fall), grizzly and black bear (fall and spring), coyote (fall to spring), wolf (open), lynx (fall and winter), wolverine (fall), blue, spruce and ruffed grouse (fall), and ptarmigan (fall and winter). With the exception of mule deer and possibly ptarmigan, all of these species are available in the deposit site area or immediate vicinity. Mountain goats, which may not be hunted in this area, are also present.

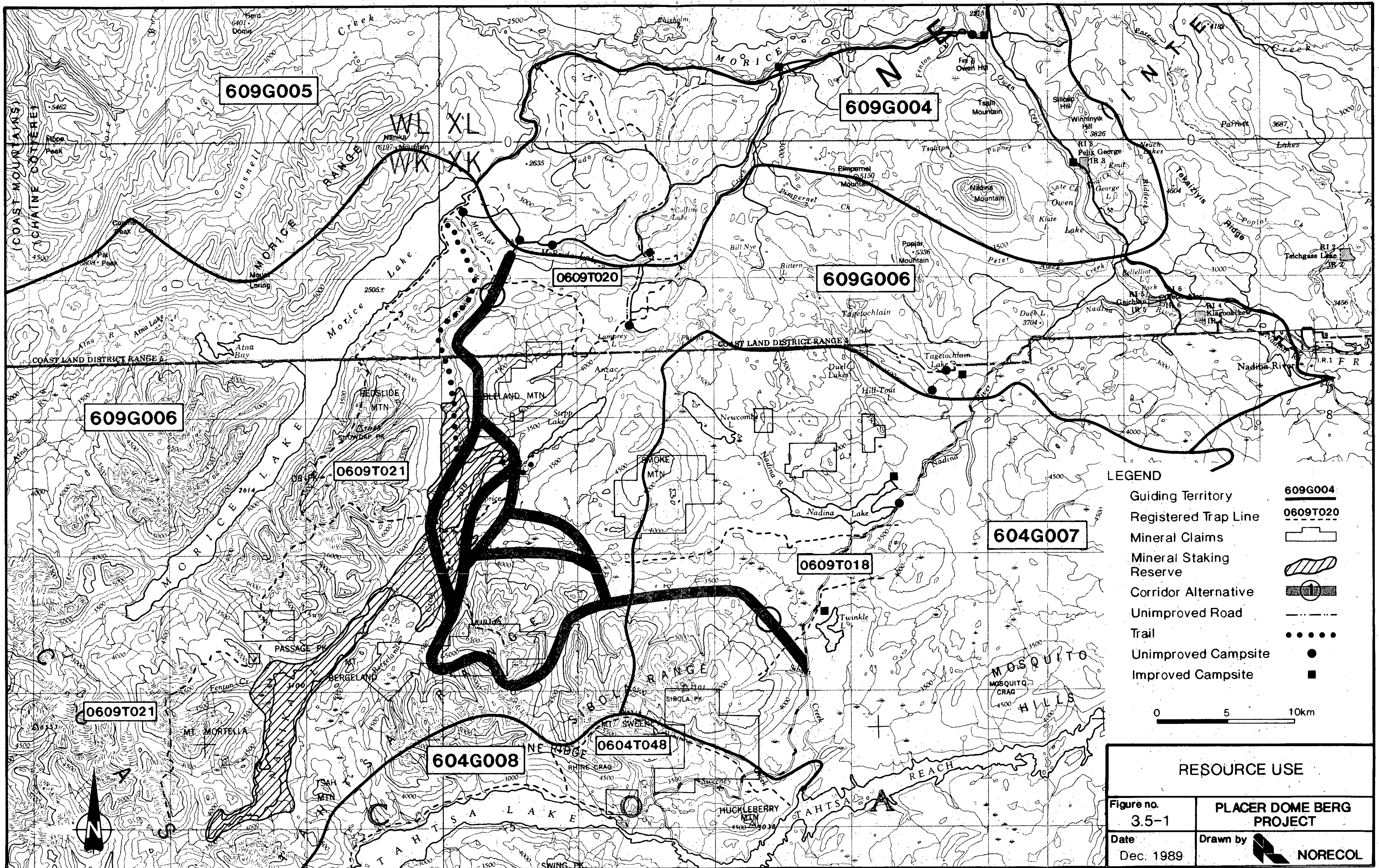
The remote location of the area and lack of road or trail access generally precludes hunters from using the area.

The Berg deposit is contained within a large guiding area held by Mrs. Barbara Peden of Burns Lake, B.C. (Figure 3.5-1). One branch of registered trapline 0609T021 ends near the Berg deposit. The owner of this trapline only harvested martin in the 1987/88 season, the last for which there are records at the time of writing. As this animal is an inhabitant of forests, mining of the alpine Berg deposit would not interfere with its harvest by the trapline owner. Table 3.5-1 lists guiding territory and trapline numbers along with owners and addresses.

3.5.5 Heritage resources

Heritage resources of the deposit site and proposed access corridors are discussed in detail in Appendix 3.5-1.

The Berg property was assigned a low potential for unrecorded archaeological sites due to its rugged terrain.



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LEGEND
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Mineral Claims
Mineral Staking Reserve
Corridor Alternative
Unimproved Road
Trail
Unimproved Campsite
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RESOURCE USE
Figure no. 3.5-1
PLACER DOME BERG PROJECT
Date Dec. 1989
Drawn by NORECOL

TABLE 3.5-1

REGISTERED GUIDING TERRITORY AND TRAPLINE OWNERS IN THE NANIKA-TAHTSA LAKES AREA

TERRITORY NUMBER	OWNER	ADDRESS
609G004	J.W. Shepert	Box 216, Houston, B.C., V0J 1Z0 (604) 845-7355
608G005	R.D. Fitch	Box 452, Houston, B.C., V0J 1Z0
609G006	B.P. Peden	R.R. #2, Burns Lake, B.C., V0J 1E0
604G007	J.R. Gordeau	Box 19, Burns Lake, B.C., V0J 1E0 (604) 692-7472
604G008	G.E. Blackwell	R.R. #2, Burns Lake, B.C., V0J 1E0
604G009	M.J. Comeau	General Deliver, Southbank, B.C. V0J 2P0

TRAPLINE NUMBER	OWNER	ADDRESS
0609T018	M. Ogen	Box 692, Burns Lake, B.C., V0J1E0
0609T020	K. Crick, S. Dennis	Box 253, Smithers, B.C., V0J 2N0
0609T021	G. Legault	Box 2269, Smithers, B.C., V0J 2N0
0604T48	G. Loui	R.R. #2, Burns Lake, B.C., V0J 1E0

A portion of the abandoned exploration camp was ground surveyed. While no in situ cultural remains were found, some welded tuff flake shatter and a large tuff bifacial thinning or reduction flake were found. These materials were scattered in front of a cabin littered with a variety of other rock samples. Mr. David Heberline (pers. comm.) carried out rock sampling in the area in the early 1980s and used a cabin in the area where the flakes were noted. He suggests that it was unlikely they were found on the Berg Property, but were more likely from areas of glacial deposited boulders on Mt. Ney. Any further archaeological studies should attempt to locate this welded tuff source.

4.0

Description of Road Corridor Environments

4.0 DESCRIPTION OF ROAD CORRIDOR ENVIRONMENTS

Two access corridor options were considered: west from Twinkle Lake from the Nadina River forest access road (Option 1) and south from Morice Lake from the Morice forest access road (Option 2).

4.1 Road Option 1 - Eastern Access

4.1.1 Physical overview

The eastern access corridor (Option 1) starts near Twinkle Lake on the Nadina River forest road and ends at the Berg deposit site approximately 35 km to the west. A total of 52 km of road would be required to connect the forest road at Twinkle Lake and the proposed mine and mill sites. Approximately 10 km from Twinkle Lake west currently follows existing logging roads. The corridor splits into north and south sections at Mystery River (lower Ney Creek). The north branch carries around the foot of the Sibola Range, up Bergeland Creek to a possible mill site on Bergland Creek, and branches at Berg Creek south about 7 km to the deposit. The south branch follows the old exploration tote road constructed in the 1970s up Ney Creek and over an alpine pass into the Berg deposit site. Most of the corridor is in lowland forest and river bottom areas. The north branch up Berg Creek and the south branch up Ney Creek climb into the alpine.

This section deals with the biophysical and geotechnical aspects of the road corridor. Section 2 deals with geotechnical aspects and Section 6 discusses potential impacts with road development.

4.1.2 Surface water resources

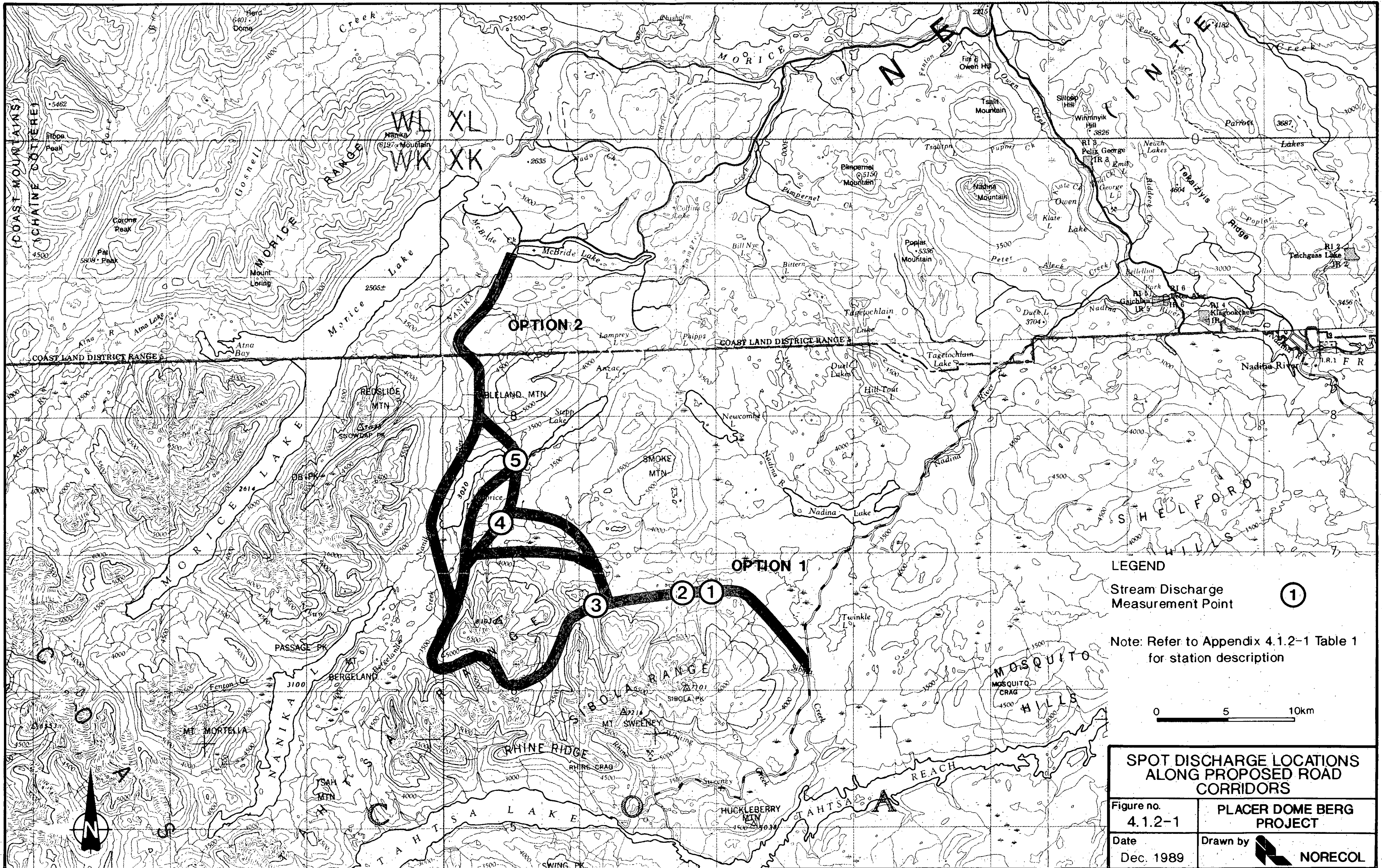
4.1.2.1 Watershed characteristics

The majority of the eastern access road is located on the north slope of the Sibola Range. All of the creeks crossed by the proposed route share the following hydrologic characteristics with upper Ney Creek; their headwaters are in the Sibola mountain range and they drain northward, their drainage basins range in elevation from about 2500 m in the headwaters down to 1000 m, and they are approximately 15 percent glacierized.

4.1.2.2 Streamflow along the road corridor

Norecol personnel carried out spot discharge measurements at selected stream crossing sites along the proposed road corridor in July and September 1989 (Figure 4.1.2-1 and Appendix 4.1.2-1, Table 1). All measurements were converted into runoff per unit area (L/s/km^2) so the runoff could be compared to that of other streams in the area including the gauged regional streams.

Although insufficient information exists at the moment to make definitive statements, all of the streams had similar runoffs during the July trip. Direct comparison of per unit area runoff information collected during the September trip is complicated by the knowledge that precipitation falling during the measurement period resulted in different hydrologic conditions in different watersheds.



SPOT DISCHARGE LOCATIONS ALONG PROPOSED ROAD CORRIDORS

Figure no. 4.1.2-1

PLACER DOME BERG PROJECT

Date Dec. 1989

Drawn by NORECOL

These streams are all expected to have similar hydrologic characteristics to those of Berg Creek (see Appendix 3.3.2-2, Table 2 for estimated mean monthly runoff). Mean monthly flow estimates (m^3/s) for these streams can be estimated by multiplying the appropriate drainage area (km^2) by the appropriate runoff per unit area ($L/s/km^2$) estimate for Berg Creek.

4.1.2.3 Flood analyses

As discussed in Section 4.1.2.2 these streams are all expected to have similar hydrologic characteristics including flood flow characteristics to those of Berg Creek. Therefore the flood flows can be estimated using runoff per unit area estimates given in Appendix 3.3.2-1, Table 2.

4.1.2.4 Water quality

Ney Creek is the only drainage in the eastern access corridor for which data are available.

Ney Creek is characterized (Appendix 3.2.3-1) by soft water (14 to 22 mg $CaCO_3$/L), low alkalinity (10 to 19 mg $CaCO_3$/L) and neutral to slightly acidic pH (6.5 to 7.0). Turbidity, suspended solids and total solids varied seasonally and were highest in September (340 NTU, 1229 mg/L and 1270 mg/L, respectively). Specific conductance was low and ranged from 26 to 43 umhos/cm, again highest in September. Sulphate concentrations were low, ranging from 1 to 9 mg/L. Total cyanide levels were below detection limit (0.001 mg/L). Nutrient concentrations varied seasonally being highest in September. Nitrogen concentrations (NH_3, NO_2 and NO_3) were low while total phosphorus ranged from 0.012 to 2.81 mg/L. However, it is likely very little of the phosphorus is available to the aquatic plants.

Total metals were highest in September with the high suspended solids. Provincial criteria (Pommen 1989) were exceeded on September 28, 1988 for aluminum, cadmium, chromium, copper, iron, lead, manganese, nickel and zinc. On other occasions criteria for aluminum, copper and iron were exceeded in Ney Creek.

4.1.2.5 Fisheries

Road Option 1 (Eastern Access) crosses several high gradient, cold, turbid tributary streams of the Mystery River (lower Ney Creek) and Desacroix Creek which drain the glacierized peaks of the Sibola Range. These streams appear to have low productivity and low fish habitat capabilities. Fisheries resources of the lower Mystery River are discussed in Section 4.2.2.5, Road Option 2, Northern Access. Desacroix Creek is part of the Nechako River drainage which flows into the Fraser River near Prince George. The fisheries resources in Desacroix Creek and Nadina Lake are described briefly below, since existing fisheries information is limited.

Desacroix Creek

The Ministry of Environment (1974) surveyed Desacroix Creek as part of their lake survey of Nadina Lake in September 1974. The stream is cold and turbid due to its glacial origin, but lower gradient areas in the lower 1 to 2 km have some spawning and rearing potential. Angling was unsuccessful and there was no evidence of rainbow trout in the system. Several kokanee (Oncorhynchus nerka) spawners (2 live and 3 dead) were observed in the lower Desacroix Creek. The owner of the Nadina Lake Lodge, who has resided in the area for the last 30 years, indicated that Desacroix Creek is a known kokanee spawning stream, but is not utilized by rainbow trout due to cold water temperatures (Gordeau pers. comm.). Norecol minnow trapping in the lower reach (site F2, Figure 3.3.4-1) yielded moderate numbers of juvenile Dolly Varden char with fork lengths ranging 4.8 cm to 14.5 cm. The presence of young-of-the-year Dolly Varden char indicates the lower reach is utilized by this species for spawning.

Nadina Lake

Nadina Lake supports a sport fishery for rainbow trout and kokanee, and trout up to 4.5 kg have been caught (Gordeau, pers. comm.). Gill netting by the Ministry of Environment (1974) during their lake survey collected a total of 180 fish. The catch was comprised of 37% longnose sucker, 34% rainbow trout, 20% mountain whitefish (Prosopium williamsoni) and 9% kokanee. A falls at the outflow of Nadina Lake is a fish migration barrier, and the Nadina River sockeye spawning channel is located a short distance below the falls.

4.1.3 Terrestrial resources

4.1.3.1 Vegetation

Vegetation information for the eastern corridor was derived from 1:50 000 forest cover maps and is general in nature. Much of the eastern access corridor has been, or is slated for logging.

The eastern corridor from Twinkle Lake is predominantly lodgepole pine forest with some mixed stands of subalpine fir and pine. Alluvial areas near Ney and other creeks are predominantly a fir-spruce mixture.

The north-facing slopes above Ney Creek are lodgepole pine forest covered at lower elevations giving way to mixed stands of pine and fir above 1000 m. Whitebark pine is occasionally found in these mixed stands.

The lodgepole pine-fir forest is described in Section 3.4.1. The Envirocon (1981) baseline environmental report for the Alcan Kemano Completion Project contains a description of alluvial fir-spruce forests on the flats between Nanika and Kidprice lakes which probably adequately describes all such forests in the general area.

The most common tree species in the fir-spruce forest type is white spruce (Picea glauca) with englemann spruce (P. engelmannii) occurring occasionally. Subalpine fir (Abies lasiocarpa) co-occurs with spruce in this forest and on drier sites is the dominant cover species. Trees reach to over 35 m and stands are typically densely stocked.

The understorey vegetation is typical of moist interior soils. Horsetails (Equisetum arvense) are abundant, together with alder (Alnus incana), twinberry (Lonicera involucrata), devil's club (Opopanax horridus), willow (Salix spp.), current (Ribes spp.), squashberry (Viburnum edule), twisted stalk (Streptopus amplexifolius), giant ragwort (Senecio triangularis), oak fern (Gynmocarpium dryopteris) and black-berry elder (Sambucus racemosa).

Wetland areas in the corridor are also likely similar to those described by Envirocon (1981). They are a bog-fen complex. Bogs are areas of impeded drainage composed of predominantly sphagnum moss (Sphagnum spp.). Fens contain a greater nutrient input from flow-through streams and grasses and sedges predominate.

Sphagnum, grasses, sedges, horsetails as well as patches of willows and alder commonly occur in these bog-fen complexes. Other plants include blue swamp violet (Viola palustrus), star flower (Trientalis europaea), avens (Geum sp.), and bedstraw (Galium sp.).

