KER, PRIESTMAN & ASSOCIATES LTD.

ENVIRONMENTAL EVALUATION

FOR

CADILLAC EXPLORATIONS LIMITED

PRAIRIE CREEK PROJECT, N.W.T.

File: 1561

October, 1980

Ker, Priestman & Associates Ltd.
Consulting Engineers
300 - 2659 Douglas Street
Victoria, B. C.
V8T 4M3

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KER, PRIESTMAN & ASSOCIATES LTD.

consulting engineers

300 - 2659 Douglas Street, Victoria, B.C. V8T 4M3
Telephone (604) 388-6676 Telex 049-7449

23 October 1980

Our File: 1561

Department of Indian Affairs
and Northern Development
Northern Affairs Program
P. O. Box 1500
Yellowknife, N.W.T.
X1A 2R3

Attention: Mr. A. G. Redshaw, P. Eng.
Assistant Director
Renewable Resources

Dear Sirs:

Cadillac Explorations Limited
Environmental Evaluation for
Prairie Creek Project

We are pleased to submit, on behalf of Cadillac Explorations Limited, twelve (12) copies of the Environmental Evaluation for the Prairie Creek Project, covering the mine, mill, camp and winter road.

We trust that your staff will undertake the distribution of these reports to the appropriate regulatory agencies.

Yours very truly,

KER, PRIESTMAN & ASSOCIATES LTD.

N. I. Guild, P. Eng.
Manager, Water Resources & Mining
Development Division

JBB/dl

1. SUMMARY

Cadillac Explorations Limited propose to bring into production during 1980 and 1981, their lead-zinc-copper-silver property at Prairie Creek, N.W.T. This report has been prepared for the purpose of outlining the project, the environmental setting and potential impacts of the mine, mill and camp development. The impact of the winter access road to the property has also been addressed.

Two earlier reports entitled "Preliminary Environmental Evaluation for Mine, Mill and Camp" and "Preliminary Environmental Evaluation for Winter Access Road" were prepared for the project and were submitted during May, 1980. Relevant data from both these reports has been included or summarized in the text of this report and has been amplified by spring and summer mining, environmental, geotechnical and hydrological field and desk studies.

Mine, Mill and Camp

The Cadillac property is located at approximately 61°33'N latitude and 124°48'W longitude, adjacent to Prairie Creek, 27 miles upstream of its confluence with the South Nahanni River in Nahanni National Park. Twelve mineralized occurrences extend over a zone 6½ miles long within four mineral leases covering an area of 6659 acres. Zone No. 3, which is scheduled for initial production, lies near the confluence of Harrison Creek and Prairie Creek.

Production at a milling rate of 1000 tons per day is proposed utilizing a total personnel complement of 221, of which 159 would be present at the site at any given time. On the basis of proven, probable and possible ore reserves, a mine life of approximately six years could be supported. The presence of as-yet undeveloped reserves within the other mineralized zones would suggest the possibility of further extending the life of the operation.

Cut-and-fill stoping, supplemented by shrinkage stoping, will be utilized as the mining methods, the former maximizing the volume of mill tailings returned to the mine. The mill process currently envisaged is a selective flotation of lead, zinc and copper concentrates employing methods and chemical reagents which are standard in the industry. The copper concentrate (containing most of the silver) will be shipped primarily by air on a daily basis, with the lead and zinc concentrates stockpiled for annual shipment over a winter road.

Wastes from the operation are those normally generated from a mining development and will include sewage, garbage, air emissions from the mine and mill, mine waste rock, mine water and tailings. Sewage will be treated in an extended-aeration, activated-sludge

treatment plant, complete with chlorination facilities. Combustible garbage will be burned and incombustible refuse will be compacted and landfilled. Emissions to the air include mine ventilation, diesel generator exhaust and emissions from standard mill equipment such as crushers and an assay laboratory. Dust abatement equipment is to be employed on those emissions which require it. No thermal drying or smelting operations are to be carried out.

Quantities of waste rock will not be large and this material will find use as mine backfill and in road construction. Drainage from waste rock and from the mine is not expected to be acidic due to the preponderance of carbonate minerals in the host rock. However, subject to verification as to its need, a treatment plant would be provided in order to remove any substances which might be present in unacceptable concentrations.

A number of sites have been identified for potential use as tailings storage, several of which would occupy side-valleys of Prairie Creek and others which would be located at the foot of the slopes bounding the Prairie Creek floodplain. The relative advantages and disadvantages of each have been investigated and it has been concluded that two sites along Prairie Creek are suitable for development as tailings impoundments. Of these two sites, the location closer to the minesite, near Harrison Creek, has been recommended.

As noted below, the tailings pond will incorporate a number of positive environmental features which include:

- essentially zero seepage
- no pond decant
- complete isolation from aquatic systems
- protection from maximum possible flood levels
- close proximity to plantsite facilitating short pumping distances and close monitoring
- long-term pollution-free storage due to no acid-generating capability.

Geotechnical studies consisting of a drilling programme, sampling and laboratory evaluations of soils and sub-soils, and engineering design of embankments have confirmed the viability of the selected site with respect to its foundation conditions, storage capability, engineering properties of dam fill material, and impermeability to seepage flows. An essentially water-tight system appears technically and economically feasible due to the abundance of sub-surface clay deposits.

The tailings embankment, as designed for a six-year mine life, would be 20 to 30 ft. high and 2600 ft. long; the pond would occupy an area of approximately 25 acres.

Tailings have been shown to have no net acid-generating capability, thus eliminating concern relative to the long-term pollution potential of the pond. Efforts have therefore been directed at ensuring the stability of the impoundment, its long-term protection from flood waters and the maintenance of a negative water balance.

Analysis of climatic and hydrological data for Prairie Creek has demonstrated the need for augmentation of existing flood control dykes on this stream. Dykes adjoining the plantsite are to be constructed to withstand a 100-year return period flood with a generous freeboard allowance. Tailings pond embankments will, at their minimum height, be built to the elevation of the maximum possible flood. Hydrological analysis has also facilitated the preliminary sizing of tailings pond diversion works, culverts and runoff channels.

In order to obtain environmental baseline information, office and field studies of water quality, aquatics, vegetation, wildlife, soils, socio-economics, archeology, climate and hydrology have been carried out. For some of these studies, field work was performed during two periods - April and July, 1980.

During the April aquatics study, Harrison Creek (adjacent to the mine) was judged to have a low habitat potential and Prairie Creek was considered to have a low to moderate habitat potential for fish. The July survey did not change this assessment but indicated that limited numbers of Dolly Varden char utilize Prairie Creek as adult summer habitat and as a rearing area. The only other fish found in the region of the minesite were sculpins. Few suitable overwintering areas were evident. Both whitefish and Arctic grayling were found at the mouth of Prairie Creek some 27 miles downstream of the minesite. Other fish species reported (but not observed) in the lower reaches of this stream were burbot, white sucker, longnose sucker and lake trout.

Aquatic invertebrate sampling was carried out in order to provide a baseline upon which possible future changes in water quality could be judged. Prairie Creek exhibited fairly wide fluctuations in the biological indices characterizing the invertebrate communities; these were considered to be a result of changes in natural conditions along the stream course.

Sampling of surface water, mine water, ground water, and sediments at the minesite was carried out. Prairie Creek and Harrison Creek surface waters were found to be slightly alkaline, and to have moderate hardness and low levels of trace elements. Groundwater samples taken from boreholes and the existing water well contained higher levels of calcium, sulphate and dissolved solids than recorded for surface waters. One groundwater sample taken from a borehole in the Harrison Creek alluvial gravels showed an abnormally high zinc level.

The vegetation study confirmed that the plantsite vegetation is dominated by white and black spruce, with lesser numbers of balsam poplar and tamarack. The understory is composed of willows, shrubby cinquefoil, Canadian buffalo-berry, dwarf birch, labrador tea, lapland rose-bay,ground juniper and others. Ground flora is composed of many species of prostrate shrubs, herbs, sedges, mosses and lichens. In a number of previously cleared areas, invading species were noted.

Wildlife surveys in the region of the minesite were principally directed at identifying the general abundance and seasonal distribution of woodland caribou and Dall's sheep, and identification of areas of special sensitivity such as calving and lambing areas and nursery sites. Only two woodland caribou and scattered tracks were observed within a radius of six miles of the mine. With respect to Dall's sheep, 47 - 49 animals were observed. The surveys confirmed the scattered distribution of these ungulates and the limited summer habitat usage near the mine. Additional surveys in the minesite area are proposed to better define winter range and calving and lambing areas for caribou and sheep.

Other animals known to exist in low densites are wolves and bears. Aquatic furbearer habitat is poor and no traplines presently exist in this area.

During the minesite summer survey, three golden eagles were sighted, but no raptor nest sites were found. In addition, three remote sightings of unidentified falcons were made, one approximately four miles southwest and two approximately seven miles north of the mine.

Additional socio-economic studies were not carried out for this phase of the project. However, as stated in the Preliminary Environmental Evaluation, the Cadillac mine should not impose any demands on the existing community services of the N.W.T., but at the same time, will provide employment opportunities and contribute substantial economic benefits. Cadillac will endeavour, over time, and in co-operation with government to increase the proportion of benefits directed to the local economy. Thus, the economic impact of the mine is expected to be strongly positive.

Potential environmental impacts which could affect the aquatic or wildlife resources of the area include disturbance, deposition of waste, erosion, siltation, potential toxicity from spills and effluents, and failure of major structures due to washout. Measures which have been proposed in order to prevent or minimize these effects include:

- isolating the plantsite area and tailings pond from Prairie Creek by dykes,
- design and operation of the tailings pond as a closed, seepage-free system,

- chemical treatment and positive control of all water discharges.
- spill contingency planning,
- reclamation and revegetation,
- good garbage disposal practice (incineration, compaction and landfill),
- monitoring
- restriction of firearms.

These matters will be under the direct responsibility of an Environmental Supervisor, resident at the site.

On the basis of studies carried out to date, the only residual impact anticipated after mine abandonment would be the visual presence of the tailings impoundment. However, over time, the visibility of this landscape alteration will diminish as reclamation efforts take effect. At no time during or after the period of mine operation are any significant deleterious effects upon Nahanni National Park expected to occur.

Winter Road

As the access road is being constructed for winter use only, many of the environmental considerations relative to all-weather routes are not pertinent. For this road, no permanent bridges or culverts are proposed and water crossings are to be carried out on snow or ice bridges, thus reducing effects upon fish and aquatic habitat. Traffic will occur over frozen ground, hence organic deposits and vegetation should not be disturbed. Due to the restricted period of use (December - March), impacts upon ungulate calving and lambing and raptor nesting will be minimal. Whenever possible, existing seismic lines or winter roads will be utilized.

The proposed winter access route heads generally southeasterly from the mine, crossing in turn the eastern portion of the Mackenzie Mountains, the Mackenzie Plain, the Nahanni Mountains and the western portion of the Interior Plateau prior to crossing the Liard River and joining up with the Liard Highway, about 20 miles northeast of Nahanni Butte. The accessibility of the mine will be enhanced by the completion, to all-weather standards, of the Liard Highway between Fort Nelson and Fort Simpson.

Once constructed, the winter road would be usable for approximately 100 days each year. It is during this period that large construction vehicles, mill equipment and supplies would be transported to the site. Movement of material during the remainder of the year would be restricted to items which could be handled by small aircraft utilizing the existing 3000 ft. gravel airstrip at the site.

During the operational phase of the mining development, lead and zinc concentrates will be shipped over the winter road and the Mackenzie Highway to Enterprise, and thence to market via C.N.Rail or, alternatively, via the Liard Highway to Fort Nelson and onto the B. C. Railway.

Construction of the winter road is now complete to Mile 20 - 25 and the route has been surveyed to Mile 54.

The watercourses traversed by the proposed route are contained within the South Nahanni, Liard or North Nahanni drainage basins. Fish of commercial or sporting significance in these systems include Arctic grayling, whitefish, northern pike, burbot, sucker, walleye, chum salmon and Dolly Varden char.

However, the only streams of any size near the proposed winter road are Prairie Creek which is paralleled at the western end and the Liard River which is crossed at the eastern end. Smaller streams include Grainger River, Fishtrap Creek and Tetcela River. A survey of these streams was carried out both in April and July, 1980.

Of these lesser streams, suitable habitat and significant fish populations have been found to be mainly restricted to the Tetcela River with Arctic grayling, lake chub, whitefish, northern pike and sculpin observed. On the basis of the investigations, the system is believed to be utilized as Arctic grayling adult summer habitat and as a nursery and rearing area, and possibly for spawning. Other species were noted and these may also spawn in the Tetcela River.

The Liard River has been reported to be utilized as an over-wintering area and a spawning migration route for many fish species; species which are found in this system include longnose sucker, northern pike, yellow walleye, lake cisco and lake whitefish. Lesser habitat suitability and fish populations were noted at other sites investigated.

Further aquatic surveys will include an evaluation of over-wintering fishery potential and spring spawning of Arctic grayling along the winter road.

Both aerial and ground reconnaissance of vegetation along the winter road route was carried out. These investigations revealed a variety of vegetation communities including floodplains dominated by willow and white or black spruce, lichen-dominated communities, barren areas, mixed forest of black spruce, white spruce, tamarack and white birch, seasonally waterlogged areas, shrub meadows and forest stands. No specialized habitats were noted except, possibly, the falls area near the western end of the road. Several species of special interest in the N.W.T. were observed.

Prior to the present investigations, no studies of ungulate populations are known to have been carried out in the area of the proposed road corridor. The focus of this study was the evaluation of woodland caribou, Dall's sheep and moose habitat.

Previous government reports have indicated the presence of scattered groups of woodland caribou and Dall's sheep along the western portion of the road. A lack of sedge meadows preferred by caribou would suggest a low density of these animals. In the Nahanni Range, no caribou were observed, but six Dall's sheep rams were observed north of the Grainger Pass and six sheep were observed south of the pass. These sightings confirm previous reports of sheep populations throughout the Nahanni Range. It is expected that this area provides good winter range for sheep.

Based on the survey data, greater numbers of moose than caribou are believed to exist east of mile 35 along the road route to the Nahanni Range during the summer. It has been reported that the valleys of the Tetcela River, Fishtrap Creek and Liard River are excellent winter range for moose.

In order to collect additional baseline data for the winter access road, on-going studies are to be carried out relative to sheep, moose and caribou winter range.

Twenty-eight wood bison were released approximately four miles west of Nahanni Butte in June, 1980. Since their release, all are believed to have moved south of the Nahanni and Liard Rivers.

Three trapping areas occur on land transected by the proposed winter road near its eastern extremity. Fur harvests are considered low.

Other mammals sighted or known to exist along the road corridor include black bear, grizzly bear, wolf and Arctic ground squirrels.

Raptor surveys in the Nahanni Range resulted in the observation of two active Golden Eagle nests, located 1.1 and 2.5 miles north of the road route, respectively. No falcon nests were sighted. A group of six Trumpeter swans was observed on a small lake east of the Silent Hills and south of the proposed road. One other unconfirmed sighting was made during an earlier survey in an area well south of the road. Due to the distance of these sightings from the winter road and its use during the winter only, few effects upon raptors or other sensitive birds are expected.

Other aquatic birds recorded were ducks, loons, grebes, coots and shorebirds. No geese were observed in the summer, but five snow geese were sighted near the Silent Hills during the April, 1980, survey.

A potential for environmental degradation along the road exists during the construction phase of the project particularly with respect to the stability of cuts and fills, disturbance of organic soils and permafrost and disposal of garbage. The only potentially toxic substance expected to be used during road construction would be diesel fuel. The handling, storage and transportation of this material will be carried out with due regard for its potential for damage to aquatic systems. All of the above factors will be under the control of geotechnical personnel during road construction in order to ensure a minimal impact on aquatic resources, wildlife, vegetation and soils along the route.

A spill contingency plan has been outlined which forms the basis for spill prevention and response actions with respect to transportation of chemicals to and from the mine during the operational period.

As discussed in the Preliminary Environmental Evaluation for the Winter Access Road, the major negative social impact of the road, as determined by interviews with citizens and government officials in nearby communities, was seen to be possible random settlement along or near the route and increased access to a wilderness area. The latter may be a negative impact with respect to the success of guides and trappers, but might be considered positive for the general population. However, increased accessibility will only be a factor during the winter months, as the road will not be passable at other times.

In summary, the proposed road should have minimal negative impact, both sociologically and environmentally. This is due to the construction to winter standards and use during the winter only, the few water crossings of significance to be made, indications of limited utilization of the area by wildlife and fish, and the economic spin-offs from the project such as employment, further diversification of the economic base of nearby communities and utilization of local supplies and services.

2. INTRODUCTION

2.1 General

Full-scale production of metal concentrates from the Prairie Creek property of Cadillac Explorations Limited will require, during 1980 and 1981, the phased development of the underground mine (currently underway), expansion of the existing camp, construction of a flotation mill to handle the ore containing lead, zinc, copper and silver, and the establishment of an essential 100 mile winter access road from the Liard River to the property.

This report deals with both the mine/mill/camp and winter access road portions of the development and brings together all relevant desk studies, spring and summer field work, and concerns of government agencies arising from their review of the Preliminary Environmental Evaluations for the mine/mill/camp and winter access road which were submitted during May, 1980.

Several consultants have participated in the preparation of this report. Golder Associates Ltd. advised on geotechnical matters relative to site selection, foundations and tailings pond construction. Environmental input concerning aquatics, wildlife, vegetation, soils, archeology, resource use, and socio-economics originated with Beak Consultants Ltd. Acid-generation tests were carried out by B. C. Research. Ker, Priestman & Associates Ltd. acted as project manager for the environmental work and, in addition, carried out the site survey, the hydrology and climate analysis, and assisted in the conceptual layout of the tailings disposal system.

Most of the project description, including the mining plan and mill process flowsheet has been obtained from the Definitive Feasibility Study prepared by Kilborn Engineering Ltd. in collaboration with H. Brodie Hicks Engineering Ltd.

This report was commissioned by:

Cadillac Explorations Limited
920 Lancaster Building
304 - 8th Avenue S. W.
Calgary, Alberta
T2P 1C2

Telephone: (403) 264-5392

Lawrence C. Morrisroe, President

2.2 The Need

The Cadillac project is one of several new mineral developments proposed for the Northwest Territories. Others include: Polaris, Cullaton Lake, Contwoyto Lake, Camlaren and Mactung. One hundred miles to the northwest along the Yukon/N.W.T. border is located Cantung, the nearest operating mine.

The Cadillac mine is isolated from any existing or proposed resource developments, places of habitation or transportation corridors. Construction of a 100-mile winter road to the Liard Highway southeast from the mine will provide the only ground link to the communities of Fort Simpson, Nahanni Butte and ultimately Fort Liard and Fort Nelson. Construction and operation of the mine and road are expected to provide considerable economic benefits to these communities. Further resource development in the region may result from the enhanced access although no specific projects are known at this time.

Year-round access to the Cadillac property is currently provided by air transportation from Fort Nelson, B. C., Fort Simpson, or Yellowknife, to a 3,000 ft. gravel airstrip located approximately one-half mile north of the mine camp, alongside Prairie Creek. However, there is a need for the aforementioned ground link to the Liard Highway.

Road access to the property is an essential requirement for development of the mine as the short length of the existing airstrip with its confined approaches precludes its use by the large aircraft which would be required for transportation of heavy construction and milling equipment, fuels, and metal concentrates.

The new winter road is expected to be open for 100 days a year between the end of December and the end of March. During the remaining nine months of the year, access will be by light aircraft to the Prairie Creek Airstrip for transport of personnel and small quantities of supplies.

2.3 Alternatives

A discussion of alternatives is not appropriate relative to the Prairie Creek Mine itself as a mine must be built where the ore is found. However, the No. 3 zone, proposed for initial development, is only one of several potentially exploitable zones on the property (Figure 3). The mineralized structure extends over a distance of some 20 miles, with over 12 known occurrences having been outlined on the Cadillac claims. Once production from No. 3 zone has commenced, a development programme for the other zones may be considered.

The location of a mill to process the ore is somewhat more flexible although there are not many feasible alternatives as any site must also offer suitable land for use in tailings disposal. The mine is located in very rugged terrain, and the Prairie Creek floodplain provides the most attractive sites. Two alternatives considered for construction of a mill were:

1) Caribou Flats on 'Fast' Creek,
2) Prairie Creek near its confluence with Harrison Creek.

Caribou Flats is located along the east fork of Prairie Creek (also known as 'Fast' Creek), approximately 10 miles north of the mine (Figure 2). While topographically this area may be well-suited for construction of a mill, it possesses several disadvantages which precluded it from further consideration. The most serious of these was its documented use by caribou, Dall's sheep and moose. In addition to this, road construction between the mine and Caribou Flats would traverse some canyon sections with major construction difficulties and maintenance problems.

Attention has therefore focussed on the second alternative for siting of a mill and camp - a 20 acre area in the vicinity of the confluence of Harrison Creek and Prairie Creek, near the 2850 ft. portal of the mine (Figure 4). A fully-equipped exploration camp, service and maintenance buildings and fuel storage are presently in place.

The main attributes of the Prairie Creek location are its proximity to the mine and suitable tailings pond sites, and the availability of adequate flat ground for plant development. Its location, relative to other ore zones within the claims and the existing 3000 ft. gravel airstrip (Figure 3), add to its attraction.

With respect to the project winter access road, alternate routes were reviewed in the Preliminary Environmental Evaluation submitted during May, 1980. Subsequently a Land Use Permit was issued by the Regional Manager, Land Resources, Department of Indian and Northern Affairs, for construction of a road which will commence at the Liard River approximately 20 miles northeast of Nahanni Butte, pass through the Nahanni Mountain Range by way of Grainger Pass, cross the headwaters of the Tetcela and Sundog Waterways and traverse Tundra Ridge of the Mackenzie Mountains to Prairie Creek. Some 20 - 25 miles of road have been constructed at the time of writing this report.

2.4 Associated Projects

The Cadillac mining development and associated winter road stand by themselves in terms of any other known projects which might benefit from improved access. Although no mining or other potential resource developments have been identified, it is expected that there will be increased exploration in the area resulting from successful activities at Cadillac. In addition, the orebody considered for production by Cadillac represents only one of a series of zones potentially exploitable and it is conceivable that development of these will follow in due course.

Nevertheless, it must be appreciated that the winter road will not provide new access but rather improved access since both the old winter road via the Mackenzie Highway and the Prairie Creek airstrip have been in place for a number of years.

3. PROJECT DESCRIPTION

3.1 Location

The Cadillac property is located at approximately 61°33' N latitude and 124°48' W longitude, on Prairie Creek. The dominant physiographic features of the site are Tundra Ridge, the Funeral Range and the Headless Range of the Mackenzie Mountains forming peaks up to 5700 ft. These mountains are incised by the southerly flowing Prairie Creek which joins the South Nahanni River some 27 miles south of the mine (Figures 1 and 2).

The property is situated approximately 200 miles north of Fort Nelson, B. C., and 300 miles west of Yellowknife, N.W.T. The nearest communities are Fort Simpson, 110 miles to the east, and Nahanni Butte, 60 miles to the southeast. Fort Simpson lies at the junction of the Mackenzie and Liard Rivers, whereas Nahanni Butte is at the confluence of the South Nahanni and Liard Rivers. Farther upstream on the Liard River is Fort Liard, not yet connected to these other communities by permanent highway.

3.2 History

The original discovery of mineralization on the property (at the showing now known as Zone No. 5) is reported to have been made by an Indian trapper in 1928. Subsequently, the ground appears to have been staked from time to time, but no significant development is recorded until 1958 when Fort Reliance Minerals Ltd., undertook a limited mapping programme. Their claims lapsed in 1965 and were restaked by a local prospector who, in the following year, conveyed them to Cadillac Explorations Limited, which also acquired a 182,590 acre Prospecting Permit. On the expiry of this Permit in 1969, Cadillac selected from it 210 claims (6,659 acres) which have been brought to lease. Additional claims have since been acquired.

During the period 1966 - 1969, work comprised bulldozer trenching on a number of the showings and driving of exploratory crosscuts on Zones No. 3, 7 and 8. Latterly, this work was directed by the consulting firm of Behre, Dolbear & Company Ltd.

In 1970, the property was optioned by Penarroya Canada Ltee. Under their direction, underground development of Zone No. 3 was further extended, and bulk sampling and preliminary metallurgical testing carried out. Some surface drilling was performed on Zones No. 6, 7, 8 & 9. Penarroya discontinued work late in 1970, and after some legal negotiations, Cadillac regained full ownership of the property plus the equipment and inventory on-site, subject to an ultimate payment to Penarroya from production.

Since that time, the Company has completed a low-level adit crosscut on Zone No. 3, together with some minor work on certain of the other zones. In 1979, resampling of the crosscuts on Zone No. 3 was carried out to provide material for definitive metallurgical testing. Drifting has now been resumed on the 2850 ft. level.

3.3 Description of Deposit

From the point of view of economic potential, the most important geological feature of the area is the existence, over a strike length of some 20 miles, of more than 15 occurrences of silver-lead-zinc mineralization. All of these lie along a lineament striking about N 10°E. It is not suggested that continuous mineralization will be found throughout this length, but one potential ore body has already been developed and it seems probable that others may exist. The criteria determining the occurrence of major mineral occurrences have not yet been established but may be slight changes in attitude of the major structure or the varying character of the enclosing wall rocks.

On the main leased claim group of Cadillac Explorations Limited, 12 mineralized occurrences, referred to as zones, have been located over a strike length of 6½ miles (Figure 3). Others are known to exist on the claims recently staked to the north while to the south, within the boundaries of a National Park, still others have been reported.

All of the underlying rocks of the area are sediments of Paleozoic age, chiefly Ordovician and Silurian. These have been faulted and folded. The main mineralized structure is believed to occur along the crest of a major anticline. No plutonic rocks have been observed.

The mineralized structure has been most fully explored on Zone No. 3. Here, on the 3050 ft. level, a drift has been driven parallel to the structure for a length of 3200 ft. with crosscuts at 100 ft. intervals. The mineralized vein was encountered in each crosscut. On the 2850 ft. level, a drift is now being driven parallel to the structure. At present, this drift has progressed 1500 ft. and three crosscuts have been driven through the vein.

The vein strikes approximately N 10°E and dips eastward at 60°. Width varies from a few feet up to 25 ft. and averages about 11 ft. Mineralized tension fractures striking N 45°E sometimes occur on the easterly side of the main structure. Most are narrow but some may prove to be of economic importance.

Mineralization comprises quartz, calcite, galena, sphalerite, freibergite, and minor pyrite and chalcopyrite. Some non-sulphide ore minerals may be observed in all of the 3050 level crosscuts with a tendency to diminish away from the surface, although in general, there appears to be a high degree of variability. In the new, low-level adit, the proportion of non-sulphide ore minerals diminishes.

Work on the other zones within the property is not sufficiently advanced to permit any conclusions with respect to their geological setting.

3.4 Ore Reserves

Ore reserves in the No. 3 Zone, including a mining dilution factor of 15%, are estimated as follows:

Category	Short Tons	Silver Oz/Ton	Total Lead %	Total Zinc %	Total Copper %	Non-Sulfide Lead %	Non-Sulfide Zinc %
Proven	740,000	5.60	10.96	12.88	0.46	-	-
Probable	377,000	5.34	11.08	12.65	0.37	-	-
Possible	512,000	5.59	11.50	10.80	0.44	-	-
TOTAL	1,629,000	5.54	11.16	12.17	0.44	1.67	2.37
Other Zones							
(Possible)	365,000	4.3	9.2	9.9	0.35	-	-
Total Ore:	1,994,000	5.3	10.8	11.75	0.42	-	-

The total of these reserves would support a mine for 5.7 years at a milling rate of 350,000 tons per year (1000 tons per day for 350 days per year).

There is a varying proportion of non-sulphide ore minerals in the deposit. On the 3050 ft. level, 17% of the lead and zinc occur as non-sulphides whereas in recent crosscut intersections on the 2850 ft. level this proportion is reduced to less than 5%. This tends to confirm the expectation that non-sulphides decrease with depth.

3.5 Mining

3.5.1 Mine Development

A large amount of trenching, diamond drilling and sampling has been completed on many of the known mineralized occurrences. Much of this work, and most of the underground exploration, has been concentrated on one zone, Zone No. 3.

Zone No. 3 has been explored to date with approximately 25 diamond drill holes and 10,800 ft. of level drifts and crosscuts. Short exploration raises and a ventilation raise were also driven.

Drifting in the zone has been carried out on three levels, the 3170 ft. (top) level, the 3050 ft. level and the 2850 ft. (bottom) level. On the 3050 ft. (middle) level, a footwall drift was driven and 32 crosscuts were driven through the mineralized zone.

At present, a footwall drift is being driven on the 2850 ft. level. From the drift, crosscuts are being driven to the vein at 400 ft. intervals.

Extensions to the No. 3 Zone will be explored on strike by both surface and underground diamond drilling. Trackless drives will be used to develop ore found by drilling. The zone will be explored at depth by underground diamond drilling from hanging wall crosscuts. Both known and additional reserves below the 2850 ft. level will be developed by a decline driven from the 2850 ft. level.

Other zones will be explored by diamond drilling and trackless adits and declines.

3.5.2 Mining Method

Initially, Zone No. 3 will be mined from the 2850 ft. and 3050 ft. levels. Ore mined in the 3050 ft. level stopes will be passed through internal ore passes to the 2850 ft. level. All ore from both levels will be hauled on the 2850 ft. level by tracked equipment to the portal area. The 3050 ft. level will remain trackless and light load-haul-dump equipment will be used for service and muck haulage. See Figure 7.

Cut-and-fill stoping will be employed to the maximum extent possible in order to utilize tailings solids as backfill. This method will be supplemented by shrinkage stoping where applicable. The method of stoping of individual blocks will be decided when detailed information becomes available. The decisions will be influenced by the availability of hydraulic fill as well as the ground conditions and ore widths of the various stoping blocks. It is expected that not more than eight per cent (8%) of the ore reserve will be lost to pillars.

Ore hauled to the portal area of the 2850 ft. level will be dumped into a large trench near the portal. This ore will be slushed to a conveyor that will transfer it to the nearby mill.

Deslimed mill tailings will be used for backfill. Daily production of backfill from the mill will be stored underground until it is required by operating stopes. Excavation of storage capacity for backfill and sump capacity for water clarification and storage will be required above the 3170 ft. level.

3.6 Milling

The mill is designed to treat 1,000 short dry tons of ore per day, operating seven days per week. Allowing for normal interruptions, it is estimated that annual throughput will be 350,000 tons. The mill will be capable of producing three separate concentrates, a lead concentrate containing approximately thirty per cent (30%) of the silver, a zinc concentrate containing minor silver, and a small quantity of copper concentrate containing forty per cent (40%) of the silver.

Laboratory testwork has shown that the ore can be treated by conventional mineral processing techniques to produce these concentrates. Further refinement of the reagent scheme appears possible and additional testwork to investigate this has been commissioned.

A conventional flowsheet (Figure 6) has been developed comprising two-stage crushing, single-stage ball-milling, differential flotation, thickening and filtration. The equipment proposed is standard and well proven in the industry with the exception of the Larox automatic pressure filters which are relatively new in Canada. They have however, been in operation in similar applications in Europe for some years, giving excellent results in terms of low moisture content in the final product. Their adoption eliminates the need for thermal drying with its attendant high fuel costs and requirement for gas-scrubbing.