4.1.3.2 Wildlife

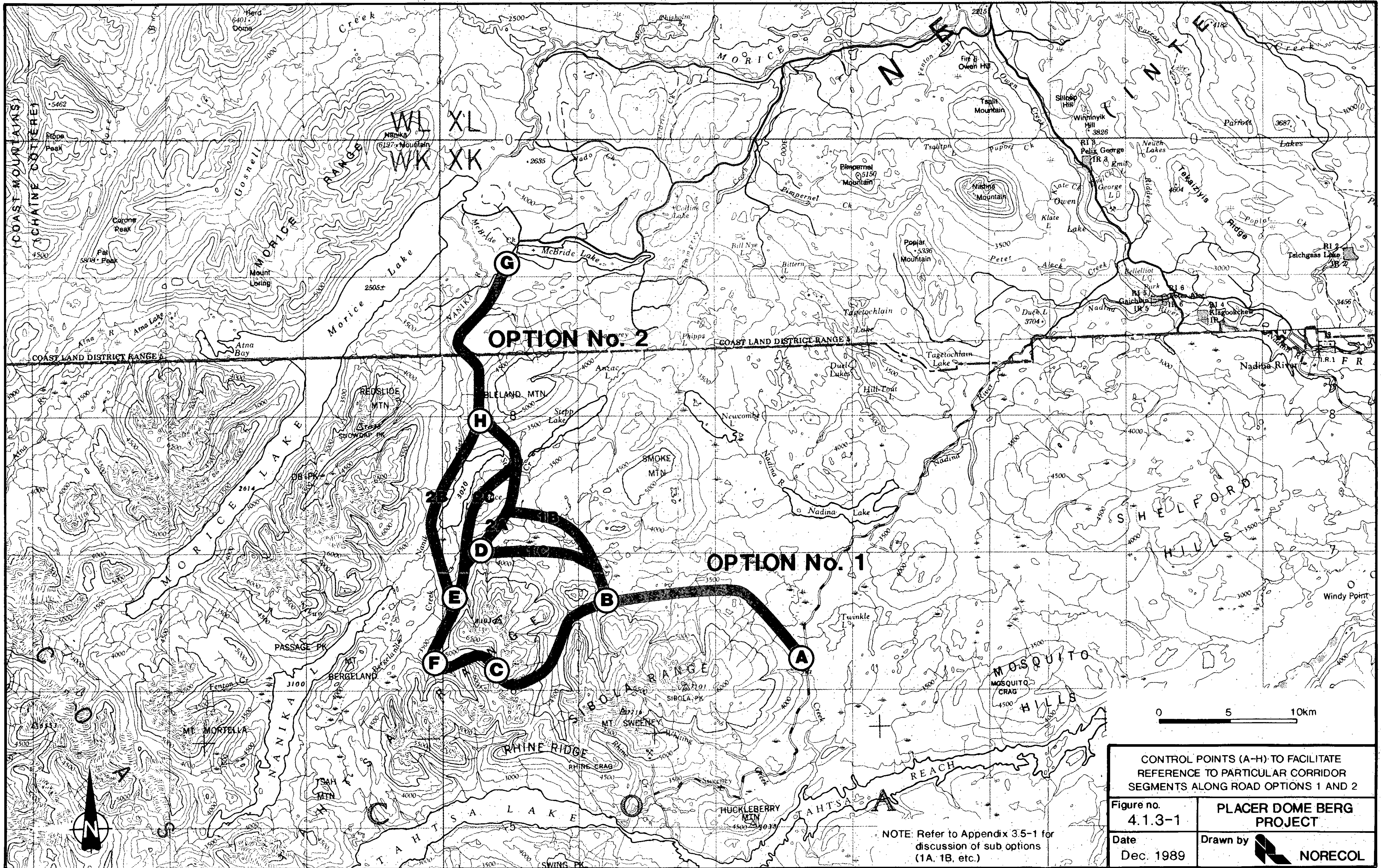
Appendices 3.4.2-1 and 3.4.2-2 describe recent field study activities and methods, and identify previous wildlife surveys in the general study area. Survey blocks 6, 7, and 8 (Appendix 3.4.2-1C), encompassing the Tahtsa and Sibola Ranges and the ESSF lowlands to the North (Nad Creek drainage) have received relatively little survey coverage in the past, since they were outside the Kemano II interest area. All of the wildlife species identified for the deposit site area (Section 3.4.2) are also potentially present along or in uplands adjacent to the Road Option 1 corridor, although not necessarily at the same levels of abundance and/or local significance.

In the context of road development and operation, the local species that can most clearly be identified as of potential concern in relation to a local road proposal are three ungulates species (moose, caribou, and mountain goat) and one carnivore (grizzly bear). Among other big game species of the region, two (black bear and wolf) are seasonally common to abundant in the general area and individuals of one other ungulate species (mule deer, Odocoileus hemionus) probably occur occasionally. However, the proposed road is not believed to have serious management implications for those three species, for furbearers, or for species designated as small game (see Section 6.3.3), and no further discussion of their occurrence is warranted here. The following statements for the four big game species of concern are based on data and interpretations given in Appendices 3.4.2-3 to 3.4.2-7, and on subjective comparisons of habitats during the July 1989 surveys. To facilitate reference to specific locations along the proposed corridors, Figure 4.1.3-1 identifies a series of check points at option intersections. Emphasis in following paragraphs is on corridor segments A-B, B-C, and B-D, since the remaining segments in Road Option 1 (D-E, E-F, and E-C) are also common to and, in terms of habitat, more continuous with Road Option 2.

Wildlife discussions in this section and Section 4.2.3.2 make reference to route nodes (points where options join). The heritage appendix (Appendix 3.5-1) makes reference to the corridor option, labeled A, B, C. Both reference methods are shown on figures.

Ungulates (General)

In many regions, winter range may be a primary limiting factor for wild ungulate populations, and that is particularly true in the mountains of British Columbia (Edwards 1956, Demarchi et al. 1983). Animals may move



CONTROL POINTS (A-H) TO FACILITATE REFERENCE TO PARTICULAR CORRIDOR SEGMENTS ALONG ROAD OPTIONS 1 AND 2

Figure no.	PLACER DOME BERG PROJECT
4.1.3-1	
Date: Dec. 1989	Drawn by NORECOL

long distances from summer and fall ranges to suitable wintering areas, and may concentrate at high densities on some winter ranges (e.g., see Eastman 1977, Van Ballenberghe 1977, Schwab 1985). The vulnerability of a local population to road access effects is probably greater if the road encroaches on an area of concentrated use than if it merely passes through habitat (e.g., summer range) in which the animals are more dispersed. Thus, a primary objective of the March 1989 survey was to document the extent of ungulate winter use in the general study area.

Moose

The nature and extent of migration to and concentration on winter ranges by moose may vary locally from year to year, primarily in relation to climatic factors. In most areas, snow depth is probably the primary factor mediating moose seasonal movements and selection of winter habitats. In a review, Eastman (1977) identified three classes of snow depth in relation to moose mobility: shallow (0-40 cm, in which moose experience little or no hindrance to movement), medium (41-80 cm--moderate impediment to movement, and deep (greater than 81 cm--movement difficult).

During the March 1989 survey, snow depth was measured at an undisturbed, wind-protected location near the lower end of Road Option 1, a few km east of its eastern commencement point on the Nadina River Road. The mean of three measurements at that location was 135 cm, thus the reason for a complete absence of moose and sign along and adjacent to that entire route at the time seems evident. Further, the 1989 result is consistent with previous winter survey results in the area (Appendix

3.3.2-4), and with early habitat capability mapping, which identified no moose winter range in the area (CLI 1972).

Thus, it would appear that the primary local concerns for this species relate to migration patterns and corridors (especially in fall, during the hunting season), and for areas of concentrated calving. A lack of observations in those seasons makes it impossible to address those concerns with certainty, but it seems likely that corridor segment A-B (Figure 4.1.3-1), along well-drained, relatively sparsely vegetated terrain, is less important to moose than are the more lush areas at the same elevation farther west (B-E-D-F) or adjacent lower areas along Nad Creek. Segment B-C, along upper Ney Creek, is used by moose, but the valley is too narrow and confined to support significant numbers.

Mountain Goat

The nature and extent of seasonal movements by mountain goats is not known in most areas, but locations used for wintering and parturition, especially, appear to be strongly traditional (Chadwick 1983). Evidence in hand indicates that goats occur only sporadically, in any season, in uplands adjacent to corridor segment A-B, but may regularly use the north face of the Tahtsa Range (above B-D) and both sides of the upper Ney Creek Valley (B-C) during snowfree and low snow periods. Neither of the two corridor segments north of the mountains (A-B and B-D) encroach directly on regularly used mountain goat habitat or movement routes, but it is likely that goats would often be found on or near the Upper Ney Creek segment (B-C), particularly along the headwaters of the tributary west from the deposit site area. That is particularly true given the apparent local importance of Berg Ridge (see Section 3.4.2.1) as winter range.

Caribou

As described elsewhere in this document (Section 3.4.2.1, Appendix 3.4.2-7), there is no recent evidence that caribou still occur in the area. Past observations were primarily in Alpine Tundra uplands adjacent to corridor segment A-B, and based on experience elsewhere (Hatler, unpubl.), some winter use of subalpine (ESSF) forests along the north face of the Sibola Range in that area, possibly down to the proposed road level, may also have occurred, while occurrence along and adjacent to segments B-C and B-D would likely have been primarily in the spring through fall period. No caribou sign was present in any of those areas in March 1989, or earlier in the winter judging from reports by the pilot, and no sign was seen during aerial and ground observations in July 1989. However, caribou may use some ranges only in some years (Hatler 1986), and it may be premature not to consider them for the general study area.

Grizzly Bear

Although it would not be unusual to find a grizzly bear anywhere in the present study area, there are no habitats along corridor segments A-B or B-D that would clearly serve as an attraction to the animals. Although no sign was documented in the area, the section of proposed Road Option 1 most likely to support regular bear use is that along upper Ney Creek, where spring foods such as Equisetum and various forbs are abundant, and there is some potential for fall foraging on berries. In addition, marmots are common in surrounding uplands.

4.1.4 Resource use

4.1.4.1 Land status

The eastern access corridor is entirely on Crown land. No mineral claims currently cover any of the eastern corridor. Commercial timber harvest is underway in the eastern part of the corridor and a road is currently being built toward Neucomb Lake from the Nadina River road near Twinkle Lake.

4.1.4.2 Forestry

Forestry in the area is covered briefly in section 3.5.2 of this report and in more detail in the Berg Overview Report (Norecol 1988). Timber harvest is slowly moving in a westward direction along the eastern access corridor. Most logging activity is north of the access corridor. The Sibola Range lies to the south and timber is of lesser quality in this direction.

4.1.4.3 Recreation

Recreation is limited along the eastern access corridor. Established hiking and canoe trails are to the north. Some hunting may occur on logging roads in the fall.

4.1.4.4 Hunting, guiding and trapping

These activities were introduced in section 3.5.4. The eastern access corridor begins in guiding territory 604G007 held by Mr. Joseph R. Gordeau, the owner of the Nadina Lake Lodge, and runs westward into territory 604G006, previously mentioned (Figure 3.5-1).

A registered trap line (0609T018) crosses the access corridor very near the Nadina Lake road. As the mine access road would likely follow the old tote road in this area, no new conflict with trapping would be expected.

4.1.4.5 Heritage

With one exception, all of the proposed eastern access corridor is located in terrain assigned a low potential for archaeological sites. The exception is the pass to the Berg property through upper Berg Creek which could have been a good location to ambush game. No evidence of a game trail was observed in the area, but as an autumn hunting camp could be located below the pass, it should retain its medium potential.

4.2 Road Option 2 - Northern Access

4.2.1 Physical overview

The northern corridor for the purposes of this report starts at Morice Lake and ends at the Berg deposit, traversing a distance of approximately 38 km to connect the existing end of road to the proposed mine and mill site. Existing logging roads are currently as far south as Tableland Mountain, or 15 km south of the Morice Lake forest road. From Tableland Mountain the corridor splits in two, one option following the west side of Kidprice Lake and the other the east. The options join once again at Bergeland Creek and from there to the proposed mine and mill site co-incide with one of the eastern corridor options. The northern corridor follows river and stream valleys and is in lowland forest throughout its length, except the last leg into the deposit site.

This section deals with the biophysical aspects of the road corridor. Section 2 discuss geotechnical aspects and 6 discusses potential environmental impacts.

4.2.2 Surface water resources

4.2.2.1 Watershed characteristics

The Northern corridor involves crossing two major creeks; the lower reaches of Ney Creek (Mystery River), and Stepp Creek. The hydrologic characteristics of Lower Ney Creek at the proposed crossing location are similar to those of Bergeland Creek; it is approximately 4 percent glacierized, and drains a predominately low gradient broad valley watershed. Stepp Creek watershed is situated north of the Hazelton Mountains. The proposed crossing location is located downstream of Anzac and Stepp lakes which appear to buffer the flows in the creek very well, as storage of water in the lakes serves to significantly reduce the flood flows and increase the low flows.

4.2.2.2 Streamflow along the road corridor

Based on spot discharge measurements conducted in July and September 1989 (Figure 4.1.2-1 and Appendix 4.1.2-1, Table 1) Lower Ney Creek is expected to have similar mean monthly runoff values to those of Bergeland Creek, (Appendix 3.3.2-2, Table 2). Mean monthly flows in Stepp Creek are expected to be significantly more buffered than those of Lower Ney Creek but were not estimated for this report.

4.2.2.3 Flood analyses

Flood flows in Lower Ney Creek (on a per unit area basis) are expected to be similar to those of Bergeland Creek (Appendix 3.3.3-1, Table 2).

4.2.2.4 Water quality

No water quality data were collected by Norecol in water bodies on the northern access route. The major drainage that would be affected is the Nanika-Kidprice system. The available data were presented in the previous report (Norecol 1988) and are summarized briefly in this report. Nanika Lake is larger and deeper than Kidprice Lake and exhibits a thermocline. No thermocline was apparent on Kidprice Lake. Summer surface water temperatures in both lakes averaged about 12 to 15°C) when measured in 1974 (Ministry of Environment 1979).

Dissolved oxygen in both lakes was quite high at all depths measured and ranged from 10 to 12 mg/L in Nanika and 7.5 to 11 mg/L in Kidprice Lake in the summer of 1974. The turbidities in Nanika and Kidprice lakes were comparable. Suspended solids were low, averaging less than 1 mg/L. Both lakes are classified as oligotrophic, that is low in nutrient content and biological productivity.

Nutrient (nitrogen and phosphorus) levels varied seasonally but were generally quite low. Waters in both lakes are very soft with hardness measurements ranging from 15 to 19 mg/L and conductivity measurements ranging from 27 to 39 umhos/cm (Envirocon 1984). Concentrations of cations (sodium, magnesium, manganese and calcium) and anions (chloride and sulphate) in Nanika and Kidprice lakes also are low.

Previous data available for metals' concentrations are of limited value due to the high detection limits employed (0.01 to 0.02 mg/L).

4.2.2.5 Fisheries

Road Option 2 (Northern Access) has common nodes at the north and south ends of the routes which traverse streams with low fisheries values. The main fisheries sensitivities occur along the nodes which lie on the east and west side of Kidprice Lake (Figure 3.3.4-1). The west node would cross the upper Nanika River, between Bergeland Creek and Kidprice Lake, and the lower Nanika River a short distance downstream of Nanika Falls. The east node would cross the Mystery River (lower Ney Creek) approximately 6 km upstream of Kidprice Lake, and Stepp Creek between Kidprice and Stepp lakes.

The fisheries resources in the upper Nanika River are discussed in Section 3.3.4 (deposit site baseline information). Therefore, the fisheries resources related to Road Option 2 presented below include the lower Nanika River, the Mystery River and Stepp Creek.

Lower Nanika River

The lower Nanika River flows in a northerly direction for approximately 24 km from Nanika Falls, at the outflow of Kidprice Lake, to the north end of Morice Lake. This area has high fisheries values and is utilized by spawning runs of sockeye salmon (Oncorhynchus nerka), coho salmon (O. kisutch), chinook salmon (O. tshawytscha) and steelhead trout (_O._ _mykiss_) which migrate upstream as far as Nanika Falls. Resident species include rainbow trout, cutthroat trout (_O._ _clarki_), Dolly Varden char, mountain whitefish and longnose dace (_Rhinichthys cataractae_). Salmon escapement data and timing of spawning for salmon species in the lower Nanika River appear in Table 4.2.2-1. Approximately 1% of the total salmon escapement to the Skeena River spawn in the lower Nanika River.

Sockeye salmon are the major salmon species in the lower Nanika River, but escapement has declined from 24 000 to 70 000 prior to 1955 to an average of about 1900 since 1970. Shepherd (1979) attributed this to the combined effects of obstructions and the native food fisheries at Hagwilget and Moricetown canyons. In spite of efforts to rebuild the stock (obstruction removal, elimination of food fishery, hatchery), numbers remain low. This may be due to the fact that since more food is available in Morice Lake as a result of fewer fry, smoltification occurs in the second year, rather than the third year as was previously the case, and smolts barely reach the threshold size causing higher mortality (Shepherd 1979). The majority of sockeye salmon in the Morice River system utilize the Nanika River (Fisheries and Marine Service 1979). Peak spawning occurs during late September and fry emerge between May and late July. Sockeye salmon juveniles migrate into Morice Lake after emergence and remain in the lake for one to two years before migrating to sea as smolts in mid May (Envirocon 1984).

TABLE 4.2.2-1

SALMON ESCAPEMENT DATA AND TIMING OF SPAWNING FOR THE LOWER NANIKA RIVER

YEAR	SOCKEYE	CHINOOK	COHO	PINK
1970	4700	N/R	300	
71	3300	25	300	
72	1800	400	200	
73	1000	N/R	N/R	
74	1200	N/R	N/R	
75	225	50		
76	100	120	N/R	
77	600	25	N/R	
78	500	50		
79	700	75		
80	400	75	N/R	
81	1000	40	500	
82	3000	150	N/R	
83	4000	100		
84	3000	100	100	
85	2000	100		
86	3000	100	N/I	100
87	4000	200		
88	1000	50		
MEAN	1870	104	280	100
TIMING				
Start	early September	early August	mid September	mid August
Peak	late September	mid September	mid October	mid September
End	late October	late October	late November	late September

N/R - no record
N/I - not inspected

Source: L. Jantz, Fisheries and Oceans, Prince Rupert

Coho salmon are the second most abundant salmon species in the lower Nanika River. Mean spawner escapement is estimated at 280, but this may be an underestimate since enumeration is difficult for this species due to the late timing of spawning, limited visibility and their widespread distribution. Peak spawning probably occurs between mid October and late November, but spawning can extend into January. Juvenile coho salmon usually spend one or two years in the lower Nanika River rearing near mainstem log jams during spring and side channels during the summer (Fisheries and Marine Service 1979). Envirocon (1984) found that coho juveniles were abundant in the Nanika River (36 to 57% of samples during 1979 and 1982) and suggest that this river is a major coho salmon producer in the Morice River system, probably second only to Gosnell Creek.

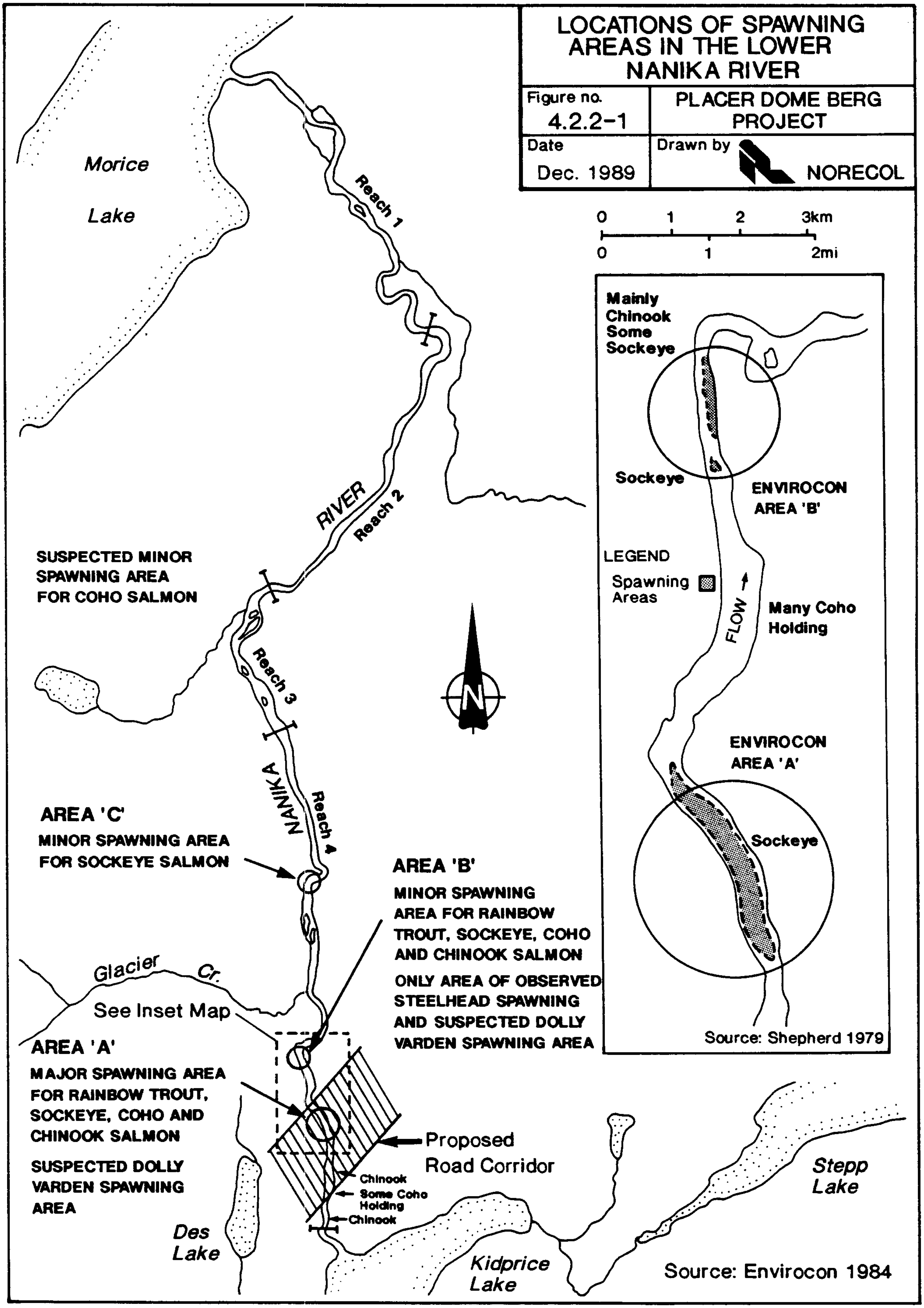
The Nanika River is the only tributary of the Morice River known to support a run of chinook salmon. Escapement has averaged around 100 fish since 1970, but Envirocon (1984) suggest the annual escapement average is probably closer to 275. Peak spawning occurs between early August and late October and fry emerge in the spring. Approximately two-thirds of juveniles spend one year in freshwater, with the remainder spending less that one year (Fisheries and Marine Service 1979). Most juveniles that reside for one year move out of the Morice River system in the spring to rear during the summer and winter in the Bulkley and Skeena rivers. This would account for the relatively low numbers (8 to 10% of samples during 1979 and 1982) found in the lower Nanika River by Envirocon (1984).

Small numbers of summer steelhead trout occur in the lower Nanika River and spawning occurs from late May to early June. Resident rainbow trout are abundant in the river. Envirocon (1984) juvenile sampling comprised 24 to 41% rainbow trout and they suggest the area may be a significant spawning area for trout from Morice Lake. Spawning for resident rainbow trout occurs in May and June, and fry of both resident and anadromous species probably emerge in August.

Major spawning areas and reach boundaries in relation to the proposed access road crossing of the lower Nanika River are shown on Figure 4.2.2-1. Virtually all spawning for salmon, trout and char species occurs upstream of Glacier Creek, and the main area (Area A) is located about 1.5 km downstream of Nanika Falls, within the proposed access road corridor. Envirocon (1984) found that coho and chinook salmon fry densities were highest in Reach 1 and rainbow trout fry and parr densities were highest in Reach 4. Reach 2 tended to have low juvenile salmonid densities and had few spawning areas due to its steeper gradient and large substrate.

Mystery River (Lower Ney Creek)

The upper watershed of the Mystery River, named Ney Creek, is a high gradient, turbid stream draining the glacierized peaks of the Sibola Mountains. It is unlikely that fish populations occur in the vicinity of the proposed road crossing in the upper reaches (near the proposed deposit site). The stream enters a deep canyon with several deep pools about 4 km from Kidprice Lake. Norecol minnow trapping above the canyon (site F1, Figure


LOCATIONS OF SPAWNING AREAS IN THE LOWER NANIKA RIVER
Figure no. 4.2.2-1
PLACER DOME BERG PROJECT
Date Dec. 1989
Drawn by NORECOL
0 1 2 3km
0 1 2mi
Morice Lake
Reach 1
Reach 2
RIVER
SUSPECTED MINOR SPAWNING AREA FOR COHO SALMON
Reach 3
NANIKA
Reach 4
N
AREA 'C'
MINOR SPAWNING AREA FOR SOCKEYE SALMON
AREA 'B'
MINOR SPAWNING AREA FOR RAINBOW TROUT, SOCKEYE, COHO AND CHINOOK SALMON
ONLY AREA OF OBSERVED STEELHEAD SPAWNING AND SUSPECTED DOLLY VARDEN SPAWNING AREA
Glacier Cr.
See Inset Map
AREA 'A'
MAJOR SPAWNING AREA FOR RAINBOW TROUT, SOCKEYE, COHO AND CHINOOK SALMON
SUSPECTED DOLLY VARDEN SPAWNING AREA
Proposed Road Corridor
Chinook
Some Coho Holding
Chinook
Des Lake
Kidprice Lake
Stepp Lake
Source: Envirocon 1984
Mainly Chinook Some Sockeye
Sockeye
ENVIROCON AREA 'B'
LEGEND
Spawning Areas
FLOW
Many Coho Holding
ENVIROCON AREA 'A'
Sockeye
Source: Shepherd 1979

3.3.4-1), in the vicinity of the proposed access road crossing, yielded moderate densities of resident Dolly Varden char with fork lengths ranging from 7.6 cm to 15.2 cm. Downstream of the canyon, the lower 1 km of the stream flows through a lowland area where it has well developed pool-riffle sequences and has several channels. While the lowland area appears to have spawning and rearing opportunities, low water temperatures and high turbidity probably limit productivity (Ministry of Environment 1979).

Stepp Creek

Stepp Creek extends 2.5 km between Stepp Lake and Kidprice Lake. The lower half of the stream generally has large substrate with limited spawning potential, although there is an extensive gravel shoal at the mouth extending about 50 m into Kidprice Lake which has spawning potential. The upper half of the stream lies in a meadow which has areas of gravel suitable for spawning and excellent rearing habitat provided by numerous side channels, large pools and abundant streamside vegetation (Morley and Whately 1974). Envirocon (1984) observed three rainbow trout spawners in this area, but electofishing of 934 m^2 of stream yielded no fish. Norecol also captured an adult rainbow trout in the stream near the proposed road crossing (site F3, Figure 3.3.4-1). The middle section of the stream, in particular, has gravel suitable for Dolly Varden char and rainbow trout spawning, and the Ministry of Environment (1979) observed about 300 fry in this area. Stepp Creek is a clear stream and has warmer water temperatures than glacierized streams in the area due to the moderating influence of Stepp Lake. Consequently, this stream is probably second in importance to the

Nanika River for salmonid production in the Nanika Kidprice lakes area.

4.2.3 Terrestrial resources

4.2.3.1 Vegetation

The northern access corridor has logging cut blocks removed from Morice Lake south to Tableland Mountain where the road currently ends. Forest cover in the access corridor is lodgepole pine forest. Subalpine fir is mixed with pine except on drier sites where pure pine stands occur.

West of Tableland Mountain cover is mixed fir and whitebark pine with fir-spruce stands occurring on alluvial sites. This same mixed forest continues to Kidprice Lake with some intermixing of fir-lodgepole pine stands.

West of Kidprice Lake cover is predominantly subalpine fir. Dry sites may contain whitebark pine especially where alpine areas are adjacent to the corridor. Alternately a mixed forest of fir and lodgepole pine occurs. Alluvial sites along this part of the corridor are predominantly spruce or a fir-spruce mixture.

East of Kidprice Lake forest cover is dominated by a fir-lodgepole pine mixture.

Forest types have been previously described in Sections 3.4.1 and 4.1.3.

Wetlands are likely similar to those previously described for the eastern access route.

4.2.3.2 Wildlife

Appendices 3.4.2-1 and 3.4.2-2 describe recent field study activities and methods, and identify previous wildlife surveys in the general study area. Because much of the Nanika-Kidprice area traversed by Road Option 2 (Survey Blocks 1-5 in Appendix 3.4.2-1C) has been under serious consideration for the Kemano Completion hydro project, it received relatively regular and intensive wildlife survey coverage in the 1970's. As was the case for the Road Option 1 area, all of the wildlife species identified and discussed in the deposit site section (3.4.2) are also potentially present along one or more sections of the Option 2 corridor(s), and some in significant numbers. However, moose, mountain goat, caribou, and grizzly bear are again the species of primary interest in the context of the proposed road developments. The following interpretations of those four species' occurrence in relation to Road Option 2 are based on survey data in Appendices 3.4.2-3 to 3.4.2-7, and on subjective habitat comparisons during the July 1989 surveys. Labelled intersection points in Figure 4.1.3-1 again serve to facilitate reference to particular corridor segments in following species statements.

Moose

As was the case for the eastern route (Option 1), there is no significant winter moose occurrence in the Road Option 2 area. The mean of three snow measurements in a lowland meadow beside the Nanika River, near the northern commencement point of the proposed road, was 108 cm. Although less than on the lower end of the eastern route, that is still deep enough to greatly impede moose movements. Further, the snow cover farther up the river and in the upper Nanika Lowlands (Survey Blocks 4 and 5) were probably deeper still. During the early Kemano II studies (Sutherland 1979) it was concluded that those lowlands constituted a locally significant calving and summer use area, and that the primary movement routes to and from the main wintering areas along the Morice River were both along the Nanika system below Kidprice Lake, and from Kidprice Lake northwestward along Stepp and Anzac Lakes and Lamprey Creek (see also, Appendix 3.4.2-4). The comparative importance of those two routes is not clear, nor is it a certainty that some of the seasonal migration from the Nanika is not via the lowlands along lower Ney Creek and out Nad Creek to the Nadina River system.

On a corridor segment by segment basis, the area along the lower Nanika (G-H) is important to at least part of the local population as a seasonal migration route, and some use for calving and summer through early winter foraging. The upper Nanika segment (H-E) is probably also in the local migration corridor, and it crosses what may constitute one of the most important calving concentration areas in M.U. 6-09. Segment H-D also crosses an area used for calving and migration (extent unknown) and for general summer subsistence. Segments D-E, E-F, and the lower portions of F-C are farther upslope, and are in summer use areas where concentrations of animals would be unlikely, while the upper portion of F-C reaches into habitats that would be only rarely used by moose.

Mountain Goat

The March 1989 survey located wintering goats on the northwest end of Tableland Mountain (overlooking corridor segment G-H), on the south side of the low ridge east of Kidprice Lake (near the southern end of segment H-D), and just south of the proposed road terminus in the deposit site area at Berg Creek (F-C). The July survey and/or past observations (Appendices 3.4.2-3, 3.4.2-5 to 3.4.2-7) indicate that the above areas may be occupied by goats throughout the year, and that all of the other corridor segments except that along the upper Nanika (H-E) are adjacent to slopes used at least occasionally by this species.

In terms of direct encroachment on regularly used goat habitat, the upper portion of segment F-C up Berg Creek is a certain candidate, as discussed previously in relation to proposed deposit site developments (Section 3.4.2.1). In addition to movements back and forth across the upper valley, occasional movement downslope along Berg Creek or nearby slopes (along F-C or across D-E) may also occur as there are records of goat tracks along the floodplain of Bergeland Creek in that general area (Appendices 3.4.2-6 and 3.4.2-7). There is also a possibility of a lowland movement off the west side of Tableland Mountain to or across corridor segment G-H, judging from heavy trails into timber from the ridge in that area. The low rocky ridge ("Kidprice Mountain") along the east side of Kidprice Lake was believed to have been used by goats mainly in winter, with most individuals migrating north to Tableland Mountain, east to Smoke Mountain, and/or south to the Tahtsa Range for summer, i.e., across road corridor segments H-D or D-E. Intensive observations in July 1989 failed to locate significant trails leading to or from any of those areas, and brief observation of a nursery group in thick cover on the west side indicate that the goat population on Kidprice Mountain is probably resident there.

Caribou

Anecdotal evidence suggests that caribou may have been seen on Tableland Mountain (corridor segment G-H area) as recently as the early 1970s, thus it is possible that the species formerly occurred throughout the study area. Indeed, early habitat capability mapping listed all of the area as either Class 3 (lowlands) or 4 (above 1075 m) for both moose and caribou. The most recent documented evidence, as presented in previous sections, indicates that the Sibola Range (along Road Option 1) was the last known area of concentrated use, and that even then occurrence was sparse in uplands and valleys immediately to the west. Thus, there appears to be little point in speculating on the potential occurrence of caribou along the Option 2 corridor until the current status of caribou in the general area is better defined.

Grizzly Bear

The lower Nanika River along corridor segment G-H supports spawning salmon, and is frequented by bears in the fall (Appendix 3.4.2-7, Sutherland 1979). Indeed, that is the only area within the proposed Berg development area, i.e., along either road option or the deposit site, where regular seasonal use can be predicted with certainty. The second most important area would be the upper Nanika segment (H-E), where lush vegetation, moose calves, small mammals, and berries would all serve as an attraction in the spring through early fall period.

Occurrence along or near segments H-D, D-E, and E-F would be strictly "occasional", i.e., similar to that described for the outer segments (A-B-D) of Road Option 1. Potential occurrence along segment F-C has already been discussed in relation to the deposit site developments (Section 3.4.2.2).

4.2.4 Resource use

4.2.4.1 Land status

The northern access corridor is on Crown land. One block of mineral claims at Tableland Mountain currently covers part of this access route. Commercial timber harvest is underway as far south as Tableland Mountain. Land below 938.8 m on the northern access corridor around Nanika and Kidprice lakes is within a flooding reserve for the Kemano completion project. Land below this elevation would be flooded if Alcan completes the Kemano power expansion proposed. Access is still possible above this elevation by moving the corridor east of the north end of Kidprice Lake. A significant crossing involving a large bridge would be required.

4.2.4.2 Forestry

Logging is currently occurring as far south as Tableland Mountain and will slowly move southward over the next two decades, when it will have reached Nanika Lake (Section 3.5.2).

4.2.4.3 Recreation

Recreation in the northern access corridor was discussed in detail in the Berg Overview Report (Norecol 1988).

Camping, fishing, hiking and canoeing are the main recreational activities in the area. Several camp sites are located at Morice and McBride lakes at the northern end of the northern access corridor. Campsites were established as a result of road access provided by logging. Camp sites may be established on Kidprice and Nanika lakes once logging roads reach them if the same pattern follows. At present camps on these lakes are limited to temporary sites established by canoeists and mineral exploration personnel.

A canoe - hiking trail exists through the Anzac-Stepp lakes area with portage trails between lakes. The trail end is the north end of Kidprice Lake. The northern access corridor would cross this canoe route and may cause some concern for recreational conflicts. However, before the mine is built, logging may have already reached the area of the canoe-hiking trail.

4.2.4.4 Hunting, guiding and trapping

These activities have been discussed previously under the deposit site and eastern access corridor.

4.2.4.5 Heritage

The northern access corridor approaches the Berg property from existing logging roads on the western side of Tableland Mountain. As it would not be necessary to upgrade this piece of road to accommodate mine traffic, no impacts are anticipated to nearby sites.

The northern corridor from Tableland Mountain along the north shore of Kidprice Lake to Stepp Creek has been assigned a high potential for archaeological sites. This rating was based upon the presence of a site at the outlet to Kidprice Lake, another on Stepp Creek, reports of an old trapping trail, and possible hunting camps on the south slopes of Tableland Mountain.

A ground survey at the mouth of Stepp Creek found no evidence of archaeological sites. No suitable site locations for camps or settlements were observed from the air, nor was the location of the pit feature reported by Aresco Ltd. (Envirocon 1981) found. Previous archaeological research has established that cache pits without associated cultural materials are part of the archaeological record of the area.

The portion of the northern corridor from Stepp Creek to Berg Creek has been assigned a low potential for archaeological sites, with the exception of the upper approaches of Berg Creek near the Berg Property which is shared with the eastern access corridor. It is possible that a Native Indian trail may have followed the Bergeland Creek valley to access game using the alpine portions of Mt. Ney, perhaps from an autumn hunting camp in the lower Berg Creek valley. Further work is required to investigate this area.

Alternate routes that may be selected in the northern corridor, such as down the west side of Kidprice Lake have also been assigned a medium to high potential due to the possibility of trails and presence of artifacts.

5.0

Potential Deposit Site Impacts and Mitigation Options

5.0 POTENTIAL DEPOSIT SITE IMPACTS AND MITIGATION OPTIONS

5.1 Potential Impacts of Aquatic Resources

5.1.1 Acid generation

5.1.1.1 Background

Exposure of sulphide-bearing rock during mining can result in the production of acidic waters due to the reaction of sulphides with oxygen and water. These waters may contain high concentrations of heavy metals as a result of breakdown of sulphides of the metals or contact of the acidic waters with other minerals. Experience at several mines in British Columbia and elsewhere shows that, if acidic water (acid mine drainage, AMD) is allowed to enter streams directly or through groundwater circulation, downstream water quality is degraded and aquatic resources (such as fisheries) may be adversely affected. This problem may be avoided by:

- o predicting the extent of the acid generation problem through laboratory and field testing; and

- o designing controls to prevent acidic waters from entering the receiving environment.

The Berg porphyry copper and molybdenum deposit shows several features which suggest that acid generation should be investigated. These features include:

- o Regionally-widespread, disseminated pyrite in the main host rocks of the deposit (Hazelton Volcanics) resulting from low grade sub-greenschist metamorphism.

- o Style of mineralization which typically involves low carbonate, sulphur-rich, reducing hydrothermal solutions and extensive fracturing.

- o Post-glacial weathering of the exposed deposit. This weathering has resulted in formation of a thick oxidised cap which lacks abundant sulphide minerals (pyrite, chalcopyrite, molybdenite) and contains hydrous iron oxides, locally jarosite $[K(Fe,Al)_3(SO_4)_2(OH)_6]$ and minor ferrimolybdite (oxidized molybdenum mineral). The oxidized cap is underlain by a copper-enriched supergene zone. These weathering features indicate that sulphides were oxidised and acid solutions produced, thereby mobilizing copper but not molybdenum. Under less oxidizing conditions in the supergene zone, copper-rich minerals such as covellite (Cu_2S), chalcocite (CuS) and native copper were precipitated. An essential component of this process is the ability to develop acidic solutions over several thousand years in order to mobilize metals near the surface.

- o Streams and springs in the area of the deposit are acidic and metal-rich. Seeps occurring at breaks in slope have resulted in extensive deposition of ferricrete. Stream sediments downstream of the Berg deposit have been reported to contain up to 47,000 ppm copper and 60 ppm molybdenum (Panteleyev 1981). These observations suggest that oxidation of sulphides occurs at depth, liberating iron and sulphur, and leading to dissolution of other metals.

In summary, acid generation in highly fractured rock occurs naturally at Berg resulting in an obvious surface expression of the deposit (thick weathered cap and transported iron precipitates). Qualitatively, generation of acid from newly exposed pyritic material in waste dumps and pit walls below the natural zone of oxidation and from shallow unoxidized material in the periphery is possible. However, the source of acidic waters is not known, nor is the rate of acid generation.

The approach taken in this investigation of acid generation is to predict through laboratory testing the likely extent of potentially acid generating materials (static predictive geochemical tests) and the short term rate of acid generation (kinetic predictive geochemical tests).

5.1.1.2 Static predictive geochemical tests (acid-base accounting)

The purpose of static predictive tests is to provide an indication, through theoretical considerations of the process of net acid generation, of the potential for acid generation in the various rock units encountered at the deposit. Ideally, the overall process consists of two components, namely, oxidation of sulphide (typically pyrite, FeS_2) to produce hydrogen ions, sulphate and hydrous iron (III) hydroxides, for example:

$$FeS_2 + 7/2H_2O + 15/4O_2 \rightarrow 2SO_4^{2-} + 4H^+ + Fe(OH)_3, \quad (5.1.1\text{-}1)$$

and acid neutralization through reaction of acidity with other minerals (typically calcium-bearing carbonates), for example:

$$CaCO_3 + 2H^+ \rightarrow Ca^{2+} + H_2CO_3^\circ. \quad (5.1.1\text{-}2)$$

Where neutralizing minerals are available and can neutralize acidity at the same rate that it is produced, drainage from the rock under oxidizing conditions should be neutral to moderately alkaline. However, should all the neutralizing minerals be dissolved and sulphide minerals continue to be available to generate acid the drainage will be acidic. Therefore, theoretically the concentration of sulphur and neutralizing minerals will indicate the potential for the rock to produce acidity in the long term. This assumption is the basis for the combination of analytical techniques and interpretation known as acid-base accounting (ABA).

Sampling Program

Sampling design for ABA testwork was based on the need for representative samples of each major rock type present in open pit designs for the deposit produced by Placer Development Ltd. (1973). Assumptions were made that the deposit will be developed at a similar scale as previously proposed and that geological mapping through drilling is essentially complete and will not change extensively with subsequent work. The combination of fresh rock types, hydrothermal alteration assemblages and oxidation types results in roughly 10 major units which could report to waste rock dumps or be present in the final pit walls, depending on the eventual cutoff grade.

The number of samples required to adequately represent the potential for acid generation depends on the level of confidence required in the prediction. As the number of samples increases the width of error bounds surrounding the mean value decreases. Furthermore, the natural variability in abundances of minerals in rock indicates that as the volume of rock increases the number of samples required to adequately represent the variability of acid generation potential increases. Considering the large volume of waste rock likely to be produced at the Berg deposit, up to 400 rock samples may eventually be required (B.C. Acid Mine Drainage Task Force, 1989) to fully represent the potential for acid generation. In this study, the sampling program was designed to represent recognisable geological features (such as rock type, alteration and depth of weathering). Ideally, at least three samples should be collected to represent each feature and more samples collected for larger geological units.