The mill heads grade and the expected composition of the lead, zinc and copper concentrates, and the flotation tailings solids are given in the table below:

	WT%	Cu%	Pb%	Zn%	Ag oz/t
Head	100.00	0.44	11.16	12.17	5.54
Pb Conc.	13.27	0.07	60.10	6.76	13.26
Zn Conc.	14.40	0.31	1.94	60.00	3.46
Cu Conc.	1.05	27.61	16.35	7.36	207.00
Flotn.Tail.	71.28	0.14	3.84	3.59	1.56

Cadillac Explorations Limited have purchased the former mill of Churchill Copper Corp., near Fort Nelson, B. C. Dismantling of the plant is now proceeding. Transport of the equipment is to take place during the winter of 1980-81.

a) Crushing

Run-of-mine ore will be transported from a slusher trench at the 2850 ft. level portal by conveyor belts to a 150-ton capacity coarse ore bin. Coarse ore will be fed to a grizzly, with oversize fed to a jaw crusher and the undersize along with crusher product conveyed to a 50-ton surge bin. The bin will discharge to a vibrating screen operating in closed circuit with a short-head cone crusher. Screen undersize will move to a 2000 ton capacity fine ore bin.

b) Grinding

Ore from the fine ore bin will discharge by belt to a 14-ft. ball mill operating in closed circuit with a cyclone classifier.

c) Copper-Lead Flotation

The cyclone overflow will be fed to a bulk conditioner in which the pulp will be mixed with reagents including copper-lead collectors, frother and zinc and gangue depressants. From the conditioner, the pulp will flow to the bulk rougher flotation cells. The copper-lead rougher concentrate will be reground in a ball mill in closed circuit with a cyclone. After conditioning, the cyclone overflow will be upgraded in a bank of cleaner cells. The cleaner concentrate will be pumped to the copper separation circuit, and the combined cleaner tailings will be pumped to the lead thickener.

d) Zinc Flotation

The copper-lead rougher tailings will be conditioned in a tank with lime, copper sulphate, frother, xanthate and gangue depressant. The conditioned pulp will be fed into a bank of zinc rougher flotation cells. The rougher tailing will be pumped to the backfill plant. The rougher concentrate will be upgraded in two stages of closed-circuit cleaning cells with the final product pumped to a thickener.

e) Copper Flotation

The product of the copper-lead flotation will first be upgraded through two stages of cleaning. After conditioning, the lead minerals will be depressed and the copper minerals recovered in a bank of flotation cells, and further upgraded in one stage of cleaning. The tailings from the copper rougher and cleaning cells will be combined with those from the second and third cleaning stages of the copper-lead circuit to constitute the lead concentrate.

f) Dewatering

The underflow from the lead and zinc thickeners will be stored in surge tanks and then pumped to automatic pressure filters, reducing the moisture content to seven per cent (7%). The filter cakes will be transported to concentrate storage buildings by conveyor belts.

The copper concentrate will be stored in a 12' diameter by 18' stock tank from which it will be fed periodically to the lead filter, which has the required capacity for this additional service. The filter cake at ninety-three per cent (93%) solids will be bagged and stored for shipment.

g) Concentrate Storage

Because of the limited trucking season, on-site covered storage will be provided for nine months' production of concentrates. Protection from the weather is necessary to prevent handling difficulties caused by wetting and subsequent freezing and to eliminate losses caused by dusting.

Concentrates will be conveyed from the filters to separate storage buildings constructed close to the mill. The conveyors will discharge to conical piles, from which the concentrates will be stacked to a height of 30 ft. using front-end loaders.

The zinc concentrate storage building will have a capacity of 44,100 tons (wet), or 630,000 $ft.^3$ of concentrate. The lead concentrate storage area will have a capacity of 40,500 tons (wet) or 450,000 $ft.^3$. Copper concentrates will be bagged in the lead storage building.

h) Backfill Plant

The flotation tailings with the overflow from the lead and zinc concentrate thickeners, will be deslimed in two stages of cyclone classification. The final underflow will be diluted to forty per cent (40%) solids and pumped by four centrifugal pumps in series, to the underground storage plant, 400 ft. above the concentrator. Standby pumping capacity will be provided. The cyclone overflows will be pumped to the tailings impoundment area.

3.7 Water Supply

Potable water, mine service water and makeup water for the mill will be supplied by an electrically driven well pump. Standby and emergency water will be supplied by a gasoline pump at the river. Water will be pumped to a 170,000 gallon tank located on the hillside at an elevation of 3050 ft. The top portion of the tank will supply the normal plant and site requirements for 24 hours. A second standpipe in the tank will assure 150,000 gallons of emergency water for fire-fighting purposes. It is expected that treatment of well water will not be necessary to make it potable.

Water from the tailings area will be re-used in the mill. This water will be piped to a surge tank located on the hillside in the valley of Harrison Creek at an elevation of 2950 ft.

Some of the overflow water from the underground hydraulic fill storage tanks will be stored in a nearby 80,000 gallon sump for reuse when pouring fill. This sump water will be supplemented, when necessary, by mine drainage water pumped to the fill tank area.

3.8 Electrical Power

The plant will be powered by a 4,300 kVA on-site diesel-electric generating facility. Three 1,150 kW (1,438 kVA) dual fuel diesel engine electric generators will be used to provide 2,400 volt, 3-phase power for motor loads, lighting and miscellaneous loads in the mill building, underground mine, service building, shops and other locations.

3.9 Heating and Ventilation

Heating of buildings and of water will be provided by the use of propane and by surplus heat from the electric generator engines.

Individual gas furnaces in the residential units and recreation hall will provide heat and ventilation.

Heat for the shops and the mill building will be provided by propane space heaters.

3.10 Additional Service Facilities

Additional service facilities include maintenance shops, warehousing, offices and change-houses. Disposal of sewage and garbage are discussed in later sections of this report.

3.10.1 Maintenance Shops

Central maintenance for all mine, mill and surface equipment will be provided in two 40-ft. by 100-ft. metal buildings. One building is now on site and an additional one will be erected. Both buildings will be heated with propane space heaters. Tool cribs, small offices for mechanical-electrical supervision and a lunchroom will be provided in one of the buildings.

3.10.2 Office - Changehouse - Warehouse Complex

A pre-engineeered building will be erected to form the complex. The upper floor will contain the mine changehouse and the office portion of the complex. On the lower floor, the Mine Supervisor's office, the boilers, the first aid room and a large warehouse will be located. The mill and mechanical crews will use the small changehouse presently on site.

3.10.3 Cold Storage

Cold storage will be provided in a 40' x 90' building now used for this purpose. Additional outside storage under tarpaulins will supplement this facility.

3.11 Fire Protection

The fresh water tank will be the main source of water for the fire protection system. A gasoline pump will provide extra capacity. Basic fire protection will consist of automatic sprinklers and hose stations located as required by hazard and occupancy ratings.

Areas to be covered by sprinkler systems include the residential units, office-changehouse-warehouse complex and the recreational hall. The powerhouse, control room and compressor building will be protected by an inert gas system. The mill building and service shops will have hose stations.

Dry chemical fire extinguishers will be located on all vehicles throughout the surface and underground installations as required.

All water based fire protection systems will be located inside heated buildings or will be designed as dry pipe systems when exposed to freezing conditions.

A fire-fighting trailer will be fabricated to handle fires. It will be equipped with a dry chemical system and a portable pump and fire hose. Similar vehicles will be available for underground use.

3.12 Camp

Over past years, camp facilities have been constructed and a substantial inventory of equipment, parts and supplies has been accumulated.

The existing camp comprises twelve 8-man portable sleeping units, a washhouse and kitchen. It will ultimately be necessary to upgrade these facilities to present day standards but they will serve for preliminary underground work and construction. Other existing buildings include an office, recreation hall, 3 trailer-type residences, shops, garage and cold storage warehouse.

Additional portable units have recently been purchased and will be transported to the site during the construction period. This will allow accommodation for an additional 100 men (ten 10-man units). The total accommodation for 196 men will be sufficient to house the operating crew.

A new recreation hall will be composed of portable units and will have a floor area of 2000 square feet. Facilities will include a games room, snack bar, commissary and television viewing room. A satellite television system has been purchased and installed.

The present kitchen-dining room will be replaced by larger facilities and a 20' x 40' freezer will be installed for food storage.

Camp catering will be contracted. The total number of people on-site will be 159, out of the total complement of 221.

Radios will be used to provide a communication link with the B. C. Telephone network at Fort Nelson. Telephone service will also be provided between the Mine Supervisor's office and the mine.

3.13 Personnel

3.13.1 On-Site Personnel

The following personnel will form the 221 person workforce required at Prairie Creek:

a) Administrative

	Number	
Mine Manager	1	
General Superintendent	1	
Accountant	1	
Assistant Accountant	1	
Warehouse Superintendent	1	
Warehouse Clerk	1	
Clerks (including Payroll)	4	
Environmental Supervisor	1	
Safety and Training	2	
Stenographer	2	
Sub-total		15

b) Mine Supervision

Mine Superintendent	1	
Mine Foreman	1	
Shift Boss	3	
Sub-total		5

c) Mine Technical and Clerical

Chief Engineer	1	
Mine Engineer	1	
Technician	1	
Surveyor	3	
Chief Geologist	1	
Geologist	1	
Sampler	2	
Mine Clerk	1	
Sub-total		11

d) Mine Operating Labour

Stope Miner	45	
Ore Haulage (Locomotive & L.H.D.)	12	
Development Miner	6	
Raise Miner	3	
Subdrift Miner	3	
Slusher Trench & Backfill Operator	3	
Spare Miner	3	
Labourer	6	
Diamond Driller	2	
Sub-total		83

e) Maintenance and Construction Labour

	Number	
Timberman	2	
Pipefitter	1	
Helpers	3	
Sub-total		6

f) Mill Supervision

Mill Superintendent	1	
Mill Foreman	1	
Sub-total		2

g) Mill Technical and Clerical

Mill Metallurgist	1	
Chief Assayer	1	
Assayer	2	
Mill Clerk	1	
Sub-total		5

h) Mill Operating Labour

Flotation Operator (Lead Hand)	4	
Grinding Operator	4	
Filter Operator	4	
Crusher Operator	4	
Sampler	2	
Labourer	4	
Sub-total		22

i) Service Supervision

Services Superintendent	1	
Mechanical Superintendent	1	
Mechanical Foreman	1	
Electrical Superintendent	1	
Electrical Foreman	1	
Mobile Equipment & Carpenter Foreman	1	
Sub-total		6

j) Service Operating Labour

	Number	
Diesel Mechanic	4	
Mechanic	10	
Stationary Engineer	4	
Welder	4	
Electricians	7	
Carpenters	4	
Machinist	2	
Rock Drill Mechanic	1	
Pipe Fitters	2	
Equipment Operator	6	
Labourers (Includes Dryman & Janitor)	10	
Sub-total		54
k) Contract Services		12
Grand Total		221

The total number of personnel on-site at any given time is 159, as tabulated below:

PERSONNEL ON-SITE

Area	Total Personnel	Out of Camp	In Camp
Administration	15	5	10
Mine Supervision	5	2	3
Mine Technical	11	4	7
Mine Operating	83	27	58
Mine Maintenance	6	2	4
Total Mill	29	12	17
Total Services	60	21	39
Visitors	-	-	9
Contract Services	12	-	12
	221	73	159

3.13.2 Off-Site Personnel

Off-site facilities consist of the Fort Nelson office and warehouse, and the truck stop en-route to Enterprise. An expeditor and an assistant expeditor will be required at Fort Nelson.

An annual cost allowance will be provided for private operation of the truck stop, and no Cadillac personnel will be involved.

3.14 Access and Transportation

Access to the site for transport of materials in any significant volume is initially limited to trucking by a winter road (Figure 2). This route passes from a point on the east bank of the Liard River, near its confluence with Blackstone Creek, through the Nahanni Mountain Range by way of the Grainger River Pass, follows the Tetcela and Sundog Waterways and passes through the Tundra Ridge of the Mackenzie Mountains to Prairie Creek.

The winter road is expected to be open at least for 100 days per year, between December and the end of March. For the remainder of the year access will be by aircraft only.

For the plant construction phase of the project, scheduling will be arranged for the shipment of major equipment and much of the bulk construction materials during the first 3 months of 1981. With the closure of the winter road in the spring of 1981, any remaining materials will have to be air freighted or left for transport by truck in 1982. Production is scheduled for early 1982.

In general, transportation of materials will be on a backhaul basis using trucks and aircraft scheduled to transport concentrates. Fuel will be the major item that will not be hauled on a backhaul basis.

a) Transportation of Concentrates

The copper concentrate will be flown from the site to an existing airstrip at Fort Liard. The zinc and lead concentrates will be trucked either to Fort Nelson, or to Enterprise. Shipping by rail from Fort Nelson would utilize the B. C. Railway and, from Enterprise, the C. N. Railway.

Air transportation will be used to ship the copper concentrate in order to provide current income from the relatively high value concentrate. A Caribou aircraft (17 flights/week) will carry the bagged concentrate to the airstrip at Fort Liard, from where it will be trucked to a smelter. During the trucking season copper concentrate will be shipped by truck only.

An aircraft will be purchased for copper concentrate haulage. The aircraft will also be used for personnel transportation to and from the site. An air charter company will operate and maintain the aircraft on a contract basis.

All lead and zinc concentrates will be trucked over the winter road.

Approximately 40 trucks per day, will be required to haul the concentrate from the mine site. These trucks will carry supplies to the mine on a backhaul basis. Discussions with trucking contractors in the Fort Nelson and Hay River areas have confirmed the availability of the trucks required. Trucks will be lined with plastic sheeting and covered with tarpaulins while shipping concentrate.

b) Transportation of Materials

The greater tonnage of materials will be shipped on a backhaul basis from Fort Nelson by the concentrate haulage trucks. A lesser tonnage will be shipped by aircraft returning to the site for copper concentrate. The air freight will be limited by the amount of copper concentrate to be shipped. Air freight will consist of perishable goods (foodstuffs), high value consumables and emergency supplies.

Fuel oil and propane will be shipped from Fort Nelson to the site over the winter road in tanker trucks. Seventeen trips per week will be required for fuel oil and two trips per week for propane, during this period.

c) Transportation of Personnel

The aircraft purchased for copper concentrate haulage will also be used for personnel transport. Personnel will be moved to and from the site in 20 passenger loads. This will require four return flights per week from Fort Nelson to the site.

The 3000 foot airstrip now located at the site will have a lighting system installed for operations during dark winter days. In addition, navigational aids are now being installed.

3.15 Off-Site Facilities

Off-site facilities include the winter road, a storage and loading facility for concentrates at Fort Nelson and an office and warehouse at Fort Nelson. Also required are a storage and loading facility for concentrates at Enterprise and a truck stop on the Mackenzie Highway between the mine site and Enterprise.

a) Winter Road

The winter road will be maintained by the contractor providing concentrate trucking services. A single grader will be used on a double shift basis 20 hours per day. A mobile grader camp will be required.

b) Storage and Loading at Fort Nelson

Sufficient industrial land, complete with a rail siding will be leased from B. C. Rail. A concentrate storage building designed to hold 22,500 dry tons will be erected near the siding. A portable conveyor complete with hopper will be purchased for loading purposes. Loading services will be contracted to a local contractor.

c) Office and Warehouse at Fort Nelson

The operation will be located in leased premises at the Fort Nelson airport. Office space and sufficient warehouse space are available in an existing hangar. Two vehicles (a pickup truck and a small bus) will be purchased for expediting purposes. In addition to expediting supplies and personnel, a primary function of the Fort Nelson office will involve interviewing and hiring new personnel.

Control of concentrate shipments from Fort Nelson will also be handled from the office. Personnel en route to the site and delayed by poor weather will be accommodated in local hotels.

d) Storage Loading Facility at Enterprise

Loading facilities at Enterprise will be similar to those at Fort Nelson. However, a much smaller building will be required, because of the faster rail shipping schedule. It will have a capacity of approximately 8500 dry tons.

e) Truck Stop on the Mackenzie Highway

Some local inhabitants on the highway now provide food and minor maintenance and fuel services. Funds will be provided to these businesses so that they can upgrade their facilities.

3.16 Flood Protection

As fully discussed by Golder Associates in Appendix I, a river dyke is required to protect the plantsite area from possible floodwaters of Prairie Creek and Harrison Creek. This dyke would follow the location of the existing river dyke for much of its length but, at its southeastern extremity, would tie into a similar dyke running northerly along the west bank of Harrison Creek. Total dyke length would be approximately 3000 ft.

Most of the embankment fill would be taken from an excavation in the tailings pond area, as discussed in Section 4.1. The dyke would be constructed to 3 ft. or more above the calculated 100-year return period flood on Prairie Creek and suitably rip-rapped on the outside. Predicted flood levels are shown on Figure 18.

3.17 Project Schedule

The following schedule is envisaged with respect to the key steps in the development:

Full production - mine and mill	January, 1982
Winter road construction completed by	December, 1980
Dismantle Churchill Mill	Sept. - Oct., 1980
Refurbish & transport mill to site	Nov./80 - Feb./81
Transport material to site	Dec./80 - Mar./81
Engineering design	Oct./80 - Dec./81
Surface construction	Mar./81 - Dec./81
Pre-production mine development	On-going.

3.18 Winter Access Road

In May, 1980, the Preliminary Environmental Evaluation for the Winter Access Road was submitted; this report outlined the proposed alignment of the access corridor to be constructed between the minesite and the Liard River, a distance of nearly 100 miles. Since that time, the western portion of the route has been surveyed to approximately mile 54 and construction has been completed to between mile 20 and 25, as of October, 1980.

Attached as Appendix 10 is Golder Associates' report entitled Progress Report to Ker, Priestman & Associates Ltd. re Cadillac Explorations Ltd. Prairie Creek Project - Mine Access Route which outlines the route selection, final alignment, watercourse crossing locations, construction details and recommendations regarding further construction on the remainder of the route. Topographic plans of the proposed and final routes at a scale of 1:50,000 and photographs of typical sections are also included.

Construction of the access road has been underway since July, 1980. The initial (western) section traverses the slopes and valleys of the Mackenzie Mountains lying to the east of Prairie Creek. Portions of this road have been constructed or will be constructed along the floodplain reaches of some waterways, on both north and south aspect slopes by cut-and-fill, and over areas of muskeg and permafrost. Careful attention has been given to alignment and construction practices in order to ensure that environmental degradation does not result from the construction. Such practices include the selection of south aspect slopes where possible to avoid permafrost, insulation of exposed permafrost by layers of insulating gravel, and construction over muskeg only after freeze-up. The use of geotextiles has been proposed for permafrost areas which may be subject to construction vehicle traffic before freeze-up.

Completion of the road is expected during the winter of 1980-81.

4. ENVIRONMENTAL PROGRAMME

4.1 Tailings Disposal

4.1.1 General

Preliminary investigations of five potential tailings pond sites (designated T-1 to T-5) were carried out and reviewed in the Preliminary Environmental Evaluation, May, 1980. Of these five, T-1, T-4 and T-5 were side-valley sites which would have required the construction of major water diversion works in order to deal with floods of large magnitude. For this reason, and because of other favourable conditions which exist along the wide flood-plain reaches of Prairie Creek, it was considered that sites T-2 and T-3, upstream and downstream from the camp respectively, were the only sites worthy of additional study. The locations of T-2 and T-3 are shown on Figures 4 and 5.

A geotechnical field study was conducted by Golder Associates, between July 7th and September 3rd, 1980. This study and subsequent laboratory testing encompassed the following:

a) a drilling programme at potential tailings pond sites T-2 and T-3 and the plantsite area adjacent to the present camp in order to determine subsoil and foundation strata.

b) the collection of soil and aggregate samples for engineering evaluation

c) the installation of water level and temperature sensing instrumentation in boreholes for the on-going recording of data.

From this data, along with topographic ground survey plans prepared during this period by Ker, Priestman & Associates Ltd., Golder Associates prepared plans of a recommended tailings impoundment, commented on foundation conditions at the proposed plantsite, reviewed river flood protection dykes and designed suitable fuel tank farm dykes.

Golder Associates' full report is attached as Appendix 1.

4.1.2 Design Criteria

Pond storage requirements have been based upon quantities given in the Kilborn Engineering Ltd. flowsheet (Figure 6) for the approximate design life of the mine. Because backfilling of tailings sands to the mine is proposed, only a portion of the total tailings solids will require impoundment. Although preliminary evaluations considered the extra storage required for some permanently frozen tailings, it is now considered that, by careful operation, this can be avoided.

Reclaim of supernatant tailings pond water will be carried out, with the water re-used in the mill. Although no direct discharge from the tailings pond is contemplated, the discharge of excess backfill carriage water will be required. As described in section 4.2, this effluent will receive treatment as required to meet the Metal Mining Liquid Effluent Regulations and other relevant criteria imposed, and thus is expected to be of good quality.

It should be noted that the strongly alkaline nature of the tailings solids will preclude acid generation, all as discussed in the Preliminary Environmental Evaluation for Mine, Mill and Camp (KPA May, 1980). Tables 1 and 2 give the spectrographic and chemical analyses of tailings solids.

The design criteria used are as follows:

tailings discharge to pond		15.0 short tons/hour of solids @ 12% solids (by weight, approx.)
storage life required		6 years minimum
precipitation,	mean	20 inches/year
	maximum	28 inches/year
	minimum	11 inches/year
evaporation		13 inches/year
moisture in settled pond solids		30% (by weight)

4.1.3 Geotechnical Considerations

On the basis of five boreholes drilled at T-2 to a depth of between 47 and 74 feet, Golder Associates determined that a 10 to 20 ft. thick layer of compact to dense alluvial sands and gravels with cobbles overlie a stratum of stiff silty clay. The clay was found to be between 22.5 and 31.5 ft. thick except at one borehole adjacent to Prairie Creek, where no clay was found. Beneath the clay layer was a further deposit of alluvial sands and gravels extending to an undetermined depth.

No permafrost was encountered in any of the boreholes at T-2 and groundwater was at approximately the level of Prairie Creek.

At site T-3, four holes were drilled. The stratigraphy was found to be similar to that at T-2 with a 10 to 15 ft. surficial layer of compact to dense alluvial sands, gravels and cobbles overlying the 28 to 32.5 ft. of very stiff, silty clay. Underneath the clay layer was alluvial sands and gravels. The presence of bedrock at shallow depth in one hole, together with bedrock outcroppings near the midpoint of T-3 was noted.

An artesian condition was found to exist in a standpipe connected through to the sand and gravel stratum beneath the clay layer in one borehole at T-3. However, standing groundwater, as at T-2, was approximately at the level of Prairie Creek. No permafrost was encountered.

It was concluded that both sites T-2 and T-3 were suitable for construction of tailings ponds, but that the shorter distance from the plantsite to T-2, the existence of river dyking at T-2 which could be incorporated into future tailings embankments, and the substantial amount of clearing which has already taken place at T-2 combine to favour this site over T-3.

Further pond evaluation and embankment design has proceeded on the assumption that T-2 will be initially utilized, as recommended by Golder Associates. However, site T-3 would be the most likely area to be developed once site T-2 is completely utilized, should the mill continue to operate beyond the initial design life of six years.

4.1.4 Tailings Impoundment T-2

A full description of the impoundment configuration, the embankment design and construction sequencing for the T-2 pond can be found in Golder Associates' report, Appendix 1.

The tailings pond will occupy a floodplain area of approximately 25 acres bordered by Prairie Creek on the south and west, the camp and mill site on the southeast, and the mountain slopes on the north. The area is only partially timbered, with the lower slopes and floodplain area having been altered by earlier deposition of mine rock, construction of river dyking and grooming of slopes by caterpillar tractor. Rock predominates higher up on the slopes whereas scree deposits of considerable depth are found at the base in some locations. A small channel enters the area from the north with an alluvial fan at its point of entry into the Prairie Creek valley. This channel does not normally carry any measurable flow.

The tailings pond has been designed to be essentially impermeable to seepage. This will be accomplished by use of a clay seal within the embankment, suitably tied into the clay layer which exists beneath the alluvial deposits on the pond base. In order to effect this seal, to obtain the required volume of construction material, and to provide storage capacity within a dam of modest dimensions, it will be necessary to excavate approximately 420,000 yd^3 of sand/gravel and clay from this area, to a depth of between 15 and 25 ft. below existing grade. Special construction procedures have been outlined by Golder so that the excavation may proceed without inundation by groundwaters originating from Prairie Creek.

The proposed ultimate tailings embankment would be 2600 ft. long, 150 ft. wide at the base and 20 to 30 ft. above existing grade, for a final crest elevation of 2867 ft. Approximately 34,000 yd^3 of clay and 95,000 yd^3 of sand/gravel fill would be required for its construction, all of which would be taken from the excavation beneath the pond area. The existing river dyke would be incorporated within the final embankment.

As the full storage capacity will not be immediately required, it is proposed to construct the embankment in two stages. The crest elevation of the initial lift would be equal to the maximum possible flood (MPF) level of Prairie Creek; this level is 3 - 4 feet above the calculated 100-year flood level of Prairie Creek. Rip-rap bank protection would be provided to the MPF level.

The final crest elevation of the tailings pond embankment would be 2867 ft. which offers a minimum additional 9 feet of freeboard above the water level of the calculated maximum possible flood.

4.1.5 Runoff Diversion

In order to minimize the amount of surface water entering the tailings pond, a runoff diversion scheme is proposed, as shown on Figure 5.

The mine access road leading to the Prairie Creek airstrip and ultimately to the Liard River crossing will be re-routed upslope from its present location so that it follows the northern perimeter of the tailings pond. A roadside ditch to handle the maximum 100-year slope runoff would be constructed on the up-hill side of this roadway. Grades would be such that the flows would split east - west, thus discharging approximately equal quantities around the extreme ends of the tailings pond. Pertinent catchment areas, flows, and sizing of ditches and culverts are shown on Figures 4 and 5.

On the basis of its relatively large catchment area of 100 acres, the valley lying to the north of the east corner of the pond may generate a 100-year return period flow of around 100 cfs. Containment and energy dissipation must be provided for this stream in such a way that it will not wash out the tailings embankment either during the operating life of the mine or after abandonment. Because the eastern abutment of the tailings dam must be tied into bedrock, its orientation is relatively inflexible. Thus, the stream course must either be diverted around this corner or be directed across the top.

The required permanent nature of this facility and possible objections to use of culverts suggest that a combination of weirs and rock-lined channel be constructed across the northeast corner of the embankment in order to provide the necessary containment, energy dissipation and dam protection.

Excess excavation material not required for initial tailings embankment construction, river dykes or construction fill, would be stacked in the area between the east section of the tailings dam and the camp area, as shown on Figure 5. A channel would be formed between this storage pile and the tailings embankment. Water from the road diversion ditch and flood flows from the side-hill valley discussed above would flow to Prairie Creek through this channel which would be suitably protected with rip-rap on its invert. The channel would discharge through an opening between the tailings embankment and the river dyke. Flood waters would back up into the channel under conditions of high flow in Prairie Creek.

4.1.6 Tailings Discharge and Reclaim

Tailings will be discharged at a rate of 469 USgpm of slurry containing approximately 12% solids by weight. An insulated, above-ground tailings line will be brought up the slope from the mill area to the level of the initial lower dam crest, 2848 ft. It will follow the tailings embankment at this elevation to the far end, with provision made at intervals to spiggot tailings into the pond at any selected location. Thus the total tailings line will be behind dykes and spills, if any, would flow naturally into the pond or into the plantsite area.

A floating reclaim pump barge would be located approximately at the midpoint of the pond. Reclaim water lines will follow the same route as the tailings line. Both the tailings and reclaim lines would require re-locating as the dam is raised to its ultimate elevation.

A water balance for the pond is presented in Figure 5.

4.1.7 Pond Operation

The pond will be divided into cells of 3 - 4 acres in size by the creation of non-engineered internal dykes constructed from coarse mine waste rock or other suitable material. The purpose of the cells is to permit alternate summer/winter discharge of tailings into different segments of the pond, and thus facilitate the summer melting of ice accumulated during the winter discharge. Because of the southerly aspect of the pond, it is fully expected that this concept will be successful in preventing the accumulation of permanent ice lenses within the pond.

Discharge of tailings in early 1982 would commence at the extreme east cell (cell 1). At or near the end of the winter period, discharge to this cell would cease and recommence at the opposite end of the pond, in cell 5. Meltwater and free water would flow from these cells through the porous internal dykes toward the reclaim pump located in cell 3 at the centre. By suitable alternate use of cells, the progressive buildup of solids from the pond extremities to the centre, the collection of water where it is wanted at the reclaim pump, the clarification of reclaim water, and the melting of ice deposits would all be simultaneously satisfied. The above operational sequence is premised on the assumption that the complete sub-grade excavation is carried out prior to startup and that the internal cell dykes are similarly constructed at this time. Other variations of this sequence or the number of cells can, of course, be imagined which would have the same effect.

4.2 Effluent Treatment

4.2.1 Surface Runoff

To the maximum extent possible, surface runoff from the slopes above the operation area will be diverted away by ditches. This will be particularly critical at the tailings pond where a negative water balance must be maintained.

However, due to the rocky slopes, diversion ditches cannot be constructed around the entire perimeter of the operating area and, furthermore, direct precipitation will fall on the plantsite, thus necessitating some control over surface water in this area.

Due to the presence of the river protection dyke which will separate the plantsite from both Harrison and Prairie Creeks, surface runoff and precipitation will tend to collect behind the dyke. In addition, during high flow periods there may be seepage from Prairie Creek through the dyke into the plantsite area. This water, in flowing over the plantsite, may pick up sediment, oil and grease, and possibly other materials in use.

A series of small ditches and culverts is proposed to channel surface water away from the active areas to a 2-acre pond to be located at the southeast corner of the plantsite. To this pond, flocculants would be added (if necessary) in order to aid in settling of fine entrained sediment. An oil-sorbent boom would be in place at the pond outlet to remove any floating oils which might be present. The pond would be emptied by a culvert discharging through the river dyke. The ditches and overflow would be sized to handle the 100-year return period inflow and the pond will be shallow to facilitate its cleanout by a cat or dragline.

A weir or Parshall flume would be constructed at the inlet or outlet of the pond for flow measurement and a control gate structure would be provided on the pond outlet works.

4.2.2 Mine Water

Water from the mine will constitute the main source of effluent from the operation. It is estimated to consist of:

	Estimated Daily Average (IGPD)
excess backfill water	86,000
drilling and washdown water	72,000
natural seepage	144,000
	302,000 IGPD

During certain periods of the year when the surface of the ground is frozen, natural seepage into the mine will drop to a very low quantity. During heavy rainfall, the rate will increase. Similarly, backfilling may be suspended for short periods of time depending on the scheduling of stope development and this will cause a decrease in the quantity of mine water. For these reasons, the rates given above may vary considerably from day-to-day and from month-to-month.

Mine water may contain a variety of contaminants including suspended solids, oil and grease, and traces of ammonia and nitrates from explosives. In addition, because the backfill water originates from the mill, contaminants may be present. Mutual dilution of these sources, aging and further reactions within the mine will likely reduce the concentrations to low levels, however, it has been assumed for the present that treatment of mine water will be required.

Further metallurgical and chemical testwork is to be carried out during 1980. Unless these tests indicate that treatment is unnecessary, it is proposed to direct the mine water (after settling in underground sumps) to an alkaline chlorination plant where lime and chlorine (or hypochlorite) would be added to the fluid under controlled conditions for the oxidation of cyanide, precipitation of heavy metals and destruction of organic mill reagents (Figure 12). Precipitated metal hydroxides along with suspended sediments originating from the mine would be settled and removed in a protected settling basin or mechanical settler and discharged back to the tailings sump in the mill for disposal to the tailings pond. The clarified effluent would be discharged to Prairie Creek. A suitable flow measuring device would be provided either at the inlet or outlet of the plant.

Previous laboratory tests (Preliminary Environmental Evaluation for Mine, Mill and Camp, May, 1980) have shown that Cadillac <u>ore</u> is potentially acid-generating due to the excess of acid-generating minerals (sulphides) over acid-consuming minerals (carbonates). However, the ore is to be removed from the mine and the veins are located within a host rock with a very large proportion of carbonates; consequently, it is very likely that the ore plus the matrix considered together do not constitute a potentially acid-generating combination as Cadillac waste rock is strongly acid-consuming. If acidic mine water was to develop, it would do so slowly over a period of years permitting a full evaluation of treatment strategy. Certainly, there is no evidence of acidity from the analyses of mine water to date (see Section 5.3).

The alkaline chlorination scheme proposed has the advantage that it would also serve as a viable treatment for mine-water acidity. All the essential features of a typical acid water treatment plant are present, including:

a) oxidation of ferrous iron by the stronger oxidant chlorine or hypochlorite rather than by air which is usually employed,

b) neutralization by lime to precipitate ferric and other metal hydroxides,

c) flocculation and sedimentation.