In reality, limited availability of fresh, accessible core at the project site dictated that sampling was based on fresh rock type only and that alteration type was a secondary criterion. In addition, the phases of the quartz monzonite body were treated as one unit for the purpose of sampling.

Two or three samples were collected from most of the 19 diamond drill holes which could be identified and footage intervals determined. Core which had obviously been weathered following drilling was not collected as it is likely that sulphide oxidation had occurred. The roofs of most of the core racks were intact however, exposure to weathering has occurred through the open sides. Oxidation of sulphides, as shown by rusty coating on core boxes and in places copper sulphate crystals, was most common in highly fractured core with poor recovery. Competent core was generally fresh, except for a 1 mm rind of sulphide oxidation on the surface. Pyrite in the interior of this core was not generally weathered. As a result of the need to select samples based on be most competent and not necessarily from uniformly spaced locations (Figure 5.1.1-1).

For each sample, material was composited from approximately two metres of core (mostly NQ size) and placed in a plastic bag. The samples were examined briefly for major minerals, proportion of sulphides, presence of oxidation products and physical characteristics such as competency and degree of fracturing.

Laboratory Methods

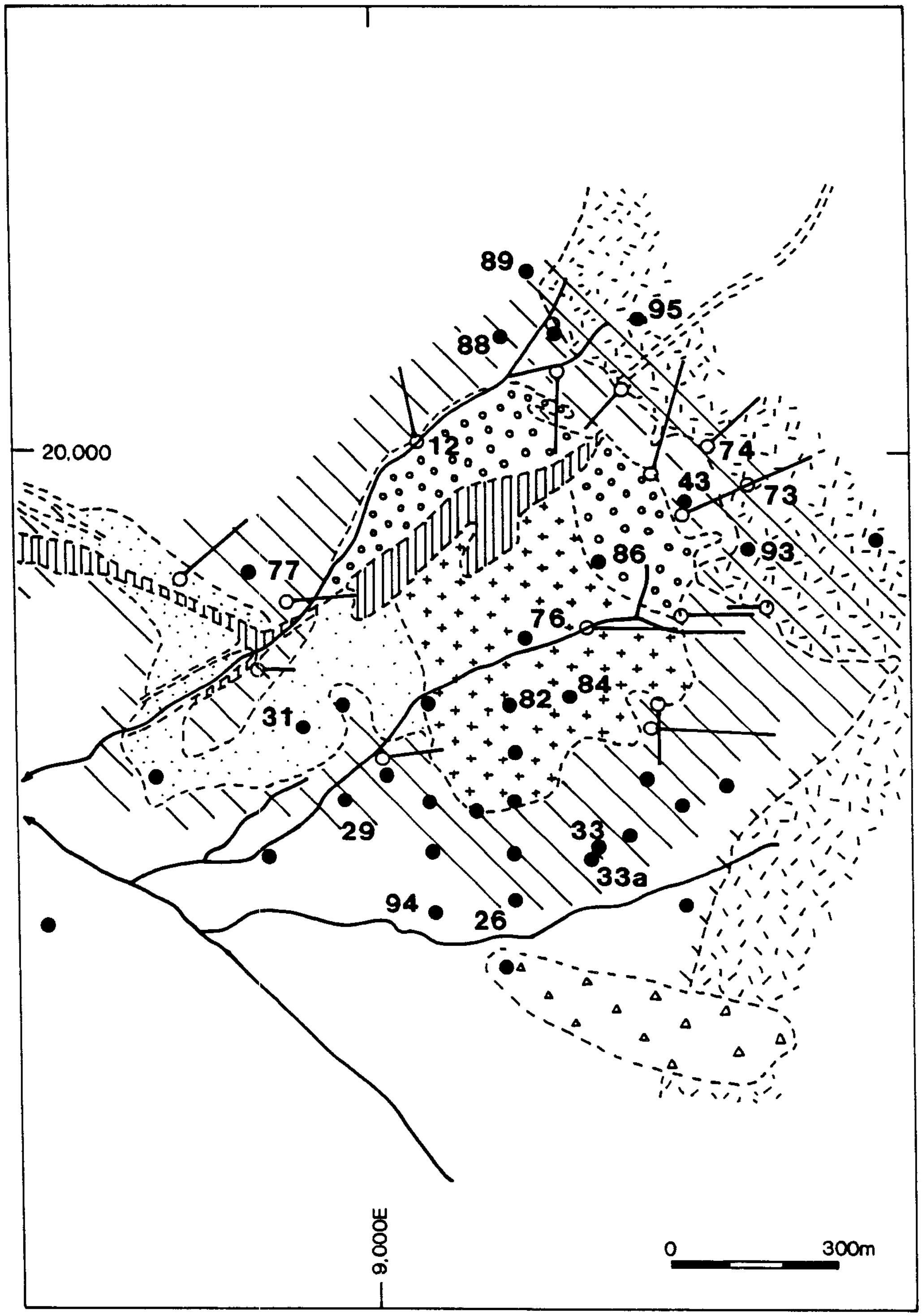
Forty samples were submitted to Chemex Labs of North Vancouver for determination of parameters necessary for acid-base accounting. Prior to analysis each sample was crushed to -170 mesh and sub-samples analyzed. The following conventional ABA parameters (Sobek et al. 1978) were determined for all samples:

Total sulphur: directly by Leco furnace.

Neutralization Potential: short term consumption of hydrochloric acid. Typically reflects presence of carbonates and some hydroxides.

Paste pH: direct measurement of pH of a thick mixture of the powdered sample and deionized water. Provides a measure of the pH of short term hydrolysis of major minerals.

In addition all samples were analyzed for sulphur species and carbonate:



breccia

PBQP — qtz monz - granodi or qtz bearing monzodi (hbde QFP)

ser QPP — qtz monzonite

QMP — qtz diorite

hornfels, volcanics

SAMPLES FROM:

Drill hole - vertical ●

Drill hole - inclined o—

LOCATION OF SAMPLED DRILL HOLES	
Figure no. 5.1.1-1	PLACER DOME BERG PROJECT
Date Dec. 1989	Drawn by NORECOL

Inorganic CO_2: CO_2 liberated by reaction of the sample with hot hydrochloric acid, measured using Leco furnace. Indicates concentration of CO_2 present in carbonates which react in the short term with HCl.

Sulphate: determined gravimetrically following dissolution of the sample with dilute hydrochloric acid. Indicates concentration of readily dissolved sulphates of calcium, iron, magnesium and copper.

Sulphide: determined gravimetrically following dissolution of sample with concentrated nitric acid and bromine. Dissolves all sulphides including pyrite, chalcopyrite and molybdenite. Concentration of sulphur as sulphate is subtracted.

Description of Sulphide, Sulphate, Hydroxide and Carbonate Mineralogy

The most abundant sulphide in the samples is pyrite. It occurs as very fine (<0.1 mm) disseminations throughout the rocks to coarser (>1 mm) cubic grains. In places, massive (several centimetres across) pyrite was observed in quartz veinlets, though this form is uncommon. Concentrations of pyrite vary from less than 0.5% to more than 15%. Less commonly chalcopyrite (finely disseminated) and molybdenite (finely disseminated and coarser platy masses in veinlets) was observed.

Gypsum was the only sulphate noted in abundance. The mineral occurs as large crystals and fracture fillings in the samples from deeper core. Iron sulphates occur, particularly in the oxidized cap, however they are mixed with iron hydroxides. Copper sulphate crystals were observed as a coating on some drill core.

Small amounts of calcite were identified in a few samples. Calcite amygdules are seen in the small basic dykes which were encountered in several drill holes. Here, the concentration of calcite was estimated to be between 10 and 20%. Slight to moderate reaction to cold 10% hydrochloric acid in several samples indicated that calcite is present, though probably in amounts not exceeding 5%. Calcite is typically present as infillings of very thin fractures, though a small amount is disseminated in the matrix.

Oxidation of sulphides was indicated in some samples by the presence of extensive limonite (mix of iron-bearing hydroxides and sulphates) coatings on fractures (oxidized cap rocks) and around individual grains (several other samples). In these samples, large well crystallized pyrite grains and masses were not oxidized where finer grained sulphides in the samples were partially or totally oxidized. This was particularly apparent in oxidized core from within 50 m of the surface, in which some pyrite was still fairly fresh despite exposure to several thousand years of weathering. Fresh pyrite grains were also observed in incompetent "rotten" core.

General Results and Interpretation

Results for each parameter for acid-base accounting (Table 5.1.1-1) cannot be considered in isolation but should be examined in the general context of acid generation prediction. Therefore, the general interpretation approach is presented followed by description of results in terms of depth (the most recent

TABLE 5.1.1-1

PLACER DOME - BERG PROJECT
ACID-BASE ACCOUNTING RESULTS SORTED BY ROCK TYPE AND MAJOR ALTERATION ASSEMBLAGE

Sample Number	Alteration Assemblage	Total Sulphur (%)	Paste pH	Inorganic CO_2 (%)	Sulphate by HCl (%)	Sulphide by HNO_3 (%)	NP (kg $CaCO_3$/t)	NP(s)	PA	PA(s)	NNP	NNP(s)
Basic Dyke												
86-200	None	0.031	8.5	6.5	0.04	0.01	69	148	1	0	68	147
Quartz Diorite												
93-208	Biotitic	1.68	6.2	0.2	0.13	1.43	5	5	53	109	-48	-105
73-170	Propylitic	0.70	7.2	0.2	0.12	0.11	8	5	22	3	-14	1
73-230	Propylitic	1.29	7.2	0.2	0.08	0.84	7	5	40	26	-33	-22
74-118	Propylitic	1.06	6.1	0.2	0.16	0.49	2	5	33	15	-31	-11
74-300	Propylitic	1.49	7.6	0.2	0.05	0.98	7	5	47	31	-40	-26
89-112	Propylitic	4.73	8.2	1.4	0.08	4.85	41	32	148	152	-107	-120
95-140	Propylitic	4.36	7.3	0.2	0.26	4.16	6	5	136	130	-130	-125
95-231	Propylitic	3.48	7.9	1.0	0.26	3.02	30	23	109	94	-79	-72
95-240	Propylitic	3.2	8.2	0.4	0.10	3.05	13	9	100	95	-87	-86
Hazelton Volcanics												
29-164	Argillic	4.49	8.3	1.0	0.08	4.38	14	23	140	137	-126	-114
29-260	Argillic	4.63	8.2	0.5	3.13	4.10	13	11	145	128	-132	-117
89-315	Argillic	4.38	8.5	1.2	0.09	4.21	26	27	137	132	-111	-104
33A-052	Biotitic	1.50	4.4	0.2	1.61	0.82	-3	5	47	26	-50	-21
33A-162	Biotitic	2.83	6.7	0.2	0.10	2.06	4	5	88	64	-84	-60
33-328	Biotitic	3.68	8.2	0.4	4.30	1.80	5	9	115	56	-110	-47
43-310	Biotitic	2.24	8.4	0.4	3.93	0.83	13	9	70	26	-57	-17
43-318	Biotitic	3.60	8.2	0.4	7.44	1.20	13	9	113	38	-100	-28
77-140	Biotitic	2.93	8.4	1.3	0.05	2.58	25	30	92	81	-67	-51
77-238	Biotitic	3.35	8.4	0.9	0.13	3.13	23	20	105	98	-82	-77
77-311	Biotitic	6.48	8.3	3.5	0.43	6.12	63	80	203	191	-140	-112

continued . . .

TABLE 5.1.1-1 (concluded)

PLACER DOME - BERG PROJECT
ACID-BASE ACCOUNTING RESULTS SORTED BY ROCK TYPE AND MAJOR ALTERATION ASSEMBLAGE

Sample Number	Alteration Assemblage	Total Sulphur (%)	Paste pH	Inorganic CO_2 (%)	Sulphate by HCl (%)	Sulphide by HNO_3 (%)	NP	NP(s)	PA (kg $CaCO_3$/t)	PA(s)	NNP	NNP(s)
Hazelton Volcanics (continued)												
12-168	Propylitic	3.75	8.1	1.7	1.28	2.84	28	39	117	89	-89	-50
12-301	Propylitic	2.43	8.9	0.6	1.89	1.09	16	14	76	34	-60	-20
26-100	Propylitic	9.27	7.0	0.6	0.17	8.57	15	14	290	268	-275	-254
26-324	Propylitic	8.3	7.9	0.7	0.17	7.67	27	16	259	240	-232	-224
88-090	Propylitic	2.97	8.4	0.4	0.11	3.15	15	9	93	98	-78	-89
88-320	Propylitic	3.43	8.2	0.8	0.14	3.49	23	18	107	109	-84	-91
94-110	Propylitic	8.45	8.2	1.1	0.07	7.70	19	25	264	241	-245	-216
94-285	Propylitic	8.73	8.1	0.7	0.08	8.42	17	16	273	263	-256	-247
98-115	Propylitic	0.626	7.1	0.2	0.33	0.06	2	5	20	2	-18	3
Quartz Monzonite												
82-115	Potassic	0.894	8.5	0.5	0.05	0.51	20	11	28	16	-8	-5
82-170	Potassic	1.11	8.6	1.0	0.05	0.62	28	23	35	19	-7	3
86-053	Potassic	2.42	5.1	0.2	0.24	2.23	0	5	76	70	-76	-65
86-130	Potassic	2.05	8.1	0.2	0.04	1.66	5	5	64	52	-59	-47
86-440	Potassic	2.11	8.3	0.8	1.58	1.26	23	18	66	39	-43	-21
31-145	Phyllic	1.69	8.4	1.3	0.11	1.43	21	30	53	45	-32	-15
31-200	Phyllic	1.64	8.8	1.6	0.06	1.19	30	36	51	37	-21	-1
84-058	Phyllic	1.81	5.7	0.3	0.08	1.40	-1	7	57	44	-58	-37
84-102	Phyllic	2.15	5.3	0.2	0.10	2.04	1	5	67	64	-66	-59
84-222	Phyllic	2.69	5.3	0.2	0.12	2.34	1	5	84	73	-83	-69

NP - Total Neutralization Potential
NNP(s) - Neutralization Potential from CO_2
PA - Potential acidity from total sulphur
PPA(s) - Potential acidity from sulphide
NNP = NP - PA
NNP(s) = NP(s) - PA(s)

controlling factor), host rock alteration type and primary host rock lithology (original controlling factor).

Comparison of neutralization potential (NP) with sulphur results requires that both parameters can be converted to equivalent units. The NP of the rock is usually presented as $CaCO_3$ equivalents (kg $CaCO_3$/tonne of rock). Equation (5.1.1-1) above indicates that 1 mole of sulphur produces 2 moles of H^+ which can be neutralized by 1 mole of $CaCO_3$ (equation 5.1.1-2) assuming that the pH is less than 6.4 and neutralization will not occur above this level (HCO_3^- becomes the dominant carbonate species), neutralization is due to calcite only and pyrite is the only sulphide mineral (reaction (5.1.1-1) may be different for other minerals). Using this simple relationship, total sulphur concentration can be converted to $CaCO_3$ equivalents and is called maximum potential acidity (PA). The conversion factor is 31.25 kg $CaCO_3$/t. The difference between PA and NP is the net neutralization potential (NNP):

$$NNP = NP - PA.$$

This conventional approach to ABA has limitations when applied to the Berg project. Mostly, these stem from the common presence of several sulphate minerals which contain sulphur and iron in completely oxidised forms which can not generate acid. Near the surface, oxidised iron-bearing and calcium-bearing hydrated sulphates are common due to the natural oxidation of sulphides since the last ice retreat. At depth, below the influence of surface weathering and acidic conditions primary anhydrous and hydrous calcium sulphates (anhydrite and gypsum, respectively) are common. Therefore, for the

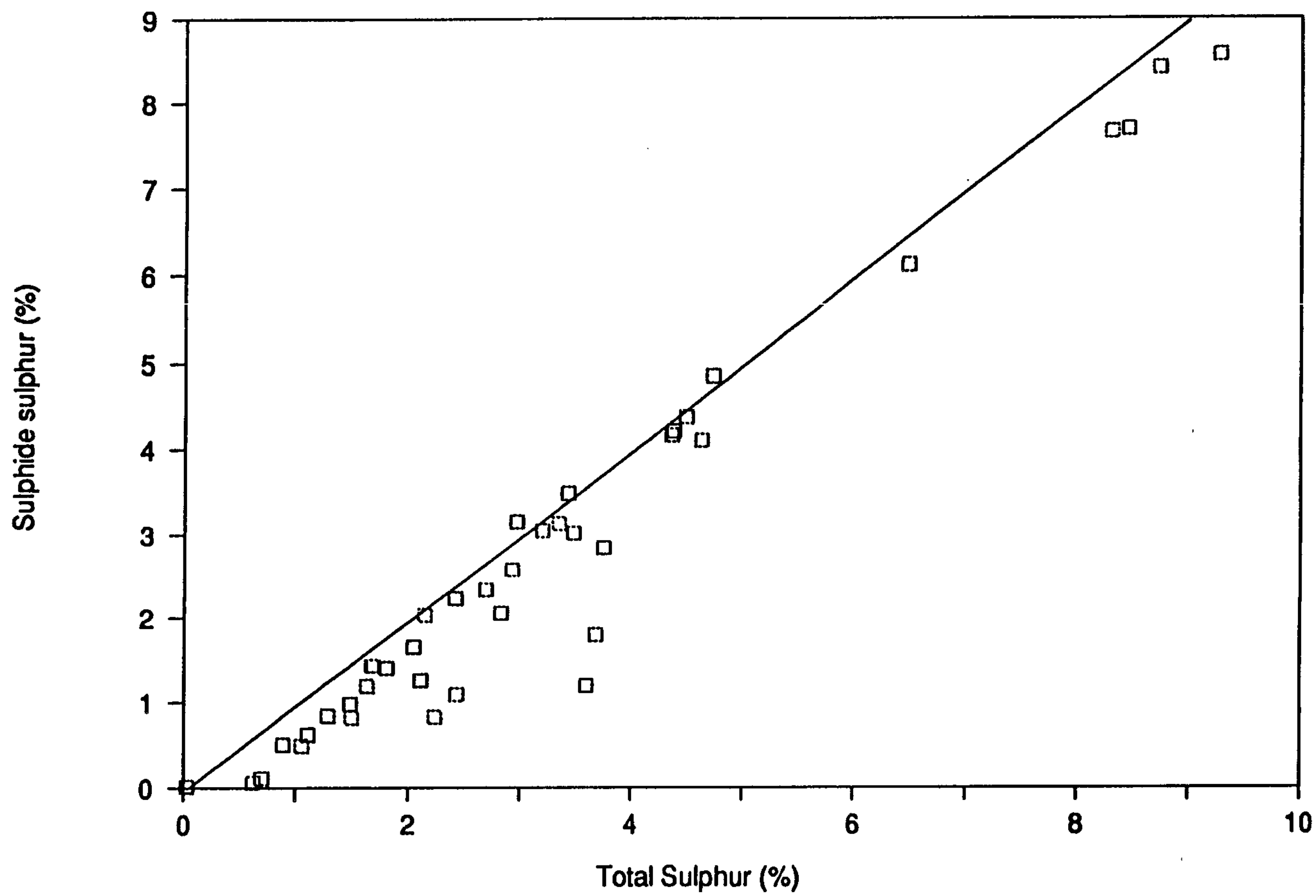
Berg deposit, potential acidity is best expressed as the sulphur available in sulphides (PA(s)). In addition, neutralization potential should be determined based on the concentration of carbonates, not other minerals (such as hydroxides of iron and aluminum) which may not be effective for long term acid neutralization. The inorganic CO_2 concentration (in %) is converted to kg $CaCO_3$/t by multiplying by a factor of 1000/44 (22.7) to yield NP(s). Net neutralization potential from sulphide and carbonate species is then calculated as:

$$NNP(s) = NP(s) - PA(s)$$

Theoretically, an $NNP(s)>0$ implies that NP is in excess over reactive sulphide and therefore the rock has no potential to generate net acidity. In the reverse case ($NNP(s)<0$), the sulphide content exceeds NP indicating a net potential to generate acidity.