Thus, it is expected that any acid generation could be readily handled by this facility, without significant modifications.

4.2.3 Sewage

All sewage will be collected by gravity sewage lines and will flow directly into a sewage treatment plant. Sewage collection lines will be of pre-insulated polyethylene piping.

The sewage plant will be capable of processing 18,000 - 20,000 imperial gallons per day, using a biological aeration system and clarifier. The clarifier effluent will be discharged downstream from the site.

The treatment plant will be installed above ground and will consist of pre-fabricated steel tanks and mechanical components enclosed in an insulated building. The temperature will be maintained several degrees above freezing and the building will be ventilated to eliminate buildup of flammable gases. The plant location is shown on Figure 5.

Treated sewage effluent quality will meet secondary standards, as noted below:

BOD_5	-	45	mg/1
Suspended Solids	-	60	mg/1
pH	-	6 - 9	
chlorine residual	-	0.2 - 1.0	mg/1

With this level of treatment, total and fecal coliform levels would be within acceptable standards.

4.3 Solid Waste Disposal

Solid waste from the operation will consist of:

a) cookhouse waste: food, paper, cardboard, glass, tins
b) combustible packaging: cardboard, wood, paper, plastics
c) incombustible containers: drums, glass
d) construction wastes: wood, metal, concrete, plastics
e) miscellaneous sources

Salvageable drums and scrap metal will be stored on the site for removal and resale.

Cookhouse waste and changehouse paper waste will be incinerated on the site, along with combustible packaging and other suitable wastes. A commercial incinerator with underfire air, pre-ignition and screening of ash will be provided for this purpose. Wastes will be burned daily in order to prevent accumulation and odours which might attract bears.

Timbers and other combustibles too large for the incinerator would be disposed of at the landfill site. Smaller incombustible materials such as unsalvageable metal wastes, incinerator ash, glass, etc., would also be buried at the landfill site after the volume was reduced by a compactor.

The landfill site will be located approximately 2000 ft. south-east of the mill, in the area identified as T-3 on Figures 4 and 5. The dump will be operated as an 'area' landfill. The following operating technique would be employed, as recommended by Environment Canada (1978):

1. Deposit refuse at bottom of slope for best compaction and control of blowing litter.

2. Spread and compact refuse against slope of previous lift, progressing horizontally along slope.

3. Cover with earth excavated from adjacent area or from off-site borrow area and compact. The thickness of the compacted layer should be at least six inches.

4. A uniform layer of suitable cover material compacted to a minimum depth of two feet should be placed over the entire surface of each portion of the final lift, not later than one week following the placement of refuse within that portion.

This technique is also described pictorially in Figure 25.

4.4 Air Emissions

The number of air emissions from the industrial operations at the Prairie Creek mine will be few, and those that are proposed should have no significant impact on air quality. Emission sources and estimated discharge rates are given below, along with a list of potential contaminants:

	SCFM	Potential Contaminants
mine ventilation	40,000	traces of particulate matter, diesel fumes, products of combustion from blasting (CO, CO_2, NO_x)
two crushing plant emissions	40,000	particulate matter
mill reagent area ventilation	5,000	traces of reagent fumes
three diesel generators	18,000	particulate matter, unburned hydrocarbons, CO_2
assay lab	1,000	traces of reagent fumes
maintenance shop	2,000	particulate matter, welding fumes, vehicle exhaust
changerooms	2,000	
cookhouse	2,000	

Of these sources, only the crushing plant is considered to be a significant potential source of air pollution; for this reason, two fabric-filter dust collectors are proposed to treat ventilation air from the jaw crusher, cone crusher, screens, conveyors and transfer points ahead of the fine ore bin. It should be noted that no thermal drying of concentrates, roasting, or smelting operations are to be carried out.

4.5 Waste Rock

No firm estimate of the quantity of waste rock to be generated from the pre-production and on-going underground development programme is available. Nevertheless, the rate of waste rock production is expected to be small and further diminished once the pre-production phase of level, stope, and raise development is completed prior to production.

Quantities of waste rock will be sufficiently small that temporary storage of this material at the portals, followed by complete utilization as fill, aggregate for concrete manufacture, use for construction of dykes, and possible augmentation of the backfill supply can be anticipated to completely consume its production. Hence waste rock dumps will be small and temporary.

As discussed in the Preliminary Environmental Evaluation for the Mine, Mill and Camp (KPA, May, 1980), the strongly alkaline nature of waste rock will preclude acid generation. Sediment loads originating from runoff over waste rock piles will be collected by ditching and directed to a settling pond, as described in Section 4.2.

4.6 Chemical Spills

4.6.1 Introduction

The sensitive location of the Prairie Creek Mine which is upstream from Nahanni National Park, and its distance from outside sources of spill response equipment combine to underscore the need for environmental self-sufficiency and spill preparedness.

As for any industrial operation of this type, the use of certain chemical substances is contemplated for the fuelling of vehicles and machinery, heating, mining and recovery of metal concentrates. Some of these substances will possess a toxicity, flammability, or other hazard which would require them to be handled with special care. Plans must also be formulated for cleanup of spills, should they occur in spite of preventative measures being taken.

The information presented in this section is intended to cover the potential hazards associated with the use of chemical substances at the Prairie Creek Mine, to describe their transportation, storage and handling, and to outline the key features of a spill prevention and spill contingency plan. The programme is as detailed as is possible at this time. However, rather than being a complete contingency plan for the Cadillac operation, the information in this section would form the basis for such a plan, subject to further revision as planning progresses.

4.6.2 Spill Contingency Plan

4.6.2.1 General

A spill contingency plan is a specific programme which outlines the duties of spill-control personnel, identifies response actions and provides all information which may be required in order to effectively prevent, contain and clean-up a spill. The preparation of the document is as important as the information it contains, because the exercise will identify areas of weakness and force a review of actions, before a spill actually occurs.

The contingency plan should be up-dated regularly to incorporate new information, equipment, procedures and personnel. What follows is as detailed as is possible at the stage of planning which currently exists for the Cadillac project.

Many features of the programme outlined herein have been adapted from the "Spill Response Contingency Planning Guidelines" prepared by the B. C. Ministry of Environment.

4.6.2.2 On-Scene Co-Ordinator

An on-scene co-ordinator (OSC) would be appointed to take overall responsibility for the spill prevention and contingency plan. The Environmental Supervisor would be designated as OSC with other personnel assigned as back-up.

The responsibilities of the OSC would be:

1. familiarization with potential spills and confinement, recovery and restoration techniques,
2. directing activities during and after a spill,
3. notification of government and other authorities in the event of a spill,
4. acting as spokesman and 'single-point contact' for the media, public and authorities regarding a spill.
5. collecting any required samples for analysis.
6. preparing a report on all aspects of the spill,
7. training of back-up staff and clean-up personnel,
8. up-dating the contingency plan,
9. ensuring the availability and maintenance of all equipment required for preventing and clean-up of spills, and for protection of clean-up personnel.
10. maintaining a log concerning all spills, both major and minor.

4.6.2.3 Notification

It would be the responsibility of the person discovering the spill to take immediate action to stop the leak or spill if such is possible (e.g. by closing a valve). Otherwise immediate notification of the OSC, or his back-up if the OSC was not available, should be made. All personnel on-site or involved in transportation to-and-from the mine should be educated as to the notification procedure.

The OSC or other person receiving a spill report should review a check-list contained in the contingency plan which would include the following as key pieces of information required:

- name of person reporting the spill
- type and quantity of material spilled
- location of spill
- weather and other conditions
- cause of spill
- action already initiated
- names of all parties involved
- names of persons or authorities already notified.

The contingency plan should provide a list of telephone numbers of key government personnel who should be notified by the OSC in the event of a spill. The present government contact is given below; the Department of Indian Affairs and Northern Development maintains a 24-hour answering service and will undertake notification of other agencies concerned:

Department of Indian Affairs and Northern Development
(403) 920-8230

Advice on emergency spill procedures may also be obtained by calling collect, 24-hours per day:

Transport Canada Information and Emergency Centre
(613) 996-6666.

or:

The Canadian Chemical Producers' Association
Transportation Emergency Assistance Program (TEAP)
(403) 477-8339.

Further information on TEAP is included in Appendix 7.

4.6.2.4 Spill Report

A spill report would normally be prepared by the OSC as soon as possible after the clean-up and site restoration work had been completed. The purpose of the report is to examine the cause and results of the spill and the success of clean-up efforts in order to learn from the experience. Copies would be forwarded to the regulatory agencies of concern. If required, the spill contingency plan procedures should then be modified in accordance with the experience.

4.6.2.5 Equipment Inventory

In order to respond quickly and effectively to spills, the OSC and response personnel must know what equipment is available and know how to use it. The required equipment must also be provided and maintained in a state of readiness. Much of the equipment useful in emergencies will be standard mining and earthmoving machinery, such as caterpillar tractors, trucks, front-end loaders, stand-by diesel pumps, hoses, fire-fighting apparatus, etc. However, the OSC should ensure that additional equipment is available and maintain an inventory of such equipment, including, as required:

- self-contained breathing apparatus
- portable pumps and hoses
- oil adsorbent materials such as peat moss or polyurethane foams
- oil burning promoters
- oil booms, skimmers
- water sampling supplies
- air quality measuring apparatus (e.g. Drager tubes)
- polyethylene or PVC pond lining material
- portable radios
- devices for sealing leaks in tanks
- hatch-cover adaptors for draining fuel trucks
- portable tanks.

Many devices for spill clean-up are available commercially. One such supplier is:

Bennett Pollution Controls Ltd.
119 Charles Street
North Vancouver, B. C.

4.6.3 <u>Chemicals Proposed for Use</u>

Chemicals proposed for use at Cadillac are standard throughout the industry and can be categorized as fuels, explosives, mill reagents and miscellaneous substances as listed below.

4.6.3.1 Fuels and Other Petroleum Products

Fuels to be used at Cadillac in large quantities are gasoline, propane and diesel fuel. Much smaller quantities of aviation fuel, solvents and lubricants would also be required.

4.6.3.2 Explosives

Explosives proposed for use at Cadillac are ammonium nitrate/fuel oil (ANFO) and water gels, the latter providing 75% of the mine needs.

Water gel explosives consist of a gelled mixture of a nitrated organic compound and an oxidant such as ammonium nitrate, calcium nitrate or sodium nitrate. ANFO is a slurry of prilled ammonium nitrate (94%) and fuel oil (6%). Incomplete detonation of these explosives would result in the release of ammonium and nitrate ions which, if available to be picked up by mine water, would be released to the environment. Ammonium and nitrate ions can both cause an increase in the nutrient content of water. Nevertheless, the concentrations of ammonia and nitrate ions will be very low based on experience at other mines.

4.6.3.3 Mill Reagents

The following mill reagents are to be used for the production of separate lead, copper and zinc concentrates:

Reagent	Purpose	Consumption lb/ton	Consumption lb/day
hydrated lime $Ca(OH_2)$	pH modifier	0.50	500
sodium cyanide (NaCN)	Zn depressant	1.00	1000
sodium isopropyl xanthate	collector	0.10	100
potassium amyl xanthate	collector	0.20	200
methyl isobutyl carbinol (MIBC)	frother	0.01	10
soda ash	pH modifier	4.00	4000
copper sulphate	Zn activator	2.00	2000
Dowfroth 250 (polypropylene glycol methyl ether)	frother	0.01	10
sodium silicate (Na_2SiO_3)	gangue depressant	1.20	1200
chlorine or hypochlorite	oxidant	unknown	unknown
sodium dichromate ($Na_2Cr_2O_7$)	Pb depressant	1.00	1000
activated carbon	absorb excess xanthate	0.60	600

All of the above substances are in common usage in mills throughout the country.

4.6.3.4 Concentrates

Strictly speaking, metal concentrates are not chemicals in use at Cadillac, but their chemical characteristics may conveniently be discussed here.

Production of separate concentrates containing zinc, lead and copper is proposed at this time.

The concentrates will consist mainly of sulphides of the metals: sphalerite (ZnS), galena (PbS), freibergite (sulfantimonides or sulfarsenides of copper, containing up to 18% silver), and minor pyrite (FeS_2) and chalcopyrite ($CuFeS_2$). Small amounts of the gangue minerals, quartz (SiO_2) and calcite ($CaCO_3$) will also be present.

Heavy-metal sulfides are amongst the most insoluble compounds that exist. Hence, they generally do not exhibit an immediate toxicity. Their chief environmental hazard occurs when oxidation by air (aided by bacteria) produces acidity and soluble heavy metals by the general reaction:

$$2MS_2 + 2H_2O + 7O_2 = 2MSO_4 + H_2SO_4$$

If neutralizing materials, such as calcium carbonate, are also present, the acidity will be neutralized, and the pH will be maintained high enough that sulphates of the heavy metals will be precipitated as hydroxides or similar compounds.

Acid-generation requires the correct combination of moisture, oxygen and temperature to develop. It also requires time which makes feasible the clean-up of spills before the onset of any acid release can reach significant rates.

4.6.3.5 Miscellaneous Chemicals

Small quantities of chemicals would be required for the routine analysis of ores and concentrates, including acids, bases, organic reagents, fluxes, etc.

It should be noted that no polychlorinated biphenyls (P.C.B.'s) are to be used in electrical equipment at Cadillac.

4.6.4 Transportation and Storage

4.6.4.1 Fuels

Essentially all fuels will be brought in by tanker trucks over the winter road during the months of December through March. Supplies will be marshalled at Fort Nelson and transported approximately 180 miles north to the Liard River crossing which is 20 miles northeast of Nahanni Butte. This all-weather road (the Liard Highway), presently under construction, is expected to be complete by the time it is required. From the Liard River crossing, the winter road (presently being built by Cadillac) will be traversed westerly for 100 miles to the mine.

The number of vehicle return trips is expected to be approximately 17 per week for diesel fuel, 2 per week for propane and 3 per season for gasoline. Properly equipped and serviced tanker trucks belonging to the fuel suppliers will be utilized. Spill contingency planning for transportation accidents is the responsibility of the supplier; such plans have been prepared and are scrutinized by the B. C. Ministry of Environment. Nevertheless, the OSC would establish liaison with the oil company in order to ensure that a workable plan was in effect, and that equipment was available to handle a spill at any location along the route.

All vehicles traversing the winter road will be required to have radios such that movement between checkpoints is strictly controlled in order to prevent accidents. This system will be similar to that successfully used by the logging industry in British Columbia.

Diesel fuel will be stored at two separate locations at the site. An existing tank farm provides 280,000 imp. gallons of storage. In addition to this, a new tank farm with an additional 700,000 imp. gallons capacity will be constructed northeast of the crusher building as shown on Figure 5. Impermeable dykes and an impermeable base will be constructed at the new site. Dykes at the existing tank farm will be upgraded and the base made as impermeable as possible by suitable placement of clay. Dyke construction is further discussed in Appendix 1. The capacity of the dyked enclosure would be approximately 125% of the capacity of the largest tank within the enclosure. Oil reclaim facilities and adsorbent material would be maintained at the site for spill cleanup.

Gasoline storage will be 12,000 imp. gallons. This tank will be located in the general area of the existing tank farm but separate from oil tanks. Because of the explosion hazard, recovery of a gasoline spill would not be attempted; instead, the fuel would be permitted to evaporate.

The propane tank storage consists of eight 30,000 U.S.gallon tanks. Propane will be piped to the various points of use through the utilidors used for water distribution. Two tanks will be located near the 3050 ft. level portal to provide fuel for mine air heating. Several portable 6000 gallon tanks will also be provided to supply heat to remote locations when required.

4.6.4.2 Explosives

Explosives will be transported on trucks specially flagged and marked. Both ANFO and water-gels will be packaged in strong, waterproof containers to prevent their deterioration in transit.

Explosives will mostly be stored underground to avoid freezing. Total storage will consist of 45,000 lb. of ANFO and 135,000 lb. of water-gel. A surface explosives magazine will be used to supplement underground storage.

4.6.4.3 Mill Reagents

Mill reagents will be transported in various containers on backhaul trips using concentrate trucks. Special care is to be taken in packaging and loading in order to prevent loss or damage during transit. Reagent containers for the various products are as noted below:

hydrated lime:	60 lb. bags
soda ash:	88 lb. bags
sodium cyanide:	200 lb. drums
Xanthates:	Drums
copper sulphate:	55 lb. bags
sodium silicate:	Bags
sodium dichromate:	Bags
MIBC:	Drums
Dowfroth 250:	Drums
activated carbon:	50 lb. bags
chlorine (if used):	1 ton cylinders
calcium hypochlorite:	Drums

Shrink wrapping of pallets will be employed for those bagged chemicals which are hazardous or may be subject to breakage or damage by moisture.

At the minesite, a number of reagents will be stored outside on pallets, or in drums, covered by a tarpaulin; these include lime, soda ash, sodium silicate, MIBC, Dowfroth 250 and activated carbon. These products represent a relatively low order of toxicity. The remainder including sodium cyanide, copper sulphate, xanthate, sodium dichromate, chlorine (if used) and calcium hypochlorite would be stored in the cold storage warehouse.

Additional storage of small quantities of reagents would be required at the reagent mixing area in the mill. A sump will be provided below the reagent area in order to collect spills and facilitate their return to the circuit.

Other sumps will be provided with pumps and strategically located within the mill building to collect local spillage. In the event of a large spill which exceeded the capacity of the sumps, the curbs around the lower floor would provide containment.

4.6.4.4 Concentrates

As noted earlier, metal concentrates are not environmentally hazardous but spills would obviously still be undesirable.

Zinc and lead concentrates are to be stored under cover at the minesite (Figure 5) until they can be trucked away during the winter months. Copper concentrate will also be stored but will be shipped out in bags by air on a regular basis during non-winter periods. Protection from the weather is necessary to prevent handling difficulties caused by wetting and subsequent freezing and to eliminate losses due to dusting. Concentrates will be transferred from the filters to the storage buildings by covered conveyor.

Lead and zinc concentrates will be loaded into trucks by front-end loaders at the storage buildings and covered by tarpaulins. Concentrates will be transported to Fort Nelson for loading onto B. C. Railway cars or to Enterprise (near Hay River, N.W.T.) via the Mackenzie Highway for shipping by the C. N. Railway.

Approximately 40 trucks per day will be utilized for concentrate and back-haul transport during the months the winter road is open.

4.6.5 Spill Prevention

The best method of dealing with spills is to prevent them from occurring. Critical aspects of the spill prevention programme will include:

1. Design

Spill prevention features such as drainage sumps, protective berms, curbs, ditches and alarms, careful design of valving and drains, etc. will be incorporated into the design of the mill and related facilities. Proper choice of construction materials would also be carried out with full knowledge of the chemical characteristics of the material being contained.

2. Inspections

Once operational, all facilities potentially subject to spills would be carefully inspected on a regular basis by the OSC and reports prepared which would identify vulnerable areas requiring attention and recommend preventative measures which should be taken. The oil company supplying fuel would also be requested to inspect storage facilities, in order to benefit from their experience.

3. Education

It would be the responsibility of the OSC to foster an attitude of spill awareness by supervisory and operating personnel and to make known the proper methods for handling and disposing of chemicals and procedures following a spill.

4. Information Accessibility

Proper handling of chemicals requires a knowledge of the dangers inherent in their use. The OSC, as part of his responsibility for preparation and up-dating of the Spill Contingency Plan, would compile literature on the chemical characteristics, toxicity and handling of the chemicals in use. Such information can be obtained from the chemical suppliers, or manufacturers' associations, including:

Canadian Industries Limited
Chemicals
P. O. Box 10
Montreal, P. Q. H3C 2R3

Dow Chemical Company
Modeland Road
P. O. Box 1012
Sarnia, Ontario N7T 7K7

Cyanamid of Canada Limited
635 Dorchester Blvd. West
Montreal 2, P. Q.

Manufacturing Chemists Association
1825 Conneticut Avenue N.W.
Washington, D.C. 20009

DuPont of Canada
1550 Alberni Street
Vancouver, B. C.

5. Procedures

Improper procedures for the transportation and handling of chemicals, transfer operations and maintenance of equipment may be the most likely cause of accidents, leaks and spills. The OSC would be responsible for preparation of standard procedures for routine operations and their review with respect to changing personnel, responsibilities, equipment, and experience.

4.6.6 Spill Response

The first consideration following a spill of a toxic or hazardous substance is the safety of on-site or emergency response personnel. Once their safety has been assured, the next priority is the protection of the environment. Obviously, a spill contingency programme must address both aspects in such a way that quick action can be taken. Notification of government spill response personnel would also be a priority.

An Emergency Response Guide for Dangerous Goods has been prepared by Transport Canada for use in such situations. This guide provides critical information for dangerous substances which may be rapidly referred to in emergency situations. The following listing gives the appropriate UN identification number for the dangerous substance and the action code. An explanation of the action code and response actions are given in Appendices 8 & 9, respectively.

Substance	UN Identification No.	Action Code
diesel fuel	1268	3WE
gasoline	1203	3YE
propane	1978	2WE
aviation fuel	1203	3YE
ammonium nitrate	0223	2WE
explosives	various	2WE
sodium cyanide	1689	4X
M.I.B.C.	2053	3W
copper sulfate	NA 9109*	3Z
chlorine	1017	2XE
calcium hypochlorite	1748	2PE
sodium dichromate	NA 9145*	3Z

* not a UN number.

This guide, while providing emergency response action, does not address adequately the environmental protection measures which must follow the immediate response action.

Many options are available for spill clean-up, but specific actions will depend on a variety of factors including the type of chemical spilled, the quantity, the location, weather conditions, ground conditions, location and size of waterbody, presence of particular wildlife or aquatic sensitivities, etc.

Therefore, the response actions can only be outlined with the choice of the appropriate option being left to the OSC acting in concert with government spill personnel. A discussion of procedures for dealing with those materials posing the greatest hazard follows below:

4.6.6.1 Spills of Petroleum Products

Following a report of a petroleum-product spill, the OSC would attempt to contain the spill as a first priority after shutting off the leak or source (if possible). Suitable equipment such as a cat, front-end loader, or backhoe would be deployed to the site in order to immediately contain the spill by dyking. If the spill was near to the minesite, mine equipment would be used. However, if the spill was near the eastern end of the mine access road or along the Liard Highway it might be more expedient to obtain equipment from Fort Simpson or Fort Liard. It would be the responsibility of the OSC to establish in advance the availability of heavy equipment at suitable nearby communities.

If the spill progressed along a small water course before containment was possible, then oil booms would be constructed from timber and placed at strategic locations to prevent its entry into larger streams.

Once the spill was contained, various options would be available for clean-up depending on the material spilled, the quantity and the location. The best alternative, selected by the OSC in consultation with government personnel, would likely consist of one or more of the following:

- recovery by pumping
- burning with or without the use of burning promoters
- absorption by peat moss, straw, polyurethane foam or other suitable material
- excavation of oily soil and removal to the mine site or other location for ultimate disposal.

An overturned tanker truck should be emptied of its load before attempting to move the vehicle. This can be done by special hatch-cover adaptors which are commercially available. The recovered oil can be flowed or pumped to portable tanks (also commercially available) or, preferably, to an empty tanker.

A direct spill into a large stream would require the rapid deployment of booms followed by use of oil skimmers, suction nozzles or adsorbents to recover the floating oil.

An inventory of equipment and materials and up-to-date knowledge of procedures for the use of such equipment would be the responsibility of the OSC.

Spills within the plantsite area would be very much simpler to deal with due to the proximity of personnel and equipment and the provision of impermeable berms around fuel storage tanks. Following repair of leaking equipment, oil retained behind the dykes would be pumped back into the tanks.

4.6.6.2 Spills of Sodium Cyanide

A spill of sodium cyanide resulting in the dissolution in water would require containment to as small an area of influence as possible. However, the most likely event would be a ruptured cyanide drum spilling its contents due to an accident along the mine access road; in this case, due to the road being used only during the winter period, streams will be frozen and it would likely be possible to recover the cyanide pellets in solid form, by hand shovelling.

If it was not possible to completely recover all cyanide spilled (e.g. due to heavy snowfall), the area would be isolated from surrounding runoff by dyking and be treated by applications of hypochlorite (household bleach) solutions to oxidize cyanide to the cyanate form, a considerably less toxic product. This procedure would not be suitable under all conditions, particularly where excess chlorine residuals might enter watercourses. In this case, an alternate procedure would be excavation of the contaminated soil to the minesite where it could be processed through the mill with the ore and any cyanide content be destroyed by the alkaline chlorination proposed for treatment of the mine water.

4.6.6.3 Copper Sulphate

Copper sulphate, like sodium cyanide, is soluble in water and toxic to aquatic life. Response action would consist in preventing its contact with water, isolation of contaminated areas and excavation of contaminated soil to the mine site. Burial of this soil in the tailings pond would isolate it from the environment and provide the alkaline pH conditions favourable for precipitation of insoluble hydroxides.

4.6.6.4 Chlorine or Calcium Hypochlorite

A cylinder of chlorine, if ruptured, would release chlorine in gaseous form and provided the cylinder was not under water, the gas would eventually disperse to the atmosphere. A cylinder which had ruptured and entered a watercourse would be recovered if possible so that gases would not be solubilized. Due to use of the road under winter conditions and the few large waterways along the access route, this situation is not considered likely.

Spills of solid calcium hypochlorite would be treated in the same manner as copper sulphate, by preventing access of the chemical to waterways, and isolation and removal of contaminated soil. However, unlike copper sulphate, hypochlorite ions will rapidly lose strength by reactions with the soil and exposure to sunlight and hence would be rendered inactive with time.

4.6.6.5 Other Chemicals

Spills of other chemicals listed pose a much smaller hazard in terms of the lesser toxicity and quantities used. It is expected that spills of these materials could be handled using variations of the methods outlined above.

Concentrate spills, while not considered an environmental problem, would require clean-up and removal by heavy equipment and return to the mill for reprocessing.

4.7 Monitoring

4.7.1 Mine Water

It is expected that a monitoring programme will be specified under the water licence for the operation and will reflect requirements under the Metal Mining Liquid Effluent Regulations (Appendix 2).

In accordance with these regulations and unless otherwise specified by the government, the treated mine effluent would be sampled and analyzed at an initial rate of once per week for the first six months of operation. Thereafter, the frequency would be decreased (depending on the actual levels recorded) as per Schedule 2 of the Metal Mining Regulations. Parameters monitored would be:

pH
suspended solids
total arsenic
total copper
total lead
total nickel
total zinc
dissolved sulphate
total cyanide
total iron

plus any others required by the water licence. Once per month (initially) a toxicity bioassay test would also be carried out in order to determine if the effluent was acutely lethal towards fish. The standard procedure uses rainbow trout fingerlings for the bioassay test (though trout are not a species found at this site).

A flow measurement of the treated mine water would be made at weekly intervals to permit the determination of an average monthly discharge rate.

4.7.2 Treated Sewage

According to the draft Guidelines for Municipal Type Wastewater Discharges in the Northwest Territories (1980), the monitoring programme for this type of discharge will be specified by the Water Board in order to ensure that it meets the terms of the water licence. However, the initial programme is expected to encompass the following parameters, as applicable:

Parameter	Frequency	Sample Type
BOD_5	quarterly	C_1
Dissolved O_2	weekly	C_1
Suspended Solids	weekly	C_1
pH	weekly	C_1
temperature	weekly	C_1
oil and grease	weekly	C_1
phosphorous	monthly	C_1
nitrogen	monthly	C_1
coliforms	weekly	G

C_1 = composite consisting of 4 grabs over 2 hours
G = grab sample

Residual chlorine determinations (field measurements) would be made at frequent intervals until it could be ensured that the chlorination facilities were operating properly.

A flow measurement would be made at least once per week in order to permit the calculation of the average monthly discharge rate.

4.7.3 Surface Runoff

The only characteristics of surface runoff which should require monitoring are:

suspended solids
oil and grease
pH

Sampling would be carried out once per week initially until it was established that levels of these parameters were not of concern. At that time, it is expected the frequency could be reduced.

4.7.4 Receiving Waters

Any reasonable programme for monitoring the receiving waters of Prairie Creek as required by government in a Water Licence would be carried out.

4.7.5 Air Monitoring

It is not anticipated that any air monitoring will be required.

4.7.6 Analytical Methods

Certain analyses will have to be carried out in the field by mine personnel - these include temperature, residual chlorine, dissolved O_2, and pH. Other analyses would require the services of a commercial laboratory which would normally utilize approved analytical techniques.

4.7.7 Reporting

The Metal Mining Liquid Effluent Regulations specify that a monthly monitoring report be submitted which contains individual analytical results, arithmetic mean concentrations and flowrates.

For simplicity, it is proposed that sample results from all discharges be reported in the same manner, at the same time, and to the same agencies (in Yellowknife) which would include:

- Department of Indian and Northern Affairs
- Environmental Protection Service
- Government of the Northwest Territories

4.8 Reclamation

4.8.1 Reclamation Objectives

Mine reclamation may be defined as the restoration of the surface of the land and watercourses, during and after active mine operation, to a condition which is satisfactory in terms of aesthetics, water quality, stability and safety so as to permit its maximum utilization by fish, wildlife and humans. This implies that the total usefulness of the land and water will not suffer, although its character may be altered as a result of mining activities.

A mine reclamation programme would mainly take effect upon mine closure, however, there are measures that can be taken prior to this time and, in addition, the final task will be simplified if the ultimate objectives are known.

The objectives of the Cadillac reclamation plan may be summarized as follows:

1. to minimize land disturbance during development and operation
2. to leave the site in a condition which is stable, safe and aesthetically satisfactory.
3. to revegetate disturbed areas.
4. to take measures to prevent future deterioration of water and air quality.

4.8.2 Nature of Disturbance

The land disturbed by the total operation will consist of the following approximate areas, for a mine life of six years.

	acres
winter road (100 miles long x 25 ft. wide)	300
mine, camp, mill and related facilities	20
tailings pond	25
Total	345 acres

Materials disturbed by or created by the mining operation include the following:

a. topsoil
b. waste rock
c. mill tailings.

The nature of the soils has been explored in the Preliminary Environmental Evaluation for Mine, Mill and Camp (Ker, Priestman, May, 1980), according to soil mapping. Soils are described as predominantly Orthic Eutric Brunisols with Cumulic Regosols and Rockland subdominant. The soil, climate and topography of the area result in low productivity.

Organic topsoils suitable for reclamation exist only in isolated pockets in the region of the minesite. Any suitable topsoils which do exist will be stockpiled separately for re-use in reclamation at a later date.

Waste rock from the mine will be comprised of siliceous and carbonate rock from underground development. The quantity generated during the 1980 programme was approximately 25,000 tons, most of which has been placed at the entrance of the two portals, or used as fill around the property. This material has no acid-generating capability.

As discussed in section 4.5, only a small amount of waste rock will be produced. Consequently, dumps will not be large, thereby facilitating reclamation. As discussed under section 5.5.6, revegetation of mine waste will require special procedures due to nutrient deficiency, moisture deficiency and unfavourable ratios of coarse-to-fine particle size.

The mineralogical nature of tailings solids will resemble waste rock. Therefore, tailings will also be deficient in nutrients, but as opposed to mine waste, it will likely contain an excess of fines. Poor drainage and the accumulation of alkaline salts may be further limiting factors for its reclamation.

4.8.3 Reclamation Plan

It is possible to state only in general terms the nature and extent of a reclamation programme to take place following mine shutdown since the ultimate extent of the disturbance, the final mine life and future government requirements are not precisely known at this time.

Final reclamation at the mine site will encompass stabilization of unstable rock slopes, provision of permanent and well-protected surface drainageways, further rip-rapping (if necessary) of dykes along Prairie and Harrison Creeks in order to protect against any conceivable flood waters, sealing of abandoned mine portals, removal of buildings, equipment, vehicles, fuels, etc. and establishment of a vegetative cover on disturbed areas.

Seed plots will be established during the operating period of the mine in order to determine suitable seeds, nutrient and water requirements and long-term survival. Reseeding of areas not subject to on-going disturbance, would be initiated prior to shutdown and will provide valuable experience.

4.8.4 Revegetation

Successful, long-term revegetation at the Prairie Creek Mine is expected to be difficult due to the northern latitude, cold climate, short growing season, low precipitation and poor soils at the site.

Site preparation prior to seeding would consist of some or all of the following:

- ripping compacted ground,
- recontouring and resloping waste dumps to stable angles capable of supporting vegetative cover,
- spreading of suitable overburden or topsoil
- soil amendments where necessary,
- harrowing or scarifying
- application of fertilizer.

It is expected that the annual fertilizer application rate would be approximately 500 lb./acre of 13-16-10 or 400 lb./acre of 20-20-10, as recommended for alpine areas of British Columbia (B. C. Ministry of Mines and Petroleum Resources, 1977). This rate is also similar to that recommended for reclamation of sub-arctic areas by Environment Canada (1978).

Seed would be applied in June in order to optimize survival of germinated seedlings. It would be applied either by drilling, hydroseeding or broadcasting by cyclone seeders, depending upon the terrain and on-site evaluations carried out prior to mine abandonment.

Appropriate seed mixtures require evaluation prior to use. Environment Canada recommends (based upon Alaskan experience) initial seeding with annual ryegrass (*Lolium multiflorum*) at a rate of 10 - 25 lb./acre, followed by seeding the following spring with perennial grasses such as native bluejoint (*Calamagrostis canadensis*) and fall arctic-grass (*Arctagrostis latifolia*).

The B. C. Ministry of Energy, Mines and Petroleum Resources (1977) recommends the following general mixture for alpine areas, seeded at a rate of 50 lb./acre.

	% By Weight
Boreal creeping red fescue	25
Meadow foxtail	25
Climax timothy	20
Canada bluegrass	5
Carleton bromegrass	10
Alsike clover	15

Use of native species, as discussed in section 5.5.6, or other species recommended by Environment Canada (1978) would also be considered.

Test plots would have to be established during active mine operation to properly assess site preparation, seeds, and fertilizer mixes suitable for this specific location.

4.8.5 Winter Road and Airstrip

The degree of reclamation required and the decision regarding the fate of the airstrip and winter road would be dependent on government requirements at the time of mine closure. The available options are:

a) leave road and airstrip for public use, fire access, future mineral exploration, etc.,

b) completely remove all traces of both the road and airstrip by backfilling cuts and revegetating all disturbed areas.

c) restrict access by blocking road to vehicle access.

d) revegetate only.

5. EXISTING ENVIRONMENT

5.1 Climate

5.1.1 General

The equivalent section of the Preliminary Environmental Evaluation (P.E.E.) Reports of May, 1980 covered the initial findings on the climate of the area. Climatic data which has since become available is incorporated into this report.

The minesite is located in the eastern Mackenzie Mountains at an elevation of approximately 2850 feet and is characterized by a continental climate pattern with a very low mean daily temperature.

The temperature changes associated with the beginning and end of the summer season (June - August) are typically rather abrupt. Precipitation is low, with the annual peak occuring in July.

Long term temperature and precipitation records are available from the Atmospheric Environment Service for several centres including Fort Simpson, Wrigley, Watson Lake and Fort Nelson. These stations and others within the area are listed in Table 3 and their locations are shown on Figure 13.

Snow cover data has also been recorded at various locations since the early 1960's.

Rainfall data and the Intensity-Duration-Frequency curves are only available for Watson Lake, Fort Simpson and Fort Nelson, and are based on 8 to 11 years of records.

The Atmospheric Environment Service recorded weather at Cadillac Minesite for approximately one year in 1970. Other data hás been recorded sporadically since that time.

Evaporation data is very limited.

5.1.2 Temperature

The monthly and mean annual temperatures for Cadillac Minesite have been estimated by examining 12 or more years of record at each of the Tungsten, Fort Simpson and Watson Lake climate stations. The temperature differences at these three stations are not great and, together with a simple correlation with the 10 months of climate data collected at the site in 1970, it is possible to develop reasonably reliable temperature estimates. In general, Cadillac appears to have less extreme temperatures than Fort Simpson or Watson Lake. However, temperatures are very similar to those recorded at Tungsten. The temperatures at these four stations are given in Table 4. The mean annual temperature for Cadillac minesite is estimated as 23° F. The lowest monthly mean of -14° F occurs in January and the highest monthly mean of 55° F. occurs in July.

5.1.3 Precipitation

Monthly and mean annual precipitation figures for the Study Area have also been estimated in the same manner as for temperature. However, the data recorded at the site in 1970 did not correlate well with the surrounding stations. This was partly due to the extreme rainfall which occurred in August (total 8.06 inches) at the minesite. Cadillac appears to have similar precipitation patterns to Fort Simpson through the winter, but in the summer the rainfall is greater than at Fort Simpson, and appears closer to that recorded at Tungsten.

Rainfall and precipitation for the investigated stations are also included in Table 4. It should be noted that the long term precipitation at Fort Simpson and at Watson Lake may not exactly agree with those values given in the table because only the overlapping period of record with Tungsten was studied. Because of the high rainfall in the summer months (like Tungsten) and low precipitation (snow) through the winter (like Fort Simpson), the ratio of rain to total precipitation is .59, higher than the surrounding stations at .50. The mean annual precipitation is estimated at 20 inches. About 3 inches/month falls in the summer and the annual low of 0.8 inches/month occurs in March.

Maximum and minimum annual precipitation for the 10 and 50 year return periods has also been estimated. The maxima are 25 inches and 28 inches, respectively; and the minima are 14 inches and 11 inches, respectively. These values have been estimated through a simple statistical analysis of Cantung and Fort Simpson data then transferring the results to Cadillac using the same prorating factors that were used for mean precipitation.

Use of the intensity-duration-frequency (IDF) rainfall curve for Fort Nelson is recommended for design and is reproduced in Figure 14 because it is based on a longer period of record and gives higher values than either Fort Simpson or Watson Lake. In the one year of data collection at the site, the maximum recorded rainfall in a 24 hour period was 3.52 inches on August 16, 1970. None of the other climate stations studied showed significant rainfalls near that date and the recorded value is greater than ever recorded at the same surrounding stations. Its position on the IDF curve is at the 25 year return period.

Rate of rainfall has been recorded at Virginia Falls, Cantung and Nahanni Hot Springs since 1973 but has not yet been developed as IDF curves.

5.1.4 Evaporation

There were no changes in the available data for mean monthly and annual evaporation. Therefore the evaporation rates given in the P.E.E., which were taken from Climatic Mapping, are also reproduced in Table 4.

5.1.5 Snow Cover

Snow cover data is available for Watson Lake, Norman Wells and Fort Nelson from 1962 to date, and for Tungsten for the two winters ending in 1977 and 1978. The average accumulations at the three longer term stations are similar and their aggregate average is 25 inches. Based on the 2 years of record at Tungsten, the mean snow cover there is probably 50% greater, or 35 to 40 inches annually.

The maximum informally recorded snow depth at the minesite over the last 12 years, however, was only 14 inches, which does not compare well with the surrounding snow cover stations. Consequently, it has not been possible to provide good estimates of snow cover at Cadillac on the basis of projections from these other locations.

5.1.6 Data Collection

The present meteorological data collection programme at the minesite only includes measurement of 12 hour rainfalls. The Atmospheric Environment Service has agreed to provide a rate of rainfall recorder together with the equipment necessary to establish a Climatic Observer Station at the minesite which will complement the two stream crest gauges installed at the site in July, 1980.

5.2 Hydrology

5.2.1 General

Runoff shows a marked peak in June, decreasing through the fall and winter to a low in February and March. Groundwater storage would be low in winter due to frozen ground, hence extremely low winter flows occur. For Prairie Creek, the ratio of the June: March average flows is 73:1. The index hydrograph, Figure 15, for flows on Prairie Creek illustrates this seasonal fluctuation.

Periods of ice cover are indicated. Smaller creeks will have a more extreme variation and larger creeks, less extreme. Annual peak flows on the larger drainage basins such as Prairie Creek are usually due to spring snowmelt, but may also be due to widespread rain, whereas the smaller creeks will produce flash floods as a result of localized thundershower activity.

5.2.2 Records

Published runoff data is available from the Water Survey of Canada. Additional data is being collected by the Water Resources Division of the Department of Indian & Northern Affairs, but no reference index is available at this time.

The relevant stream gauging stations are listed in Table 5 with their locations shown on Figure 13.

Data from Station 10EC002 (Prairie Creek at Cadillac Mine), and Station 10EC001 (South Nahanni River near Hot Springs) is considered to be the most pertinent to this study.

Because of a shortage of data having a reasonable period of record for small basins (i.e. less than 50 sq. miles), runoff characteristics for small catchments are not known.

5.2.3 Mean Flows

Based on the Prairie Creek and South Nahanni River gauges, the long term water yield for the Study Area is 1.1 cfs per square mile. Mean annual flow in the South Nahanni River is 14900 cfs with a minimum monthly average of 2000 cfs and a maximum monthly average of 50500 cfs. The catchment area above this gauge is 12900 sq. miles.

Mean annual flow in Prairie Creek is 204 cfs,with a minimum monthly average of 10 cfs and a maximum monthly average of 696 cfs, respectively. The catchment area above the Prairie Creek gauge is 191 sq. miles.

The mean annual yield ratio is defined as equivalent volume of annual runoff divided by volume of total annual precipitation. For the Study Area it is equal to 0.7. (Yield ratio is not the same as runoff coefficient (C) which relates rates of runoff and precipitation).

5.2.4 Peak Flows

Streamflow and Rational Method Analysis

Information presented in this section is based on streamflow records, discussions with J. N. Jasper (Hydrologist for Water Resources Division, Dept. of Indian & Northern Affairs, Yellowknife), and use of empirical calculations such as the Rational Method. The estimation of peak flows for small basins is very uncertain due to the unavailablity of reliable data.

A Gumbel (extremal probability paper) plot was prepared from the recorded peak flows in Prairie Creek and the South Nahanni River (Fig. 16). These curves, extrapolated to a 100-year return period, provided estimates of peak flows as follows:

$Q_5 = 0.8\ Q_{10}$ where Q_5 = flood flow with 5 year return period

$Q_{25} = 1.3\ Q_{10}$

$Q_{50} = 1.5\ Q_{10}$ where Q_{10} = flood flow with 10 year return period

$Q_{100} = 1.7\ Q_{10}$

The unit peak flows (cfs/mi^2) for the two recording stations were plotted for the 10year return period (Fig. 17). Instantaneous flows for typical small basins of 1 and 10 square mile catchment areas, calculated by the Rational Method, were also plotted on this graph.

The Rational Method gives estimates of peak flows by a formula relating rainfall intensity, runoff coefficient and drainage area. Rainfall intensity was determined from the Fort Nelson IDF curves for a 10-year return period, assuming a 50-minute time of concentration for the 1 mi^2 basin and 90-minute time of concentration for the 10 mi^2 basin:

1 mi^2 basin - rainfall intensity 30 mm/hr. (1.2 in./hr.)
10 mi^2 basin - rainfall intensity 20 mm/hr. (0.8 in./hr.)

These times of concentration and corresponding rainfall intensities were based on estimates of overland and creek flow velocities at times of peak flow for typical basins in the Study Area.

Runoff coefficient (C) values of 0.3 to 0.5 were considered to be representative of ground conditions during peak rainfalls in the summer. The Suggested Design Curve (Fig. 17) has been drawn through C=0.3 because a C-value greater than this would likely only result from an infrequent combination of events (i.e. less frequently than once in 10 years).

Comparisons were also made with work done previously by others, including the Department of Indian & Northern Affairs (1979) for the Tungsten, N.W.T. area. Generally the Design Curve for the Cadillac Study Area (Fig. 17) gives higher flood values than those for the Tungsten area.

Streamflow Data Extensions

An isolated analysis of the short period of record on Prairie Creek is not sufficient to make confident predictions of the magnitude of major events. Therefore, an extension of the record was attempted by correlation with longer term records at both stations on the South Nahanni River. Because there was a poor correlation between the recorded peaks on Prairie Creek and those on South Nahanni River no further attempt was made to extend Prairie Creek flow data.

Application of Liard Highway Hydrology Regression Formula

In a report by M. M. Dillon Ltd., the hydrology studies of four other consultants were reviewed and a new hydrological design method was developed for creek and river crossings along the Liard Highway.

The hydrological design method developed in the report uses a regression formula and this was applied to the Prairie Creek and Harrison Creek basins. The 10 and 100 year return period flows obtained for Prairie Creek were 10,500 cfs and 15,800 cfs, respectively; for Harrison Creek they were 780 cfs and 1,180 cfs, respectively. These values compare fairly well with flows obtained from the Design Curve on Figure 17.

The regression formula is very sensitive to the precipitation and mean daily temperature and variations of 2 inches in the mean annual precipitation or of 2^{o} F in the mean daily temperature entered in the formula result in peak flow differing by 25% to 50%. However, the Dillon formula gives good confirmation of the streamflow and rational method analysis performed initially.

Kinematic Wave Flood Analysis

The Water Resources Division of the Department of Indian and Northern Affairs in Whitehorse has developed a computer model based on the kinematic wave theory of flood runoff routing and on data collected by Water Resources and Water Survey of Canada on smaller streams in the Yukon Territory.

Use of this model by government personnel gave the 10 and 100 year return period flows for Prairie Creek as 2970 cfs and 5010 cfs, respectively; for Harrison Creek flows were 128 cfs and 213 cfs, respectively. These results are not at all in agreement with other stronger and better corroborated evidence. It is felt that they are either in error or that the computer model has been poorly calibrated in the MacKenzie Mountain area. Therefore, the kinematic wave flood analysis has been disregarded.

Summary and Recommended Design Method

After reviewing many of the approaches available for hydrologic design in the area, it is believed the peak flows should be derived from the Design Curve shown on Figure 17. Design flows for Prairie and Harrison Creeks are therefore as follows:

	10 Year Flow (cfs)	100 Year Flow (cfs)
Prairie Creek	11,000	18,000
Harrison Creek	510	870

It must be remembered that the estimation of flood flows by statistical methods, from data with a short period of record, is uncertain at best. Usually flood estimates are not reliable to any great extent beyond the period of record. For example, if there are 15 years of record (as for the South Nahanni River), the 10 year flood can be estimated with confidence and the 15 and 30 year floods with somewhat lesser confidence. Confidence in estimates of the 100 year return period flood is poor. It would be safe to say that the 100 year flood on Prairie Creek at the minesite would fall in the range of 10,000 cfs to 22,000 cfs. Similar ranges would apply to the other small drainage areas.

5.2.5 Maximum Possible Flood (MPF)

From Chow (1964) and Fawkes, the maximum possible flood is the largest flood for which there is any reasonable expectancy in this climatic era. It is used in design where failure could lead to great damage and loss of life. The MPF is rigorously determined through detailed study of storm patterns and/or snowmelt patterns, transposition of the storms to a position that will give maximum runoff and calculation of the flood by unit hydrograph or computerized routing methods. It is assumed that the MPF will not result from a catastrophe such as the failure of an ice dam or similar failure of an earth obstruction.

In this study empirical methods have been utilized to calculate the MPF.

The first of 2 methods which were investigated is an extension of a calculation developed by D. M. Herschfield (1977) for probable maximum precipitation. The basic equation is:

MPF = (mean of recorded annual peaks) + k(standard deviation of the recorded peaks)

A value for k in the Study Area would be between 15 and 20 (Fawkes, pers.com.). This gives an instantaneous MPF of about 38,000 cfs on Prairie Creek. The period of record is extremely short for this type of analysis.

The second method utilizes the results of studies of MPF carried out on the Columbia and Peace Rivers and utilized by SIGMA Resource Consultants Ltd. (1974) in The Development of Power in the Yukon. For the purposes of this work the MPF can be taken as 2.5 times the 25 year return period flood. The calculation gives 34,000 cfs.

The two results are reasonably consistent. However, in order to be conservative, the instantaneous MPF for Prairie Creek is taken as 38,000 cfs.

5.2.6 Flood Elevations and River Dyking

General

MPF and 100-year flood elevations on Prairie Creek and Harrison Creek in the vicinity of the mine have been estimated on the basis of the creek profile and cross sections which were surveyed in August, 1980.

Manning's equation has been used to develop the flood profiles and an estimation of Manning's "n" is from a lengthy discussion in Chow 1959. The value selected is 0.04. At the Prairie Creek gauge site, Water Survey of Canada estimated flows on the basis of the Slope-area Method which involves an estimation of "n". They selected a value of 0.032 for the improved reach immediately upstream from the gauge. However, there is no evidence to support an "n" value as low as 0.032 for design purposes. Manning's formula calculations are based on the assumption of uniform flow since the channel cross-section does not change abruptly. The flow is normally subcritical, hence the calculated flood profiles have been inspected for possible backwater effects and adjusted accordingly.

The design flood velocities are in the range of 7 to 13 feet per second for the 100-year return period flood and 9 to 16 feet per second for the MPF depending on the particular slope and cross section. These velocities are sufficiently high that some form of bank and dyke protection (i.e. riprap) will be necessary to prevent erosion and possible river breakthrough. As there appears to be few fines in the bank and dyke material, downstream siltation, as a result of dyke erosion, should not be a problem. 100-year and MPF flood elevations and their effects are detailed below and a flood profile on Prairie Creek covering the man-made dyke section and the T3 area is shown in Figure 18.

The design flood for the plant-site surround dyking is the 100-year flood plus a 3 ft. freeboard and for the tailings dam is the maximum possible flood. The plant-site and its associated dyking will be abandoned after a period of years but the tailings dam will become a permanent feature and it is intended that its structural integrity be maintenance free.

Airstrip

The airstrip appears to have sufficient elevation to be above the 100-year flood but the road immediately upstream of the airstrip is just below flood elevations. The design flood velocity here is 11 feet per second and the required waterway area is approximately 1700 square feet.

T2 Area

The maximum possible flood elevation is 2 ft. above the top of the natural bank and the existing man-made bank/dyke. Design velocities are 14 ft. per second and the required waterway area is 3000 square ft.

Camp Area

The present camp is built on the Harrison Creek alluvial fan and it is at this natural obstruction that Prairie Creek flow is most constricted.

Opposite the present water supply well there is good freeboard on the present dykes for the 100-year flood but this gradually reduces to zero at the fuel storage area. To prevent possible washout and overtopping, the present dyke should be raised and strengthened downstream from this point and tied into higher ground, preferably the Harrison Creek diversion dyke.

Design velocities in this reach of Prairie Creek are 13 ft. per second with a required waterway area of 1400 sq. ft.

T3 Area

This area is relatively high and clear of the flood waters. There is a natural bank behind the edge of the vegetation and the maximimum possible flood limits would be 1 ft. - 2 ft. above the top of this bank. At the upstream end of this reach the top of the bank has an elevation of approximately 2820 feet with a slope downstream of .008. Material at the toe of a tailings dam should not be placed below this point unless it is protected with riprap.

Design velocities here are 11 ft. per second and the required waterway area is 4000 sq. ft.

Harrison Creek

The present diversion dyke on Harrison Creek appears to have sufficient height to prevent overtopping but it also may be subject to erosion during peak flows, because the 100-year design velocities are 13 ft. per second.

Field Observations on Flood Levels

A check on the calculated design flood levels is often made by comparison with observed high water marks; however, in this analysis, the high water marks only confirmed that the calculated design flood levels were above recent flood levels. The 100-year return period flood elevations just reach the existing bank elevation for the natural sections near the camp area.

5.2.7 Low Flows

Seven day average low flows for the South Nahanni River and Prairie Creek have been plotted on logextremal probability paper (Figure 19). The logextremal paper causes the low flows (which in almost all cases are the same as the annual minimum flows) to plot as a straight line. The 10 year seven day average low flow for Prairie Creek appears to be about 2 cfs. Beyond this period it is difficult to determine whether or not the creek will totally freeze but J. N. Jasper (pers.com.) believes that there is enough groundwater storage in the valley to prevent freeze-up.

5.2.8 Further Data Collection

In order to improve the knowledge of the mechanics of runoff from small creeks, two peak (crest) gauges have been installed at the minesite. With the anticipated complementary installation of a rate of rainfall gauge these gauges should provide valuable data. The peak gauges were provided by Mr. J. N. Jasper of the Water Resources Division, Dept. of Indian and Northern Affairs.

5.3 Water Quality and Sediments

5.3.1 Surface Water

Prior to the initiation of the water quality data collection programmes associated with the environmental assessment of the Cadillac project in 1980, the only previous data available for the creeks and streams in the vicinity of the mine was that collected in 1975 (DIAND 1975). DIAND 1975 results are reproduced in Appendix 6.

The 1980 surface water quality programme involved sampling of Prairie Creek (2 stations) and Harrison Creek on two occasions, during April and July. Stream sampling locations are illustrated on Figure 21. The results of the preoperational baseline water quality monitoring are listed in Tables 6, 7, 8 and 9. Water samples obtained in the 1980 programme were preserved in the field and dispatched to BEAK's laboratory in Richmond, B. C. for analysis.

The baseline surface water quality data indicates the waters of Prairie Creek and Harrison Creek are slightly alkaline in nature, have moderate water hardness and generally low levels of trace elements. In both 1975 (DIAND) and 1980 (BEAK), levels of arsenic, cadmium, chromium, molybdenum and nickel were very low to less than detectable. Mercury (not sampled in 1975) was found to be less than detectable in July, 1980. Copper levels were occasionally in the detectable range in Harrison Creek in the 1975 survey, whereas in 1980 copper was found to be less than detectable on both occasions. Iron was found to range from 0.1 to 2.06 mg/l in Prairie Creek in 1975 whereas in the 1980 data the highest value measured was 0.03 mg/l. Lead values reported in 1975 were generally less than 0.005 mg/l in Prairie and Harrison Creeks. The 1980 data indicates baseline lead values ranging from less than 0.01 mg/l to 0.04 mg/l (total) with little difference in upstream/downstream stations. A value of not greater than 0.03 mg/l for lead is considered desirable to protect freshwater aquatic life (Environment Canada 1979). In 1975 zinc values ranged from 0.006 mg/l to 0.034 mg/l in Prairie Creek whereas Harrison Creek ranged from 0.001 to 0.25 mg/l. In 1980 zinc values ranged from 0.05 to 0.031 mg/l (total) in Prairie Creek to 0.009 to 0.14 mg/l in Harrison Creek. Dissolved values of zinc were found to be considerably less than totals indicating the natural turbidity contains considerable amounts of the element zinc. A maximum value of 0.03 mg/l zinc is considered desirable to protect and maintain freshwater aquatic life (Environment Canada 1979).

5.3.2 Groundwaters

Groundwaters were sampled in the mine site area at four locations as shown in Figure 21. Except for the exploration camp domestic well, all other groundwaters were samples obtained from boreholes drilled in the tailings pond site investigation programme. The waters of the mine camp well and Borehole No. 3 have qualities not dissimilar to Prairie Creek except for a somewhat higher calcium component and lower pH values. Borehole No. 7 in the alternate tailing pond area (T3) was artesian. This groundwater contains considerably higher dissolved solids, mainly calcium and sulfates. Borehole No. 10 in the campsite area also contains higher dissolved solids, sulfate, calcium and magnesium than Borehole No. 3 and the camp well. A high level of zinc (0.76 mg/l) was also found in this groundwater in comparison to the other stations sampled. Borehole logs for the Stations 3, 7 and 10 are included in Appendix 1. It appears that Borehole No. 10 is located in alluvial material in an old Harrison Creek channel whereas all other stations show alluvial material over a significant depth of very stiff lacustrine clay which overlies a buried gravel aquifer.

5.3.3 Mine Water

Mine water from the two existing adits has been sampled on two occasions during the 1980 water quality monitoring programme. The locations of the mine water sampling stations (Portals) are shown on Figure 21. The results of the mine water analysis are shown in Table 8. During the April sampling no water was discharging from either portal (the lower (2850) portal contained ice to the roof level) and thus a sample was collected from free standing water inside the upper (3050) portal. The July sample from the lower portal was taken prior to exfiltration into the ground outside the mine portal entrance and reflects entrained sediment from drilling and mucking operations inside the mine. The levels of trace elements are generally low except for significant levels of iron, lead and zinc in the particulate fraction and a high dissolved zinc level present in the July sampling.

5.3.4 Stream Sediments

Samples of stream sediments were collected from two stations in Prairie Creek (as shown on Figure 21) for determination of pre-operational baseline trace element composition. Sediment samples were sieved to obtain the fine fraction (Minus 16 Mesh) and analyzed for total trace elements following digestion with aqua regia. The results of the sediment monitoring programme are shown in Table 9. The results indicated relatively little difference between the upstream and downstream stations. The sediment fines contain about 16%, 8-9.7% and 28-30% of the major constituents calcium, iron and magnesium, respectively. This compares with 9%, 23% and 21% found by others in the Liard River suspended sediment (Environment Canada, 1973). Levels of minor constituent trace elements are in most cases lower than reported in the Liard River. Lead ranged from 48-56 micrograms per gram in Prairie Creek as compared with 46 in the Liard River. Zinc levels ranged from 93-120 micrograms per gram compared to 170 in the Liard River. Copper ranged from 13-14 micrograms per gram in Prairie Creek compared to 24 in the Liard River system. These sediment analyses on Prairie Creek are considered good baseline data with which to compare any future post-operational monitoring of sediments.

5.4 Aquatic Invertebrates and Fisheries

Data was collected for the aquatic study between July 21 and July 25. The field programme was designed to evaluate fish habitat potential, document present fish habitat utilization and collect information on the benthic invertebrate community along watercourses which could potentially be influenced by the proposed development. In addition, the study was designed to determine metal levels for resident and migrant fish populations in Prairie Creek.

5.4.1 Aquatic Invertebrates

5.4.1.1 General

Biological systems are dynamic, i.e. populations and species composition will change with conditions. This metamorphosis in community composition may be a function of life history of aquatic organisms and/or changes in natural abiotic features of the environment. Industrial operations near water systems may cause changes in aquatic environments and directly influence biological components of the system. The effect of this could be a shift in composition of aquatic organisms to those species better adapted to cope with the altered physico-chemical conditions.

Changes in community structure can be detected with adequate sampling, good pre-operational and control data and the appropriate analysis of information. Continuous monitoring of these changes in biological systems enables the recognition of adverse changes and facilitates remedial action before serious degradation of the environment can occur.

Within the area of the minesite, four benthic invertebrate sampling sites on Prairie Creek and one site on Harrison Creek were established (Figure 21). As shown on Figure 20, benthic invertebrate sampling was also conducted at points approximately 100 yards above and 100 yards below the proposed winter road crossing sites on the following watercourses: Unnamed Creek (Site R2), Unnamed Creek (Site R3), Tetcela River (Site R4), Tetcela River (Site R5), and the Grainger River (Site R7). Fishtrap Creek (Site R6) was sampled in only one location due to the uniformity of the substrate and the observed minimal flows. The Unnamed Creek at Site R1 was sampled only at one site.

At each sampling site, 4 samples were taken with either a standard 144 $in.^2$ Surber sampler or a 78.8 $in.^2$ Eckman dredge. Samples were collected, wherever possible, in areas of similar depth, substrate and current. The collection bag used with the Surber sampler had a mesh size of 0.018 in. (750 microns). The Surber was placed on the substrate with the net extended downstream in the current. Large substrate particles enclosed within the frame of the Surber were scrubbed to dislodge any adhering organisms. The substrate was then disturbed to a depth of approximately 4 in. to dislodge organisms living within the substrate. Each sample was then individually labelled and preserved with 10 per cent formalin. To facilitate sorting of the invertebrates, rose bengal dye was added to the samples at the laboratory. Ekman dredge samples from Fishtrap Creek were washed in the lab through a sieve with 0.02 in. (0.5 mm) mesh to reduce the volume of the sample by removal of extraneous debris.

During the identification phase of laboratory analyses, the following taxanomic references were employed: Pennak (1953), Edmondson (1959), Johannsen (1934-1937), Stewart and Loch (1973), Wood et al. (1963), Allen and Edmunds (1912), Edmunds et al.(1976), Morihara and McCafferty (1979), Needham et al. (1935), Ross (1944), Smith (1968), Wiggins (1977), Baumann et al. (1977), Claasen (1931), Jewett (1959), Needham (1925) and Ricker (1952).

5.4.1.2 Biological Indices

An analysis of community structure was undertaken on benthic invertebrate data employing a series of indices which consolidate several data units into a single comparative index. These data were subjected to a number of tests which were interpreted with regard to river conditions; analyses included the biotic index, dominance, Shannon-Weaver diversity, equitability, richness and Keefe-Bergersen diversity.

Biotic Index

Invertebrates living in or on bottom sediments can be used as indicators of adverse changes in aquatic environments because they display varying degrees of sensitivity to degradation in water quality (Hynes, 1958; Wilhm and Dorris, 1966 and 1968; Cairnes and Dickson, 1971). Natural benthic communities are relatively stable or exhibit predictable oscillations in structure and composition. This phenomenon, coupled with their respective sensitivities to water quality, enables the use of benthic fauna as a biological measure of environmental conditions.

Benthic invertebrate data facilitate the analysis of the effects of alterations in water quality over time. Water quality data are time specific. However, a benthic community at any given time is representative of water quality and general habitat conditions not only at the instant of sampling, but also during periods prior to the actual collection of benthos. The ultimate effect of past environmental conditions is reflected in benthic communities; therefore, it is advantageous to perform biological sampling in conjunction with chemical analyses.

Since benthic organisms exhibit varying degrees of sensitivity to changes in the conditions of an aquatic environment, Beak (1965) has segregated benthos into three groups: those typical of clean water are categorized as pollution sensitive organisms - Group 3; those typically found in moderately polluted waters are labelled as moderately tolerant or facultative - Group 2; and those inhabiting highly polluted waters are classed as pollution tolerant organisms - Group 1. It is important to note that 'pollution' in this sense is not restricted to anthropogenic influences. Natural events (e.g. heavy rains causing sediment erosion) constitute a potential disruptive factor in aquatic systems and may also be regarded as pollution.

Group 3 organisms contain aquatic larval stages of insects which are sensitive to adverse changes in water quality and are the first to disappear if conditions deteriorate. Included in Group 3 are primarily the mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera). These organisms require clean water conditions which include high concentrations of dissolved oxygen, fairly swift currents, low turbidity and relatively low concentrations of toxic chemicals. Group 3 organisms respire primarily by external gill structures. The respiratory surfaces of the organs are extremely sensitive to abrasive action of fine sediments and the negative effects of chemical pollutants.

Group 2 consists of a number of organisms such as leeches (Hirudinea), midges (Diptera), water mites (Hydracarina), clams (Pelecypoda) and others. These organisms can tolerate a moderate amount of water quality degradation. The degree to which tolerance to pollutants is expressed varies according to individual levels.

Group 1 organisms are tolerant of some toxic conditions and low concentrations of oxygen and will survive in areas where less tolerant organisms would be eliminated. Within this group, for example, are some Oligochaetes, leeches and chironomids (Diptera).

The biotic or tolerance index is not a rigid classification scheme. Independent research studies have revealed a hierarchy of invertebrate taxa based on sensitivity to environmental degradation. Consequently, use of these categories has found wide application in the study of aquatic systems that may potentially be impacted by industrial activities.

Dominance Index

Natural biological communities include groups of organisms that are not equally successful. This is a function of the biotic/abiotic restrictions of an environment. A few may dominate a community with the spectrum then extending to groups of intermediate abundance and finally to rare organisms. An index used to measure relative abundance in biological samples was proposed by Simpson (1949).

Shannon-Weaver Diversity Index (H)

An index of diversity was also calculated for each sampling station based on the detailed identification of invertebrates. This method was adopted from information theory in communication engineering (Shannon and Weaver, 1949) by Margalef (1958) and MacArthur(1955) and applied to biological systems.

A simplified biological interpretation of information theory would be that ecological systems (e.g. rivers) act as a source of information and the output of information containing characters are the biological organisms themselves. A definition of ecological diversity is:

> "Diversity is thus equated with the amount of uncertainty (information) which exists regarding the species of an individual selected at random from a population. The more species there are and the more nearly even their representation, the greater the uncertainty (information) and hence the greater the diversity" (Pielou, 1966b).