General Results for Sulphur Species

Sulphide sulphur is less than total sulphur in almost all samples (with some discrepancies due to analytical errors), as is expected (Figure 5.1.1-2). The balance is made up by sulphate sulphur which can be as high as 2.86% (8.57% sulphate) and sulphur in unknown forms. Significant absolute concentration of unknown sulphur forms (that is, concentrations that cannot be explained by analytical errors of less than 10%) averages 0.5%, with no apparent correlation with rock type or total sulphur content. This sulphur may reflect:



Relationship Between Total Sulphur and Sulphur	
Figure No. 5.1.1-2	Placer Dome Berg Project
Date Nov 1989	Drawn by NORECOL

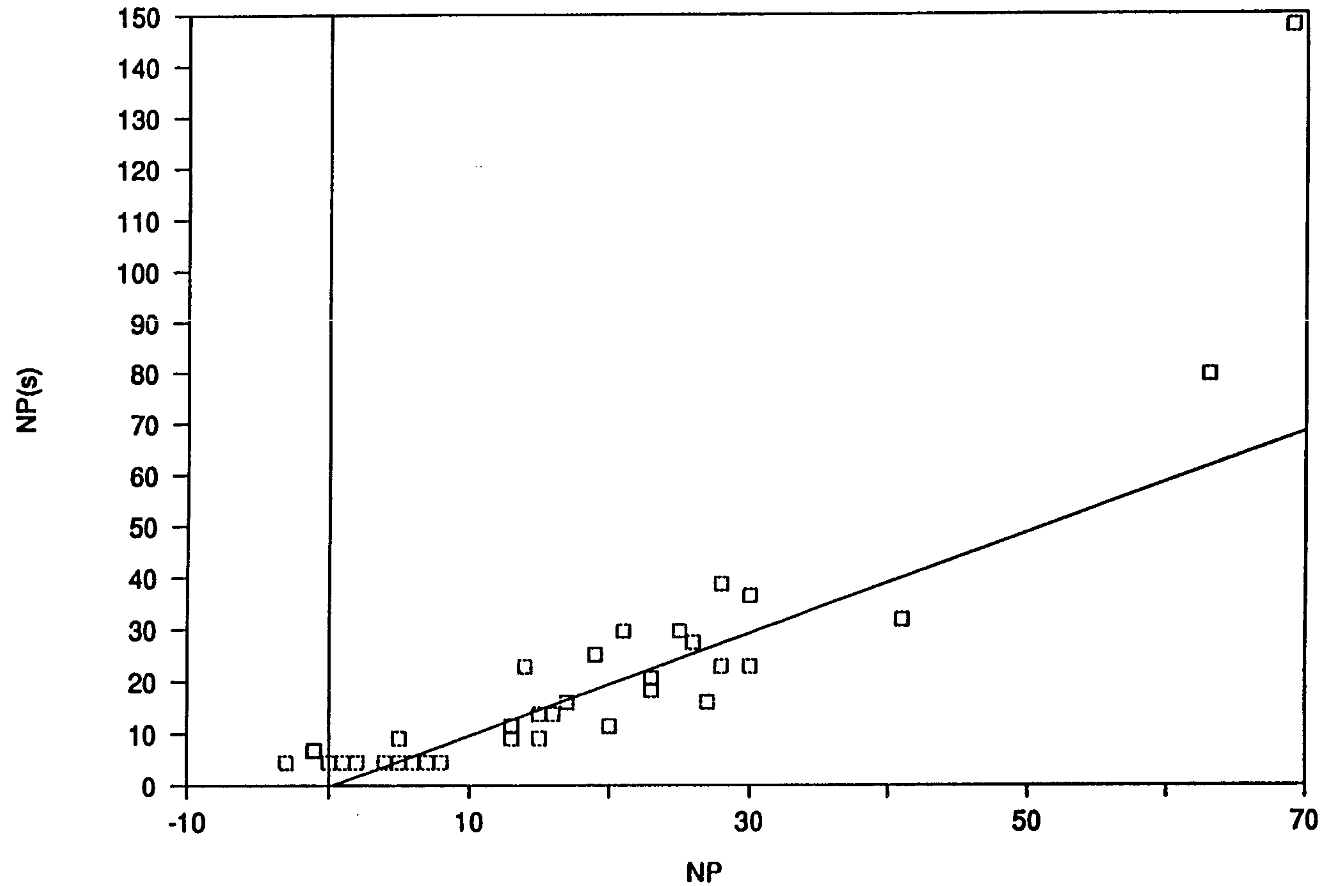
- o sulphur-bearing minerals which are not completely decomposed by the nitric acid-bromine digestion but are reported in the total sulphur analysis, for example elemental sulphur, some sulphides, and barite ($BaSO_4$); and

- o very fine-grained pyrite which is completely encapsulated by the silicate matrix and is not liberated by grinding to 170-mesh.

Given the strongly oxidizing nature of the concentrated nitric acid-bromine digestion and fine texture of the test samples, it is unlikely that the unaccounted for sulphur will be a significant component of acid generation.

General Results For Neutralization Potential Species

Conventional net neutralization potential (NP) is well-correlated with NP(s) indicating that the potential to neutralize hydrochloric acid is largely due to carbonates (Figure 5.1.1-3). There is some scatter about the 1:1 line because the detection limit for CO_2 is 0.2% (4.54 kg $CaCO_3$/t) and CO_2 concentrations are typically less than 1.0%. Neutralization potential is also correlated grossly with paste pH (Figure 5.1.1-4); NP greater than 15 kg $CaCO_3$/t corresponds to paste pH greater than 7.9, and NP less than 5 kg $CaCO_3$/t corresponds to pH less than 7.0. Paste pH values greater than 8.0 are obtained when carbonates (and some silicates) are hydrolysed.



Relationship Between NP and NP(s)

Figure No. 5.1.1-3

Placer Dome
Berg Project

Date Nov 1989

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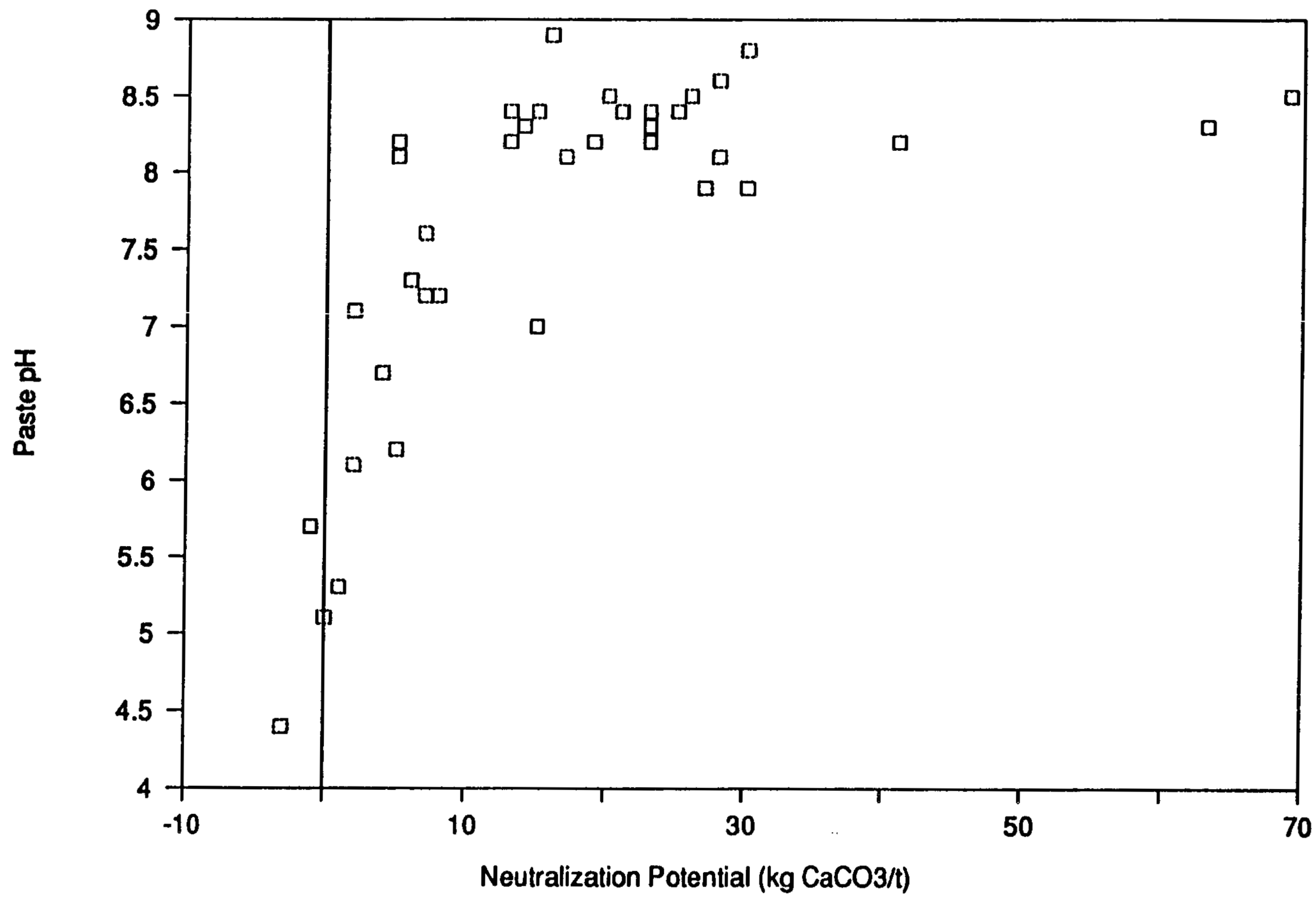


Relationship Between NP and Paste pH	
Figure No. 5.1.1-4	Placer Dome Berg Project
Date Nov 1989	Drawn by NORECOL

Effect of Oxidation and Prediction of Effective Available Sulphur for Oxidation.

Natural oxidation in the cap provides useful information regarding the eventual availability of pyrite in the samples for acid generation. This is based on the assumption that rock which has undergone several thousands of years of oxidation since the end of continental glaciation is essentially inert and will oxidize at a negligible rate. Components in this material which would normally be part of the acid generation and neutralization process but which remain in these samples are presumably resistant to rapid oxidation (for example, highly crystalline grains) or are encapsulated to the extent that oxygen is almost completely excluded.

Oxidation appears to have occurred to varying degrees in up to 14 samples. This is indicated by a break in the distribution of paste pH values. Material which has undergone oxidation has a paste pH of less than 7.5, whereas material which is relatively fresh has a paste pH greater 7.9 to a maximum of 8.8. Complete oxidation (shown by limonitic coatings on the samples, and pervasive oxidation of sulphides) was identified in five samples (Table 5.1.1-2); in these cases the paste pH is in the range 4.4 to 5.7, and NP varies from -3 kg $CaCO_3$/t kg to 1 kg $CaCO_3$/t. Three of these samples are from less than 60 m below the surface.

TABLE 5.1.1-2

PLACER DOME - BERG PROJECT
ACID-BASE ACCOUNTING DATA FOR STRONGLY OXIDIZED SAMPLES

Sample Number	Rock Type	Total Sulphur (%)	Paste pH	Inorganic CO_2 (%)	Sulphate by HCl (%)	Sulphide by HNO_3 (%)	NP	NP(s)	PA	PA(s)	NNP	NNP(s)
							(kg $CaCO_3$/t)					
33A-052	Hazelton	1.5	4.4	0.2	1.61	0.82	-3	5	47	26	-50	-21
86-053	Q. Monz.	2.42	5.1	0.2	0.24	2.23	0	5	76	70	-76	-65
84-102	Q. Monz.	2.15	5.3	0.2	0.10	2.04	1	5	67	64	-66	-59
84-222	Q. Monz.	2.69	5.3	0.2	0.12	2.34	1	5	84	73	-83	-69
84-058	Q. Monz.	1.81	5.7	0.3	0.08	1.4	-1	7	57	44	-58	-37

Mineralogical data and the determination of total sulphur and sulphur as sulphides indicates that, despite the long duration of oxidation of five samples, a significant amount of sulphide (>0.82%) remains unoxidized. In other samples that have undergone partial oxidation (paste pH greater than 6.0), absolute sulphide sulphur contents are typically greater than 1.0%. In comparison, NPs for the partially or completely oxidized samples are less than 8 kg $CaCO_3$/t and NP(s) values are typically undetectable (that is, NP(s)<4.5 kg $CaCO_3$/t).

These results indicate that when rocks at Berg undergo long term oxidation:

- a significant amount of sulphur remains as sulphide in a form which is not available to generate acid after several thousands of years of oxidation; and

- all neutralization potential as carbonate is completely removed, reflecting the typical occurrence of calcite as a readily available form in thin fractures, though a small amount remains (less than 4 kg $CaCO_3$/t) probably in a form which is not useful for acid neutralization.

For the purpose of interpreting ABA data and predicting the potential for net acid generation, sulphur in fresh rocks which is not available for acid generation should be removed from the equation for NNP. Unavailable sulphur is a combination of sulphur as sulphates, sulphides and other sulphur minerals which are not oxidized by concentrated nitric acid and bromine, and encapsulated or resistant sulphides which are not oxidized during prolonged natural oxidation. Because some NP remains after all available sulphur has been oxidized but acid generation potential probably exceeded neutralization potential, NP(s) from CO_2 determination is best used in the equation for NNP. Although some calcite will be encapsulated and therefore not available to neutralize acid, this amount is assumed to be small (less than 4 kg $CaCO_3$/t) when compared to the encapsulated non-reactive sulphide content.

A useful predictive form for NNP at Berg deposit is given by:

$$NNP(Berg) = NP(CO_2) - \{PA(sulphide) - PA(unavailable\ sulphide)\}.$$

The theoretical critical value for NNP(Berg) at which acid generation may occur in rock at Berg is 0 kg $CaCO_3$/t. When used conservatively, NNP(Berg) can be used to determine which rock types may be used in construction because the potential for acid generation is very low.

Determination of PA(unavailable sulphide) for any particular unweathered sample is complicated because there is no equivalent oxidized sample available for comparison. Two approaches were taken to estimate a proportion of non-oxidizable sulphide. In the case of quartz monzonite, a conservative estimate was made by assuming that the oxidized sample with the least remaining sulphide (1.4%) was derived from the unoxidized sample with the most sulphide (2.34%). In other words, approximately 40% of pyrite is available for oxidation. This assumption is conservative because the most oxidized quartz monzonite sample has a sulphide content of 2.23%, which in the same ratio would yield an original sulphide content of 3.6%. This level is much greater than observed sulphide concentrations in the stock.

For the Hazelton Volcanics, only one sample is completely oxidized (33A-052, sulphide at 0.82%), however samples from deeper in adjacent hole 33 are unoxidized. The deepest sample was assumed to be the unweathered equivalent of the oxidized sample (33-328, sulphide at 1.8%) yielding an unavailable sulphide proportion of 46%. This value was also used for quartz diorite due to its fine grained texture and similar alteration to the Hazelton Volcanics. In the data presentation that follows NNP- and NNP(s)-values are presented for comparison with NNP(Berg) because NNP(Berg) is predicted from a small data set which will require refinement.

Effect of Depth on Potential for Acid Generation

Distance from the current ground surface has resulted in a major overprint on other lithological features which will affect the potential for acid generation. At least two samples were collected from most diamond drill holes, and three samples were collected from holes 33 (including 33A), 77, 84, 86 and 95 (Table 5.1.1-3). In these holes samples were collected where possible from depths between 0 and 100 m, 100 and 200 m, and 200 and 300 m.

Several common trends occur with increasing depth (Figure 5.1.1-5):

- o Paste pH, increases typically with the most rapid changes in the first 100 m;

TABLE 5.1.1-3

PLACER DOME - BERG PROJECT
ACID BASE ACCOUNTING DATA SORTED BY DIAMOND DRILL HOLE

Hole and Interval (m)	Rock Type	Total Sulphur (%)	Paste pH	Inorganic CO_2 (%)	Sulphate by HCl (%)	Sulphide by HNO_3 (%)	NP	NP(s)	PA	PA(s)	NNP	NNP(s)
							(kg $CaCO_3$/t)					
Hole 12												
168	Hazelton	3.75	8.1	1.7	1.28	2.84	28	39	117	89	-89	-50
301	Hazelton	2.43	8.9	0.6	1.89	1.09	16	14	76	34	-60	-20
Hole 26												
100	Hazelton	9.27	7.0	0.6	0.17	8.57	15	14	290	268	-275	-254
324	Hazelton	8.3	7.9	0.7	0.17	7.67	27	16	259	240	-232	-224
Hole 29												
164	Hazelton	4.49	8.3	1.0	0.08	4.38	14	23	140	137	-126	-114
260	Hazelton	4.63	8.2	0.5	3.13	4.10	13	11	145	128	-132	-117
Hole 31												
145	Q. Monz.	1.69	8.4	1.3	0.11	1.43	21	30	53	45	-32	-15
200	Q. Monz.	1.64	8.8	1.6	0.06	1.19	30	36	51	37	-21	-1
Hole 33, 33A												
52	Hazelton	1.5	4.4	0.2	1.61	0.82	-3	5	47	26	-50	-21
162	Hazelton	2.83	6.7	0.2	0.1	2.06	4	5	88	64	-84	-60
328	Hazelton	3.68	8.2	0.4	4.3	1.80	5	9	115	56	-110	-47
Hole 43												
310	Hazelton	2.24	8.4	0.4	3.93	0.83	13	9	70	26	-57	-17
318	Hazelton	3.6	8.2	0.4	7.44	1.20	13	9	113	38	-100	-28
Hole 73												
170	Q. Diorite	0.70	7.2	0.2	0.12	0.11	8	5	22	3	-14	1
230	Q. Diorite	1.29	7.2	0.2	0.08	0.84	7	5	40	26	-33	-22

continued . . .

TABLE 5.1.1-3 (continued)

PLACER DOME - BERG PROJECT
ACID BASE ACCOUNTING DATA SORTED BY DIAMOND DRILL HOLE

Hole and Interval (m)	Rock Type	Total Sulphur (%)	Paste pH	Inorganic CO_2 (%)	Sulphate by HCl (%)	Sulphide by HNO_3 (%)	NP	NP(s)	PA	PA(s)	NNP	NNP(s)
							(kg $CaCO_3$/t)					
Hole 74												
118	Q. Diorite	1.06	6.1	0.2	0.16	0.49	2	5	33	15	-31	-11
300	Q. Diorite	1.49	7.6	0.2	0.05	0.98	7	5	47	31	-40	-26
Hole 77												
140	Hazelton	2.93	8.4	1.3	0.05	2.58	25	30	92	81	-67	-51
238	Hazelton	3.35	8.4	0.9	0.13	3.13	23	20	105	98	-82	-77
311	Hazelton	6.48	8.3	3.5	0.43	6.12	63	80	203	191	-140	-112
Hole 82												
115	Q. Monz.	0.894	8.5	0.5	0.05	0.51	20	11	28	16	-8	-5
170	Q. Monz.	1.11	8.6	1.0	0.05	0.62	28	23	35	19	-7	3
Hole 84												
58	Q. Monz.	1.81	5.7	0.3	0.08	1.40	-1	7	57	44	-58	-37
102	Q. Monz.	2.15	5.3	0.2	0.10	2.04	1	5	67	64	-66	-59
222	Q. Monz.	2.69	5.3	0.2	0.12	2.34	1	5	84	73	-83	-69
Hole 86												
53	Q. Monz.	2.42	5.1	0.2	0.24	2.23	0	5	76	70	-76	-65
130	Q. Monz.	2.05	8.1	0.2	0.04	1.66	5	5	64	52	-59	-47
200	Basic dyke	0.031	8.5	6.5	0.04	0.01	69	148	1	0	68	147
440	Q. Monz.	2.11	8.3	0.8	1.58	1.26	23	18	66	39	-43	-21
Hole 88												
90	Hazelton	2.97	8.4	0.4	0.11	3.15	15	9	93	98	-78	-89
320	Hazelton	3.43	8.2	0.8	0.14	3.49	23	18	107	109	-84	-91

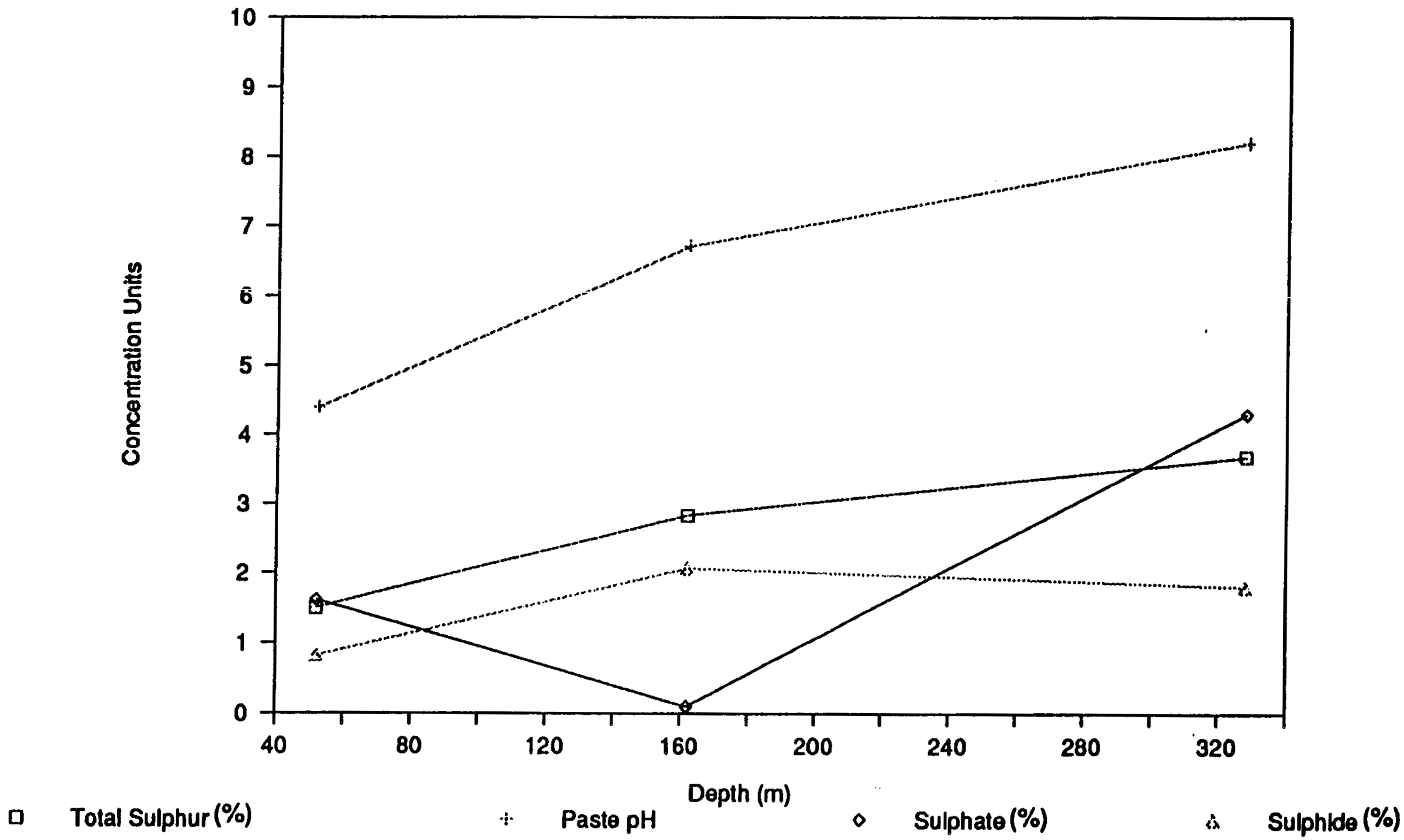
continued . . .

TABLE 5-1.1-3 (concluded)

PLACER DOME - BERG PROJECT
ACID BASE ACCOUNTING DATA SORTED BY DIAMOND DRILL HOLE

Hole and Interval (m)	Rock Type	Total Sulphur (%)	Paste pH	Inorganic CO_2 (%)	Sulphate by HCl (%)	Sulphide by HNO_3 (%)	NP	NP(s)	PA	PA(s)	NNP	NNP(s)
							(kg $CaCO_3$/t)					
Hole 89												
112	Q. Diorite	4.73	8.2	1.4	0.08	4.85	41	32	148	152	-107	-120
315	Hazelton	4.38	8.5	1.2	0.09	4.21	26	27	137	132	-111	-104
Hole 93												
208	Q. Diorite	1.68	6.2	0.2	0.13	1.43	5	5	53	45	-48	-40
Hole 94												
110	Hazelton	8.45	8.2	1.1	0.07	7.70	19	25	264	241	-245	-216
285	Hazelton	8.73	8.1	0.7	0.08	8.42	17	16	273	263	-256	-247
Hole 95												
140	Q. Diorite	4.36	7.3	0.2	0.26	4.16	6	5	136	130	-130	-125
231	Q. Diorite	3.48	7.9	1.0	0.26	3.02	30	23	109	94	-79	-72
240	Q. Diorite	3.2	8.2	0.4	0.10	3.05	13	9	100	95	-87	-86
Hole 98												
115	Hazelton	0.626	7.1	0.2	0.33	0.06	2	5	20	2	-18	3

NP - Total Neutralization Potential
NP(s) - Neutralization Potential from CO_2
PA - Potential acidity from total sulphur
PPA(s) - Potential acidity from sulphide
NNP = NP - PA
NNP(s) = NP(s) - PA(s)



Variation of Sulphur Species and Paste pH with depth, Hole 33, 33A

Figure No. 5.1.1-5	Placer Dome Berg Project
Date Nov 1989	Drawn by NORECOL

- o Total sulphur content increases though local variations result in the opposite trend (hole 95, diorite);

- o Sulphide sulphur content increases;

- o Neutralization potential increases;

- o NNP and NNP(s) become more negative; and

- o Sulphate concentration increases.

These trends all reflect the process of oxidation and zonation of the deposit into oxidized, supergene and hypogene zones (Section 2.2.2). Circulation of oxygenated groundwater near the surface leads to oxidation and destruction of a high proportion of pyrite, formation of limonite and acidity, and subsequent dissolution of carbonate. At depth, oxidation potential is lower and pH increases as a result of neutralization by carbonates which are still available, and mixing with neutral groundwater. Below the supergene zone fractures are sealed with gypsum, and oxidation cannot occur due to the low permeability of the rock which prevents influx of oxidizing agents and removal of the products of oxidation. This depth zonation results in the observed chemical trends: destruction of sulphide, production of readily soluble sulphates (decrease in total sulphur), production of minerals which, when dissolved, produce acid solutions (low pH), and dissolution of primary calcite and gypsum.

Effect of Hydrothermal Alteration and Lithology on Potential for Acid Generation

Trends in acid generation parameters due to the lithological and hydrothermal alteration variations (Table 5.1.1-1) are apparent if those samples significantly affected by vertical zonation are discounted. Since hydrothermal alteration is zoned from the centre of the quartz monzonite intrusion and roughly follows lithological variations, these two factors can be considered at the same time, especially due to the relatively small number of samples from certain lithological/alteration combinations. The most commonly represented combinations are potassically- and phyllically-altered quartz monzonite, biotitically- and propylitically-altered Hazelton Volcanics and propylitically-altered diorite.

Overall the greatest total sulphur, sulphide sulphur and most negative values for NNP occur in the propylitically-altered zone of the Hazelton Volcanics. This zone corresponds to the greatest pyrite levels reported by Panteleyev (1981) which encircle the deposit 200 to 300 metres from the quartz monzonite - Hazelton Volcanics contact. Even if non-reactive sulphide is removed as discussed above, very little of this material can be considered potentially non-acid generating. Values for NNP(s) are, at the most negative, -254 kg $CaCO_3$/t and average -96.9 kg $CaCO_3$/t. Only one sample yielded an NNP(Berg)>0 kg $CaCO_3$/t. Biotitically-altered Hazelton Volcanics are closer to the quartz monzonite - Hazelton Volcanics contact and are in a zone of lower pyrite content. Nonetheless, NNP(s) values are highly negative.

Samples collected from propylitically-altered quartz diorite to the northeast of the quartz monzonite yielded lower sulphur contents than the Hazelton volcanics. The sampling was biassed towards this area because drilling has not been carried out to the southeast; however, Pantelyev indicates that pyrite levels are very high and comparable to propylitically-altered Hazelton Volcanics in that area. The lower sulphide levels are matched by lower NP and NP(s), although on average, NNPs are still significantly negative. Removal of a proportion of sulphide sulphur as potentially non-acid generating reduces some NNP(Berg) values to less negative than -10 kg $CaCO_3$/t although this must still be considered potentially acid generating.

Lowest sulphur and sulphide contents are found in quartz monzonite, which is consistent with observed pyrite levels which show a distinctive <3% pyrite region in the middle of the stock. Although samples are equally distributed between potassically and phyllically-altered zones, the zones cannot be readily distinguished in terms of sulphur/carbonate geochemistry.

Values for NP and NP(s) are comparable or slightly greater than those found elsewhere in the deposit, as a result NNP-values not adjusted for unavailable sulphide are marginally less negative than in the Hazelton Volcanics and diorite. Removal of non-oxidizable sulphide (to 60%) yields positive NNP(Berg) values for several unoxidized samples. A limitation of the current assumption of unavailable sulphide is apparent in that all four oxidized samples were apparently net acid generating, but five out of six unoxidized samples are predicted to be potentially acid consuming. This may result from biassed sampling (an effort was made to collect oxidized samples) or in situ removal of neutralizing potential by circulating acidic groundwaters. This latter explanation may be valid given the position of the stock at the bottom of the cirque in a groundwater discharge zone.

Drill hole 82, which is located in the region of pyrite <2%, and drill hole 31 have positive NNP(Berg) values indicating that deep rock in this area may be suitable for mine construction purposes where non-acid generating material is required.

One sample was collected from a basic dyke at 200 m in hole 86. This dyke had the lowest sulphide content and greatest carbonate content of any rock type at the deposit. The NNP(s) is moderate at 147 kg $CaCO_3$/t when compared to pure carbonate rock. This rock would be suitable for construction, however NNP(s) is not high enough in the volumes available to be used in blending with potentially acid generating waste.

Finally, strongly oxidized material in the cap represents a waste rock type of potentially significant volume which must be removed prior to mining supergene and primary mineralization. Although, the assumption is that this material is essentially inert, in terms of acid generation (except where breakage during blasting and dumping results in exposure of encapsulated sulphide), NP is less than 0 kg $CaCO_3$/t indicating that products of acid generation have accumulated in the rock and may be released when leached. Therefore, this material may require special handling in terms of preventing or controlling initial acid release in a waste dump.

Conclusions of Static Tests

Static tests seek, through chemical determination of the balance between potentially acid generating and acid neutralizing components, to predict the potential for acid generation in terms of identifiable geological features or spatial information. The tests cannot indicate with certainty whether or not acidic drainage will be produced but can suggest areas where the risk is very low, moderate or very high.

Forty samples were collected from all major rock units and analyzed for total sulphur, neutralization potential, paste pH, nitric acid-bromine leachable sulphide, hydrochloric acid leachable sulphate and inorganic CO_2. These results were converted to equivalent $CaCO_3$ units (kg $CaCO_3$/t) and net neutralization potentials determined.

In order to consider the effective potential for net acid generation, several factors were considered:

- There are several minerals in the rocks which contain sulphur in a high oxidation state which cannot be oxidized to yield acidic waters.

- Neutralization potential is best represented by carbonate content because there are oxides and silicate clays present in the rock which may not be effective neutralizing agents. However, the most NP is present as carbonate.

- Oxidized cap rocks represent the end-product of several thousands of years of oxidation but still contain more than 1% pyrite which is in a form not available for oxidation. Neutralization potential is almost completely exhausted indicating that it is readily available for acid neutralization.

A high proportion of sulphur can be removed from potential for acid generation while not decreasing neutralization potential.

Results can be summarized as follows (Table 5.1.1-4):

- Depth is a strong controlling factor on acid generation potential. Rock near the surface is strongly oxidized and contains some remnant products of acid generation and unoxidized sulphide. This rock has a potential for short term release of acidity after mining and has negligible potential for acid generation providing that exposure of unoxidized pyrite is minimized. Deeper, unoxidized rocks have a very high potential for net acid generation due to high sulphide contents.

- Lithological type and position in the hydrothermal alteration zones is a secondary control, of particular importance at depth. The Hazelton volcanics and diorite have a very strong potential to generate acidity. Low sulphide rock near the centre of the quartz monzonite stock is the only material that, despite excess sulphide when compared to carbonate content, may be non-acid generating due to encapsulation of a high proportion of sulphide.

TABLE 5.1.1-4

PLACER DOME - BERG PROJECT
SUMMARY INTERPRETATION OF POTENTIAL FOR NET ACID GENERATION

Sample Number	Paste pH	Non-oxidized sulphide (%)	NP	NP(s)	PA	PA(s)	NNP	NNP(s)	NNP(Berg)
			(kg $CaCO_3$/t)						
Basic Dyke									
86-200	8.5	0	69	148	1	0	68	147	147
Min	8.5	-	69	148	1	0	68	147	147
Max	8.5	-	69	148	1	0	68	147	147
Mean	8.5	-	69	148	1	0	68	147	147
Quartz Diorite									
95-240	8.2	46	13	9	100	95	-87	-86	-42
89-112	8.2	46	41	32	148	152	-107	-120	-50
95-231	7.9	46	30	23	109	94	-79	-72	-28
74-300	7.6	46	7	5	47	31	-40	-26	-12
95-140	7.3	46	6	5	136	130	-130	-125	-66
73-230	7.2	46	7	5	40	26	-33	-22	-10
73-170	7.2	46	8	5	22	3	-14	1	3
93-208	6.2	46	5	5	53	45	-48	-40	-54
74-118	6.1	46	2	5	33	15	-31	-11	-4
Min	6.1	-	2	5	22	3	-130	-125	-66
Max	8.2	-	41	32	148	152	-14	1	3
Mean	7.3	-	13	10	76	66	-63	-56	-29

continued . . .

TABLE 5.1.1-4 (continued)

PLACER DOME - BERG PROJECT
SUMMARY INTERPRETATION OF POTENTIAL FOR NET ACID GENERATION

Sample Number	Paste pH	Non-oxidized sulphide (%)	NP	NP(s)	PA	PA(s)	NNP	NNP(s)	NNP(Berg)
			(kg $CaCO_3$/t)						
Hazelton Volcanics									
12-301	8.9	46	16	14	76	34	-60	-20	-5
89-315	8.5	46	26	27	137	132	-111	-104	-44
43-310	8.4	46	13	9	70	26	-57	-17	-5
77-140	8.4	46	25	30	92	81	-67	-51	-14
77-238	8.4	46	23	20	105	98	-82	-77	-32
88-090	8.4	46	15	9	93	98	-78	-89	-44
29-164	8.3	46	14	23	140	137	-126	-114	-51
77-311	8.3	46	63	80	203	191	-140	-112	-24
88-320	8.2	46	23	18	107	109	-84	-91	-41
43-318	8.2	46	13	9	113	38	-100	-28	-11
29-260	8.2	46	13	11	145	128	-132	-117	-58
94-110	8.2	46	19	25	264	241	-245	-216	-105
33-328	8.2	46	5	9	115	56	-110	-47	-21
12-168	8.1	46	28	39	117	89	-89	-50	-9
94-285	8.1	46	17	16	273	263	-256	-247	-126
26-324	7.9	46	27	16	259	240	-232	-224	-114
98-115	7.1	46	2	5	20	2	-18	3	4
26-100	7	46	15	14	290	268	-275	-254	-131
33A-162	6.7	46	4	5	88	64	-84	-60	-30
33A-052	4.4	-	-3	5	47	26	-50	-21	-
Min	4.4	-	-3.0	4.5	19.6	1.9	-274.7	-254.2	-
Max	8.9	-	63.0	79.5	289.7	267.8	-17.6	2.7	-
Mean	7.9	-	17.9	19.1	137.6	116.0	-119.7	-96.9	-

continued . . .

TABLE 5.1.1-4 (concluded)

PLACER DOME - BERG PROJECT
SUMMARY INTERPRETATION OF POTENTIAL FOR NET ACID GENERATION

Sample Number	Paste pH	Non-oxidized sulphide (%)	NP	NP(s)	PA	PA(s)	NNP	NNP(s)	NNP(Berg)
			(kg $CaCO_3$/t)						
Quartz Monzonite									
31-200	8.8	60	30	36	51	37	-21	-1	21
82-170	8.6	60	28	23	35	19	-7	3	15
82-115	8.5	60	20	11	28	16	-8	-5	5
31-145	8.4	60	21	30	53	45	-32	-15	12
86-440	8.3	60	23	18	66	39	-43	-21	2
86-130	8.1	60	5	5	64	52	-59	-47	-16
84-058	5.7	-	-1	7	57	44	-58	-37	-
84-102	5.3	-	1	5	67	64	-66	-59	-
84-222	5.3	-	1	5	84	73	-83	-69	-
86-053	5.1	-	0	5	76	70	-76	-65	-
Min	5.1	-	-1	5	28	16	-83	-69	-
Max	8.8	-	30	36	84	73	-7	3	-
Mean	7.2	-	13	14	58	46	-45	-32	-

NP - Total Neutralization Potential
NNP(s) - Neutralization Potential from CO_2
PA - Potential acidity from total sulphur
PPA(s) - Potential acidity from sulphide
NNP = NP - PA
NNP(s) = NP(s) - PA(s)
NNP(Berg) = NP(s) - PA(due to available sulphide)

- Two types of material that may be non-acid generating in places and therefore suitable for construction are quartz monzonite below the oxidized zone, and oxidized cap material. In the latter case there would be a need to control short term release of acidity from mine structures, or release acidity prior to construction. In both cases, exposure of fresh sulphide by breakage would need to be minimized.

5.1.1.3 Kinetic test results

Background to Testing

Static predictive geochemical tests involve the use of mineralogical and geochemical techniques which are conducted to determine the sulphur/carbonate geochemistry and estimate the very long term reactivity of minerals in the rock. These tests do not provide any indication of the rate of acid generation in the short term and the potential quality of water which may emanate from waste rock dumps, pit walls, tailings impoundments and other mine structures which use sulphide-bearing rocks.

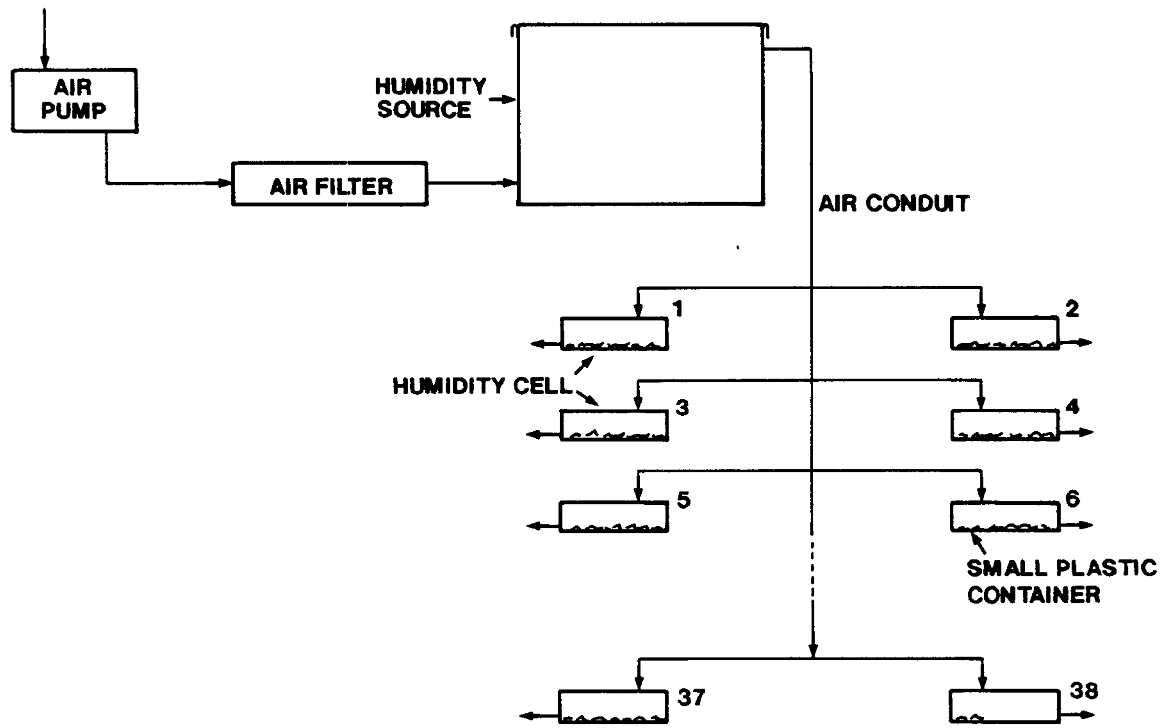
Background to Testing

Kinetic predictive tests may provide limited information on the rate of rock weathering, and in some cases their resultant water quality. A large number of tests have been developed (B.C. Acid Mines Drainage Task Force 1989). Some of these tests can be conducted at the mine site during active development using pilot scale waste dumps, however, the need for continual monitoring precluded using these tests at the Berg deposit in 1989. Several laboratory kinetic tests have been designed which allow control of such important limiting variables as temperature, particle size, water infiltration rate and the effect of sulphur-oxidizing bacteria which can be highly variable at the project site.

Humidity cells conducted over a period of 25 weeks were selected as suitable for estimating sulphide oxidation rates. These tests, which were developed by Ferguson (1985), have been accepted as an industry standard in British Columbia and elsewhere (California, Ferguson, personal communication 1990). On going additional research is being conducted to refine the testing protocol and to correlate lab data wth field results. Results from humidity cells may provide acid generation rates though demonstration of correlation and relevance to field results is limited to a few detailed studies (for example, City Resources 1988).