Equitability Index

An important characteristic of the Shannon-Weaver diversity index is that it provides an objective measure of community complexity by incorporating within this single measure several variables that affect community structure. The primary components of diversity are equitability, or the evenness with which individuals are distributed among sampled genera, and richness, or the number of different genera sampled. A measure of equitability used in this study is presented in Pielou (1966a).

Stability is an inherent property of living systems. Ricklefs (1973) defines stability as the state where, "... variation in some characteristic of a system is less than the variation in a pertinent environmental variable". It is the ability of a system to accommodate environmental changes and dampen the effects of these exogenous forces so any perturbation elicited in the community is of a lesser magnitude. This dampening effect is a direct function of community complexity in terms of organisms and their relative abundance. In general, the more complex a system (high equitability), the greater its stability due to alternate routes of energy transfer (MacArthur, 1955). However, there are limits to the magnitude of change that any system can withstand. Beyond some maximum tolerance level, negative environmental forces will be evidenced in the biotic community by a decrease in stability and a decrease in overall community complexity.

Richness Index

Richness or variety in its simplest form is the number of genera encountered without considering the number of individuals actually examined. It is an indicator of the relative wealth of species or genera in a community (Peet, 1974). This function has been utilized in some studies as a measure of diversity. However, it is not an entirely correct approach to diversity since it does not incorporate the variable of equitability as does the Shannon-Weaver function.

Any richness measure is inherently dependent on sample size; the larger the sample size the greater the opportunity to sample greater numbers of species. This sample size - species number relationship is asymptotic. At some point additional sampling does not result in an increase in the number of species.

An index of richness is, therefore, best expressed with the inclusion of numerical abundance in the sample (Hurlbert, 1971; Shafi and Yarranton, 1973). The index employed in this study was from Margalef (1958).

Keefe-Bergersen Diversity Index(TU)

The Keefe-Bergersen diversity index (TU Index; Keefe and Bergersen, 1977) was developed primarily for use in the assessment of changes in water quality on biological components of aquatic communities. The apparent advantage of this method over other diversity calculations is that a high degree of taxonomic expertise is not required in the identification of invertebrate fauna. Organisms are compared on the basis of shape, colour and size and compared with other specimens in the sample. The basic approach of this method is centred around the theory of runs - "if an organism being examined is identical to the previous organism considered, it is part of the same run, if it is not, it is part of a new run". Therefore, a greater number of runs would indicate greater diversity within a sample. Although this index was designed for more general taxonomic considerations, it can also be applied to detailed taxonomic data. The determination of TU facilitates the calculation of a variance which may be used in test of significance between TU values.

5.4.1.3 Discussion

Detailed taxonomic information from samples collected near the minesite and along the access road are presented in Appendix 3. Tables 10 to 13 summarize benthic macroinvertebrate data. Information obtained during the study period quantify existing conditions of benthic communities inhabiting aquatic systems that may be affected by the mine and access road facilities. These data constitute baseline biological conditions prior to any major development in the area.

In the vicinity of the minesite, populations of invertebrates in Prairie Creek ranged from 94 organisms m^{-2} at Station M2 to 349 organisms m^{-2} at Station M5 (Table 10). Harrison Creek supported 334 organisms m^{-2}. Cobbles and gravel were the primary substrate in Prairie and Harrison Creeks.

In terms of tolerance groups, Group 3 (sensitive) fauna were most abundant at Stations M1, M2 and M3. The ephemeroptera (mayflies) dominated numbers. Stations M4 and M5 exhibited a proponderance of dipterans and nematodes, respectively (Group 2 organisms). The high dominance values at Station M1 and M2 also indicate a great abundance of one particular group of benthic fauna (i.e. Group 3).

The analysis of detailed taxonomic data indicated that Harrison Creek (M3) supported invertebrate communities that were the most complex and the most stable of the minesite complement of stations. Diversity (H and TU) was also high at this sampling location. Harrison Creek exhibited the highest equitability, 0.81, and the highest richness, 3.27, suggesting that Harrison Creek provided a greater variety of niches to benthic inhabitants and the numbers of individuals in the area were distributed quite evenly in the taxa collected.

The Prairie Creek system exhibited fluctuations in diversity, richness and equitability along the study length from Stations M1 through M5 (Table 10). There was no clear indication of significant community change. Chemical analyses of water samples from Prairie Creek showed no significant variation in water quality along the system; consequently, the observed oscillations in community statistics near the minesite are probably related to natural system variability. A comparison of TU diversity values at the upstream Prairie Creek station (M1) and the farthest downstream site (M5) indicated no significant difference in community diversity ($Z=1.591$, DF greater than 120, P greater than 0.05). These data provide a solid base for future data comparisons.

Table 11 summarizes data for the Ram River tributaries that were sampled as well as a single Prairie Creek tributary. In general, Unnamed Creek (Site R2, Fig. 20) supported the highest population of the three, this being due primarily to the great abundance of black fly larvae (simuliidae). As a result of the high dominance and low equitability, even though richness figures were relatively comparable, Unnamed Creek (Site R2, Fig. 20) exhibited the lowest community diversity. The Prairie Creek tributary supported ephemeropteran and nematode individuals primarily, with Unnamed Creek (Site R3, Fig. 20) supporting relatively low numbers of organisms but exhibiting high diversity levels due to the equitability structure of inhabitants. Cobbles (64-250 mm) and large gravel substrates (16-64 mm) were dominant at these stations.

The Tetcela River appeared to support rather sparse populations of invertebrates (Table 12) with samples ranging from 17 to 51 organisms m^{-2}. Equitability figures were high; however, niche variability was low relative to Prairie Creek stations (cf. Table 10) and the Grainger River (cf. Table 13). Substrates in the Tetcela River were compact consisting primarily of cobbles (64-250 mm) with some silt/clay and small gravel fractions. The nature of the substrate (i.e. compaction) may be responsible for the low numbers of fauna. Such conditions tend to minimize habitat variability thereby influencing variability of potential benthic inhabitants.

Fish Trap Creek (Table 13) was sampled with an Ekman dredge as substrates were composed entirely of silt/clay. Flows were very slow with high concentrations of organic debris instream. Undoubtedly related to substrates and overall habitat condition, the most abundant organisms encountered were dipteran larvae (Group 2) and leeches (Group 1) with low number of mayflies, stoneflies and dragonflies. Richness was relatively high as was system diversity.

The Grainger River stations (Table 13) supported 108 organisms m^{-2} at Station 1 and 404 organisms m^{-2} at Station 2. Relatively high diversity and richness values were noted at these sites. Substrates were composed primarily of sand, gravel and cobbles with the presence of some large boulders.

5.4.2 Fishery Resource

5.4.2.1 General

Investigations were conducted in order to identify the fish species which utilize watercourses within the sphere of influence of the proposed developments, to determine the degree and extent of the habitat utilization by those species, and to assess the habitat potential.

Prairie Creek was sampled at five locations (Stations M1, M2, M4, M5 and M6 (the latter immediately upstream of the delta at the confluence of the S. Nahanni River)). Harrison Creek (Station M3) was sampled near its confluence with Prairie Creek. The following major watercourses which are to be crossed or parallelled by the proposed winter road were investigated during the study (see Figure 20): Unnamed Creek (Site R1), Unnamed Creek (Site R2), Unnamed Creek (Site R3), the Tetcela River (Site R4), the Tetcela River (Site R5), Fishtrap Creek (Site R6) and the Grainger River (Site R7). During the helicopter reconnaissance of the proposed winter road alignment, additional watercourses were evaluated from the air and a physical description of their aquatic habitats is presented in Appendix 4 (Sites R8 to R11). The systems sampled on the ground included all of the watercourses that could potentially support fish populations. All other watercourse crossings along the route were examined from the air and were considered unsuitable as fish habitat because of negligible discharge, barriers, or other criteria.

Electrofishing was carried out by one two-man crew for approximately 275 yards using a Smith-Root Type VII electrofisher. Gillnets composed of 12 yards or 27 yards of 2" or 3" stretched mesh were set at sites M1 and M5 on Prairie Creek. All fish were released unharmed, with the exception of those taken at Prairie Creek sites M1 and M5, which were retained for laboratory analysis of trace metal concentration in muscle tissue.

5.4.2.2 Trace Metal Analysis

Table 14 summarizes trace metal analyses of fish tissue collected from Prairie Creek. Upstream of the minesite (Station M1) samples consisted of 6 slimy sculpin. Downstream samples (Station M5) were comprised of 5 slimy sculpin and 2 Dolly Varden char. Fish samples were bagged, labelled and immediately frozen. In the laboratory, individuals were measured and weighed. Since slimy sculpin individuals were small, dorsal musculature from the 6 specimens from Station M1 and 5 specimens from Station M5 were combined to form a single homogenate from each area.

The Canadian Food and Drug Directorate has established maximum levels of specific metals in consumable tissues, these being:

arsenic	-	5	μg/g
copper	-	100	μg/g
lead	-	10	μg/g
zinc	-	100	μg/g
mercury	-	0.50	μg/g

(All Values in Wet Weight)

It is evident that for these parameters, concentrations were well below the standard. The most noticeable difference between upstream and downstream stations was the concentration of zinc. Also, the difference between sculpins and char is noteworthy.

Sculpins inhabit the bottom of creeks, streams, etc. Consequently, they are closely associated with bottom sediments. Analyses of sediments from upstream and downstream sites indicated concentrations of zinc in the order of 93 μg/g and 120 μg/g, respectively (See section 5.3). Concentration of zinc in slimy sculpin similarly indicated upstream/downstream differences (Table 14). As Dolly Varden char are not a resident species, as are slimy sculpin, and are not bottom-oriented, the zinc content of tissues was not considered significant.

5.4.2.3 Study Methods

The following formulae were used to determine gillnet and electroshocker catch per unit effort (C.P.U.E.) during the July field activities:

$$\text{Electrofisher C.P.U.E.} = \frac{\text{total no. fish caught or identified}}{\text{total no. minutes electrofishing}} = \text{fish/min.}$$

$$\text{Gillnet C.P.U.E.} = \frac{\left(\dfrac{\text{total no. fish caught}}{\text{total length of net (m)}}\right)}{\text{effort (hr.)}} = \frac{\text{fish/m}}{\text{hr.}}$$

Fish catch information is tabulated in Appendix 5.

The physical parameters recorded for the stream were:

1. water colour
2. water temperature
3. wetted width
4. channel width
5. valley flat width
6. mean depth
7. maximum depth
8. bar or island presence
9. bank stability
10. channel stability
11. substrate particle-size
12. degree of shading
13. discharge (measured or estimated)
14. gradient (estimated)
15. pool/riffle ratio
16. vertical stability
17. channel confinement
18. side channel development
19. flow stage
20. flood signs
21. channel pattern
22. floodplain debris
23. channel debris
24. stable debris
25. obstructions to fish migration

Many of these parameters were measured directly while others, such as channel stability, involved qualitative assessments. Water temperatures were measured with a hand-held mercury thermometer ($\pm$ 1°F; 0.5°C). The pH ($\pm$ .2) and dissolved oxygen concentrations ($\pm$ 1 ppm) were measured with a model OX-9 Hach Kit. Stream discharges were determined with a Marsh-McBirney Model 201 electromagnetic current meter. Conductivity was also determined for some of the systems sampled.

5.4.2.4 Results

All physical and chemical data collected at the sampling sites are summarized on data sheets presented in Appendix 4. These parameters are also discussed in the text if judged to influence habitat utilization by fish.

Prairie Creek - General

Prairie Creek originates in an area of high relief in the Manetoe Range of the Mackenzie Mountains. This high-energy tributary of the South Nahanni River is characterized by extensive riffle sections and infrequent, small shallow pools. Prairie Creek appears prone to flooding as numerous dry channels are abundant in the valley flat.

Extensive side, transverse and mid channel bars were also evident. The stream substrate appears to be stable under the observed discharge and is composed primarily of boulder, cobble and gravel-sized particles. On July 22, 1980, the waters of Prairie Creek were colourless with a pH of 7.8, a temperature of 44^{o}F (6.5^{o}C), a dissolved oxygen content of 11 ppm and a conductivity of 265 μmhos/cm.

Prairie Creek was sampled at the following five locations: M1, M2, M4, M5 and M6 (Figure 21).

Fish habitat was similar at all of the sampling sites on Prairie Creek. The following factors were judged to have a limiting influence on the potential utilization of the stream by fish: lack of instream and stream side cover, negligible pool development and apparent low productivity.

Prairie Creek (M1)

On July 22nd, 1980, Site M1 on Prairie Creek was sampled by:

electrofishing - 600 seconds (S), and
gillnetting - 71 hours (h).

The above sampling resulting in the capture or observation of:

Dolly Varden char - (*Salvelinus malma*) - 2 juvenile, and
slimy sculpin - (*Cottus cognatus*) - 11 individuals.

The catch per unit effort was 1.30 for electrofishing and 0 for gillnetting.

Prairie Creek (M2)

Electrofishing was conducted at site M2 for 330 s on July 22, 1980.

The following fishes were observed or captured:

Dolly Varden char - 1 juvenile, and
slimy sculpin - 11 individuals.

The catch per unit effort for electrofishing was 2.18.

Prairie Creek (M4)

Prairie Creek was electrofished in the region of M4 for 239 s on July 22, 1980.

This sampling effort resulted in the capture or observation of:

Dolly Varden char - 1 juvenile, and
slimy sculpin - 16 individuals.

The catch per unit effort for this portion of Prairie Creek sampled by electrofishing was 4.27.

Prairie Creek (M5)

Site M5 on July 22, 1980, was sampled by:

electrofishing - 324 s, and
gillnetting - 16 h.

The above sampling effort resulted in the capture or observation of:

Dolly Varden char - 2 adult, and
slimy sculpin - 13 individuals.

The catch per unit effort was 2.41 for electrofishing and 0.01 for gillnetting.

Prairie Creek (M6)

This region of Prairie Creek was sampled on July 25, 1980, by electrofishing for 414 s.

The following fish were captured or observed:

Arctic grayling - (*Thymallus arcticus*) - 2 fry,
round whitefish - (*Prosopium cylindraceum*) - 1 juvenile, 1 adult,
whitefish sp. - (*Prosopium* sp.) - 2 fry, and
slimy sculpin - 9 individuals.

The catch per unit for electrofishing was 2.17.

Prairie Creek, in the region of the proposed minesite, is utilized by Dolly Varden char as a rearing area and as adult summer habitat. It is not known if Dolly Varden char utilize this section of Prairie Creek for all phases of their life history, however, no young-of-the-year and few suitable overwintering areas were observed. Slimy sculpin were captured in Prairie Creek at all sampling sites.

Although whitefish have been reported to utilize Prairie Creek in the region of the minesite (R. Fast pers. comm.), none were encountered during this study. Juvenile and adult round whitefish and whitefish fry were captured only at M6. Arctic grayling fry were also observed at this location. Burbot (*Lota lota*), white sucker (Catostomus commerson) and Arctic grayling adults have been reported to utilize the lower reaches of the creek (R. D. Wickstrom, 1977). Lake trout (Salvelinus namaycush; no positive identification) have also been reported to utilize the lower reaches of Prairie Creek (L. Comin pers. comm.). In addition, Arctic grayling, longnose sucker (Catostomus catostomus), Dolly Varden char and possible mountain whitefish (P. williamson) are reported to utilize Prairie Creek for a spawning area (Land Use Infor. Ser. 95F).

An aerial examination of the total length of Prairie Creek on July 25, 1980, did not identify barriers or steep stream gradients sufficient to prevent upstream movement of fish into the region near the minesite. It is believed, however, that extensive stretches with steep gradient and the lack of holding areas may discourage migration into upper reaches of Prairie Creek by many fish species found near the confluence with the South Nahanni River.

Harrison Creek (M3)

Harrison Creek, a tributary of Prairie Creek, originates in an area of high relief directly east of the proposed minesite.

When investigated on July 22, 1980, Harrison Creek exhibited only marginal fish potential. The lower reach of the creek exhibited inadequate flow and was occasionally subterranean. The upper reaches of Harrison Creek had a mean depth of 0.5 feet and were characterized by steep gradients and an absence of pool development. Mine water from the lower portal entered Harrison Creek approximately 200 yards upstream of the confluence of Harrison and Prairie Creek.

When sampled on July 22, 1980, the waters of Harrison Creek were colourless with a pH of 7.7, a temperature of 44°F (6.5°C), a conductivity of 410 μmhos/cm and a dissolved oxygen concentration of 11 ppm.

Harrison Creek was electrofished on July 22, 1980, near its confluence with Prairie Creek for 216 s.

The following fish were captured or observed:

slimy sculpin - 7 individuals.

The catch per unit effort for electrofishing was 1.94.

Fish utilization of Harrison Creek upstream of the mouth area is not expected due to steep gradient, absence of pools, low discharge and subterranean flows.

Unnamed Creek (Site R1 on Figure 20)

When investigated on July 23, 1980, the waters of this creek were colourless with a pH of 7.8, a temperature of 45°F (7°C), a conductivity of 310 μmhos/cm and a dissolved oxygen concentration of 9 ppm. This unnamed stream was approximately 16 feet wide and exhibited a mean depth of approximately 1 foot. The stream had tumbling flow and a steep gradient approaching ten per cent (10%).

Due to steep gradient, lack of pools and slow waters, this creek was judged to have no potential as fish habitat.

Unnamed Creek (Site R2 on Figure 20)

This unnamed mountain stream enters the North Nahanni River via Sundog Creek and the Ram River. The proposed winter road alignment closely parallels this high energy stream on the north side for several miles.

The waters of this mountain stream were colourless with a temperature of 45°F (7°C) when investigated on July 24, 1980. The pH was 7.8 and the dissolved oxygen concentration was 9 ppm.

Two waterfalls upstream of the sampling site constitute barriers to the upstream movement of fish into the headwaters.

Electrofishing was conducted for 535 s. on July 24, 1980, below the lower falls. No fish were observed.

The lack of fish utilization may be the result of gradient, limited instream cover and low productivity.

Unnamed Creek (Site R3 on Figure 20)

This small unnamed creek and its many tributaries drain the southwestern slopes of the Ram Plateau before discharging into Sundog Creek.

On July 24, 1980, the waters of this creek were colourless and had a dissolved oxygen content of 8 ppm. The pH was 7.7 and the temperature was 58°F (14.5°C). The unnamed creek was sampled on July 24, 1980, by electrofishing for 337 s.

This sampling effort resulted in the capture or observation of:

Arctic grayling - 2 fry, 3 juvenile.

The catch per unit effort for electrofishing was 0.89. Although instream cover is generally quite limited, debris accumulations and localized undercut banks are utilized by Arctic grayling as nursery and rearing areas. It is suspected that Arctic grayling may also use this section of the creek as a minor spawning area and as adult summer habitat. In addition, longnose sucker, longnose dace (*Rhinichthys cataractae*) and lake chub (*Couesius plumbeus*) have been reported to use the Ram River as a nursery area (Land Use Info. Ser. 95G), and may penetrate upstream into this tributary.

Tetcela River - General (Sites R4 and R5 on Figure 20)

The Tetcela River, a tributary of the North Nahanni River, originates on the southeast facing slopes of the Ram Plateau. The proposed winter road crosses this system at two locations. The westerly crossing site (Site R4) is located apprioximately 0.3 miles upstream of the confluence of the Tetcela River with a large unnamed tributary. The easterly crossing (Site R5) is located approximately 0.8 miles downstream of this confluence.

Tetcela River (Site R4 on Figure 20)

When investigated on July 23, 1980, the Tetcela River was narrow (10 ft.) and shallow (1 ft.) at the location of the proposed winter road crossing site. The water was light grey in colour with a pH of 7.9 and temperature of 52°F (11°C). The conductivity was 290 μmhos/cm and the dissolved oxygen concentration was 10 ppm. Electrofishing was conducted for 300 s on July 23, 1980.

The following fish were captured or observed:

Arctic grayling - 4 fry, 1 juvenile, 1 adult,
lake chub - 15 individuals, and
slimy sculpin - 13 individuals.

The catch per unit effort was 6.80.

The region of the proposed road crossing site was utilized to a limited extent by Arctic grayling as a nursery and rearing area and as adult summer habitat. Although satisfactory Arctic grayling spawning areas were not abundant, this species may spawn in this region of the Tetcela River. Extensive utilization by adult Arctic grayling is not anticipated due to the shallowness of the watercourse and the limited amount of adequate cover.

Tetcela River (Site R5 on Figure 20)

As the unnamed tributary that joins the Tetcela River 0.8 miles upstream of the proposed crossing site is substantially larger than the Tetcela River, the habitat present at the east crossing was considerably different from that at the noted westerly site (Site R4).

The stream width was approximately 35 feet and the mean depth was estimated to be 1.5 feet when investigated on July 23, 1980. The water of the Tetcela River was pale yellow in colour with a temperature of 52°F (11°C), a pH of 7.9, a conductivity of 350 μmhos/cm and a dissolved oxygen concentration of 9 ppm.

A total of 308 s of electrofishing on July 23, 1980, resulted in the capture or observation of:

Arctic grayling - 5 fry, 2 juvenile, 1 adult,
whitefish sp. - 1 fry,
northern pike (*Esox lucius*) - 1 juvenile,
1 juvenile/adult (undetermined maturity)
lake chub - 7 individuals, and
slimy sculpin - 22 individuals.

The catch per unit effort for electrofishing was 7.79.

Arctic grayling utilize this region of the Tetcela River as adult summer habitat and as a nursery and rearing area. Arctic grayling are suspected to utilize the Tetcela River as a spawning area. The region of the proposed crossing site was also utilized by whitefish sp. as a nursery area, and whitefish are suspected to spawn in the area as well. Northern pike, lake chub and slimy sculpin are also present in this section of the Tetcela River.

The observed higher numbers of fish at the eastern crossing of the Tetcela River is likely the result of an increase in the quality of aquatic habitat: mean depth, the number and depth of pools and the availability of cover from bank vegetation and undercuts. Longnose sucker and longnose dace have been reported to utilize portions of the Tetcela River approximately 30 miles downstream of the proposed winter road crossing (Site R5) as a nursery area (Land Use Info. Ser. 95G).

Fishtrap Creek (Site R6 on Figure 20)

Fishtrap Creek originates in a small lake situated west of the Silent Hills and drains a low marsh valley before discharging into the South Nahanni River.

Throughout its length, Fishtrap Creek was characterized by numerous beaver dams, negligible current and dense growth of aquatic macrophytes. When investigated on July 24, 1980, the water was colourless with a pH of 7.9, a temperature of 68°F (20°C) and a dissolved oxygen content of 9 ppm.

No fish were captured or observed during 150 s of electrofishing on July 24, 1980. Fishtrap Creek has very low habitat potential for utilization by prominent fish species other than northern pike (*Esox lucius*).

Grainger River (Site R7 on Figure 20)

The Grainger River originates in the Nahanni Range and flows generally in a southerly direction to its confluence with the Liard River. The winter road crossing is located at a site that was previously used for the same purpose.

On July 24, 1980, the pale amber coloured water of the Grainger River had a temperature of 57°F (14°C), a pH of 7.7 and a dissolved oxygen concentration of 9 ppm.

Electrofishing was conducted at the site on July 24, 1980, for 547 s. Sampling resulted in the capture or observation of:

> Arctic grayling - 3 juveniles, and
> slimy sculpin - 24 individuals.

The catch per unit effort for electrofishing was 2.96.

The section studied is utilized by Arctic grayling as a rearing area, and slimy sculpins are common. Although extensive utilization of the Grainger River in the vicinity of the proposed winter crossing sites by other prominent fish was not documented, the Grainger River appears to have habitat potential for rearing and adult summer usage. The availability of suitable spawning gravel for regionally prominent fish species is limited at the proposed crossing location. Gravel areas, which provide suitable spawning habitat, exist up and downstream of the proposed crossing (Hatfield *et al*. 1972).

Northern pike, longnose dace and longnose sucker have been reported to use downstream regions of the Grainger River for rearing (Hatfield *et al* 1972). Utilization of the lower reaches of the Grainger River as a nursery area by longnose sucker has also been reported. (Land Use Info. Ser. 95G). Adult northern pike, walleye (*Stizostedion vitreum*) and Arctic grayling have been reported at the mouth of the Grainger River (L. Comin, pers. comm.). As suitable habitat exists in the area of the proposed winter road crossing, utilization of the area by many of the species reported from downstream areas could be expected.

Liard River (Site R12 on Figure 20)

As reported in the Preliminary Environmental Evaluation, the Liard River is utilized as an overwintering area and a suspected spawning migration route for many fish species (Hatfield *et al*. 1972b, McCart *et al*. 1974). Longnose sucker, northern pike, walleye, lake cisco (*Coregonus artedii*) and lake whitefish are reported to be the most common fish in the Liard River (Land Use Info. Ser. 95G, Hatfield *et al*. 1972a).

5.5 Vegetation

5.5.1 Background

Overall, the vegetation of the South Nahanni and Liard River areas is not well-known. According to Raup (1947), the upland forest of white spruce, jack pine, aspen and balsam poplar, with its accompanying muskegs, is probably the most widespread timber type in southwestern Mackenzie district east of the mountains, that is, the Nahanni Range. Field investigations carried out for this report tend to confirm this statement. West of the Nahanni Range, the vegetation is quite variable, ranging from non-treed wetlands through mixed forest to alpine lichen-dominated communities. No vegetation maps or detailed descriptions of the Cadillac mine area are available; however, a number of studies of vegetation in Nahanni National Park and vicinity have been useful. A field programme was designed to gain more information regarding the vegetation of both the Cadillac mine property and the proposed winter road corridor.

5.5.2 Study Approach

To determine in greater detail the vegetation present on the Cadillac property and adjacent to the proposed winter road, field investigations were carried out in July, 1980. On-site studies concentrated on the mine, mill and camp site, and the preferred tailings pond locations, site T-2 and site T-3. A more general reconnaissance of other potential tailings pond locations was conducted. Vegetation communities along the proposed alignment of the road were determined by aerial observation, supplemented by ground surveys. In all cases, appropriate information obtained from the literature and personal communications has been incorporated into the report.

For each site examined, the general vegetation communities present were determined. Species representative of each community were noted and unknown species were collected for later identification. No attempt was made to quantitatively determine abundance or frequency of each species.

The following sections describe the vegetation of each site, with identification at the species level provided in most cases. If identification at the species level was not possible, genus name only has been given. In the text of the report, common names are used if they exist, with the scientific name being included only at the first point of reference to a species. In some cases, it has been possible to use the common genus name as only one species of that genus was seen. A complete listing of vegetation species by scientific and common names identified at the mine area, tailings pond sites and adjacent to the route of the winter road is included in Table 15.

5.5.3 Site Investigations

5.5.3.1 Mine and Mill Site

The area selected for the mine-mill site (P-2) is situated on the floodplain of Prairie Creek, adjacent to the existing camp facilities. Vegetation is dominated by a mixture of black and white spruce (Picea mariana and P. glauca respectively), which grow up to 30 feet in height. Less frequently occurring trees are balsam poplar (Populus balsamifera) and tamarack (Larix laricina). The understory is composed of a variety of shrubs including several willow species (Salix spp.), netted willow (Salix reticulata), shrubby cinquefoil (Potentilla fruticosa), Canadian buffalo-berry (Shepherdia canadensis), dwarf birch (Betula glandulosa), labrador tea (Ledum groenlandicum), lapland rose-bay (Rhododendron lapponicum)and ground juniper (Juniperus communis). Prostrate shrubs in this area are bog cranberry (Vaccinium vitis-idaea), bearberry (Arctostaphylos uva-ursi) and alpine bearberry (A. rubra).

The ground flora is composed of many species: grass-of-Parnassus (Parnassia palustris L. var. neogaea), fireweed Epilobium angustifolium), willowherb (E. latifolium), yarrow (Achillea millifolium), four-parted gentian (Gentianella propinqua), ragwort (Senecio cymbalarioides), golden saxifrage (Saxifraga aizoides), goldenrod (Solidago decumbens), Siberian aster (Aster sibiricus), white camas (Zygadenus elegans), cut-leaved anemone (Anemone multifida), hedysarum (Hedysarum sp.), fleabane (Erigeron hyssopifolius), showy everlasting (Antennaria pulcherrima), sweet-flowered androsace (Androsace chamaejasme), loco-weed (Oxytropis sp.), eyebright (Euphrasia disjuncta), common butterwort (Pinguicula vulgaris), northern green orchid (Habenaria hyperborea), yellow dryad (Dryas drummondii), white dryad (D. integrifolia), bistort (Polygonum viviparum), horsetail (Equisetum sp.) and at least one sedge (Carex spp.).

The grasses found on the site are a wheatgrass species (Agropyron violaceum), fescue (Festuca altaica), spike trisetum (Trisetum spicatum), northern reed grass (Calamagrostis inexpansa), hairy wild rye (Elymus innovatus), and foxtail barley (Hordeum jubatum). A variety of mosses and lichens also occur at this site.

A cleared area previously proposed as a site for the mill (P1) was found to be almost barren. However, the occasional invading species was noted, including willows, golden saxifrage and a species of wheatgrass (Agropyron violaceum).

5.5.3.2 Tailings Pond Sites

Of the nine potential tailings pond sites originally identified, five were considered to be worthy of further evaluation based on investigations carried our by Ker, Priestman & Associates Ltd. At the time the vegetation field work was conducted, two of these locations (site T-2 and site T-3) had been selected as preferred sites. Thus, detailed vegetation studies focussed on these two sites, with general communities being noted for the remaining three tailings pond sites (sites T-1, T-4 and T-5). It should be noted that sites are identified as T-1, T-2, etc. for ease of reference but only site T-2 is currently being considered for tailings disposal.

Tailings Pond Site T-2

Situated on the Prairie Creek floodplain, immediately to the northwest of the existing campsite, tailings pond site T-2 consists of three general vegetation communities: a spruce forest of similar species composition to the mine-mill site, a younger floodplain vegetation community and a sparsely-vegetated disturbed floodplain gravel area.

The species characteristic of the spruce forest community will not be repeated as they are included in the previous section. The community of greatest extent on tailings pond site T-2 is the floodplain vegetation, dominated by willows interspersed with Canadian buffalo-berry, dwarf birch, shrubby cinquefoil and ground juniper. Relatively young specimens of white and black spruce, balsam poplar, tamarack and aspen (*Populus tremuloides*) also occur.

Herbs found within this community include Siberian aster, yarrow, grass-of-Parnassus, cut-leaved anemone, four-parted gentian, white dryad, goldenrod (*Solidago decumbens*), ragwort, Indian paintbrush (*Castilleja raupii*), fireweed, willowherb, northern green orchid, milk vetch (*Astragalus Robbinsii* var. *minor*), and wild strawberry (*Fragaria virginiana*). The ground cover includes the prostrate shrubs bearberry and alpine bearberry, and sedges, mosses and lichens.

Some of the area in tailings pond site T-2 has been previously disturbed, completely removing vegetation and exposing gravel material. A few species were found to have invaded this disturbed area, including willows, fireweed, willowherb, yarrow, golden saxifrage, white and yellow dryad and several grasses.

Site T-3

Site T-3 is adjacent to Prairie Creek, downstream from the existing facilities of the mine and camp site. The vegetation on this site is a fairly homogeneous black spruce/lichen community. Black spruce is the dominant tree species with the occasional tamarack and white spruce occurring. Shrubs include dwarf birch, water birch (Betula occidentalis), labrador tea, ground juniper, shrubby cinquefoil, willows (one of which was identified as Salix myrtillifolia), bog bilberry (Vaccinium uliginosum), and Canadian buffalo-berry.

Lichens form the dominant ground cover in this black spruce/lichen community. Although extensive collections were not made, an area considered to be representative of lichen growth was sampled and the following species were found: Cladina alpestris, Cetraria cucullata, Alectoria ochroleuca, Thamnolia subuliformis, Dactylina arctica and Cetraria pinastri. Within the same sample area, two mosses were also identified: Dicranum sp. and Pleurozium schreberi. See Table 16 for a listing of lichens and mosses by complete scientific name. Other species found in the ground cover include alpine bearberry, golden saxifrage, four-parted gentian, common pink wintergreen (Pyrola asarifolia), white dryad, lapland cassiope (Cassiope tetragona) and sedge.