Humidity Cell Testwork Methodology

Construction of the humidity cell apparatus is illustrated in Figure 5.1.1-6 (B.C. Acid Mine Drainage Task Force 1989). Each cell consists of a shallow plastic container with a tightly sealed lid into which 200 g of homogenised crushed rock (screened to <2 mm) is placed. The cell is connected to a vacuum pump which continually supplies moist air from a humidifier. Several cells are linked to the pump and humidifier. Testing was conducted at the laboratories of Norecol Environmental Consultants.



EXAMPLE OF A HUMIDITY CELL APPARATUS

Figure no. 5.1.1-6	PLACER DOME BERG PROJECT
Date Dec. 1989	Drawn by NORECOL

Each week the crushed rock is leached with two 250-ml aliquots of de-ionized water and as much leachate collected without removing a large quantity of fine crushed material from the cell. The leachate is filtered using a vacuum apparatus equipped with 0.45 ìm millipore filter. A portion of the filtered leachate is acidified with nitric acid and analyzed for dissolved iron and calcium and then archived for future metal analysis. The remainder of the filtered leachate is analyzed for pH, acidity, conductivity and sulphate which are key parameters required for determination of the onset and rate of acid generation. All samples were analyzed by B.C. Research Corp. by idential techniques as used for water quality analysis (Section 3.3-3). Any fine material in the sample bottles is returned to the cells after leaching the following week. This procedure ensures that the samples do not become depleted in the finer fractions which are a major control on the rate of acid generation. The room temperature is recorded during leaching and at other times.

Prior to testing, each rock sample selected was screened through sieves at 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm and 0.063 mm to provide an estimate of the exposed surface area of the material. This was calculated by assuming that particles are spherical and the material collected between sieves can be characterized by a logarithmic median diameter.

Material Selected for Analysis

Due to the length of time required to obtain useful information from humidity cells, and the resulting high cost of water analysis, three samples were selected based on the likely importance of represented rock types in the final waste rock dump. Two high sulphide samples were selected from the Hazelton Volcanics (one with high equivalent $CaCO_3$ concentration) and one sample was selected from the quartz diorite. Characteristics for the samples tested are provided in Table 5.1.1-5.

Preliminary Results of Humidity Cell Testing

Humidity cells were started on August 8, 1989, and at November 15 had been leached every week for 15 weeks. As of this date, analytical results have been reported for 12 weeks. The results presented below are preliminary, especially as the processes involved may be slow starting but accelerate as certain critical thresholds are passed (such as dissolution of all available calcite, development of optimal pH conditions for sulphur-oxidizing bacteria (Thiobacillus ferrooxidans).

Because each cell has a different mineralogical matrix, it is probable that each cell will show different trends in the early part of the test (Appendix 5.1.1-2). Therefore, results will be described briefly for each cell.

Cell 01 - Hazelton Volcanics

From the first week, pH conditions have remained approximately neutral and have been matched by barely detectable acidity levels and undetectable (0.1 mg/l) dissolved iron. In contrast, sulphate levels have been very high, especially in the first two weeks during which

TABLE 5.1.1-5

PLACER-DOME - BERG PROJECT
CHARACTERISTICS OF HUMIDITY CELL SAMPLES

CELL	SAMPLE NUMBER	SURFACE AREA m^2/kg	TOTAL SULPHUR %	NEUTRAL. POTENTIAL	SULPHIDE SULPHUR %	SULPHATE %	CO_2 %	PASTE pH	NORMATIVE COMPOSITION PYRITE %	GYPSUM %	CALCITE %
01	29-260	11.0	4.63	13	4.1	3.13	0.5	8.2	7.88	4.43	1.14
02	93-208	11.3	1.68	5	1.43	0.13	0.2	6.2	2.67	0.18	<0.3
03	77-311	11.3	6.48	63	6.12	0.43	3.5	8.3	11.76	0.61	7.95

The normative composition is calculated by assuming that all sulphide sulphur is pyrite, all sulphate is in gypsum, and all CO_2 is in calcite.

sulphate levels on a surface area basis were more than 500 mg/m^2 neck. These levels were matched on an approximately 1:1 molar basis by calcium concentrations. Similarly conductance (which reflects total ion content) is also very high. These trends are consistent with the dissolution of gypsum and calcite (indicated by high levels of alkalinity determined initially) present in the samples in the early part of the test. Occurrence of significant sulphide oxidation to produce these levels of sulphate would be matched by high levels of dissolved iron and greater acidity. As the test proceeds, it is expected that all available gypsum and calcite will be dissolved and pH will drop as this buffering control is removed.

Cell 02 - Quartz Diorite

Lowest pH levels of the three cells have been observed and these are matched by relatively high acidities. A paste pH of 6.2 indicated that this rock had undergone weathering prior to testing. This is confirmed by week 1, pH of 4.8, high acidity, sulphate and iron levels due to dissolution of products of sulphide oxidation. Within two weeks, dissolved ion concentrations are very low, however pH levels are moderately acidic (5.4 to 5.5). This level of pH is more or less that of the deionized water used to leach the material and is not indicative of acid generation.

Cell 03 - Hazelton Volcanics

Cell 03 is any many respects similar to cell 01. Approximately neutral pH conditions and moderate alkalinity levels indicate buffering of the leachate waters by dissolution of calcite (estimated to be 8% in this sample). Calcium and sulphate levels are consistent with the dissolution of gypsum. Low iron concentrations and low acidities imply that pyrite oxidation is not yet proceeding at a detectable rate.

Preliminary Conclusions of Kinetic Tests

After 12 weeks of testing, oxidation of sulphides was not proceeding at a rate which is detectable. Acidity and iron concentrations, and pH are not within an order of magnitude of levels characteristic of rapid, high intensity acid generation observed elsewhere. It is not possible to predict whether conditions in the cells will change as to date there are no indications of trends towards rapid sulphide oxidation.

Three important controls on short term water quality have been identified:

- Dissolution of gypsum results in very high levels of calcium and sulphate in the leachate waters. Due to the high solubility of gypsum, exposed gypsum is removed within weeks of exposure under the humidity cell conditions. This dissolution reaction does not affect pH directly, though the ionic products may affect dissolution of calcite, liberation of alkalinity and the sulphide oxidation reaction.

- Dissolution of calcite buffers the leachate at approximately neutral conditions. In the short term, this releases alkalinity (as HCO_3^-) and may retard the sulphide oxidation reaction.

- Dissolution of the products of in situ sulphide oxidation may release a short term pulse of strongly acidic, metal-rich solution. Generally, the pulse is short-lived as the sulphide oxidation products are highly soluble.

5.1.1.4 Conclusions of acid generation testwork

Forty samples representing the three major rock types (diorite, Hazelton Volcanics, quartz monzonite) and depth from the surface were selected for acid-base accounting analysis. These data indicated that diorite and Hazelton Volcanics are potentially strongly acid generating. In these units, there is potentially an excess of acid generating pyrite compared to the amount of neutralizing minerals. The quartz monzonite stock contains the lowest levels sulphides some of which are unlikely to be available for acid generation. Therefore, parts of the quartz monzonite stock may not be acid generating and may not require special waste handling.

To estimate the rate of acid generation in the Hazelton Volcanics and diorite, three samples were selected for humidity cell testing. These results may be used to estimate the duration and intensity of acid generation and therefore provide a preliminary evaluation of what acid generation control technologies may be appropriate. Results after 12 weeks of leaching indicate that acid generation is proceeding at a slow rate and buffering by neutralizing minerals is occurring. During this period, high sulphate and calcium levels are consistent with dissolution of gypsum which is an abundant primary mineral. Low acidity, slightly acidic pH levels and undetectable iron concentrations (less than 1 mg/l) indicate that the acid generation is occurring at a low rate. Testing will be continued for at least another 18 weeks.

5.1.2 Hydrology

This section assesses, in a general way, the changes in hydrologic conditions an open pit mining project could have on surface water flows. The baseline hydrology information needed to carry out this assessment is contained in Section 3.3.2. Potential sources of hydrologic impacts include open pits, waste rock dumps and tailings ponds.

Pit drainage may require treatment and storage effects within the water treatment system would likely result in some minor changes in the hydrologic regime of upper Bergeland Creek (i.e. the distribution of monthly flows). However, because the drainage area of the pit (2.3 km^2) is relatively small compared to the total drainage area of Berg Creek upstream of Bergeland Creek (30.6 km^2), any changes or impacts are expected to be insignificant.

Mining ore at Berg will result in creation of a waste rock dump. Although the runoff from the dump may require treatment before discharge to Berg Creek, this process should not result in any changes to the hydrologic regime of Berg Creek or any significant hydrologic impacts.

Creation of a tailings impoundment in any drainage produces a net effect on the hydrologic regime by the removal (isolation) of a portion of the drainage area from the watershed drainage area. This occurs because of the necessity of isolating tailings from clean water flows. Depending on the total area of the drainage compared with the area of the tailings impoundment, a more or less significant flow reduction may result (including high, low and mean flows). After closure tailings impoundments are normally reclaimed to dry land or become tributary ponds of the drainages they are located in. Either option will usually result in return to normal flow regimes in affected drainages.

5.1.3 Water quality

The waters of Nanika and Kidprice lakes and Berg and Bergeland creeks are soft, of low alkalinity and slightly acidic; therefore receiving waters have a low capacity to buffer changes in water quality due to mine discharges, in particular, acidic mine drainage (AMD) and elevated metal concentrations. With low alkalinity the pH can fluctuate rapidly and very little input of AMD will cause significant drops in the pH of the creeks. The softness of the water results in lower toxicity thresholds for heavy metals, including copper and lead, to aquatic life and therefore results in lower government criteria for these metals for receiving waters with low hardness values.

Metal concentrations (particularly aluminum, iron, copper and zinc) which often exceed criteria do not allow for any dilution of mine water discharges by the receiving waters. The Ministry of Environment may allow a 10 percent increase over natural background concentrations if they exceed criteria, but if background concentrations are extremely elevated, then usually no further increase is permitted.

Copper levels reported for Bergeland Creek (up to 0.44 mg/L Total Cu; Norecol 1988) and Kidprice Lake (0.01 mg/L Total Cu at detection limit; Cleugh and Lawley 1979) are high. These high copper concentrations appear to be due to natural copper release from the Berg copper deposit as dramatic increases in copper concentrations were observed at Site Q7 downstream of the confluence of Berg Creek which contains elevated concentrations of copper (up to 0.87 mg/L). The high Total Cu value obtained for Kidprice Lake may be an analytical artifact and subsequent evaluation of the lake is required to confirm the data. As the background levels are elevated, discharge of mine or mill effluents would likely be regulated so as not to cause any additional increase in surface receiving waters above these levels.

The possibility of elevated of nitrogen levels, in particular ammonia, resulting from the leaching of blasting residue from the pit and waste rock storage areas may require examination. The low nutrient levels in the receiving waters indicate that nutrient addition would not likely be a problem provided it entered the system as nitrate (low toxicity) and not as ammonia (high toxicity).

In summary, any discharges whether intentional (for example, via discharge pipe or spillway) or as the result of seepage through the dam or pit walls would be required to meet receiving water standards applicable at the time of mine start-up.

5.1.4 Fisheries

The potential impacts on the fisheries resources associated with mine development primarily involve indirect effects on downstream fish populations and direct effects of habitat destruction or removal. Downstream effects could occur by alteration of stream flow regimes and degradation of water quality. The open pit, waste rock dumps, and tailings pond are potential sources of acid mine drainage, elevated heavy metals, and higher sediment loadings. Access roads are also a significant potential source of increased suspended sediment. In addition, the tailings pond could cause some loss of fish habitat associated with placement of the pond in Bergeland Creek upstream of Berg Creek, if on land tailings storage is used and this site is selected. The deposit site study area is not accessible to anadromous fish species (salmon and steelhead trout) due to the falls at the outflow of Kidprice Lake. Consequently, only resident fish species occur in the watercourses potentially affected by the proposed mine and these species are under the jurisdiction of the B.C. Ministry of Environment, Fish and wildlife Branch. The species in the mine area, usually of most concern to this agency, are rainbow trout, and to a lesser extent Dolly Varden char.

The baseline fisheries information suggests that North Berg and Berg creeks do not contain fish and Bergeland Creek supports only low number of Dolly Varden char, whereas the upper Nanika River is an important spawning and rearing area for rainbow trout and Dolly Varden char. Therefore, mitigative measures to minimize water quality and quantity impacts will likely key on the Nanika River due to its importance to fish production in the Nanika-Kidprice lakes area.

5.2 Potential Impacts on Terrestrial Resources

5.2.1 Soils and vegetation

5.2.1.1 Soils

Introduction

Project impacts on soil resources of mine and mill construction and operation will result from erosion, temporary soil removal and stockpiling and compaction on intensively developed areas. Permanent surficial materials removal for use in tailings and waste rock dyke construction and permanent covering of surficial materials by the tailings impoundments and waste rock dumps if on land storage is used will further impact soil resources. There is no, or very little, soil development in the open pit area and therefore deposit site impacts will be limited to areas at lower elevations and be confined to access/haul road areas.

Soil modifications that could occur as a result of these activities include changes in texture, bulk density, soil water relations (resulting from altered water table depths, changes to external drainage characteristics and overall slope form, and compaction), and short-term fertility levels.

During operations and at closure, natural revegetation and reclamation activities will ameliorate impacts on soils and surficial materials resources of most of the subalpine and lower elevations. Soils and surficial materials of the open pit, waste rock dumps and tailings ponds (if on land) will remain permanently altered.

Erosion

Erosion is a potential impact on soil resources of the project area. Soils disturbance resulting from roads and facilities construction and operation could result in sedimentation of several streams, including Red, Pump, North Berg, Berg and Bergeland creeks.

Sedimentation from pit development can be contained on site with an appropriately located sedimentation pond. Proper construction practices for the access/haul road between the mine and mill will limit sedimentation from this source into North Berg and Berg creeks.

The largest area of disturbance will occur at the mill and tailings pond site. The most likely location for these appears to be in the Bergeland Creek drainage. Properly timed and executed construction will be required to minimize soil erosion. During operation clean water diversion ditches and appropriately placed sedimentation ponds can be used to limit export of soil from disturbed areas.

Temporary soil removal and storage

Prior to facility construction at a mill site, surficial soils materials should be removed from the mill and tailings pond (if on land tailings storage is used) areas and temporarily stored at an appropriate location. These materials can then be used for reclamation at closure, or for progressive reclamation during operation. An overburden stockpile should normally be vegetated to inhibit erosion.

Impacts resulting from temporary removal and storage will include changes in texture, bulk density, micro-organisms, water relations, and fertility. Any changes resulting in reduced vegetation production capability can be ameliorated by reclamation techniques such as fertilizers.

Compaction

Soil compaction to varying degrees will result from mine development. Heavy compaction of underlying soil materials will occur at the mill site, administration and accommodation area, and on all roads. Less compaction is expected in association with development of the diversion ditches and dykes. Soil compaction can be alleviated where practicable by site regrading and ripping during final reclamation.

Permanent removal/covering

Some soils materials in the vicinity of the waste rock dumps and tailings impoundments (if on land storage is used) is normally removed and used for dyke construction. These materials would not be salvageable.

Soils and surficial materials underlying the tailings impoundments and waste rock dumps will be permanently covered by these facilities.

5.2.1.2 Vegetation

Vegetation impacts resulting from development of the Berg project would include vegetation removal over most of the mill and tailings pond area. Vegetation removal would result in wildlife habitat loss and a reduction in forestry capability for the duration of mining. Wildlife impacts are discussed in Section 5.2.2; forest capability is limited in the probable mill-tailings impoundment areas (Section 5.3.2).

Any harvestable and salvageable timber will likely require removal prior to facility development. The tailings pond area will be permanently altered. If it is reclaimed to a wetland, vegetation could be utilized by moose. Natural revegetation and reclamation activities at closure will result in rehabilitation of wildlife habitat at the mill area. The access/haul road to the mine should be resloped and revegetated to inhibit post closure erosion and sedimentation of North Berg and Berg creeks. The pit area is in the alpine and not presently vegetated.

5.2.2 Wildlife

Development of the mine could affect the local wildlife in several ways. The purpose of this section is to identify the potential impacts, assess their magnitude and importance, and recommend ways to avoid or minimize them.

5.2.2.1 Habitat effects

The various clearings associated with mine development (roads, work areas, waste dump sites) and areas occupied by buildings and equipment storage constitute temporary to permanent removals of wildlife habitat. For most species, other than the very small ones, such habitat losses constitute only parts of individual home ranges and insignificant proportions of population ranges. Successional vegetation changes associated with clearings may result in changes in faunal composition, but that effect would be small and very local (mainly along "edges") for small patch and linear clearings. In the timbered portion of the study area there is also some potential for forest fires caused by a variety of mine-related factors, such as sparks from machinery, stoves, trash fires, slash burning, and discarded cigarettes. Such fires would be locally detrimental to individual animals and some species in the short term, but would probably be beneficial to many (e.g., bears, moose, grouse) in the long term. Mining activity also has the potential for altering the distribution and quality of water, thereby reducing the capacity of local aquatic habitats to support various birds and certain furbearers.

In the Berg area, potential habitat effects would be greatest in the lower deposit site area, where the mill and tailings pond would likely be located, but would be relatively minor since they would involve only 1) summer moose and waterfowl habitat (not believed to be limiting in the area), 2) a portion of the individual range of one or two local large carnivores (bears, wolves, wolverine), and 3) the ranges of a relatively small proportion of the other, mostly smaller mammals (including furbearers) and birds in that area. It is likely that total changes in local production/numbers of all species in the Bergeland-Nanika Lowlands would be negligible, particularly in comparison to the potential habitat loss effects of the proposed Kemano II flooding. There would appear to be little opportunity for mitigation of the lowland habitat loss, other than to keep the surface area of the tailings pond as small as possible, and to generate a reclamation plan that focuses on wildlife needs.

5.2.2.2 Indirect effects on animals

One concern in relation to industrial activity in wilderness areas is the potential effect of "disturbance" on animals. Shank (1979) noted that behaviourial or physiological responses, such as escape movements and increased heart rates, may often be documented in relation to human-caused stimuli, but those responses are not clearly of any practical concern in the sense of causing population changes. Geist (1971, 1978) discussed some possible consequences of "harassment" of wildlife, including increased energy costs, adverse effects from physical exertion and temporary confusion, and range abandonment. Forced abandonment of particular ranges may result in loss of access to resources, increased predation, and/or (again) increased energy costs for existence. However, Geist (1978) indicated that potentially disturbing factors such as "noise" are not necessarily damaging in themselves. He noted that "...naive animals initially may spook from an unusual sound, but subsequent behaviour depends on experiences associated with that sound. If the sound persists and remains localized, and the animals can approach or withdraw of their own volition, it can be expected that they will soon ignore it." In some cases there is a time factor in consideration of disturbance. For example, prolonged local noise and activity may have a detrimental effect if undertaken at a critical time, such as during parturition, but may have no significant effect if conducted earlier or later.

At the Berg site, the potential for significant disturbance applies solely to mountain goats, and primarily in relation to the winter range area along Berg

Ridge. This potential problem cannot be adequately addressed without additional studies on the nature and proportional extent of goat occurrence in that area, as it may relate to specific development plans and schedules for mine construction and operation.

5.2.2.3 Direct effects on animals

The most pervasive of potential direct effects is in the "problem wildlife" category, with animals being killed deliberately in response to property damage or perceived threats to personal safety. There is also some potential for animals being poisoned by ingesting chemicals and/or certain exposed minerals associated with mining and milling operations.

In most areas, the potential animal control problem relates primarily to grizzly and black bears, but may also involve furbearers such as marten and wolverine. It is best prevented by attention to good garbage management. The potential for negative effects from toxic materials applies primarily to ungulates, which are well known to seek certain anions (particularly sodium) in natural licks (Cowan and Brink 1949, Stockstad et al. 1953, Hebert and Cowan 1971). In the Berg area, mountain goats are probably more at risk than moose, because a larger proportion of the local population might be involved. Whether a mineral/chemical problem is actually a threat at the Berg site is speculative, depending upon the chemical characteristics and location(s) of such materials, as well as the normal movement patterns of local ungulates. A potential mitigative action, should a mineral problem be identified, is placement of livestock salt blocks to attract and keep animals away from the potential problem area(s).

5.3 Potential Impacts on Resource Use

5.3.1 Land tenure

The projected mine development is located entirely on Crown Land and will not affect any private land ownership, dwellings or other structures in the area. All deposit site developments will occur on mineral claims held jointly by Placer Dome Inc. and Kenco Exploration.