Adjacent to Prairie Creek and the existing road, willows become dominant, with more frequent occurrence of shrubby cinquefoil, fireweed, ragwort, horsetail and sedge.

Other Sites

Site T-1 is located in the valley of Harrison Creek in close proximity to the mine portals and existing camp. This steep-sided valley exhibits two distinct vegetation communities, dependent on aspect. The slope with a southeast exposure supports a black spruce/lichen community. A road following this side of the valley to the upper portal has been invaded by horsetail and some fireweed. The other side of the valley with a northwest exposure is more open, characterized by few spruce, some willows and a more dense ground cover of lichens and mosses. Some areas of exposed rock are found and permafrost is known to exist (Ker, Priestman, 1980).

Adjacent to Harrison Creek, a disturbed gravel area supports several pioneer species including willows, horsetail, bearberry, yellow and white dryad, golden saxifrage, willowherb, lapland cassiope, and sandwort (Arenaria rubella). Very young seedlings of white spruce and balsam poplar were also noted. Upstream of site T-1 on the south and north forks of Harrison Creek, sites T-4 and T-5 (respectively) are located. Aerial reconnaissance revealed both valleys to be dominated by black spruce/lichen vegetation, with species composition assumed to be similar to that described for Site T-3.

5.5.3.3 Disturbed Areas

Site investigations of disturbed areas in the vicinity of the Cadillac mine site revealed several colonizing species. The areas examined include the gravel adjacent to Harrison Creek, the dyke between the camp and Prairie Creek, the proposed tailings pond site T-2, the camp site and nearby roads, and the gravel airstrip.

The first of these areas, the gravel adjacent to Harrison Creek, has been relatively undisturbed since 1968 and several species (dominantly willows) have invaded the site. The complete species list for this area is included in the description of site T-1. Proposed mill site P-1 was last disturbed in 1969; occasional regrowth of willow species, golden saxifrage and wheatgrass (Agropyron violaceum) has occurred. The cleared area on the floodplain at tailings pond site T-2 has been invaded by willows, fireweed, willowherb, yarrow, golden saxifrage, white and yellow dryad and several grasses.

The community where vegetation appears to have most successfully re-established is the camp site floodplain adjacent to the mixed spruce forest. Species found here include: willows, netted willow, shrubby cinquefoil, rough cinquefoil (Potentilla norvegica), silverweed (Potentilla anserina), fireweed, willowherb, golden saxifrage, four-parted gentian, yarrow, sweet-flowered androsace and yellow and white dryad. A commonly occurring sedge is northern single-spike sedge (Carex scirpoidea). Grasses are frequent colonizers, the most dominant being a wheatgrass species (Agropyron violaceum); hairy wild rye is also frequently seen. Other species in the disturbed area are foxtail barley, northern reed grass and spike trisetum. One specimen of hair grass (Agrostis scabra) was observed.

The last disturbed site examined for invading species was the gravel airstrip which was built in 1966 and upgraded in 1967. Ongoing use of the airstrip appears to discourage colonizing species as most of specimens noted were along the edges of the landing strip. Species include several willows, white and yellow dryad, golden saxifrage, Siberian aster, fireweed, yarrow, goldenrod (Solidago multiradiata) and dandelion (Taraxicum sp.). Northern single-spike sedge was fairly common. Grasses include wheatgrass (Agropyron violaceum), spike trisetum and northern reed grass. Several volunteer seedlings of white spruce were also noted.

Since the above-named species appear to be natural colonizers, it seems practical to consider them when revegetation studies are undertaken. The grasses, in particular, are practical for reclamation as their seed is more likely to be available in commercial quantities. The dominant colonizer is wheatgrass (Agropyron violaceum); others are hairy wild rye, spike trisetum, northern reed grass and foxtail barley.

5.5.4 Vegetation Along the Winter Road Corridor

5.5.4.1 Introduction

The proposed winter road corridor extends a distance of nearly 100 miles between the Cadillac mine site at Prairie Creek in the Mackenzie Mountains and the Liard River east of Nahanni Butte. Along this distance, it traverses a number of environmental settings, each with a different vegetation component. To determine the vegetation communities through which the road will pass, an aerial reconnaissance was conducted. Where possible, the area was investigated on the ground and more detailed information regarding community structure was obtained. The following sections describe the vegetation communities along the winter road corridor, as determined by field investigations, supplemented by air photo analysis and literature review. The locations where ground investigations of vegetation communities were conducted are shown in Figure 22.

5.5.4.2 Floodplain Community (Site 1 on Figure 22)

The vegetation type which the road most frequently traverses at the beginning of the route along Prairie Creek is the floodplain community. The most dominant species is generally willow if the community is less well-established. In other communities, white spruce becomes important. Detailed species lists of vegetation within the willow-dominated floodplain community are given in the description of tailings pond site T-2 (section 5.5.3.2). In the Prairie Creek valley, the floodplain is flanked by valley walls supporting a black spruce/lichen community as described in section 5.5.3.2.

5.5.4.3 Lichen Dominated Community (Sites 2 and 4 on Figure 22)

As altitude increases along the route, the trees become more openly spaced and lichens begin to dominate the community. At Site 2, the vegetation consists of occasional black spruce and tamarack, as well as willows, bog bilberry and labrador tea. The ground flora is largely lichens with some mosses and bearberry, alpine bearberry, lapland cassiope, common pink wintergreen, white dryad and sedge.

Further examination of this community type was undertaken at Site 4. Species included the occasional stunted black spruce, willows, dwarf birch, water birch, labrador tea, lapland rose-bay, bog bilberry and alpine bearberry. Ground flora consisted of lapland cassiope, white dryad, elephant head (Pedicularis groenlandica), purple saxifrage (Saxifraga oppositifolia), golden saxifrage, crowberry (Empetrum nigrum), northern asphodel (Tofieldia coccinea), smooth woodsia (Woodsia glabella), bistort and sweet-flowered androsace. Northern single-spike sedge and a species of fescue (Festuca altaica) were also noted. Lichens and mosses, the dominant ground cover, were identified as Cladina alpestris, Cetraria cucullata, Alectoria ochroleuca, Thamnolia subuliformis, Dactylina arctica, Cetraria pinastri, Dicranum sp. and Pleurozium schreberi.

5.5.4.4 Barren Areas (Site 3 on Figure 22)

Further increases in altitude bring about a corresponding decrease in vegetative cover. Bedrock outcrops and loose scree slopes inhibit growth and the vegetation is characterized by a thin ground flora of ericaceous shrubs and lichens (Crampton 1973). In areas sufficiently stable to support growth, the occasional dwarfed willow or black spruce is seen.

5.5.4.5 Mixed Forest (Sites 5 and 6 on Figure 22)

A few miles beyond site 4, lower elevations prevail and more dense vegetation is seen. Tree cover becomes almost continuous, dominated by black spruce, with the occasional appearance of white spruce, tamarack and white birch (Betula papyrifera). Balsam poplar appears adjacent to stream beds and scattered throughout the forest. Jack pine (Pinus banksiana) also begins to appear more prominantly. Pure stands of black spruce with a lichen ground cover intrude and may indicate an area of 'frozen peatland'. (S. Zoltai, pers.comm.)

At the crossing of an unnamed tributary to Sundog Creek (site 5) a forested site revealed a tree cover of dominant black spruce with the occasional balsam poplar. Shrubs included willows (Salix spp. and s. myrtillifolia), labrador tea, dwarf birch, bog bilberry, prickly rose (Rosa acicularis), and the prostrate shrubs bearberry and alpine bearberry. Common pink wintergreen, one-flowered winter-green (Moneses uniflora), four-parted gentian, hedysarum sp. horse-tail, and mosses, lichens and the occasional grass species comprised the ground flora.

Closer to the stream, balsam poplar becomes more frequent and the shrubs Canadian buffalo-berry, alder (Alnus sp.), and willows were found. A milk vetch (Astragalus frigidus) was noted as part of the ground flora.

Further along the route, jack pine becomes more prominant and occurs in pure stands as well as scattered throughout the forest. This feature may be the result of past forest fires. During aerial reconnaissance, it was noted that fairly large areas have been burned; apparently, a major fire burned the area in 1942, and several smaller fires have occurred since that date. (Camp personnel, pers. comm.)

The next site that was investigated on the ground was the Tetcela River (site 6). This site is a part of the mixed forest area described above, yet the vegetation sample may reflect a more riparian nature due to its proximity to the Tetcela River. Trees found here include balsam poplar, trembling aspen, white spruce and the occasional jack pine. The shrub layer was comprised of willows, alder (Alnus rugosa), dogwood (Cornus stolonifera), rose (Rosa sp.), Canadian buffalo-berry, wild red raspberry (Rubus ideaus), low-bush cranberry (Viburnum edule), shrubby cinquefoil, ground juniper, twining honeysuckle (Lonicera dioica) and bearberry. A rich herb layer includes wild strawberry, reflexed loco-weed (Oxytropis deflexa), goldenrod (Solidago canadensis and S. decumbens), northern bedstraw (Galium boreale), hedysarum sp. (Hedysarum boreale), Siberian aster, Lindley's aster (Aster ciliolatus), fireweed, yellow dryad, one-sided wintergreen (Pyrola secunda), Siberian yarrow (Achillea sibirica), twin-flower (Linnaea borealis), western meadow rue (Thalictrum occidentale), narrow-leaved hawkweed (Hieracium scabriusculum), grass-of-Parnassus, and bunchberry (Cornus canadensis). Horsetail was observed and wheatgrass (Agropyron sp.), bluejoint (Calamagrostis canadensis) and moss are in evidence.

5.5.4.6 Seasonally Waterlogged Areas (Site 7 on Figure 22)

As the winter road corridor approaches Fishtrap Creek from the west, the vegetation changes from mixed forest to a community more characteristic of increased moisture. These areas are called seasonally waterlogged and display a mixture of treed and non-treed areas. Trees include black spruce, tamarack, white spruce, balsam poplar and white birch. The treed areas merge into treed bogs, willow flats, sedge meadows and open peat bogs (Crampton 1973). No ground examination of the seasonally waterlogged areas was conducted.

This type of terrain continues to the western edge of the Nahanni Range, interrupted only by the Silent Hills Pass upland area where mixed forest vegetation of balsam poplar and jack pine, with tamarack, black spruce and white spruce occurs once more. After crossing another seasonally waterlogged area, the winter road corridor gains elevation towards the Grainger Pass in the Nahanni Range. West of the Pass, the vegetation returns to mixed forest of balsam poplar and jack pine, with white spruce, white birch and stands of black spruce intruding. This cover thins and becomes low-growing in the pass area, with willows becoming more evident.

5.5.4.7 Shrub Meadow Community (Sites 8 and 9 on Figure 22)

East of the Nahanni Range (site 8), the vegetation is dominated by shrub meadow communities with treed and non-treed areas occurring in patterns. Detailed information for this vegetation type was drawn from Reynolds et.al. (1980) and a field site visit. At a shrub meadow site located slightly east of the Grainger Pass, plant species are water sedge (Carex aquatilis), northern single-spike sedge, spike rush (Eleocharis pauciflora), dwarf birch and willows. Associated or understory species are shrubby cinquefoil, sweet gale (Myrica gale), bog rosemary (Andromeda polifolia), horsetail spp. (Equisetum palustre, E. fluviatile), sedge (Carex spp.), alpine bearberry, cinquefoil (Potentilla sp.), cotton grass (Eriophorum scheuchzeri), false asphodel (Tofieldia pusilla), showy everlasting, labrador tea sp. (Ledum sp.), stonecrop (Sedum sp.) and meadow rue (Thalictrum sp.). A second site in this vegetation community was sampled during field investigations (site 9). The area was more densely vegetated than the previous site although it still retained a non-treed appearance from the air. Species include low-growing balsam poplar and aspen, black spruce, willows, alder (Alnus sp.), rose, shrubby cinquefoil, bog bilberry and bearberry. Ground cover was composed of bunchberry, wintergreen (Pyrola sp.), labrador tea, fireweed and Canada anemone (Anemone canadensis).

5.5.4.8 Grainger River Area (Site 10 on Figure 22)

The terrain becomes more rolling two miles west of the Grainger River crossing, and balsam poplar is more prevalent. In general as the Grainger River is approached, vegetation resembles the mixed forest community described in section 5.5.4.5. Black spruce occurs frequently with areas of balsam poplar, aspen and jack pine appearing. Tamarack is associated with the stands of black spruce.

At the Grainger River crossing (site 10), two vegetation communities were sampled: the river edge and the adjacent forested area. The river edge community included willows, balsam poplar, shrubby cinquefoil, common wild rose (Rosa woodsii), dogwood, alder (Alnus sp.), and silverberry (Elaeagnus commutata). Ground flora was composed of goldenrod (Solidago canadensis), wild strawberry, Siberian aster, ragwort, northern green orchid, bronze-bells (Stenanthium occidentale), northern bedstraw, yarrow, star-flowered Solomon's-seal (Smilicina stellata), showy everlasting, wild chives (Allium schoenoprasum), prairie gentian (Gentiana affinis), blue-eyed grass (Sisyrinchium montanum) and false asphodel (Tofieldia glutinosa). Horsetail and water sedge were part of this community as were narrow reed grass (Calamagrostis neglecta), wheatgrass (Agropyron violaceum), timber oat grass (Danthonia intermedia) and sweet grass (Hierochloe odorata).

Adjacent to the river edge community at the Grainger River, a forested area was examined. Species which form this community are balsam poplar, aspen, white spruce, black spruce, tamarack, willows, alder (Alnus sp.), Canadian buffalo-berry, low bush cranberry, labrador tea, shrubby cinquefoil and rose. The ground flora consisted of bunchberry, Canada anemone, common pink wintergreen, bastard toad-flax (Geocaulon lividum), northern bedstraw, western meadow rue and mitrewort (Mitella nuda).

5.5.4.9 Liard Forest

The area between the Grainger River and the Liard River is covered with several species of trees, which may occur as individuals or in pure stands. Species found include balsam poplar, aspen, jack pine*, black spruce, tamarack and white birch. Stands are quite variable, not only in species composition, but in height. A somewhat patterned appearance of different tree densities and heights is exhibited in this area. Crampton (1973) provides further information regarding the vegetation which occurs. Widely scattered dwarfed black spruce, with some tamarack and white birch, which surround scattered depressions containing summer pools, may indicated the presence of a peat plateau. The vegetation in these areas is dominated by labrador tea sp. (Ledum palustre). Minor components of the flora are shrubby cinquefoil, bog cranberry, cloudberry (Rubus chamaemorus) and horsetail. (Crampton 1973).

5.5.5 Botanical Interpretation

5.5.5.1 Introduction

The Cadillac property and the proposed winter road corridor lie within a region which is considered relatively unexplored in botanical terms. As much of the area has experienced a long glacier-free period, the possibility of locating species of botantical interest is fairly high. This might include the discovery of endemic species, or the occurrence of species previously documented in the literature but whose range is not well-defined.

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* The Liard area is close to the northernmost limit for lodgepole pine (Pinus contorta var. latifolia), however some interbreeding does occur between this species and jack pine (Scotter 1974). For purposes of this report, all pine in the area is referred to as jack pine, although it is probable some lodgepole pine occurs near the Liard River.

5.5.5.2 Rare Species

Most available information regarding rare flora has been obtained from studies in the vicinity of Nahannni National Park (Marsh and Scotter 1976; Scotter and Henry 1977; Scotter et.al. 1971; Steere, Scotter and Holmen 1977). The presence of unusual habitats such as mineral springs or spray zones from falls may create an environment suitable for species not generally found elsewhere, and therefore of interest. An objective of the field programme was to record any habitats along the route of the winter road or at the mine site which could be considered unusual. The area beside the falls near site 4 presents the possibility of a unique habitat; otherwise, no specialized habitats were noted.

5.5.5.3 Plants of Restricted Range

Most of the species identified during site investigations have been referred to in the botanical literature for the region and are not considered unusual. However, several species are listed as vascular plants of restricted range in the Northwest Territories (Cody 1979). They are as follows:

1. *Danthonia intermedia* Vasey
2. *Anemone canadensis* L.
3. *Rosa woodsii* Lindl.
4. *Oxytropis deflexa* (Pall.) DC. var. *sericea* Toff. & Gray
5. *Gentiana affinis* Griseb.
6. *Lonicera dioica* L. var. *glaucescens*

Of the above species, two were collected from locations which extend their known range in the Northwest Territories. These are timber oat grass (*Danthonia intermedia*), and prairie gentian (*Gentiana affinis*), both of which were collected at the Grainger River, site 10. The others were noted in locations within their known restricted ranges as described by Cody (1979). All species have distributions outside of the Northwest Territories.

5.5.5.4 Other Collections

Site investigations revealed the presence of three species of further interest:

1. *Hedysarum boreale* Nutt. var. *mackenzii* (Richards.) C.L.Hitchc.
2. *Astragalus Robbinsii* var. *minor*(Hook.) Barneby
3. *Stenanthium occidentale* Gray.

The presence of these species in the Northwest Territories has not been reported in the literature examined for this project. In the case of the Hedysarum species, which was collected at the Tetcela River site, modifications of taxonomy may account for the absence of documentation of this particular species. The fairly widespread nature of Hedysarum and the taxonomic uncertainty associated with identification place this species among those considered usual for the Mackenzie region.

The species of milk vetch (Astragalus Robbinsii var. minor) which was collected at the northwest end of tailings pond site T-2 is documented in Hulten (1968). However, the range indicated for this species does not show an extension into the Prairie Creek area. The herbarium at the University of Calgary has no samples of this milk vetch collected from the Northwest Territories, although its distribution into the Mackenzie District is mentioned in a herbarium reference (P. Dickson, pers.comm.).

The third species of interest is bronze-bells (Stenanthium occidentale), which has not been recorded in the Northwest Territories. The collection of this species from the Grainger River site may be considered an important extension of range from its documented occurrence in the southwestern regions of Canada.

It appears that the Prairie Creek study area, and the Grainger River site in particular, may yield valuable botanical information regarding species presence and distribution in the Mackenzie District of the Northtwest Territories. The amount of information obtained during the site investigations emphasizes the relatively unexplored nature of this region.

5.5.6 Revegetation

Reclamation planning for disturbed areas created both during the operation and following abandonment of the Cadillac mine site will aid the process of revegetation. The environment of the mine property is characterized by severe climate and a short growing season. Poor growth conditions on waste rock and tailings materials further restrict natural revegetation. Roads associated with mining activity and exploration disturb the vegetative mat on steep slopes, creating an additional reclamation problem. During field investigations, previously disturbed areas were examined to determine if natural revegetation was occurring. It was found that the more ideal environments, that is, floodplain gravels which are flat-lying, had been colonized by some species. These invading species are described in section 5.5.3.3. The ground cover achieved by colonizers is sporadic, and therefore active reclamation of disturbances will be necessary to restore ground cover.

Materials created during the mining process do not present optimum growing conditions for vegetation. Waste rock may be deficient in both plant nutrients and moisture due to its coarse size and inadequate fines. Tailings pond materials will not be acid-generating, according to tests conducted by B. C. Research (Ker, Priestman, 1980). It is possible that the most serious problem facing the establishment of long-term growth on the tailings pond site may be the presence of salts resulting from the alkaline nature of the host rock. A clay-lined tailings pond in which moisture tends to move to the surface through capillary action rather than draining into the ground water systems may concentrate salts at the surface.

The Cominco operation at Pine Point, Northwest Territories, where lead-zinc ore is extracted from dolomitic limestone host rock, likely represents the most comparable mine situation. At this location, the presence of high levels of salts in the tailings pond occurred over time. (R. Gardiner, pers. comm.). Several species have been used in revegetation of the area; they include alkali grass (Puccinellia nuttalliana) which was transplanted from the Fort Smith area, and agronomic varieties of wheatgrass (Agropyron spp.) and fescue (Festuca spp.). It has been found that the native species establish more successfully.

During experimental evaluation of the Pine Point mine and mill waste as growth media for plants, the following results were obtained:

1. Potential growth limiting factors associated with waste rock disposal areas include deficiencies of essential plant nutrients (Nitrogen, phosphorus, potassium), phosphorus fixation, induced potassium deficiency, moisture stress during periods of infrequent precipitation, winter-kill, compaction on the top surface of the dump and excessive steepness and inadequate fines on the slopes.

2. Growth limiting factors may vary over the surface of the tailings pond as a result of particle segregation during deposition. Deficiencies of nitrogen, phosphorus and potassium will be general over the area. Moisture stress, lack of secondary structure and inadequate aeration may limit plant growth to varying degrees depending on the particle size distribution, moisture holding capacity and related physical characteristics.

The above-mentioned factors may also be associated with waste rock disposal areas and the tailings pond site to be created at the Cadillac mine property.

5.6 Wildlife

5.6.1 Methods

Wildlife surveys were flown in a Bell 206 Jet Ranger helicopter over Cadillac Explorations Limited Prairie Creek minesite and winter road alignment during the period 6 - 10 July, 1980. The surveys were designed to provide information on the general abundance and seasonal distribution of ungulates including woodland caribou (Rangifer tarandus caribou), Dall's sheep (Ovis dalli) and moose (Alces alces), and birds such as cliff-nesting raptors including Golden Eagles (Aquila chrysaetos), Gyrfalcons (Falco rusticolus), Peregrine Falcons (Falco peregrinus) and waterfowl, with particular emphasis on Trumpeter Swans (Olor buccinator).

The surveys were concentrated primarily within a six mile radius of the mine but also included the 'Caribou Flats' area north of the minesite. The most westerly portion of the winter road route was surveyed in conjunction with the coverage of the minesite. Intensive surveys of the Nahanni Range in the 'Grainger Gap' area were flown for Dall's sheep and cliff-nesting raptors. Incidental sightings of moose and signs of beaver activity in the Fishtrap Creek and Silent Hills areas were recorded during waterfowl surveys.

In addition to the aerial surveys, inspections for signs of mammalian wildlife (e.g. tracks, fecal pellets, plus direct observations) and breeding birds were made in the vicinity of the mine. Wildlife observations were also recorded by a team of BEAK fisheries biologists during the course of a 21 - 25 July field investigation.

The extent of the ungulate/raptor survey coverage and waterfowl survey flightlines is illustrated in Figure 24. Flight paths for the ungulate survey generally followed topographic contours and were chosen to provide total survey coverage of the area similar to that described by Comin et. al. (1978) for the 'Block Survey Method'. Although observations were not restricted to a 200 m strip width, as described by Comin, emphasis was placed on this zone. For the waterfowl surveys, all wetlands within 1.2 miles of the proposed winter road right-of-way were numbered and a total of 17 surveyed. As shown in Figure 24, all were east of the Silent Hills.

Cliffs or slopes judged suitable for raptor nesting were surveyed using techniques as discussed by White and Sherrod (1973).

A helicopter was flown parallel to each cliff or slope surveyed at a distance of 100 ft. or greater depending on local wind conditions and slope aspect. Full coverage of each cliff or slope was attained by making one or several passes across the face depending on its vertical height.

All wildlife observations were plotted on 1:50,000 scale topographic maps during the survey and information relevant to each sighting was recorded on cassette tape.

A small mammal trapline was established adjacent to the airstrip to obtain specimens for possible trace metal analysis at a later date. The effort was limited to 87 trap nights.*

5.6.2 Results

Wildlife observations made during the 6 - 10 July, 1980 surveys are illustrated on Figure 24. (Wildlife information from the April, 1980 survey is shown on Figure 23.)

5.6.2.1 Ungulates

In the area of the minesite, the surveys were principally directed at providing information on the general abundance and seasonal distribution of woodland caribou and Dall's sheep. Identifcation of areas of special sensitivity such as calving and lambing, and areas used by nursery bands could not be adequately addressed owing to the timing of the field programme. The surveys covered a large portion of the potential habitat of each species within six miles of the minesite (see Figure 24) and were extended to include 'Caribou Flats' which is reported to be an important area for ungulates (R. Fast 1980 pers. comm.).

Only two woodland caribou and scattered caribou tracks were observed in the vicinity of the minesite during the course of the surveys. Two additional woodland caribou were observed north of the minesite, adjacent to 'Caribou Flats'.

A total of 47 - 49 Dall's sheep were observed during surveys in the vicinity of the minesite and 16 sheep were observed in the 'Caribou Flats' area. Several nursery bands, comprised of ewes, lambs, and frequently yearlings, were observed (see Figure 24). One small group, consisting of two ewes and two lambs, was located less than 800 yards from the Prairie Creek airstrip which services the minesite. The other two bands were 6 and 13 miles respectively, from the minesite. All of the groups were located on or near cliffs; however, it was not possible to determine if those cliffs constituted lambing areas. At the time of the survey, nursery groups had formed and post-lambing movements may have occurred.

The surveys suggest that populations of woodland caribou and Dall's sheep are scattered in the region surrounding the minesite. The ungulate usage pattern and over-all extent of the range will be further investigated by winter surveys to be carried out in 1980/81.

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* One trap-night equals one live trap set and baited for one night.

As discussed in the Preliminary Environmental Evaluation, the capability of habitat to support wildlife in the immediate vicinity of the minesite appears to be low. The pertinent Land Use Information Series map sheet, 95F Virginia Falls (Department of the Environment 1974), states that the zone supports scattered groups of Dall's sheep and woodland caribou and that few of the potential wintering areas available to these species are actually used. Parks Canada data (L. Comin 1980 pers.comm.) indicate that Dall's sheep nursery bands may concentrate as close as three miles southeast of the minesite (20 sheep including 8 lambs were observed near Prairie Creek during a September 1977 survey). BEAK observations included a group of two ewes and two lambs near the Prairie Creek airstrip. The major summer range of Dall's sheep inhabiting the northeastern end of the Park has been estimated to extend nearly to the mine. (L. Comin 1980 pers.comm.).

The surveys of the winter road right-of-way were to focus on possible woodland caribou and Dall's sheep range adjacent to the road alignment in two areas: 1) the Mackenzie Mountains between 'Folded Mountain' and the Sundog Creek tributary crossing and 2) that portion of the Nahanni Range near 'Grainger Gap'. Adverse weather conditions prevented surveys east of Prairie Creek in the Mackenzie Mountains and restricted the survey coverage in the Nahanni Range. In the Nahanni Range, no caribou were observed, six Dall's sheep rams were observed north of 'Grainger Gap' and six sheep, including two lambs, were observed south of 'Grainger Gap'.

The wildlife zone crossed by the most westerly 23 miles of winter road is reported to support scattered groups of woodland caribou and Dall's sheep (Department of the Environment 1974). Areas of special sensitivity include 'Folded Mountain' which may be used for lambing and potential sheep wintering areas along the south-facing slopes above the road. However, it is not known if any of the potential wintering areas are regularly utilized and reports of lambing on 'Folded Mountain' have not been substantiated. An evaluation of the habitat in this area indicates a lack of extensive sedge meadows preferred by woodland caribou (Oosenbrug and Theberge 1980) and this species is expected to occur only in low densities in the vicinity of the road.

Dall's sheep are reported to occur throughout the Nahanni Range (Department of the Environment 1976). The winter distribution of these sheep is not known, however, the south-facing slopes and extensive alpine ridges north of 'Grainger Gap' constitute potential winter range. L. Comin (1980 pers.comm.) has made incidental sightings of Dall's sheep in this area during winter surveys. The lambing sites of this population are unknown.

The winter road alignment east of Mile 23 crosses what is considered to be good woodland caribou and moose habitat. However, the density of deciduous vegetation cover precluded surveying for these species. Observations were opportunistic and made in conjunction with waterfowl surveys. Eight moose were observed between Mile 35 and Mile 68. On 24 July, 1980, three moose were sighted by BEAK fisheries biologists near the winter road route on the western edge of the Ram Plateau.

Based on the survey data, greater numbers of moose than caribou are believed to exist east of Mile 35 along the road route to the Nahanni Range during the summer. The winter distribution of moose in the region is not well documented, however, the Department of the Environment (1976) does indicate that the valleys of the Tetcela River and Fishtrap Creek constitute good moose winter range. The Liard River floodplain is considered excellent winter habitat for moose (ibid.).

The following information concerning the wood bison relocation project being conducted in the Nahanni Butte area was obtained from H. W. Reynolds, Wildlife Biologist, Canadian Wildlife Service, on 27 August, 1980.

Twenty-eight wood bison (Bison bison athabascae), ten of which were equipped with radio collars, were released approximately four miles west of Nahanni Butte on 27 June, 1980. Since their release, all of the radio-collared bison have moved south of the Nahanni and Liard rivers; most have remained within 20 miles of the release point. The whereabouts of the uncollared animals is uncertain and will not be determined until after leaf-fall and snow conditions provide suitable survey conditions.

Eight bison were located 19 August, 1980 in the area where the Liard Highway crosses the Blackstone River. This is approximately four miles south of the eastern extremity of the Cadillac Mines winter access road. On 21 August, 1980, one of the bison in this group was struck by a vehicle on the highway and killed.

Due to an equipment malfunction, none of the bison have been located since 19 August, 1980, but the current distribution is not expected to have changed radically.

The winter distribution of the 27 remaining bison will be determined by aerial surveys.

5.6.2.2 Furbearers

Aquatic furbearer habitat is poor in the area of the mine and no traplines presently exist within the mining lease. Trapping in the area of the Nahanni Range is discussed in section 5.10.

Signs of beaver activity were noted along the entire length of the road alignment east of the Ram Plateau. The observations of lodges and dams were concentrated in the lowlands on either side of the Silent Hills. These areas have been designated as important habitat for beaver by the Department of the Environment (1976). Beaver activity was observed infrequently east of the Nahanni Range.

One wolverine was observed 4.5 miles west of the minesite during the surveys. This incidental sighting is the only additional information collected on this species which is expected to occur throughout the region in low densities.

5.6.2.3 Small Mammals

Small mammals occurring in the general region of Nahanni Park were described by Scotter et. al. (1971) and listed in an earlier report (Ker, Priestman 1980). Small mammal trapping effort in this study was intended for possible trace metal analysis and not to provide new ecological information. However, in 87 trapnights 2 deer mice (Peromyscus maniculatus) and one red-backed vole (Clethrionomys sp.) were trapped. Compared to densities recorded by Scotter and Henry (1977), the density recorded here (3.4 animals per 100 trapnights) is low, but because of its incidental nature this data cannot be considered representative of the study area.

Observations were made of Arctic ground squirrels, principally in the camp area.

5.6.2.4 Other Mammals

Incidental observations of other large mammals, including bears and wolves, were made during the field investigations. One unidentified bear sow with two cubs was observed approximately five miles west of the Grainger River on 24 July, 1980, by BEAK fisheries biologists. On the night of 9 July, 1980, a black bear was chased from the Prairie Creek camp by camp personnel (R. Fast 1980 pers. comm.). Unidentified bear scat was observed along the winter road route approximately two miles north of the mine and below 'Folded Mountain', one-half mile from the road.

Wolves have been reported to prey upon woodland caribou wintering at 'Caribou Flats' north of the mine, however, no wolves or wolf sign were observed during our field studies.

The surveys in this programme were not directed at obtaining information concerning bears and wolves. This factor, combined with the low observability of these species during aerial surveys, and their generally reclusive nature, has resulted in the collection of little data on their distribution and abundance in this region. No denning sites of bears or wolves have been located. Good grizzly bear habitat has been documented by the Department of the Environment (1976) on the Ram Plateau and throughout the Nahanni Range. It is of note that, during the 12 years he has been involved with the mine development, R. Fast (1980 pers.comm.) has only noted four black bears, one grizzly bear, one wolf, and three wolverines in the vicinity of the minesite.

Based on this limited information and a knowledge of the habitat preferences of both species, both black and grizzly bears and wolves are likely present in the minesite area in low densities. Black bears and wolves may be encountered along the entire length of the winter access road while grizzly bears will be found in the mountainous regions traversed by the roadway.

5.6.2.5 Cliff-Nesting Raptors

The second focus of the 6 - 10 July, 1980 surveys was the search for cliff-nesting raptors. No eagle or falcon nest sites were located in the vicinity of the mine. Six Golden Eagle observations comprising a minimum of three individuals (two adults and one immature which was a minimum of one year old) were made at the minesite. Further observations included one unidentified large falcon* four miles southwest of the minesite and one Golden Eagle and two unidentified falcons along a cliff-face immediately southeast of 'Caribou Flats'.

The valley walls along the road alignment, between 'Folded Mountain' and the Nahanni Range, including a number of karst cliffs in the Tetcela River region, appear to possess the potential to support cliff-nesting raptors.

In the Nahanni Range, two active Golden Eagle nests, each containing one eaglet, were located. The nests were on cliffs 1.1 and 2.5 miles, respectively, north of the road route.

No raptor nests were found in the minesite vicinity, however, several Golden Eagle sightings were made. One of these observations included two adult eagles which were apparently displaying territorial behavior. During several minutes of observation, the adult birds pursued and harassed an immature Golden Eagle, which had nearly complete adult colouration. The pair repeatedly dove on, and actually made contact with, the third eagle a number of times before being lost from sight. This observation was made at the Prairie Creek airstrip and is an indication that the mine area may be within the nesting territory of those adult eagles sighted.

Both Gyrfalcons and Peregrine Falcons may breed in the region. The observations made during the surveys were inconclusive concerning the local status of these species. No Peregrine Falcon nests are known from the area (R. Fyfe 1980 pers.comm.). It should be noted that Peregrine Falcons are closely monitored by the Canadian Wildlife Service and other agencies and that many of the nesting sites in northern Canada are documented; Prairie Creek is not included in this documentation.

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* Based on the dark brown colouration of the bird and observed malar bars, it is probable that this bird was an immature Peregrine Falcon.

Although Gyrfalcons primarily breed further north than the study area, nesting by this species has been reported at similar latitudes elsewhere in northern Canada. Kuyt (1980) documented what he believed to be, at 61° 45'N, the southernmost breeding record for Mackenzie District, N.W.T. and successful nesting by Gryfalcons has been recorded at 60° 45'N in Yukon Territory (R.Eccles 1980 pers. comm.).

Suitable cliff-nesting habitat exists in a number of locations along the winter road. The two active Golden Eagle nests located in the Nahanni Range indicate its utilization by raptors.

5.6.2.6 Waterfowl

In addition to those flightlines directed at surveying a 6 mile section of the Grainger River, 17 ponds or wetlands were surveyed for aquatic birds. Aquatic birds were observed on 16 of these waterbodies and broods were observed on 10.

The most important observation was 6 moulting Trumpeter Swans identified on a small lake east of the Silent Hills. Identification was confirmed by landing and careful examination through a spotting scope. No signs of their breeding were observed. In April, a BEAK team observed swans in a wetland area west of the Silent Hills and well south of the road alignment (Ker, Priestman 1980), but they were not specifically identified. Though no longer considered endangered, Trumpeter Swans are nowhere very common during the breeding season. Further the exact northern limits of their breeding range in the region of Nahanni Park are not known. Breeding records in this area appear to be restricted to recent sightings of adults and young at Yohin Lake at the eastern end of the park (L.N.Carbyn, pers.comm.).

The remaining aquatic birds recorded were ducks, divers (loons and grebes), coots and a few shorebirds. The sightings at each wetland are listed in Table 17. The chief result was the sighting of 14 broods on these 17 ponds for a total of 75 ducklings. Most of these were diving ducks but owing to poor lighting created by an oncoming storm, very few were identified to species. It is believed that a large proportion was surf scoters based on their lack of distinctive markings. Ground surveys at Lake #26 confirmed the breeding of coots and the likely breeding of black terns. This provides further confirmation to Tull's observations that black terns occur as far north as Fort Simpson (L.Carbyn, pers. comm.). No geese were observed in summer but 5 snow geese were sighted in April near the Silent Hills as reported earlier (Ker, Priestman 1980). Recent reviews of the regional avifauna have not identified this species (L.Carbyn, pers. comm.).

5.6.2.7 Breeding Birds

Further to the wetland surveys, records were kept of all sightings of birds, and further records of other investigations were obtained. As a result, the species list presented earlier (Ker, Priestman 1980) has been updated (Table 18).

5.7 Geology and Soils

The geology and soils of the minesite and proposed winter road have been discussed in two previous reports (Ker, Priestman & Associates Ltd. 1980 a, b).

In addition to Crampton's (1973) mention of the soils in the Sibbeston Lake map area in his landscape survey of the upper and central Mackenzie Valley, Tarnocai (1973) has carried out a soil survey of the area. On the floodplain of the Liard River, at the eastern terminus of the road, he mapped Brunisols on the older alluvial terraces and Regosols on the recent alluvial deposits. Poorly drained deposits support Gleysols, most of which contain permafrost. Abandoned channels on the floodplain support Organic Soils and Fibric Cryosols.

From west of the Liard floodplain to the western side of the Nahanni Range, the soils are dominantly Luvisols and Brunisols on well to imperfectly drained mineral deposits. On poorly drained mineral deposits, Gleysolic Cryosols are present. Above timberline, Brunisols displaying the effects of cryoturbation are present. Fibric Cryosols are found on the peat deposits.

The geotechnical study on the soils of the minesite with respect to their engineering properties, is attached as Appendix 1.

5.8 Archeological and Historic Sites

5.8.1 General

No sites have been recorded in the files of the National Inventory of Prehistoric Sites (Ottawa) for the areas that would be affected by the proposed Cadillac development or for the immediately adjacent areas; however, it is significant that there have been no systematic site surveys of these areas with the notable exception of the comprehensive investigations of Nahanni National Park reported by Amsden (1978, 1979).

Despite the absence of archeological and historic data pertaining to the specific area under study, some general comments concerning site location based on the vegetation and physiography of the area are possible. The Boreal Forest vegetation (Alpine Forest - Tundra and Upper Mackenzie Sections) for this area imposes certain restrictions on site surveys (Millar and Fedirchuk 1975). The depth of the forest mat cover and the density of the vegetation often limit the effectiveness of site surveys. In addition, the subsistence strategies practiced in a Boreal Forest environment tend to result in archeological sites that are relatively small in size. In some cases, sites may have been buried by the sand, gravel and silt deposited by the rivers and creeks of the area or may have been damaged or destroyed by erosion along lake, creek, and river banks or by flooding resulting from spring break-up and summer storms. Furthermore, the relatively high soil acidity associated with Boreal Forest vegetation can damage or destroy perishable materials and Boreal Forest cover often precludes the use of air photos for locating sites. Factors such as these have a bearing on the amount of data that would be recovered from this area following conventional methods of site survey.

5.8.2 Archeological Sites

Inferences on existing archeological sites in the area of the proposed Cadillac development must be based on the archeological finds made in Nahanni National Park (Amsden 1978, 1979) and also the Upper Mackenzie area of the Mackenzie Corridor studies (Cinq-Mars 1973), especially Sibbeston, Cli, Little Doctor and Fisherman Lakes.

In very general terms, it appears that single component surface sites located on the banks of lakes, creeks and rivers or on terraces or ridges overlooking streams, lakes or rivers are most typical in the western part of the Upper Mackenzie area. Sites have also been discovered in some of the present-day centres such as Fort Simpson. Millar (1972) has noted that the prehistoric site locations tend to be clustered in the vicinity of lake outlets, although some surface collections of prehistoric materials have been discovered along the lakeshores. However, he questions the extent to which this observation may have been influenced by selectivity in the areas sampled; as Cinq-Mars (1973) has observed, the large lake areas to the west and east of the Mackenzie River are more accessible than the banks or high inland terraces of the Mackenzie.

These sites generally contain a small assortment of lithic material, often including flakes and sometimes points, scrapers, blades and bifaces. The artifacts tend to have few diagnostic traits of use in estabishing site chronology and in postulating cultural relationships among sites. Several complexes of artifacts have been identified at Fisherman Lake (Millar, 1968); the distinctive artifact types of this site have been useful in dealing with poorly identified and undated sites in the Upper Mackenzie area as in the case of the work reported by Dice (1973) in the Sibbeston Lake area approximately 65 miles to the northeast of the Cadillac property. The presence of a distinctive form of 'welded tuff' to a number of sites in this area has led to attempts using neutron activation analyses to determine whether this materal all came from an outcrop in the Tertiary Hills, possible through some form of trade network. In that Amsden's studies of Nahanni National Park correlate archeological data from the park with information available from the general vicinity, they are also a valuable source of information for the area under consideration.

5.8.3 Historic Sites

Historic sites have been recorded at a number of locations in the western part of the District of Mackenzie. The 1976 Land Use Information Series Virginia Falls Map (95 F) indicates the remains of cabins built by early travellers along the Flat River near its confluence with the South Nahanni River. Amsden (1979) found cabins and caches at many of the likely points in Nahanni National Park with early historic sites concentrated in the lowermost portion of the South Nahanni watershed. The Land Use Information Series Sibbeston Lake Map (95 G) indicates that an independent trading post has operated in Nahanni Butte since 1915. The historic Fort Alexander trading post located on the river bank upstream from the mouth of the Willowlake River has been partially excavated (Cinq-Mars 1973). Three historic camp sites were identified on the shores of Cli Lake and one by Fisherman Lake (Cinq-Mars 1973). It is also possible that additional finds of historic cabins and tent camps may be made along the tributary water sources to the Mackenzie River as well as in hunting localities. Millar (1972) has suggested that resource utilization strategies may account to some extent for the site locations indicated by the presently available data. In prehistoric times when fishing was an integral part of the subsistence pattern, sites often appear to have been located at or near lake outlets where the best fishing conditions are present; by contrast, historic sites often appear to be clustered along lake banks adjacent to the main creeks from which the most productive trapping areas are easily accessible.

5.9 Socio-Economics

The socio-economic conditions pertaining to the Cadillac project have been reviewed in earlier reports (Preliminary Environmental Evaluation for Winter Access Road and Preliminary Environmental Evaluation for Mine, Mill and Camp, both May, 1980).

Further discussions concerning these matters are to be held between the proponent and the Resource Development Committee of the Government of the Northwest Territories, so that the socio-economic aspects of the development are in tune with government policy for the N.W.T.

5.10 Resource Use

5.10.1 Furbearers/Trapping

Three trapping areas occur on land transected by the proposed development (D. Bentley, 1980 pers. comm.). The approximate boundaries of these trapping areas are shown on Figure 24 and are described as follows:

Area 1: East of the Nahanni Range between Bluefish Lake ('1st Gap') and the '3rd Gap' to the north (inclusive of the Grainger River Pass, or '2nd Gap').

Areas 2 & 3: These traplines are operated west of the Nahanni Range, between the 1st and 3rd gaps (in a north-south line) and between the Nahanni Range and the Tetcela River (in an east-west line), including the Silent Hills.

None of the above traplines are operated by single individuals. Total yearly fur harvests range from $8,700 to $22,000 for the 1978-79 trapping season (D. Bentley, 1980 pers. comm.). These figures represent a per-trapper income of up to $5,500 per year. Major species harvested included beaver, marten, mink, lynx, weasel and wolverine (few). In addition, five moose and nine woodland caribou were harvested on licences of the above trappers.

In a preliminary description of hunting and trapping areas in the Inuvik and Fort Smith regions, the Department of Renewable Resources (ND) noted that regions in the vicinity of the Nahanni Range (zones NB1 and NB2) produced fur harvests of $8,000 (NB1) and $2,000 (NB2) during 1977-78. This represents an annual income of $1,600 for each of the five trappers in zone NB1, and $2,000 for the single individual trapping in zone NB2.

Initial socio-economic studies conducted by Horsman & Associates suggest that furbearer productivity in the area is low (D. Bentley, pers. comm. 1980).

Comparative fur harvest data from 1977-78 for areas in the Nahanni region show per-trapper annual values of $1,000 for the Sibbeston Lake and Grainger River areas (zones S5 and S6) and $2,000 for the Fort Liard area (zone FL1). Although several factors, including trapper effort, affect trapline returns, the fur harvests noted above are considered low.

5.10.2 Hunting

5.10.2.1 Guiding and Outfitting

A summary of the Nahanni Butte Outfitters hunter kill from the area of the proposed development is provided in Table 19. A total of 49 game animals (44 sheep, 4 bear and 1 moose) were taken from this area during the period 1975-1978. None of these animals were harvested within several miles of either the mine or road alignment.

5.10.2.2 Resident Hunter Harvests

Accurate information on the game-harvest by resident hunters is more difficult to obtain.

In a study on the moose of the Lower Liard River Valley, Donaldson & Fleck (1979) reported that Nahanni Butte hunters killed 25 - 30 moose during 1978. The same study notes the moose harvest by Fort Simpson hunters to range from 50 - 65 per year. Although these figures are representative of the general numbers of animals taken in the region, specific hunting areas were not noted and kill sites are not known. Given the comparative inaccessibility of the study area, and the fact that much of the habitat along the winter road is not high-quality moose range, it is considered unlikely that much hunter effort would be directed toward this area.

6. POTENTIAL ENVIRONMENTAL IMPACTS & MITIGATIONS

As is the case for all industrial operations, there will be impacts which may result in an altered environmental condition. However, many impacts are potential, rather than actual, and can be prevented by suitable contingency planning, good design and careful construction. It is believed that the number of impacts which cannot be eliminated, or which are permanent in nature, are few.

In the following discussion, both actual and potential umpacts which might affect aquatic systems, wildlife, vegetation and soils are reviewed. The specific, in addition to the general, case has been treated.

6.1 Potential Impacts and Mitigations - Aquatic Invertebrates and Fisheries

Habitat utilization by fish has been divided into six categories: migration routes, spawning areas, nursery areas, rearing areas, summer habitat and overwintering areas. Of these, the first three are considered sensitive with respect to summer scheduled road construction. As fish behavior responses are anticipated to result in temporary emigration away from localized road construction activities for the duration of the instream disturbance, rearing and adult summer habitats are not expected to be permanently affected.

Spawning areas are considered the most vulnerable of all fish habitat. These sensitive habitats could be adversely affected by direct disturbance during reproduction, or blanketing of substrate and resultant smothering of eggs within or on the substrate. Fry in a post-hatching larvel stage may die as they are incapable of avoiding heavy concentrations of silt. Sensitive time-periods for spawning activities for regionally prominent fish species have been derived from standard references. Fish species are considered prominent if they are 'numerically significant or form the basis of existing or potential domestic, sport or commercial fisheries in the upper Mackenzie Valley' (Dryden and Stein 1975).

The suggested sensitive time periods for spawning of prominent fish species are as follows:

chum salmon	-	late September to early November;
Dolly Varden char	-	late August to late September;
Arctic grayling	-	early May to mid-June;
lake whitefish	-	early October to December;
northern pike	-	mid-May to early July;
burbot	-	January to March;
white sucker	-	early May to mid-June;
longnose sucker	-	early May to mid-June; and
yellow walleye	-	late April to late June.

Nursery areas (regions utilized by young-of-the-year) are considered to be sensitive during summer months. As fry hatch at different times and develop at different rates, sensitive time periods vary between species.

Overwintering areas are also highly susceptible to habitat disturbances, as many individuals may occur in restricted areas. In northern climates the fish of smaller watercourses congregate in the larger waterbodies resulting in regional aggregations of fish populations within localized areas. As fish populations tend to congregate in deep pools to overwinter as flow rates decrease, movement between occupied pools may be precluded. Potentially high mortality rates may then result from the inability of fish to avoid temporary adverse conditions. Therefore adverse impacts on overwintering areas may be of regional significance.

Fish migration routes are the least susceptible to disturbances. It is not anticipated that introduction of sediments into the watercourse will deter fish migrations as turbidity levels should decrease rapidly following construction activities. Many of the resident fish species have been reported to also utilize watercourses with high turbidity levels.

The following descriptions of site-specific concerns delineate potential conflicts between identified or suspected sensitive habitats and winter road construction.

1. Unnamed Creek (Site R3 on Figure 20)
   - (i) Sensitive habitat: Arctic grayling nursery area; Sensitive time period: early June to mid-July;
   - (ii) Sensitive habitat: possible Arctic grayling spawning area; Sensitive time period: early May to mid-June.

2. Tetcela River (Site R4 on Figure 20)
   - (i) Sensitive habitat: Arctic grayling nursery area; Sensitive time period: early June to mid-July;
   - (ii) Sensitive habitat: possible Arctic grayling spawning area; Sensitive time period: early May to mid-June;

3. Tetcela River (Site R5 on Figure 20)
   - (i) Sensitive habitat: Arctic grayling nursery area; Sensitive time period: early June to mid-July;
   - (ii) Sensitive habitat: possible Arctic grayling spawning area; Sensitive time period: early May to mid-June;
   - (iii) Sensitive habitat: possible overwintering area; Sensitive time period: late October to early May.

4. Grainger River (Site R7 on Figure 20)

Sensitive habitat: possible overwintering area;
Sensitive time period: late October to early May;

5. Liard River (Site R12 on Figure 20)

(i) Sensitive habitat: suspected spawning migration route for many prominent fish species;
Sensitive time period: April to late May; late August to late October;

(ii) Sensitive habitat: suspected nursery area for many prominent fish species;
Sensitive time period: Summer months;

(iii) Sensitive habitat: suspected overwintering area for many prominent fish species;
Sensitive time period: late October to late April.

As outlined above, the following watercourses are utilized by Arctic grayling as nursery areas and are sensitive to disturbance from break-up to late summer: Unnamed Creek (Site R3) Tetcela River (Sites R4 and R5), and the Grainger River (Site R7). In addition, many prominent fish species are suspected to utilize the Liard River (Site R12) as a migration route and nursery area (Hatfield et. al. 1972).

The Tetcela River (Site R5), the Grainger River (Site R7) and the Liard River (Site R12) may be utilized as fish overwintering areas and therefore are particularly sensitive from late October to early May to disturbances which could result in substantial increases in silt loads. Construction of road approaches to these watercourses during the above time periods should be carefully conducted. Disturbance to streamside vegetation should be kept to a minimum.

Prairie Creek and Harrison Creek may be particularly susceptible to habitat disturbances due to their nature and close proximity to the proposed minesite. Limited numbers of Dolly Varden char utilize Prairie Creek as a rearing area and as adult summer habitat. It is unlikely that Dolly Varden char utilize Prairie Creek in the vicinity of the mine as overwintering habitat.

As the lower reaches of Prairie Creek are within Nahanni National Park, good construction practices should be followed in order to reduce the risk of disturbance of this important recreational watershed.

Potential environmental impacts and mitigative measures relative to the road and plantsite construction and operation are summarized below:

	Potential Impact	Mitigation
i)	Debris in streams, causing damming, covering of aquatic habitat, or oxygen deficiencies	- avoid introduction of debris into water - remove deposited material
ii)	Siltation causing reduction in species number and diversity covering of habitat, smothering of eggs, mortality of fry, increased stress or mortality of adult fish, migration delays	- vegetation buffer strips between road or construction activity and stream where possible - stabilization of stream banks, including riprapping, maintenance of vegetative cover and proper grading. - complete confinement of tailings, as per section 4.1 - isolation of borrow sources and waste dumps from watercourses - construction of runoff collection ditches and settling ponds, as per sections 4.1 and 4.2.
iii)	Aquatic substrate disturbances, causing increased silt load or alteration of stream bed	- borrow material obtained from upland sites - minimal heavy equipment activity in streams.
iv)	Toxic substances causing mortality of aquatic organisms bio-accumulation, alteration of zooplankton, phytoplankton and benthic communities	- safe storage and transportation of fuels and potentially toxic materials, as per section 4.6 - impermeable dykes, as per section 4.1 - treatment of sewage, mine water and runoff, as per section 4.2

	- spill contingency planning, as per section 4.6
	- monitoring of effluent, as per section 4.7.
v) Explosives, possibly causing fish kills	- no blasting to be done near important fish habitat.
vi) Drainage alteration, causing reduced or altered flows and deterred fish migration	- removal of ice or snow bridges at critical water crossings at the end of winter period
	- retain natural drainage patterns
	- design of diversions so as to simulate existing streambed morphology
	- minimization of water requirements by maximizing water re-use.
vii) Increased fishing pressure, causing reduction in sports fish resources	- fishing closures by regulatory agencies
	- enforcement of regulations.

6.2 Potential Impacts and Mitigations - Water Quality

The planned mine site area developments will involve discharge of water and effluents from three sources - site and environs surface runoff, sanitary sewage effluent and mine water.

6.2.1 Surface Runoff

Uncontaminated surface runoff waters from snowmelt and rainfall originating on the slopes above the tailings pond will be diverted around the pond into Prairie Creek.

Potentially sediment-laden site runoff water will be collected and treated in a sedimentation pond prior to entry to the Prairie Creek system. The suspended solids in the treated runoff would normally be less than 25 - 50 mg/l. Suspended solids might conceivably attain levels higher than this during extreme precipitation events, however, the receiving stream carrying capacity and natural suspended solids levels would most likely be higher at this time as well, thus the effect of the mine site runoff water would be small.

6.2.2 Sanitary Sewage

The projected quantity of sanitary sewage that would be generated at the operating mine and associated camp is 18,000 - 20,000 IGPD. This effluent would be collected and given full secondary treatment prior to discharge to the receiving water system. The effluent quality specifications for the sewage treatment plant would be: BOD_5 - 45 mg/l; Suspended Solids - 60 mg/l. Residual chlorine would be controlled to less than 1.0 mg/l as it leaves the plant. Even under the 2-year low-flow condition, this level would result in only .005 mg/l of residual chlorine in Prairie Creek.

The treated sanitary sewage effluent would add a very minor BOD_5 load of less than 10 lb. per day to Prairie Creek which is a small fraction of the assimilative capacity of the system under normal low winter flow conditions. The impact of this discharge is considered minimal provided the sewage plant is operated and maintained to design specifications.

6.2.3 Mine Water

The largest source of effluent requiring disposal will be the mine which will produce natural seepage water, drilling and washdown water and excess backfill water. Assuming that quantities remain unchanged from those presently recorded, it is estimated that approximately fifty per cent (50%) of the total will result from natural groundwater seepage into the mine.

The average projected quantities are:

Natural Seepage (100 IGPM)	144,000 IGPD
Washdown and Drill Water (50 IGPM)	72,000 IGPD
Excess Backfill Water (60 IGPM)	86,000 IGPD
TOTAL	302,000 IGPD

The exact nature of the combined water requiring discharge is difficult to predict. The natural mine seepage together with the drill waters may not be significantly different from mine portal water sampled in July, as reported in Table 8. The excess backfill drainage water will likely have characteristics of diluted raw mine tailings water. Because the combined waters have the potential to contain elevated levels of some trace metals, residual cyanide from the ore processing, and suspended solids, this combined effluent stream in all likelihood will require treatment to acceptable levels prior to discharge to the receiving waters of Prairie Creek. The treatment proposed and described elsewhere in this report (section 4.2) includes alkaline chlorination, flocculation and sedimentation prior to discharge. The treated effluent quality is projected to be equal to or better than that specified in the

Metal Mining Liquid Effluent Regulations (Appendix 2). Based on a flowquality mass balance calculation, the potential change in Prairie Creek water quality during low flow and average flow conditions after mixing of the treated effluent has been made and is shown in the table on the following page.

COMPARISON OF PRESENT AND PROJECTED WATER QUALITY

Parameter mg/l	Treated Effluent	Average Existing Prairie Creek	Projected Prairie Creek at Low Flow*	Projected Prairie Creek at Mean Annual Flow**
pH units	9.0	8.1	8.1	8.1
Suspended Solids	25	3	4	3
Arsenic	0.5	< 0.005	< 0.037	< 0.007
Copper	0.3	< 0.005	< 0.024	< 0.006
Lead	0.2	< 0.023	< 0.036	< 0.024
Nickel	0.5	< 0.013	< 0.045	< 0.014
Zinc	0.5	< 0.018	< 0.049	< 0.020
Cyanide	0.1	Assumed Undetectable	0.006	0.0003

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* Two-year, 7-day low flow in Prairie Creek is 8 cfs.

** Mean annual flow in Prairie Creek is 204 cfs.

Levels shown as less than the detection level in the table have been assumed to be equal to the detection level for the purpose of calculation. This, of course, results in the projected level of a given contaminant in Prairie Creek being conservatively high.

These projections indicate that on average the change in water quality will be minor. During the low flow conditions some parameters could reach levels above the desirable guidelines for aquatic life (Environment Canada, 1979). They would, however, not exceed the reported 'threshold concentration' (McKee and Wolf, 1963). The threshold concentration is defined as the level below which waters should be suitable habitats for mixed fauna and flora and are normally not deleterious to fish life.

	Desirable Guidelines For Protection of Aquatic Life (Environment Canada, 1979)	Threshold Concentrations for Aquatic Life (McKee and Wolf, 1963)
pH	6.5 - 9.0	6.5 - 8.5
Arsenic	0.05	1.0
Copper	0.005	0.02
Lead	0.03	0.1
Nickel	0.025	0.05
Zinc	0.03	0.1
Cyanide	0.005	0.02

The residual primary (changes in water quality) and secondary impacts (effects on aquatic resources) should be acceptable with the mitigation measures and waste water management plans proposed for the mine development.

6.2.4 Ground Waters

The tailings pond will be located on a thick layer of highly impermeable clay over the majority of the pond area. Those areas not underlain with natural clay and retaining dykes will be built with a clay barrier to mitigate seepage losses. The annual seepage loss from the tailings pond has been estimated at 4.5 - 9.0 imp. gallons per day (250 - 500 cubic feet per year). The quality of the seepage would likely be similar to the raw tailings supernatant. Data available from other lead-zinc operations indicates the quality of the seepage could be in the range as shown below:

Lead-Zinc Tailings Supernatant Quality
(Sources: DINA, Water Management - Northwest Territories, Pine Point Mines Monitoring Data and Province of British Columbia, Ministry of The Environment, 1977)

	Mean Range		
pH	7.3	-	9.6
Copper	0.07	-	5.7
Lead	0.024	-	0.4
Zinc	0.027	-	1.2
Cyanide	0.01	-	5.7

Many trace elements are known to be removed as seepage travels through various types of surficial materials and thus the farther the travel the higher the attenuation. One study on waste material indicated that for seepage travel in a 15 metre sandy layer (Permeability 5.1 x 10^{-4} cm/s), after 10 years operation the concentration of copper and zinc in the seepage would be less than 5% of the pond concentration (U.S. Dept. of the Interior, 1978). Travel in the same period through a clay layer 10 metres thick (Permeability 7.4 x 10^{-6} cm/s) would also reduce these trace elements to 5% of the original concentration. Highly impermeable clay (5 x 10^{-8} cm/s) permits very little seepage flow and offers virtually complete protection (U.S. Dept. of the Interior, 1978).

In consideration of the low seepage flow, probable attenuation and high dilution potential available in Prairie Creek (500,000 - 12,000,000) the impact of the extremely small amount of seepage is negligible.

6.3 Potential Impacts and Mitigations - Vegetation and Soils

6.3.1 Introduction

Some potential impacts on the vegetation and soils have been discussed in previous reports and will not be repeated in detail in this section. Other areas of concern are outlined in the following paragraphs.

6.3.2 Rare or Valuable Species

Impact

The removal of the vegetational cover for the development of the mine, and along the route of the winter road may lead to some loss of rare or valuable species. As the region is relatively unexplored in a botanical sense, the extent of rare species or endemics remains unknown. Field investigations in the area revealed the presence of several species of interest.

Mitigation

If further inspections by government or other personnel reveal the presence of unusual habitats, these areas should be examined prior to disturbance to determine the vegetation species present.

6.3.3 Erosion

Impact

Clearing along the winter road corridor and at the mine area may create erosion, particularly on sloping land. Thermokarst erosion may result from vegetation removal in areas of permafrost.

Mitigation

The impact of clearing will be reduced by keeping the road right-of-way to the minimum width necessary, particularly in sensitive areas such as stream crossings. Further exploration roads will be carefully planned and constructed to reduce their number and thereby minimize the impact of vegetation removal and subsequent erosion. Mitigation measures for permafrost areas have been discussed in previous reports (Ker, Priestman 1980).

6.3.4 Fire

Impact

Man-induced fires may become more frequent due to the increased number of people in the area. As the Cadillac property is adjacent to Nahanni National Park, it is important that non-natural fire occurrences be minimized.

Mitigation

Some firefighting equipment will be kept on-site and mine personnel will be available should a fire be started in the immediate vicinity. The Prairie Creek airstrip would be available for use by spotting and fire-fighting aircraft.

6.3.5 Loss of Vegetation

Impact

Areas disturbed by the mine and road development will have the vegetative cover damaged..

Mitigation

Reclamation of disturbed areas both during operation and upon abandonment of the mine will be carried out to speed up the process of revegetation and to minimize residual impacts of the development.

Further investigation of species suitable for reclamation use at the mine site will be carried out. Species which have been noted as colonizers and therefore exhibit potential as initial reclamation species will be included along with non-native species. Trial plots on mine and mill waste material will be treated with various amendments and seed mixtures to determine the success of each species over time.

6.3.6 Non-Native Species

Impact

Development in most regions is commonly followed by the establishment of non-native plant species due to revegetation efforts. Long term changes in the composition and structure of local plant communities may be anticipated.

Mitigation

Consideration will be given to the possible long-term impact of non-native species introduced through reclamation programmes. Native species would be given priority in revegetation work.

6.4 Potential Impacts and Mitigations - Wildlife

As discussed in the Preliminary Environmental Evaluations, the potential impacts and mitigations of the Cadillac project include the following:

Potential Impacts		Mitigations
i) increased access by public	-	route will not be passable except in winter at which time public access will be restricted due to truck traffic.
ii) direct disturbance to or mortality of wildlife	-	avoidance of known raptor nests, nursery areas, calving and lambing sites, and dens.
	-	use of road during non-critical time (i.e. winter)
	-	harassment of animals and use of firearms forbidden.

iii) habitat alteration	-	minor alteration unavoidable, however, no significant aquatic, bird or wildlife habitat known to be directly affected.
	-	control of fires.
iv) attraction of wildlife	-	proper garbage disposal, and no feeding of wildlife.
v) interference with seasonal movements	-	no barriers to be constructed.

The additional data collected for this report has provided further information concerning the distribution of wildlife species in the study area during the summer period. Based on that information, the potential impacts of the project generally remain unchanged from the Preliminary Environmental Evaluations.

One site-specific concern identified during the course of the field work was the potential Dall's sheep lambing area in the cliffs near the Prairie Creek airstrip. Aircraft may be a source of disturbance to ewes and lambs utilizing this area. If this disturbance is severe enough, the ewes could abandon the cliffs, or sheep could be injured during avoidance behavior. Dall's sheep have been documented to react to aircraft up to 1 km away (Price 1972 and Reynolds 1974 in Hoefs 1977), and aircraft landing or taking off at Prairie Creek may disturb maternal groups which may be in the area. Unfortunately, no feasible mitigation measures exist for this source of disturbance, except for building an airstrip at another location and minimizing air traffic to the minesite airstrip. Air traffic to and from the minesite should follow any altitude regulations that apply to Nahanni Park.

A second concern is the possibility of wood bison road-kills along the Liard Highway and the Cadillac Mines winter access road. If the bison released as part of the relocation project remain in the vicinity of the roads during the winter, the increased traffic resulting from mine development will increase the potential for road kills. Protective measures which may be taken are the establishment of reduced speed zones and the posting of warning signs. This will be effective only if supplemented by a government-sponsored public awareness programme concerning the bison project and the consequences of vehicle-bison collisions. The focus of this public awareness programme should be the drivers servicing the minesite, as they will account for a large proportion of winter traffic on the proposed road.

The only raptor nests which have been located in the study area are two Golden Eagle nests in the Nahanni Range. Mossop and Milligan (1977) recommend that a two mile development buffer zone be maintained around known nest sites. One of the nests is 2.5 miles from the road and therefore is not of concern. Since the construction or use of the winter road is not expected to extend into the critical breeding and nesting period of the birds (7 April to 31 July, according to Fyfe and Kemper, 1975), the second nest site which is 1.1 miles from the alignment should not be disturbed.