5.3.2 Forestry

Little merchantable timber would be lost by mine and mill development. The mineral deposit is entirely in the alpine; the most probable mill site is in the Bergeland Creek drainage. An area of perhaps 2 ha would be required for the mill and an additional 9 km^2 for tailings impoundments, if on land tailings storage is used. The tailings could be stored in what is presently upper Bergeland Creek. No assessment of timber values of this area has been made, other than a subjective appraisal made by Envirocon (1981) which concluded that the majority of merchantable timber in the Nanika-Kidprice lakes area was located between the lakes, or away from any likely mine and mill developments.

5.3.3 Recreation

There are no parks, reserves or recreation sites that would be affected directly or indirectly by the Berg project. Recreational pursuits in the Morice Lake area were identified by Envirocon (1981) as mainly fishing and boating on the larger lakes and rivers. There is no estimate available of the extent of recreational use of the Nanika-Kidprice lakes area. Numbers are likely to be relatively small because the only access by land is hiking trails. Mine development would not be visible from Nanika or Kidprice lakes at water level and would not conflict with a wilderness experience. Mine development would have much less potential for impacts on recreation than logging in areas that give access to the lakes.

5.3.4 Hunting and guiding

There are presently no guiders camps on Nanika or Kidprice lakes and use of the area is very limited. No conflict with hunting or guiding would be expected from mine development at this time. Future use of the area may change, as logging roads improve access.

5.3.5 Heritage

Since no archaeological concerns were identified for the Berg property there are no archaeological impacts likely from deposit site developments.

6.0

Access Road Potential Impacts and Mitigation Options

6.0 ACCESS ROAD POTENTIAL IMPACTS AND MITIGATION OPTIONS

6.1 Introduction

Potential road access corridors were assessed for impacts on the following biophysical parameters: hydrology, water quality, fisheries, wildlife, resource use conflicts, and heritage.

Additional work in the engineering and environmental design and alignment of the access road will be required to assess and mitigate impacts. Careful route selection, sound engineering design, construction window scheduling and good construction practices are elements required in the following design stages for road access. If required, the section of the road build exclusively for mine access can be designated a private road with no access to the public. This will limit access for hunting and fishing along that part of the corridor.

6.2 Potential Impacts on Aquatic Resources

6.2.1 Hydrology

During the construction of the access road there is a potential for the following short term hydrologic impacts:

1. Changes in the local drainage patterns for the short time before the network of roadside ditches and frequent cross culverts allows runoff to return to its natural (or baseline) drainage pattern.

2. Changes in stream velocities, flow patterns and other hydraulic parameters as structures such as

culvert and bridges are put in place at access road stream crossings.

Careful adherence to proper construction procedures especially as they relate to stream crossing and erosion control should ensure that no significant impacts occur during the construction phase. As well, incorporation of Ministry of Environment design criteria and guidelines into the design of the stream crossings will ensure that during the operation phase of the road the stream hydraulics at the stream crossing will allow for the safe passage of both flood flows and fish.

6.2.2 Water quality

Water quality impacts would be limited to sedimentation from construction. Proper construction practices can be used to largely eliminate siltation of streams due to loss of soil to streams during construction or erosion once the road is constructed.

6.2.3 Fisheries

The high fisheries values along certain proposed access routes requires that suitable mitigation measures are employed to minimize impacts particularly in areas of high sensitivity. The following discussion provides an overview of potential fisheries concerns, identifies sensitive areas in general terms, and suggests mitigative measures based on the present understanding of the fisheries resources.

6.2.3.1 Potential concerns

Certain fish life history phases and habitats are particularly sensitive to disturbances associated with road construction. Spawning, rearing and migration activities are most sensitive to stream disturbance.

Specific and limited areas are generally used for spawning and require suitable substrate, water temperature and flow conditions. Alteration or destruction of spawning habitat from instream activities can occur at both the crossing and in downstream areas as a result of siltation. Silt deposition in spawning areas may cause filling of interstitial spaces within the substrate and result in the suffocation of incubating eggs or in the prevention of fry escapement from spawning gravels.

Alteration or destruction of rearing habitats may occur at road crossings resulting in a general reduction in carrying capacity. Crossing structures, bridges or culverts, and right-of-way clearing will alter existing habitat. Habitat alteration will also occur as a result of the placement of stabilizing material to armour the streambank and from deposition of large organic debris from right-of-way clearing during preconstruction or construction activities.

Adult fish movements to spawning or overwintering habitats may be blocked or delayed by improper placement of bridges and culverts, alienating reaches upstream of the barrier. Culverts in particular can cause velocity barriers during high flows which can result in delays to fish movements to spawning areas, and reduced spawning success.

6.2.3.2 Areas of sensitivity

Important stream crossings along the proposed access route are those which will require bridge crossing in areas of moderate to high fisheries values. The most sensitive of the major crossings is considered to be the lower Nanika River. This river has high fisheries values, particularly for sockeye, coho and chinook salmon, steelhead trout and resident rainbow trout. The proposed crossing is located at major spawning and rearing areas for sockeye, coho and chinook salmon and rainbow trout (Figure 4.2.2-1). The upper Nanika River is another area of high sensitivity due to its importance to trout and char populations in Nanika and Kidprice lakes. Stepp Creek has moderate to high sensitivities since it is a spawning and rearing area for fish populations in Stepp Lake and possibly Kidprice Lake.

The Mystery River (Ney Creek) crossing, located about 6 km upstream of Kidprice Lake, has moderate fisheries values since it supports a resident population of Dolly Varden char.

6.2.3.3 Mitigation

The crossing of the lower Nanika River is probably the site with the greatest potential for concern for impact on fisheries values. Salmon and trout spawning and egg incubation occurs in this river downstream of the crossing. This location is also a major rearing area for juvenile salmonids, therefore, disturbance of sensitive rearing habitats such as side channels, debris accumulations, and low velocity areas should be minimized. Envirocon (1984) identified Reach 2 of the lower Nanika River (Figure 4.2.2-1) as the least sensitive area for spawning and rearing due to higher water velocities and larger substrate. This area is the narrowest portion of the lower Nanaka River and appears to be a preferable crossing location.

Similar construction timing would be anticipated for the crossings of the upper Nanika River and Stepp Creek, but more flexibility may be allowed since these populations are resident. Other streams crossed by the proposed access road either have no fish or have low densities of resident Dolly Varden char. Therefore, the construction schedule for those streams need not be as stringent as streams with higher fisheries values.

Removal of riparian vegetation along fish-bearing streams should be minimized. Clearing and grubbing should not extend beyond the required area for cut and fill. Culverts and bridges must allow fish passage at all times of the year. All streams should be retained in their natural channel above and below the road crossing. Vegetation cut for survey lines and removed during road construction should not be left in any watercourses.

Specific mitigation techniques for environmentally sensitive crossings should be developed after the detailed survey work is conducted with input through discussions with appropriate government agencies. Site specific engineering designs, methods of sediment control and, possibly, relocation of stream crossings which could cause significant unavoidable impacts on fisheries resources, will need to be detailed once the final alignment has been chosen.

6.3 Potential Impacts on Terrestrial Resources

6.3.1 Soils

Soils on the access road will be removed over a 10 m wide area for the length of the road. Depending on method of construction, these soils may be available for regrading and resloping of the road right-of-way upon mine closure. The major potential impact from road construction is erosion.

Erosion mitigation measures available for mine access roads consist of diversion ditches and associated erosion control structures. These will minimize sediment loss during the construction and operation phases. Localized slumping of side-cast materials may be expected to occur.

Increase in sediment loadings to streams from the access road will be minimal after the construction phase. Vegetation cover established during the construction and operation phases by natural revegetation and reclamation will further ameliorate soil erosion and resultant stream sedimentation. Final reclamation by resloping and revegetation can provide long term erosion control.

6.3.2 Vegetation

Impacts on vegetation along the access corridor will consist principally of removal of commercial forest cover. Merchantable timber on the 10 m right-of-way will require harvest by the forest company holding the timber lease at the time of construction. Vegetation removal will result in some wildlife impact (discussed in Section 6.3.3). Natural revegetation and reclamation activities at closure will result in rehabilitation of wildlife habitat along the corridor. Relatively unpalatable species such as alder are normally used to stabilize steep slopes and drainages in an effort to minimize traffic on these areas until stabilization has been achieved. Grasses and legumes can be used to achieve quick ground cover on most other areas. Relatively rapid natural succession should occur throughout the corridor and will result in rapid natural reforestation over most the access corridor.

6.3.3 Wildlife

Previous sections (4.1.3.2 and 4.2.3.2) have described the wildlife and habitats existing along the proposed access corridor options. Construction of a road and subsequent operation of vehicular traffic along it may affect wildlife in a number of ways. The purpose here is to identify the potential impacts, describe their magnitude and importance, and recommend ways to avoid or minimize them. The following paragraphs discuss the major kinds of potential impacts as related to particular species or species groups. The items are listed in order of their perceived importance (least to highest), in the context of a new road although, as summarized in Table 6.3.3-1, there is variation among species in local vulnerability to particular impacts.

6.3.3.1 Habitat effects

Clearing a road corridor will permanently remove a linear cross section of all habitats crossed along the selected route. As for the small clearings associated with deposit site developments (Section 5.2.2), that will involve only parts of individual home ranges and/or insignificant proportions of population ranges for most

TABLE 6.3.3-1

SUMMARY OF POTENTIAL WILDLIFE IMPACTS ALONG PROPOSED ACCESS CORRIDORS TO THE PLACER DOME BERG PROPERTY, NORTHCENTRAL B.C.

Entries in the table indicate maximum potential impacts (i.e., assuming no mitigation), on a subjective relative scale of 0-4:
0 - No impact Expected.
1 - Minor impact possible   2 - Minor impact likely
3 - Major impact possible   4 - Major impact likely

LOCATION[1]	POTENTIAL IMPACTS[2]					
			MOBILITY			
SPECIES	HABITAT EFFECTS	DISTURB.	MIGR.	PRED.	COLLISION	ACCESS
A-B (OPTION 1)						
Moose	0	0	1	0	1	0
Mountain Goat	0	0	0	1	0	0
Caribou	0	1	1	1	1	3
Grizzly Bear	0	0	0	0	0	1
Other Mammals	2	1	0	0	2	1
Birds	2	1	0	0	2	1
B-C (OPTION 1)						
Moose	0	1	1	0	1	2
Mountain Goat	0	1	3	3	1	4
Caribou	0	1	1	1	1	3
Grizzly Bear	0	1	0	0	0	2
Other Mammals	2	1	0	0	2	1
Birds	2	1	0	0	2	2[3]
B-D (OPTION 1)						
Moose	0	1	1	0	1	2
Mountain Goat	0	1	0	1	0	3
Caribou	0	0	1	1	1	1
Grizzly Bear	0	1	0	0	0	2
Other Mammals	2	1	0	0	2	1
Birds	2	1	0	0	2	2[3]
G-H (OPTION 2)						
Moose	0	1	3	1	1	2
Mountain Goat	0	1	0	3	0	3
Caribou	0	1	0	0	1	1
Grizzly Bear	0	3	0	0	0	4
Other Mammals	2	1	0	0	2	3[4,5]
Birds	2	1	0	0	2	2[6]

continued . . .

TABLE 6.3.3-1 (continued)

SUMMARY OF POTENTIAL WILDLIFE IMPACTS ALONG PROPOSED ACCESS CORRIDORS TO THE PLACER DOME BERG PROPERTY, NORTHCENTRAL B.C.

LOCATION[1]	POTENTIAL IMPACTS[2]					
			MOBILITY			
SPECIES	HABITAT EFFECTS	DISTURB.	MIGR.	PRED.	COLLISION	ACCESS
H-D (OPTION 2)						
Moose	0	1	3	1	1	2
Mountain Goat	0	1	0	3	0	3
Caribou	0	1	1	1	1	1
Grizzly Bear	0	1	0	0	0	1
Other Mammals	2	1	0	0	2	1
Birds	2	1	0	0	2	1
H-E (OPTION 2)						
Moose	0	3	3	1	2	4
Mountain Goat	0	0	0	0	0	0
Caribou	0	0	1	0	1	1
Grizzly Bear	0	1	0	0	0	3
Other Mammals	2	1	0	0	2	2[4,5]
Birds	2	2	5	0	0	2[6]
D-E (OPTIONS 1 & 2)						
Moose	0	1	1	0	1	2
Mountain Goat	0	1	0	1	1	3
Caribou	0	0	1	1	1	1
Grizzly Bear	0	1	0	0	0	2
Other Mammals	2	1	0	0	2	2[4]
Birds	2	1	0	0	2	2[3]
E-F (OPTIONS 1 & 2)						
Moose	1	1	0	0	1	2
Mountain Goat	0	1	1	1	1	3
Caribou	0	1	1	1	1	1
Grizzly Bear	1	1	0	0	0	2
Other Mammals	2	1	0	0	2	2[4]
Birds	2	1	0	0	2	2[3]

continued . . .

TABLE 6.3.3-1 (concluded)

SUMMARY OF POTENTIAL WILDLIFE IMPACTS ALONG PROPOSED ACCESS CORRIDORS TO THE PLACER DOME BERG PROPERTY, NORTHCENTRAL B.C.

LOCATION[1]	POTENTIAL IMPACTS[2]					
			MOBILITY			
SPECIES	HABITAT EFFECTS	DISTURB.	MIGR.	PRED.	COLLISION	ACCESS
F-C (OPTIONS 1 & 2)						
Moose	0	0	0	0	0	0
Mountain Goat	1	3	1	3	1	3
Caribou	0	1	1	1	1	1
Grizzly Bear	0	1	0	0	0	1
Other Mammals	2	1	0	0	2	1
Birds	2	1	0	0	2	2[3]

1 Location: Corridor segments as shown in Figure 4.1.3-1 (A-H), and road option (1-2).

2 Potential Impacts: HABITAT EFFECTS (loss and/or successional changes due to clearing); Disturbance (effects of construction/operation-related noise and activity, or deliberate harassment); MOBILITY: (MIGR. - Interference with seasonal movements; PRED. - Facilitating predator access); COLLISION (Wildlife-vehicle collisions); ACCESS (effects of hunting, poaching).

3 Grouse and/or ptarmigan.

4 Black bear.

5 Carnivore furbearers, especially wolverine, wolf, river otter, and marten.

6 Waterfowl.

wildlife species. Successional vegetation changes associated with clearing may result in changes in faunal composition, but that effect would also be small, very local and directed primarily to small species for linear clearing. As at the deposit site, a fire caused by activities of road-related construction or subsequent road users would be detrimental to some species in the short term, but probably beneficial to many (e.g., moose, bears, grouse) in the long term.

6.3.3.2 Disturbance

The general comments about the potential effects of disturbance at the deposit site (5.3.3) apply also to road construction and operation. Among northern ungulates, moose are generally thought to be about the least "sensitive" to stimuli such as strange or loud noises, including those from aircraft and other large machinery (Peterson 1955, Mutch 1977). There appears to be some chance that grizzly bears might be adversely affected by disturbance along the lower Nanika River, if it were to keep them from using the rich fish resources in the area. However, other local effects (e.g., increased local hunting and poaching) would probably mask any disturbance effect. The potential for serious disturbance effects seems greatest for mountain goats within a few km of the deposit site; mitigation of those effects would depend upon the as yet unknown nature and extent of the animals' use of that area.

6.3.3.3 Animal mobility effects

Linear developments across important seasonal migration routes or other regularly used animal movement corridors have the potential for interrupting or preventing movements. It seems prudent to assume that regular movements are not frivolous, i.e., are undertaken because they enhance survival, therefore such interference is potentially serious, particularly for ungulates. As listed in Table 6.3.3-1 under "Migration", the potential for this kind of effect may be greatest for mountain goats using the winter range near the deposit site, and for moose along the Nanika-Kidprice lowlands. The best mitigation is avoidance of heavily used migration corridors.

The proposed road may also alter present ecological relationships in the area, by enhancing the mobility of some species in winter. In particular for the present study area, wolves are not normally present in winter, probably because food sources are too scattered to warrant the great expenditure of energy necessary to travel through the deep snow to them. However, a cleared roadway may enable them to penetrate the area with relatively little effort, and make inroads on mountain goats concentrated on the relatively few slopes they use in winter (Tableland and Kidprice Mountains, and the Tahtsa Range near the deposit site). Caribou, if present in the area in winter, would be also be subject to such opportunistic predation. There is no universally accepted mitigation for this problem, other than avoidance of the important ungulate ranges to the extent possible.

6.3.3.4 Vehicle/wildlife collision

There is a large body of literature devoted to describing the nature and extent of wildlife losses, property damage, and human casualties resulting from collisions with wildlife on human transportation corridors (e.g., Guiguet 1978, Damas and Smith 1982). There has also been some research directed to reducing the incidence of wildlife collisions, especially in the Rocky Mountain national parks (e.g., Harrison et al. 1980). Exacerbating factors include growth of roadside vegetation that attracts wildlife to road corridors, snow effects on animal mobility, and excess vehicle speed. It can be expected that individuals of the smaller species will be killed along most roadways, but there are rarely any population implications for such losses. Individuals of most of the larger species are also at risk, but less so than in areas where ungulates and their predators concentrate, for winter, in roadside habitats. Signs and speed restrictions at known crossing sites are the primary means for mitigating the potential collision problem.

6.3.3.5 Access effects

A consistent concern in relation to transportation developments in wilderness is that they may provide a new source of access to potential users and abusers of fish and wildlife resources, usually with no concomitant increase in local monitoring and enforcement capability. Regulations such as road closures (no transportation of hunters or game), "no shooting" or "no hunting" areas within specified distances from corridor centre lines, limited entry, ATV and snowmobile closures, and local species closures are all potentially applicable. However, local regulations do not, by themselves, protect wildlife because poachers, by definition, do not observe regulations.

In the present study area, the highest perceived access risks are for grizzly bears along the lower Nanika River in the summer/fall period, moose in the Nanika-Kidprice lowlands, and mountain goats at Tableland Mountain, Kidprice Mountain, and in the northern Tahtsa Range. The negative effects of access development on mountain goats has been well documented elsewhere in B.C. (Phelps et al. 1983), and officials are becoming increasingly concerned on the effects of new access to wilderness grizzly bear populations (Peek et al. 1987, Tompa 1984). The best mitigation is to restrict road use, as required and in consultation with the local management agency. Secondarily, it is important to keep the areas where wildlife may be most vulnerable, as identified above, so that they are relatively inconspicuous and/or inaccessible from the road.

New access may also stimulate and/or make feasible additional resource extraction activities, such as logging, resulting in a multiplication of potential impacts beyond those presently understood in consideration of the road itself. It should be noted that logging is currently occurring as far south as Tableland Mountain and northwest of Twinkle Lake on the Nadina River road. Commercial timber harvest in the Nanika-Kidprice lakes area is presently not scheduled for 20 years, however.

6.4 Potential Impact on Resource Use

6.4.1 Land tenure

Land tenure has been discussed in baseline sections (3.4, 4.1.4 and 4.2.4).

6.4.2 Forestry

Logging is presently occurring in both the eastern and northern access corridors and will continue to move south in the northern access corridor and west in the eastern access corridor. Mine access construction before logging reaches the general project area would likely be viewed as a positive, rather than a negative, impact on logging, as it would provide access to timber at no cost to logging companies or the Crown.

6.4.3 Recreation

The recreational potential of the eastern corridor is limited because of the lack of lakes or rivers. Improved access would increase recreational potential of the area for stream fishing and hunting. The northern corridor crosses a canoe-hiking trail in the Chain lakes area and would therefore potentially present some conflict. Logging road construction may reach the trail site before mine development and any perceived recreation conflict will have to be resolved at that time.

6.4.4 Hunting and guiding

Access roads will increase hunting opportunities in the study area beyond what is currently provided by logging roads, unless the area is closed to hunting by Ministry of the Environment, Fish and Wildlife Branch. In this sense roads will have a positive impact for use of the resource.

Some reduction in potential for wilderness fly-in hunting by guided parties may be experienced at Nanika and

Kidprice lakes, although this activity is not currently being carried out at these lakes.

6.4.5 Heritage

Only two potential direct impacts to archaeological resources were identified during this study; both are located in the northern corridor.

The first is a lithic scatter/general activity site possibly used as a hunting camp during game migrations. Only flake scatters had been reported at this site prior to the present study which recovered two artifacts. Additional artifacts may be present.

The second is the possibility of a cache pit located on Stepp Creek. It is clear from proposed models of Athapaskan adaptation to the study area, and from Athapaskan adaptation in similar environments elsewhere, that it is part of the archaeological record of the study area.

Although the northern corridor has the greatest potential to impact recorded archaeological sites, it should be possible to avoid direct impacts with minor route realignments. The eastern corridor will not impact any recorded archaeological sites. Detailed engineering studies of route alignments are required before further archaeology studies are conducted.

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