If Golden Eagles nest in the vicinity of the site, an unavoidable disturbance will result, particularly from aircraft.

6.5 Potential Impacts and Mitigations - Air Quality

Emissions to the air from the Cadillac mill have been listed in Section 4.4. None of these are considered to possess a potential for degradation of air quality, since the entire process is carried out wet except for the crushing and screening circuit, for which bag filters will be provided. Dewatering of concentrate to around 7% moisture will be carried out with a belt filter. No thermal dryers, roasters or other pyrometallurgical operations are proposed. Dry concentrate storage is envisioned.

Because the mine is underground, no surface blasting will be required. Dusting from mine roads, waste rock piles and the tailings pond would not normally be a problem in this climate as most of the annual precipitation falls in the summer months and during much of the rest of the year, the surface of the ground is frozen. If unusual weather conditions were experienced such that excessive dust was created, spraying of the surfaces with water would be carried out.

The mine access road will be used only during the December to March period when the ground is frozen; consequently, road dusting will not occur.

In short, the effect of the operation on air quality is expected to be negligible.

6.6 Residual Impacts Upon Abandonment

The mitigation methods proposed for construction, operation and abandonment of the Prairie Creek mine and winter road have been fully explored in previous sections and earlier reports. These efforts are expected to result in a small, temporary disturbance to the environment during the construction phase, and a lesser disturbance during operation. Upon abandonment and after implementation of the reclamation programme, the residual impact should be visual only.

The visual impact of the mine will consist mainly of the presence of the tailings impoundment along the floodplain of Prairie Creek. As presently envisaged the impoundment will consist of embankments approximately 30 ft. above existing grade between the active river channel and the mountain slopes. The 6-year (±) impoundment will occupy approximately 25 acres, although if mine reserves are extended, additional tailings storage facilities would be required, probably downstream of the present camp. The embankments have been designed to be stable and permanent features under maximum possible flood conditions of Prairie Creek. Upon abandonment, facilities to safely convey slope drainage, precipitation and accumulated pond water to Prairie Creek will be provided. The pond will be revegetated by the use of grasses and/or native species, depending upon the results of seed test trials.

Similarly, the plantsite area will be reclaimed. Machinery, buildings and all evidence of activity will be removed. Seeding will be carried out. Mine portals will be blocked off to prevent access.

As discussed under section 4.8, the winter access road from the Liard River can be maintained, made impassable, or reclaimed, depending on the wishes of government. Mine exploration roads which had not revegetated naturally would be revegetated to the degree which is possible under the constraints of climate, soils and grade.

Environmental impacts other than visual are not expected to exist upon mine shutdown. Acid generation in the tailings and waste rock will not develop due to the strongly alkaline nature of these materials. Tailings pond water will cease to contain significant concentrations of contaminants once discharges to the pond are discontinued and existing contaminants are broken down by naturally-occurring oxidation reactions. All unused chemicals will be removed from the site.

7. ON-GOING WORK

On-going work is proposed as follows in order to expand those aspects of the environmental programme which would benefit from increased data input:

a) Engineering

Detailed engineering is now underway, and facilities will be designed consistent with general environmental and operational constraints.

b) Metallurgical/Chemical

In conjunction with metallurgical tests, a technical evaluation of the need for alkaline chlorination treatment of mine effluents will be made. It should be noted, however, that provision has been made for an alkaline chlorination system in the conceptual design.

c) Climate and Hydrology

The collection of on-site basic climate data (temperature and precipitation) will be facilitated once equipment has been installed by the Atmospheric Environment Service.

Further readings of crest gauges installed earlier on Harrison Creek and the unnamed creek at site T-3 will be made during 1981 and the remainder of 1980.

d) Geotechnical

Mine personnel are recording temperature and groundwater level information from boreholes installed during the geotechnical field programme.

e) Aquatics

Further baseline aquatic surveys would include an evaluation of overwintering fishery potential and spring spawning of Arctic Grayling along the winter road route.

f) Wildlife

Additional baseline wildlife surveys are to be carried out to evaluate ungulate winter range. As well, surveys to identify calving and lambing areas for caribou and Dall's sheep are planned for the minesite area.

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Dr. C. D. Bird	Formerly of the Unviersity of Calgary
L. Comin	Park Superintendent, Nahanni National Park
P. Dickson	University of Calgary Herbarium
R. T. Gardiner	Reclamation Agronomist, Cominco Ltd.
G. P. Kershaw	Department of Geography, University of Alberta
K. McKinnes	Environmental Scientist, EPS, Yellowknife
S. Zoltai	Northern Forest Research Centre, Canadian Forestry Service.

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Golder Associates
CONSULTING GEOTECHNICAL ENGINEERS

REPORT TO
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September 1980 802-1073

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1.0 INTRODUCTION

On the basis of previous Golder Associates (GA) work, and in consultation with Ker Priestman & Associates (KPA), Kilborn Engineering Ltd. (KEL) and Cadillac Explorations Ltd. (CEL), two potential tailing retention areas, namely T2 and T3, were selected for further study. These were two of nine possible sites detailed in GA Report 802-1073, dated May 1980. This report details the results of the field and laboratory investigation undertaken for the tailing storage areas and provides design and construction recommendations for the proposed construction.

The report also deals with mine plant foundations. Two areas, P1 and P2, had been selected for detailed investigation; however, on closer inspection in the field, site P1 was eliminated because of undesirable foundation and topographic conditions. Consequently, detailed investigation was carried out only at site P2 and, in particular, at a location selected in the field by CEL personnel.

Recommendations with respect to general flood control embankments for the mine and camp sites are made, together with comments regarding general foundation conditions for ancillary structures at the site. Recommendations are also made for spill control works for the fuel tank farm.

The mine site location is shown on the Key Plan, Figure 1, and the tailing disposal areas, plant site location, and other facilities dealt with in this report, are shown in detail on Figures 2, 3 and 4.

2.0 SITE LOCATION AND DESCRIPTION

The proposed mine and camp site are located in the Prairie Creek Valley at approximately 61° 34' North latitude, 124° 47' West longitude in the Northwest Territories. The area is typically mountainous and the topography and surface drainage patterns are controlled by the underlying rock units.

Alternative tailing retention area T2 is located on the floodplain of Prairie Creek near the existing camp site location, as shown on Figure 2. Alternative T3 is located approximately 1/2 mile downstream of the present camp site location on the floodplain on the left bank of Prairie Creek, as shown on Figure 4. The location of alternative plant site P2 and the proposed locations for ancillary construction and stream training works are shown on Figure 3.

3.0 SEISMICITY

The mine site is located near the boundary between Zones 1 and 2 of the National Building Code Seismic Zoning Map (1970). This implies a design earthquake acceleration of approximately 3 per cent gravity for a 100 year return period. According to the Pacific Geoscience Center, the closest recorded earthquake epicentre is approximately 350 miles to the northwest of the proposed mine site. Consequently, bedrock accelerations higher than 3 per cent gravity, due to local earthquakes, are not considered and this value is used for design calculations.

4.0 FIELD INVESTIGATION

4.1 Introduction

The field investigation was carried out between July 7th and September 3rd, 1980. Two tailing retention areas, T2 and T3, and one plant site area, P2, were selected for detailed subsurface investigation from the nine potential tailing retention areas and two potential plant site areas identified in our preliminary report (GA Report 802-1073, dated May 1980).

A total of 11 boreholes were put down in the three areas using a skid mounted Longyear 38 diamond drill supplied by Cadillac Explorations Ltd.

Samples obtained from the boreholes were air freighted to our Vancouver laboratory for detailed examination and testing. Descriptions of the soils encountered in the boreholes are presented on the Records of Boreholes in Appendix A. The locations of the boreholes are shown on Figures 2, 3 and 4.

Permanent water level and temperature sensing instrumentation has been installed in the 3 proposed construction areas and will be continuously monitored by mine personnel. The recovered data will provide further information regarding ground water level and ground temperature profile variations with time.

The field investigation was conducted under the full time supervision of a member of our engineering staff.

4.2 Tailing Retention Areas

4.2.1 Site T2

The proposed T2 tailing retention area is located on the floodplain of Prairie Creek immediately upstream* of the existing camp site, as shown on Figure 2. Five boreholes, 1 to 5 inclusive, were advanced in this area to depths ranging between 47 and 74 ft. The results of the subsurface investigation indicate that the surficial deposit of compact to dense alluvial sands and gravels with cobbles is between 10 and 20 ft. in thickness and overlies a stratum of very stiff, dark grey silty clay. The clay stratum was found to be between 22.5 and 31.5 ft. in thickness and was encountered at four of the borehole locations. At the location of borehole 1, immediately adjacent to the present course of Prairie Creek, the clay has

* In this report, north is considered to be upstream, and south is considered to be downstream.

been removed by a former channel of the creek. Underlying the clay is a further deposit of compact to dense alluvial sands and gravels extending to an undetermined depth.

The ground water level in the T2 area is controlled by Prairie Creek and was found to be at approximately elevation 2,839 ft. at the time of the investigation.

No permafrost was encountered at any of the boreholes and the minimum measured ground temperature was +3.6°C at a depth of approximately 25 ft.

4.2.2 Site T3

The proposed T3 tailing retention area is located on the Prairie Creek floodplain approximately 1/2 mile downstream from the existing camp site area. The T3 area is cut at approximately its north-south midpoint by a small stream which drains the tributary area to the east. Bedrock outcrops are visible in and immediately north of the midpoint stream. Four boreholes, 6 to 9 inclusive, were put down to depths varying between 10 and 56 ft. in the area north of the midpoint stream. The locations of the boreholes are shown on Figure 4. The stratigraphy encountered at the borehole locations is essentially the same as that found at the T2 area with a surficial layer of 10 to 15 ft. of compact to dense alluvial sands and gravels with some cobbles, overlying 28 to 32.5 ft. of very stiff, dark grey silty clay. Underlying the clay layer is an undetermined thickness of compact to dense alluvial sands and gravels. At the location of borehole 8, immediately north of the midpoint stream, bedrock was encountered at a depth of 8 ft. This borehole, together with the outcrops mentioned previously, indicate that the T3 area is cut across its midpoint by bedrock at shallow depth.

Standpipes installed in the boreholes north of the bedrock cut-off and sealed in the alluvial sands and gravels beneath the glacial clay stratum recorded excess hydrostatic heads of between 1 and 5 ft. relative to standing ground water levels in the area. This indicates that the clay stratum seals into the bedrock cut-off and is continuous across the valley for roughly 1/4 mile upstream of the cut-off. The standing ground water level, as at T2, is controlled by Prairie Creek water levels and was at approximately elevation 2,805 ft. at the time of the investigation.

No permafrost was encountered at any of the boreholes at the T3 site and the minimum measured ground temperature was +3.1°C at a depth of approximately 30 ft. beneath the ground surface.

4.3 Plant Site P2

The proposed P2 plant site area is located in the former course of Harrison Creek immediately south of Adit No. 2, as shown on Figure 3. Boreholes 10 and 11 were drilled in this area to depths of 52 and 55 ft., respectively. The stratigraphy consists of between 43 and 51 ft. of compact to dense alluvial sands and gravels with some cobbles and occasional boulders, overlying bedrock. Bedrock was encountered at elevation 2785 ft. and 2792 ft. at the north and south ends of the P2 site, respectively. The standing ground water level at this site was at elevation 2829 ft., approximately 7 ft. beneath the ground surface at the time of the investigation; however, it can be expected to vary with the water levels in Harrison Creek.

No permafrost was encountered in either borehole at the proposed P2 plant site and the minimum measured ground temperature was +4.6°C at a depth of approximately 40 ft. beneath the existing ground surface.

4.4 Conclusions

Both of the proposed tailing retention areas investigated are suitable for construction of tailing ponds. However the T2 area is superior to the T3 area for initial tailing retention development in several respects. The T2 area is immediately adjacent to the proposed plant site and has been substantially cleared of brush. It is also enclosed by existing river dykes which can be incorporated into the ultimate tailing embankment cross-sections. An impermeable clay stratum is present over most of the base area and is extensive enough to provide borrow material for construction of impervious clay seals which will be required in the perimeter embankments of the proposed tailing area.

We recommend construction of tailing retention ponds in the T2 area to provide tailing storage for the initial anticipated mine life.

The P2 area is suitable for the construction of the proposed mine plant with foundations bearing in the alluvial sands and gravels.

On the basis of the results of the field investigation, no permafrost exists within any of the foundation soils over, or in, which mine facility construction is to take place.

5.0 LABORATORY INVESTIGATION

5.1 Introduction

The laboratory testing program was restricted to clay samples obtained from the T2 tailing retention area, considered the most viable of the two alternative areas for initial development. No clay was encountered at the P2 plant site and hence no laboratory testing was required. The clay samples recovered from tailing retention area T3 have been carefully stored for testing if and as required and are expected to yield results similar to those obtained from the samples recovered from the T2 area.

The testing program included water content, Atterberg Limit and laboratory vane shear strength determinations on all samples. In addition, two consolidated, undrained triaxial shear strength tests with pore pressure measurements and two one-dimensional consolidation tests were performed on selected samples. The results of these tests have been influenced to some degree by sample disturbance, since all of the samples, which were air freighted from Prairie Creek to Vancouver, were unavoidably disturbed to some extent in transport.

The numerical results of the testing program are presented on the Records of Boreholes in Appendix A. A summary of the information obtained from the testing program is presented in the following sections and the test results are given graphically in Appendix B.

5.2 General Properties

The samples tested had liquid limits of from 30 to 58 per cent and plastic limits ranging from 18 to 22 per cent with average values of 49 and 21 per cent, respectively. The natural water content of the samples ranged from 25 to 38 per cent with an average of 30 per cent.

The results of the particle size analyses indicate the samples are composed of approximately 52 per cent clay sizes, 43 per cent silt sizes and 5 per cent sand sizes.

These results classify the soil as an inorganic silty clay of low plasticity, identified as type "CL" in the U.S.C. system.

5.3 Shear Strength

Several types of laboratory shear strength tests were performed on representative silty clay samples from the T2 tailing area. A series of laboratory vane shear tests resulted in average undisturbed and remoulded undrained shear strengths of 1,450 and 350 lb/sq.ft., respectively. These values are lower than the field values due to sample disturbance in transport. A "quick" unconsolidated-undrained triaxial test gave an undrained shear strength of 1,620 lb/sq.ft.

An undisturbed, undrained shear strength of 1,500 lb/sq.ft. can be used conseratively for design purposes. Whereas the silty clay can be considered relatively insenstive to disturbance, a disturbed shear strength of 500 psf is used in design consideration.

The consolidated-undrained triaxial tests with pore water pressure measurements yielded a cohesion intercept of approximately 200 lb/sq.ft. and an angle of shearing resistance of 25 degrees. These effective shear strength parameters were used for the design of the tailing embankments except where highly disturbed clays are integral parts of the embankments, such as in the clay seal cut-off ditch (see Section 6).

5.4 Consolidation

Void-ratio-pressure curves for consolidation tests on two representative samples of the T2 silty clay are given in Appendix B. The curves, although affected by sample disturbance, are typical of a clay which is overconsolidated, or has in the past been subjected to a vertical load greater than that which now exists. An additional historical overburden thickness of approximately 100 ft. of material is indicated by the curves.

The results of these consolidation tests indicate that maximum total settlement of the completed tailing pond could be of the order of 6 inches. The calculations are based on conservative premises; however, this amount of settlement is considered acceptable for structures of the type in question.

6.0 TAILING RETENTION AREAS

6.1 Introduction

On the basis of preliminary work (GA Report 802-1073, dated May 1980) two of the nine potential tailing retention areas dealt with in that report were selected for further more detailed study. These areas have been designated as T2 and T3 and their locations are shown on Figures 2 and 4, respectively.

Both of these areas are suited for development as tailing retention areas. They are each underlain at shallow depths below their existing ground surfaces by impervious clays and/or bedrock. Sufficient amounts of clay exist at both sites for use in the construction of impervious tailing dams.

Site T2 is ideally suited for development for the first phase of mine development insofar as its area and the optimum tailing embankment height are such that, at the anticipated rate of disposal of 110,000 cu.yd. per year into the ponds, the storage capacity of this area will be exhausted within approximately 7-8 years which is the initial anticipated mine life. Consequently, if the mine is closed at that time, overall mine facility construction will encompass a small area relative to that which would be included if initial development utilizes site T3.

Site T3 is also highly suitable for development of a tailing retention area. However, its development in the initial stages would be more costly than for that of T2 insofar as initial embankment construction would involve longer and, in some cases, higher sections. Moreover, advantage could not be taken of existing dyke construction such as exists at site T2. Approximate boundaries for tailing area T3 are shown on Figure 4. It should be noted that the actual available area for storage development within T3 is substantially greater than that shown on Figure 4 since the figure does not extend to the southern limit of T3.

It is strongly recommended that site T2 be developed in the initial stages of mine development and that T3 be developed later if mine life is to extend beyond initial expectations. Consequently, only site T2 is laid out in detail for presentation in this report. Whereas embankment sections and construction procedures for T3 will be similar to those for T2, staging of embankment development in both elevation and plan may be more complex in order to achieve the desired economy and efficiency for construction and operation.

6.2 Criteria Used for Tailing Embankment Design and Pond Layout

The tailing retention system has been designed to adhere to the following criteria:

(1) The tailing retention system is to allow for storage of 7-8 years of mine production waste which will produce approximately 110,000 cu.yds. of fine tails each year.

(2) The tailing embankments are to be built in stages with the first stage to allow for 3 to 4 years of tailing storage.

(3) The pond system is to be effectively impervious so that seepage from the ponds does not damage the chemical or physical environment of Prairie Creek.

(4) The overall area of T2 is to be divided by internal embankments into segments with surface areas not exceeding 3 to 4 acres so that alternate ponds can be used for summer/winter operation in order to minimize ice storage in the system.

(5) It is understood that all of the water that enters the tailing pond with the mill refuse is to be recirculated for use in the mill and that excess water in any given pond cell is to be decanted, siphoned or spilled into adjoining pond segments.

(6) The tailing retention area is to be adequately protected from encroachment by maximum probable flows in Prairie Creek.

6.3 Tailing Pond Layout

The proposed layout for tailing retention area T2 is shown in plan on Figure 2. The locations of the Prairie Creek perimeter embankments have been determined by the locations of the existing river dykes.

The development of area T2 will involve the excavation of approximately 420,000 cu.yd. of alluvial sands and gravels and glacial clays unless bedrock is encountered at elevations higher than the proposed base elevation of the ponds in which case excavation quantities will be less. The excavated materials can be used in their entirety for tailing embankment construction, for general stream training works around mine and camp sites, for general site grading at the camp and mill sites and at the site of the fuel tank farm. The total available storage volume of the T2 retention area is estimated to be approximately 940,000 cu.yds., including the volumes of the proposed internal separator dykes. The relationship between storage volume and embankment crest elevation for the proposed storage area is shown on Figure 5. (Similar relationships have not been generated for site T3 since gross storage requirements following the initial anticipated operating life for the mine are not known at this time.)

6.4 Tailing Pond Embankment Design

The tailing pond embankments have been designed in accordance with the criteria outlined in Chapter 9 ("Waste Embankments") "Pit Slope Manual", Department of Energy, Mines and Resources, Ottawa, 1977. Typical sections through various locations of the ultimate embankments are shown on Figure 6. Typical sections through the phases of Stage 1 embankment construction are shown on Figure 7.

The soil strength parameters used in assessing the stability of the tailing embankments as designed were as follows:

	c'	ø'	γ
In Situ Glacial Clays	200 psf	25°	120 pcf
Disturbed Glacial Clays	500 psf	0	100 pcf
Compacted Alluvial Sands and Gravels	0	37°	125 pcf
Uncompacted Alluvial Sands and Gravels (existing river dykes)	0	32°	120 pcf
Coarse Rock Bank Protection	0	40°	140 pcf

The factors of safety of the embankments against shear failure were assessed using the Simplified Bishop Method of Slices for static conditions and Sarma's method for pseudo-static (earthquake) conditions. A maximum horizontal ground acceleration of 3 per cent gravity was used in the pseudo-static analyses. The minimum factors of safety were calculated to be 1.3 and 1.2 for the static and earthquake conditions, respectively. These meet the minima recommended for acceptance for tailing embankments in the Pit Slope Manual and are considered adequate for the proposed construction.

6.5 Tailing Pond Embankment Construction

The proposed base level of the tailing pond system will vary between approximately elevation 2,825 ft. at its south end to elevation 2,830 ft. at its north end, as shown on Figure 2. The ground water level in the area is determined by the water levels in Prairie Creek and are at approximately elevation 2,839 ft. during normal stream flow levels. In order to excavate the necessary quantities of clay from within the pond area and to construct safe embankments, it will be necessary to seal the pond perimeter to a sufficient level before general excavation below the ground water table can be done.

Stage construction is to be used for the tailing embankments and Stage 1 is to allow for 3 to 4 years of tailing storage. This will require construction of an embankment section to elevation 2848 ft., approximately, allowing for about 3 ft. of freeboard above the level of stored tails. However, protection of the area from Prairie Creek maximum flow levels is also required. Consequently, whereas an impervious section to elevation 2845 ft., approximately, will suffice for the inside of the embankment structure, the outside of the section will have to be built to the estimated maximum flow levels in Prairie Creek, as given on Figure 8. Typical sections through successive phases of Stage 1 construction are shown on Figure 7. It should be noted that heavy rock armour is not required on the embankment along the southern boundary of the tailing area which does not border directly on Prairie Creek, as shown on Figure 6.

Construction for Stage 1 should take place in accordance with the following sequence and constraints, as shown on Figure 7.

(1) The T2 area should be cleared of all brush, debris and surface organic materials.

(2) Excavate all materials down to ground water level along the alignment of the required clay seal except along the backslope on the east side of the tailing storage area. The excavation will have to be of sufficient width to allow operation of construction equipment for ditch excavation below the ground water table for the purpose of placing the clay seal. Excavation for this phase should not be carried below the ground water table.

(3) Prepare an area or areas within the pond perimeter from which clay for the seal can be excavated. The amount of clay required for this phase of the construction is estimated to be approximately 15,000 cu.yds. The purpose of this phase is to prepare a seal to above the level of the ground water table along the dyke alignment to tie into bedrock at the north and south ends of the retention area so that see-

page into the pond area from Prairie Creek is effectively cut-off. It may be necessary to bulldoze clay to form temporary dykes around clay excavation areas within the pond area so that excavation of clay can proceed in the dry, unless a dragline is used, in which case underwater excavation can be carried out.

(4) Excavate a ditch along the seal alignment down to the underlying clay or bedrock and replace the excavated granular materials with the clay excavated from within the pond area. The ditch should be a minimum of 4 ft. and a maximum of 6 ft. in width at its invert. The excavation should be flooded at all times and the length of open excavation should be as short as possible so that sloughing of material from the sides into the bottom of the excavation is minimized. The upper surface of the clay fill should be taken to approximately 2 ft. above the ground water level, the clay being contained at its sides by the in situ sands and gravels. Compaction of the clay fill under these conditions would be extremely difficult; consequently, every effort should be made to break the excavated clay down as much as possible so that large voids are not left in the ditch seal. Since no compactive effort, per se, can be applied to this part of the clay fill, some consolidation of this portion of the seal can be expected to continue after it is placed. This will not deter from safe pond operation provided that the embankment crest elevations are periodically checked and

maintained as required until the consolidation is completed. Initial consolidation can be accelerated by placing a temporary surcharge over the ditch infill, as shown on Figure 7.

(5) Some areas near the proposed embankment alignment may be underlain by granular materials too great in thickness to allow the preparation of a ditch seal as described above. In these cases, excavation should be done over the affected areas only to the ground water level and a layer of clay approximately 2 ft. in thickness placed in 6 inch lifts over the area and compacted using a sheepsfoot roller. Subsequently, this seal can be connected to underlying clay or bedrock with a ditch seal as described in sub-paragraph (4) above. The 2 ft. thick layer of clay should be overlain by about 3 ft. of sand and gravel. A schematic view of this condition is shown on Figure 6.

(6) When the perimeter embankment seal is completed, the water in the pond area can be pumped into Prairie Creek and excavation, leaving an in situ sand and gravel berm, as shown on Figure 7, and construction of the embankments as designed, can continue. Excess materials excavated from within the pond area can be stockpiled for future stage construction or, alternatively, used for other construction requirements.

(7) Ground water entering the excavation from the backslope on the east side of the proposed storage area should be collec-

ted in ditches leading to sumps from where it can be pumped away from the pond area.

(8) Construction should not be carried out in freezing temperatures in order to avoid inadequate compaction of embankment soils.

(9) The clay seal for each phase of embankment construction should be raised only to an elevation 3 ft. below the crest elevation of each phase. The uppermost 3 ft. of each stage should consist of compacted sands and gravels. However, these materials must be removed and replaced with clay prior to construction of subsequent stages so that a continuous clay seal is maintained in the embankment.

(10) Subsequent stages for embankment construction will lead to a completed section as shown in Figure 7.

(11) If an ultimate crest width in excess of 16 ft. is desired for a roadway or any other purpose, then the entire cross-section of the embankment must be widened by the desired amount. The design width of 16 ft. is the minimum acceptable for a tailing embankment of the height in question, and is in accordance with criteria given in the Pit Slope Manual.

6.6 Internal Tailing Embankments

The division of the tailing pond into segments not exceeding 3 to 4 acres in surface area so that disposal can be alternated between pond segments for alternate summer/winter operation will minimize ice accumulation from winter tailing disposal insofar as winter accumulated ice can be allowed to melt over the summer period with the net result that little, if any, ice is permanently stored in the ponds. Ice accumulation, if unchecked, can reduce tailing pond storage efficiency substantially.

Suggested locations for internal tailing pond embankments are shown on Figure 2. Specific locations of these dykes is only important insofar as those segments of the overall pond system which are used for winter operation do not exceed 3 to 4 acres in surface area. Provided this criterion is met, the mine operators can locate the internal embankments at whatever locations are convenient.

Since the purpose of these embankments is only to control ice accumulation in the ponds, their construction does not have to include impervious sections nor is their stability of crucial import insofar as small embankment failures will not endanger the environment outside the perimeter of the T2 area.

Construction of the internal embankments can be carried out using the locally available alluvial sands and gravels, mine waste rock, coarse mine plant waste, or any other material that will maintain itself at a reasonable angle of repose when placed for embankment construction so that pond storage volumes which are lost due to internal embankment construction are minimal.

6.7 Surface Drainage Around Tailing Ponds

The flows from the small stream that exits into the T2 area from the valley on the east side of Prairie Creek are normally very small. However, in the interests of safety, it is recommended that these flows, together with any other surface water with potential for entering the pond area, be ditched away from the T2 area and directed into Prairie Creek.

6.8 Seepage from the Tailing Retention Area

Due to the presence of an in situ impervious clay layer on the base of the T2 tailing area and the construction of an impervious seal in the embankments, seepage from the T2 pond area into Prairie Creek will be small. During the early years of operation, the level of stored tails in the pond will be lower than the level of the water in Prairie Creek, consequently, any seepage flows will be into, not out of, the pond area. Once the tailing storage level exceeds approximately elevation 2845 ft., seepage, if any, will tend to flow from the pond into the Creek. When the ponds are full to their maximum capacity, that is to elevation approximately 2864 ft., seepage quantities are estimated to be of the order of 250 to 500 cu. ft. per year (approximately 0.8 to 1.6 x 10^{-5} cfs).

7.0 GENERAL STREAM TRAINING WORKS

Dykes will be required along Prairie Creek and Harrison Creek to provide flood protection for the mill and camp sites. These embankments can be constructed using the sands and gravels excavated from within tailing pond T2 and which are in excess of the materials required for building the T2 tailing embankments, or from sands and gravels excavated from other suitable borrow areas.

It is not considered necessary to construct impervious embankments for general flood protection since high flood levels in these streams will be of short duration and the amount of seepage through the embankments will, therefore, be limited. However, appropriate ditching within the embankment perimeter to collect any excess seepage water so that it can be sumped and subsequently pumped back into the streams would be prudent.

The flood protection dykes should be built and maintained to elevations at least 3 ft. above the elevations of the estimated 100 year flood levels in the streams as shown on Figure 8. The slopes of the embankments can be built with gradients of 1 1/2 horizontal to 1 vertical and the outside slopes should be protected with heavy rock for their full height.

Construction of the dykes should be carried out by placing the sands and gravels in lifts approximately 1 ft. in thickness. Adequate compaction for this construction will be achieved by equipment traffic during construction.

Typical sections showing the recommended embankment construction are shown on Figure 9.

8.0 MINE PLANT AND ANCILLARY STRUCTURE FOUNDATIONS

8.1 Mine Plant Foundations

Site P2 has been selected for construction of the mine plant. The foundation soils at this location consist of compact to dense alluvial sands and gravels with cobbles and some boulders, overlying bedrock at a depth of between 43 and 55 ft. beneath the ground surface.

An allowable bearing capacity of 4,000 lb/sq.ft. can be used for the design of spread footings for the mine plant. The footings should be founded at a depth of at least 10 ft. beneath the final outside ground surface elevation for frost protection. Most of the consolidation within the foundation soils due to structural loads will occur during construction. Subsequent settlements should be no more than 1/2 inch.

Individual mill units which will subject the foundation soils to vibratory loads should be analyzed independently prior to final foundation design.

Due to the presence of cobbles and boulders in the foundation soils, foundation locations should be over-excavated by approximately 1 ft. and the excavation brought up to the final desired footing base elevation with properly compacted sands and gravels. This will avoid undesirable stress concentrations on footing bases.

8.2 Ancillary Structures

No subsurface investigations have been carried out at the sites of the concentrate storage sheds or other ancillary structures. No serious problems are anticipated for these structures; however, it is recommended that prior to construction, exploratory drilling or test pitting be carried out at these sites to confirm that the conditions are favourable.

9.0 FUEL TANK FARM SPILL PROTECTION

Spill protection for the fuel tank farm can be achieved by lining its base and perimeter dykes with a layer of clay excavated from within the T2 or T3 tailing retention areas. The clay liner should be a minimum of 1 ft. in thickness and should be covered with a protective layer of sands and gravels at least 3 ft. in thickness so that heavy traffic does not reduce the effectiveness of the seal.

In the event that the tank farm is founded in an area that is underlain at a shallow depth by in situ clays, spill protection can be achieved by constructing a seepage cut-off joining the in situ clay layer to sealed perimeter embankments.

Schematic sections showing both of these alternatives are shown on Figure 10.

Both the in situ sands and gravels and the in situ clay deposits have adequate shear strength and consolidation characteristics to safely support the fuel tanks.

The foundation soils for the fuel tanks should be treated so that deleterious deflections due to loads from the filled tanks do not result in damage to the tanks. Ideally, a layer of 3/4 inch crushed stone at least 1 ft. in thickness should be placed at tank locations to provide suitable foundations. Alternatively, a minimum of 18 inches of well graded gravel with a maximum particle size of 1-1/2 inches, placed in 6 inch lifts and compacted to a density equivalent to 100 per cent standard Proctor density in accordance with ASTM-D-698 can be used. The treated foundation soils should be placed at tank foundation locations after all surface organic and other soft or loose earth materials are removed from these locations.

10.0 CONCRETE AGGREGATE ASSESSMENT

Samples from potential concrete aggregate sources were collected during the field program for assessment by B.H. Levelton & Associates Ltd. The samples were taken from the mine waste rock and from the alluvial gravel deposits at the location of tailing area T3.

Since the area of concrete technology is not within Golder Associates expertise, no comments with respect to the testing program are made; however, the B.H. Levelton report, received by GA on September 30th, 1980, is included, in its entirety, as Appendix C to this report.

11.0 CONTRACT DOCUMENTS

It is assumed that appropriate contract documents will be prepared for the work described in this report before construction begins. The contents of this report can serve as the geotechnical input for the preparation of such documents. Golder Associates would be pleased to review the geotechnical content of any contracts that are drawn up.

Yours very truly,

GOLDER ASSOCIATES

E.B. Fletcher, P. Eng.

D.J. Shirley

EBF/DJS/ba

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